SEDAR

Southeast Data, Assessment, and Review

SEDAR 87

Gulf of Mexico White, Pink, and Brown Shrimp

SECTION II: Data Workshop Report

August 2024

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

1 INTRODUCTION 5

1.1 WORKSHOP TIME AND PLACE 5

1.2 TERMS OF REFERNCE 5

1.3 LIST OF PARTICIPANTS 6

1.4 LIST OF DATA WORKSHOP WORKING PAPERS & REFERNCE DOCUMENTS 7

2 COMMERCIAL FISHERY STATISTICS 10

2.1 OVERVIEW 10

2.2 COMMERCIAL EFFORT AND LANDINGS WORKGROUP PARTICIPANTS 11

2.3 COMMERCIAL LANDINGS TERMS OF REFERENCE (ToRs) 11

2.4 REVIEW OF WORKING PAPERS 12

2.5 ISSUES DISCUSSED AT DATA WORKSHOP 15

2.6 COMMERCIAL EFFORT 16
2.6.1 Overview 16
2.6.2 Recommendations 17

2.7 COMMERCIAL CATCH/LANDINGS 17
2.7.1 Gulf Shrimp System (GSS) 17
2.7.2 Trip Ticket Programs 18
2.7.3 Summary of Issues 18

2.8 MAPS 22

2.9 COMMENTS ON ADEQUACY OF DATA FOR ANALYSIS 22

2.10 RESEARCH RECOMMENDATIONS 23

2.11 LITERATURE CITED 23

2.12 TABLES 24

2.13 FIGURES 27

3 ENVIRONMENTAL DRIVERS/INDUSTRY REPORT 30

3.1 OVERVIEW 30
3.1.1 Group Membership 30

3.2 TERM OF REEFERENCE 3 30

3.3 TERM OF REFERENCE 6 31
3.3.1 Life history and seasonality 31
3.3.2 Environmental drivers 33

3.3.3 Salinity 34
3.3.4 Temperature 35
3.3.5 Dissolved oxygen 36
3.3.6 Larval and postlarval transport 36
3.3.7 Nutrients and primary production 36
3.3.8 Habitat quality and availability 37

3.4 Episodic events 37

3.5 Inshore Environmental Data from Fisheries and State Water Quality Monitoring Programs 38

3.6 Environmental Drivers Conclusions 38

3.7 DATA GAPS AND ADDITIONAL RESEARCH RECOMMENDATIONS 39

3.8 LITERATURE CITED 39

3.9 TABLES 43

3.11 FIGURES 53

4 INDICES OF POPULATION ABUNDANCE 55

4.1 OVERVIEW 55
4.1.1 Terms of Reference 56
4.1.2 Group membership 56

4.2 REVIEW OF WORKING PAPERS 56

4.3 SURVEY EVALUATIONS 57

4.4 FISHERY-INDEPENDENT INDICES 58
4.4.1 SEAMAP 58
4.4.2 TEXAS 60
4.4.3 LOUISIANA 62
4.4.4 MISSISSIPPI 64
4.4.5 ALABAMA 66
4.4.6 FLORIDA 67
4.4.7 COMBINED ALABAMA, MISSISSIPPI, AND LOUISIANA INDICES 70

4.5 CONSENSUS RECOMMENDATIONS 71

4.6 RESEARCH RECOMMENDATIONS 71

4.7 LITERATURE CITED 72

4.8 TABLES 73

4.9 FIGURES 82

5 ECONOMICS AND SOCIAL SCIENCES 84

5.1 OVERVIEW 84

5.1.1 Terms of Reference 85
5.1.2 Participants 86
5.1.3 Objectives 86

5.2 REVIEW OF WORKING PAPERS AND CONSENSUS RECOMMENDATIIONS 86

5.3 QUANTITATIVE DATA 87
5.3.1 Fuel Price Index 87
5.3.2 Inflation Adjustment 87
5.3.3 Discount Rate 87
5.3.4 Economic Survey Results including Economic Performance 87
5.3.5 Shrimp Price Indices 88

5.4 QUALITATIVE INFORMATION 90

5.5 ECONOMIC DATA AND THE PROPOSED DATA STRATIFICATION 91

5.6 LITERATURE CITED 91

5.7 FIGURES 92

1 INTRODUCTION

1.1 WORKSHOP TIME AND PLACE

The SEDAR 87 Data Workshop was held September 18-22, 2023, in Tampa, FL. In addition to the in-person workshop, a series for webinars were held before (August 2023) and after (November 2023 – May 2024) the meeting.

1.2 TERMS OF REFERNCE

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.

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

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.

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.

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.

   a. 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.

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.
   a. Detail the early 2000 industry consolidation and impacts of ex-vessel price on effort

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.

1.3 LIST OF PARTICIPANTS

Data Process Participants

Lisa Ailloud, Co-Lead Analyst .... NMFS Miami
Moll Stevens, Co-Lead Analyst .... NMFS Miami
Don Behringer .... NMFS SEFSC
Peyton Cagle .... LDWF
Jade Chau .... NMFS SEFSC
Roy Crabtree .... GMFMC SSC
Kevin Craig .... NMFS SEFSC
Kyle Detloff .... NMFS SEFSC
Dwayne Edwards ....
Ryan Gandy .... FWC
Gary Graham .... AP
David Griffith .... GMFMC SSC
David Hanisko .... NMFS SEFSC
Holden Harris .... NOAA
Kimberly Johnson .... NMFS SEFSC
Mandy Karnauskas .... NMFS SEFSC
Christopher Liese .... NMFS SEFSC
Alan Lowther .... NMFS SEFSC
Jessica Marchant .... AL DCNR
Matthew McPherson .... NOAA
Jim Nance .... GMFMC SSC
Corky Perrett .... AP
Cassidy Peterson .... NMFS SEFSC
Cheston Peterson .... NOAA
Adam Pollack .... NMFS SEFSC
David Records .... NOAA
Jason Saucier .... MS DMR
Meagan Schrandt .... FWC
Katie Siegfried .... NMFS SEFSC
Ted Switzer .... FWC
Jim Tolan .... TXPWD

Workshop Observer
Laurie Picarello ....

Data Process Webinar Observers
Jason Adrinace .... LDWF
Sarina Atkinson .... NMFS Miami
Suzanna Blake .... NOAA
Leann Bosarge .... Industry Rep
Matt Freeman .... GMFMC Staff
Carissa Gervasi .... NOAA
Bob Gill .... GMFMC
Jack Isaacs .... LDWF
Fernando Martinez-Andrade .... TPWD
Akbar Marvasti .... NOAA
Skyler Sagarese .... NMFS SEFSC
Chris Schieble .... LDWF
Jody Shirley .... Industry
Rebecca Smith .... NOAA
Jo Williams .... NMMFS SEFSC

Council Representation
Billy Broussard .... GMFMC

Staff
Julie Neer .... SEDAR
John Froeschke .... GMFMC Staff
Meisha Key .... SEDAR
Dominique Lazarre .... SERO
Michelle Masi .... SERO
Ryan Rindone .... GMFMC Staff
Bernie Roy .... GMFMC Staff
Charlotte Schiaffo .... GMFMC Staff
Carrie Simmons .... GMFMC Staff

1.4 LIST OF DATA WORKSHOP WORKING PAPERS & REFERNCE DOCUMENTS

Document #	Title	Authors	Date Submitted
Documents Prepared for the Data Workshop			
SEDAR87-DW-01	Estimation of Commercial Shrimp Effort in the Gulf of Mexico	Kyle Dettloff	30 August 2023 Updated: 27 Sept 2023

			Updated: 7 Nov 2023 Updated: 14 December 2023 Updated: 2 April 2024 Updated: 17 May 2024 Updated: 20 August 2024
SEDAR87-DW-02	Social Dimensions of the Gulf of Mexico Shrimp Fishery: Overview	David Griffith	31 August 2023
SEDAR87-DW-03	Commercial Landings of Gulf of Mexico Shrimp Self-Reported Survey 2005-2020	Rebecca Smith, Alan Lowther, J. Williams	5 September 2023
SEDAR87-DW-04	Vessel and Gear Characterizations of Gulf of Mexico Shrimp Self-Reported Survey 2005-2020	Rebecca Smith, Alan Lowther, J. Williams	5 September 2023
SEDAR87-DW-05	Gulf of Mexico Brown, Pink, and White Shrimp Weight-Length Regression using SEAMAP Data	Molly H. Stevens	1 September 2023
SEDAR87-DW-06	Commercial Shrimp Landings of Gulf of Mexico Final Title: Gulf of Mexico Commercial Brown, Pink and White Shrimp Landings	Jade Chau, Alan Lowther, and Kimberley Johnson Final Document Authors: Sarina Atkinson, Alan Lowther, Kyle Dettloff, and Steven Smith	1 September 2023 Updated: 6 Nov 2023 Updated: 5 February 2024 Updated: 13 June 2024
SEDAR87-DW-07	*Economics of the Federal Gulf of Mexico Shrimp Fishery*	Christopher Liese	1 September 2023
SEDAR87-DW-08	General Economic Measures for Fuel Price Trend, Inflation Adjustment, and Discounting	Christopher Liese	1 September 2023

SEDAR87-DW-09	Gulf of Mexico Spatial-Temporal Environmental Data	Holden Harris	14 September 2023
SEDAR87-DW-10	Shrimp Import Data	Alan Lowther	18 September 2023
SEDAR87-DW-11	Indices of relative abundance for Pink Shrimp, and summary of data availability for Pink, Brown, and White Shrimp, from inshore surveys of Florida's Gulf coast estuaries	Dwayne D. Edwards, Derek M. Tremain, Meagan N. Schrandt, and Theodore S. Switzer	21 September 2023 Updated: 30 November 2023
SEDAR87-DW-12	Inshore brown and white shrimp relative abundance in Louisiana	Office of Fisheries, Louisiana Department of Wildlife and Fisheries	1 November 2023 Updated: 4 January 2024
SEDAR87-DW-13	Brown, White and Pink Shrimp Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico	Adam G. Pollack and David S. Hanisko	18 Oct 2023
SEDAR87-DW-14	Summary of the Gulf of Mexico Shrimp Effort Data Collection	Alan Lowther	6 Nov 2023 Updated 5 January 2024
SEDAR87-DW-15	Social Dimensions of Gulf of Mexico Shrimping	David Griffith, Christopher Liese, Mike Travis, Matt Freeman, David Records	29 November 2023
SEDAR87-DW-16	SEDAR 87 Commercial Fishery Landings and Effort Figures for White, Pink, and Brown Shrimp in the US Gulf of Mexico, 1960–2021	Jo A. Williams, Kimberley Johnson, and Alan Lowther	12 February 2024

Reference Documents

SEDAR87-RD01	SEAMAP Trawl Shrimp Data and Index Estimation Work Group Report	

SEDAR87-RD02	The Annual Economic Survey of Federal Gulf Shrimp Permit Holders: Implementation and Descriptive Results for 2008	Christopher Liese and Michael D. Travis
SEDAR87-RD03	Mississippi Department of Marine Resources and University of Southern Mississippi Gulf Coast Research Laboratory Inshore Trawl Monitoring Programs: Sampling and Lab Protocols	
SEDAR87-RD04	Marine Fisheries Crustacean Section - Independent Sampling Activities: Field Manual	Louisiana Wildlife and Fisheries
SEDAR87-RD05	Fisheries Assessment and Monitoring Program (FAMP)	Alabama Marine Resources Division
SEDAR87-RD06	AL FAMP Assessment Sampling - Standard Operating Procedures	Alabama Marine Resources Division
SEDAR87-RD07	TPWD's Gulf Trawl Sample Design	Texas Parks and Wildlife Division
SEDAR87-RD08	Commercial brown, white, and pink shrimp tail size: total size conversions	Susan L. Brunenmeister
SEDAR87-RD09	Final Report: U.S. Gulf of Mexico Commercial Shrimp Conversion Factors Validation 2020	GSMFC
SEDAR87-RD10	Conversion of "whole" and "headless" weights in commercial Gulf of Mexico shrimps	Joseph H. Kutkuhn (1962)

2 COMMERCIAL FISHERY STATISTICS

2.1 OVERVIEW

The Commercial Landings and Effort Workgroup met in Tampa on September 18–22, 2023 to examine and discuss available data sources for SEDAR 87 Gulf of Mexico White, Pink, and Brown Shrimp. Subsequent post-workshop webinars were held in November 2023, January 2024, and May 2024 to resolve remaining issues identified in the Data Workshop.

For the Data Workshop, shrimp effort estimates were available from 1960-2022. A new method for estimating shrimp effort developed by Dettloff (2023) was presented. This method uses cellular electronic logbook (cELB) vessel location data, allowing the new method to be used for years 2015–2022[1]. Commercial landings for Gulf shrimp were compiled from 1960 to 2022 using data from the Gulf Shrimp System (GSS) and State Trip Ticket (STT) data. Data providers recommended the first year in which to use STT data for each Gulf state. After the initial in-person Workshop, these decisions were reexamined in detail and some of these initial start dates were modified, as described later in this report.

Information regarding vessel and gear characteristics, as well as estimated landings, for the federal Gulf shrimp fleet were compiled annually using the Gulf Shrimp Landings Report and the Gulf Shrimp Vessel and Gear Characterization Form. The survey data is self-reported and has a one-year recall period. Gear aspects such as number of nets were added to the survey in 2011.

Shrimp import data were also reported for non-processed products (i.e. excluding frozen dinners containing shrimp, canned shrimp, and shrimp chips) for better comparison with domestic landings data.

[1] 2015 is the first full year in which cELB data were collected. 2022 is the most recent year in which cELB data is available for analyses.

2.2 COMMERCIAL EFFORT AND LANDINGS WORKGROUP PARTICIPANTS

Alan Lowther	Workgroup Leader	SEFSC Miami
Kyle Dettloff	Data Provider	SEFSC Miami
Jade Chau	Data Provider	SEFSC Miami
Rebecca Smith*	Data Provider	SEFSC Galveston
Jo Williams*	Data Provider	SEFSC Galveston
Sarina Atkinson#	Data Provider/Analyst	SEFSC Miami
Steven Smith#	Data Provider/Analyst	SEFSC Miami
Roy Crabtree	Assessment Development Team	GMFMC SSC
Jim Nance	Assessment Development Team	GMFMC SSC Chair
Corky Perret	Panelist	GMFMC Shrimp AP member
Gary Graham	Panelist	GMFMC Shrimp AP member
Cheston Peterson	Rapporteur/Panelist	SEFSC/CIMAS Panama City
Laura Picariello	Panelist	GMFMC Shrimp AP member
Dominique Lazarre	Rapporteur/Panelist	SERO
Kimberley Johnson	Panelist	SEFSC Galveston

* Attended workshop via phone
\# Added after initial in-person workshop

2.3 COMMERCIAL LANDINGS TERMS OF REFERENCE (ToRs)

The Commercial Workgroup reviewed the terms of reference for SEDAR 87 and highlighted the following ones as the most relevant for the group to address:

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

Effort and landings data were provided and discussed extensively by the Workgroup.

DW ToR #2: *Review, discuss, and tabulate available life history information for each stock being assessed.*

Regarding life history aspects, the Workgroup investigated the impact of updated conversion factors (heads-on to heads-off weight) on landings data estimates. A brief summary of these discussions is presented in this report and an extensive discussion appears in the Commercial Landings working paper (WP6).

DW ToR #5*: Provide commercial catch statistics for each stock where possible. Document species-specific issues. Provide maps of 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.*

This was a primary focus of the Workgroup and is discussed in detail in subsequent sections.

DW ToR #8: *Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment.*

Research recommendations were discussed and are summarized in Section 3.9 below.

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

Drafting of the Data Workshop report presented here began at the in-person Data Workshop and has continued to this point. A draft report was sent to the assessment panel in January 2024, at which point extensive comments were made and corrections were requested. We are optimistic that these Workshop participant concerns have been addressed and that this report now represents a much-improved summary of the available commercial data products and recommendations for their use.

2.4 REVIEW OF WORKING PAPERS

SEDAR 87-DW01: Estimation of Commercial Shrimp Effort in the Gulf of Mexico
This Working Paper discusses the new effort estimation algorithm (Dettloff method) implemented for the period 2015-2022.

This method uses 10-minute interval ping cELB data to estimate the spatial and temporal distribution of shrimp effort and trip ticket reported landings to scale this estimated effort to the total fleet. In 2014, 500 Gulf of Mexico Shrimp Permit (SPGM) permit holders were selected to carry cELB units, supplemented by 100 additional vessels in 2018. Estimates with the new method are produced beginning in 2015 as this is the first year in which trip ticket data are reasonably complete Gulf-wide alongside continuously available cELB data. In general, total effort estimates under the new approach show a very close correspondence with previous LGL estimates for the years where available data allowed for a direct comparison (See Figure 12 in Dettloff 2023).

As opposed to the trip matching approach employed previously by LGL to calculate catch per unit effort (CPUE), the new approach does not depend on direct matching of effort with landings at the trip level, but instead uses landings for cELB equipped vessels at aggregate levels of quadrimester and area to scale effort. Within each time/area strata, landings from the total fleet are divided by landings from vessels with cELB devices to calculate scalars. This allows the complete distribution of cELB effort to be used in the final calculation, rather than only effort from trips that are able to be matched to landings (historically ~50% of effort). This new method also no longer relies on partial interview data or reported depths associated with landings, which are no longer available. The new scaled effort estimates can, however, be divided into custom finer-scale cells, including by depth, based on the observed cELB effort distribution. A detailed description of additional modifications is available in Dettloff (2023), as is the simplified R code upon request.

SEDAR 87 DW-03: Commercial Landings of Gulf of Mexico Shrimp from Gulf Shrimp Landings Reports 2005-2020

This Working Paper discusses the annual self-reported landings survey that is collected yearly by the Southeast Fisheries Science Center on the Annual Gulf Shrimp Landings Report. Completion of this survey is mandatory for all SPGM permit holders. It has been conducted from 2005 to present. To date, landings data are available through 2020 from this survey.

The survey data are self-reported and have a one-year recall period (i.e. shrimp landings by species for the entire previous year are requested). This annual survey collects the entire previous year's aggregated heads-off pounds and ex-vessel dollar value for each commercial shrimp species landed in the Gulf of Mexico (includes bays, bayous, State inshore and offshore waters, or U.S. Federal waters exclusive economic zone (EEZ)). This data collection will require an update to the back-end conversions of the revised Gulf States Marine Fisheries Commission (GSMFC) conversion factors for heads-on to head-off (tails) weight to ensure that the proper size category is associated with the shrimp weight. Comparison of GSS/STT landings to these annual self-reported total landings did show a similar trend over time, with a trend towards convergence in later years. However, total landings obtained by summing the self-reported landings were generally 5-20% lower than corresponding trip ticket landings. Possible reasons for these differences were discussed at the Workshop, the most likely being that only federally permitted vessels are required to submit Annual Gulf Shrimp Landings Reports. In addition, there may be issues with misidentified shrimp species by the dealers due to regional common names and differences in market values, and differences in how the species were binned (i.e. dealers may record a mixed catch as all belonging to one species if the market price is the same). Previous vessel-by-vessel comparisons indicated that the self-reported landings from the Gulf Shrimp Landings reports were higher than those from trip tickets (Mike Travis, personal communication). However, this issue was not extensively discussed at the Workshop as there was no realistic expectation that the landings from the Gulf Shrimp Landings reports would be used as a primary landings source for SEDAR 87.

SEDAR 87 DW-04: Vessel and Gear Characterization of Gulf of Mexico Shrimp Self-Reported Survey 2005-2020

This Working Paper discusses the description and quantities of gear used to catch the commercial landings that are sold to wholesalers and dealers as reported in the Vessel and Gear Characterization of Gulf of Mexico annual survey. This survey is mailed to all SPGM permit holders annually, and completion of the survey is mandatory for permit renewal. It has been conducted from 2005 to present. To date, data are available through 2020 from this survey.

The survey data are self-reported and have a one-year recall period. Data include confirmation that shrimping occurred in the Gulf of Mexico, the specific gear characteristics and types used to catch shrimp, the total days at sea and total number of trips from previous year's landings. The Vessel and Gear Characterization survey does not collect specifics to vessel size nor horsepower because that information is collected via permits. However, the number of nets used was included after 2011 as an important indicator of fishing effort. Data are only collected once each year, and represent the gear characteristics for the most frequently used gear type as only the "primary" gear is requested. In years before 2010, fishers were asked how many of their days at sea were not for fishing, as days at sea do not always mean a day of fishing (e.g., travel days). For 2010 and 2011, questions about days helping with the BP oil spill were added.

SEDAR 87 DW-06: Gulf of Mexico Commercial Brown, Pink and White Shrimp Landings

This Working Paper discusses the comprehensive landings data for all Penaeid shrimp species caught and landed in the Gulf of Mexico. It discusses the Gulf Shrimp System (GSS) and the various Gulf state trip ticket (STT) reporting systems (implemented by states in different years).

After the initial Data Workshop, this working paper was extensively edited to make corrections, clarifications, and modify recommendations on when to make the switch from GSS to STT data based on a state-by-state analysis. These modifications were discussed and reviewed at the three post-workshop webinars held between November 2023 and May 2024. This revised Working Paper serves as the primary source for the landings data recommended for use in this SEDAR and is discussed more extensively later in this document.

SEDAR 87 DW-10: Shrimp Imports Data

This Working Paper discusses the volume of shrimp products imported into the United States. Much concern and discussion has been raised regarding the amount of shrimp imported into the United States and the effect this has on the domestic shrimping industry in the Gulf of Mexico.

The paper summarized the imports on an annual basis taking data from the NOAA Fisheries Office of Science and Technology's Fisheries One-Stop Shop reporting tool (https://www.fisheries.noaa.gov/foss). All shrimp products were selected and then those most heavily processed products were removed (e.g. frozen shrimp pasta dinners). The Workgroup recognized the increasing amount of shrimp imports over the period from 1972-2022 (the years available in the FOSS database), as shown in Figure 1, and the potential consequences and effects on the Gulf shrimp fishery. A more extensive discussion of trends in shrimp imports can be found in Fissel et al. (2023).

The Commercial Landings and Effort Workgroup discussed concerns from industry that these large increases in imports are causing substantial competition with locally sourced shrimp catch. Industry members discussed an improvement in the quality of imported shrimp that are less expensive to source (e.g. wild red shrimp imported from Argentina and farmed whiteleg shrimp from Ecuador). Fishermen highlighted a decrease in ex-vessel price, in part due to a surplus of shrimp imported during the height of the pandemic. This has led to a reduction in shrimping effort because vessels are sometimes unable to sell catch to processors and dealers with limited freezer capacity. Many groups (fishing, county, and state groups) have written to Congress about the issue of foreign shrimp imports creating competition that is making domestic shrimping less viable. These concerns about imports were also a source of much discussion in a concurrent session with industry stakeholders. However, the Workgroup agreed that extensive discussions of shrimp "anti-dumping" duties and overseas environmental standards were political issues beyond the scope of the group's scientific mission.

SEDAR 87 DW-14: Summary of the Gulf of Mexico Shrimp Effort Data Collection
This Working Paper discusses the methodologies used to estimate effort in the Gulf shrimp fishery prior to 2015.

Beginning in 1960, there have been several changes in effort data collection methodologies employed in the Gulf Shrimp fishery, and the paper outlines the various procedures and methods employed. From 1960 to the early 1990's, effort data were collected by state and federal port agents stationed at major ports around the Gulf of Mexico. In the late 1990's, the National Marine Fisheries Service (NMFS) in partnership with a private company, LGL Ecological Research Associates, began working on an automated system to collect vessel position data from vessels for the purpose of estimating effort. This location data could then be used to calculate vessel speed between 10-minute recordings and assess when and where shrimping activity was occurring (i.e. calculate effort). Devices were installed on vessels and the data were collected from the vessels by LGL on Secure Digital (SD) cards. In 2012, NMFS began developing a 3G cellular system that would allow vessels to automatically transmit their data to the NMFS network once the vessel was in cellular range, and, thus, the manual retrieval of SD cards would no longer be required. In 2014 a new sample of vessels was selected to use these 3G devices. This method worked well for several years, but, in December 2020, the 3G cellular network ceased to operate. Consequently, NMFS, with the assistance of the GSMFC, has asked vessel operators to periodically remove the SD cards, return them to NMFS, and install a new SD card that has been provided. Currently, NMFS and the Gulf of Mexico Fishery Management Council are seeking a new, modern approach for this data collection.

2.5 ISSUES DISCUSSED AT DATA WORKSHOP

The list below represents a summary of the ancillary conversations between Workgroup members (fishing industry, data providers, and subject experts) describing the changing state within the shrimp fishery over time.

- *Impact of Freezer Vessels on Fishing Effort*–Industry members discussed the introduction of freezer vessels to the fleet and the resulting impact on fishing effort. Freezer vessels have the ability to stay offshore for upwards of 40 days, allowing them to cover larger distances. There were concerns that recall of fishing areas associated with catch and trip information used for effort estimation might be more difficult for industry members.

- *Effort Changes Due to Natural Environmental Impacts*–Industry members highlighted a loss of shrimping effort, specifically white shrimp vessels, in the 1950s as a result of a three to four year drought in the northern Gulf of Mexico.
- *Increase in Inshore Fishing Effort*–In more recent years, some felt that there has been an increase of inshore landings and effort. There is concern that this possible increase may be impacting offshore fishing effort and catch.
- *Shrimp Peddling*–Industry members discussed concerns about "peddling" (direct to consumer sales or trading of shrimp) occurring in the sector. The fishermen believe the "peddling" has always occurred, so landings should be considered a lower bound of what is caught due to some underreporting from the sector. Some thought that peddling increased as prices offered by traditional dealers decreased and, in particular, was more common with larger size shrimp as these exhibited a greater difference in price between what dealers would pay and what could be obtained selling direct to consumers.
- *Species Misidentification*–The Commercial Landings and Effort Workgroup discussed issues with species confusion and potential misidentification that exist throughout the region. The term "hopper browns" is colloquially used to describe pink shrimp in some parts of the Gulf of Mexico (primarily, South Texas). The difference in terminology has led to a mismatch between dealer categorization of some shrimp species and the accepted scientific classification for those shrimp species. One of the problems that makes identification so difficult at the unloading facilities is that some of the hoppers have the distinctive pink spot and others do not. When freshly caught, body color is discernable from other species but becomes less distinctive with time.

2.6 COMMERCIAL EFFORT

2.6.1 Overview

An overview of a new method to calculate effort by species for brown, pink, and white shrimp detailed in Dettloff (2023) was presented. The method pairs Southeast Area Monitoring and Assessment Program (SEAMAP) Trawl Surveys data with the distribution of cELB classified fishing effort to obtain a relative allocation of effort between the three Penaeid species (brown, pink, white) and royal reds. Hence, effort estimates between species are additive to the total estimated effort. This method diverges from the historical approach for calculating effort by species (estimates available from 2012-2019) in that the previous method was based on CPUE of trips that could be potentially targeting multiple species. Thus, estimates for individual species effort could sum to values well in excess of the total effort. For this reason, estimates resulting from the two methods are not directly comparable.

Estimates by species are available from 2015-2022 under the new method (Figure 13, Dettloff 2023). Given that this method depends on the fine spatial scale of raw cELB pings, the methodology cannot be directly extended to pre-cELB historical effort estimates. As it was determined the assessment group likely will not require estimates to be divided by species for their modeling exercises, it was decided that work attempting to estimate species-specific effort back in time was not a priority, though alternative methods to produce such estimates are currently being explored.

A few suggestions/limitations were brought forward regarding the new effort allocation method. First, the suggestion was made to explore using reported trip ticket landings rather than SEAMAP data to allocate effort across species. The reasoning being that there may be differences in catch composition between a standardized, fishery independent sampling program, like SEAMAP, and commercial fleets given known differences in gear (including turtle-excluder devices and bycatch reduction devices) and targeting practices. This data source, however, comes with many limitations of its own, including potential species misidentification, multi-species trips reported as a single species, lack of depth information, lack of information relating to time of day, and limited spatial resolution (i.e., landings from trips that occur over multiple statistical areas are only associated with a single stat zone on the trip ticket). Thus, given that SEAMAP data contain these important variables known to be strongly associated with relative species abundances at a finer spatial resolution (i.e., 30-minute tows within a single stat zone), SEAMAP data are thought to be a more robust source of informing effort allocation across species. There are some limitations present in using SEAMAP data as well, in that: 1) the sampling frame does not contain data collected shallower than 5 fathoms in depth, so it is thought that white shrimp may be relatively underrepresented in the Northern Gulf's 0-10 fathom zone, and 2) we are relying on the assumption that relative species distributions are constant over time within strata (season, stat zone, depth zone, time of day). There is some preliminary visual evidence that this assumption is met, and relative distributions over time are certainly less variable than those across strata in any given year. However, this will not be formally explored any further until species specific estimates are deemed necessary for assessment models.

2.6.2 Recommendations

Development of a new effort estimation method began in late-2021, after the original code was unable to be executed in a timely manner to generate 2020 estimates (Dettloff 2024). Given the close correspondence with historical LGL estimates as shown in Dettloff (2024), the Workgroup recommends using the Dettloff method for total effort estimates (brown, pink, and white combined) from 2015-present, while continuing to use LGL estimates prior to 2015 as best available scientific information If species-specific estimates are required, estimations from the new method should be utilized as they are now additive to the total effort, and are able to be divided into custom spatial aggregations as needed.

2.7 COMMERCIAL CATCH/LANDINGS

2.7.1 Gulf Shrimp System (GSS)

Commercial shrimp landings data have been provided from 1960 to 2022. For this assessment the Workgroup is considering GSS data beginning in 1960, which is consistent with that used in previous Gulf shrimp stock assessments (Nichols, 1984 and Nance et al. 1989). Note that throughout this document and the Working Papers, the term “landings” refers to shrimp caught in the Gulf of Mexico as reported by the area of catch in GSS or the STT.

The data collection procedures have changed over the years. From 1960 to 1983, the federal port agents interviewed seafood dealers and recorded the landings data on paper forms. These were sent for processing to the Bureau of Commercial Fisheries (1960-1971) in Washington, DC and then, after its founding in 1971, to National Marine Fisheries Service (NMFS) Headquarters in Silver Spring, MD. Some changes were made during the mid-1970’s, including the addition of a vessel identification number (i.e. The Coast Guard documentation number for Coast Guard documented vessels) in later records.

Beginning in 1984, responsibility for processing the collected data was assumed by the SEFSC. Port Agents began collecting and recording landings data in size ranges from the seafood dealers after the trips were unloaded. Ex-vessel prices were recorded by size for both heads-on and heads-off (also referred to as “tails”). The overarching objective of the GSS was to provide ex-vessel landings, ex-vessel value, and area caught for individual commercial fishing trips. This information was entered into a desktop program using the GSS coding standard.

2.7.2 Trip Ticket Programs

Concurrent with the GSS data collection, STT reporting systems were implemented by each Gulf state in different years. Generally, the commercial seafood dealers were responsible for completing the tickets within 72 hours of taking possession of seafood purchased directly from commercial fishermen. Completed tickets were submitted to the respective state office by the 10th of the month for the preceding month. Trip tickets can be submitted as often as dealers like, as long as all of the trip tickets generated during a month are sent by the 10^{th} of the following month. This information is sent to the Gulf States Marine Fisheries Council (GSMFC) by the Gulf states in the Fisheries Information Network (FIN) coding standard. In the case of the West Coast of Florida, the data are sent to the Atlantic Coast Cooperative Statistics Program (ACCSP). Both GSS and STT programs were primarily designed to collect information on food shrimp, so shrimp caught for bait were either not included in the first place, or, if they were included, they were excluded from the SEDAR dataset for consistency.

2.7.3 Summary of Issues

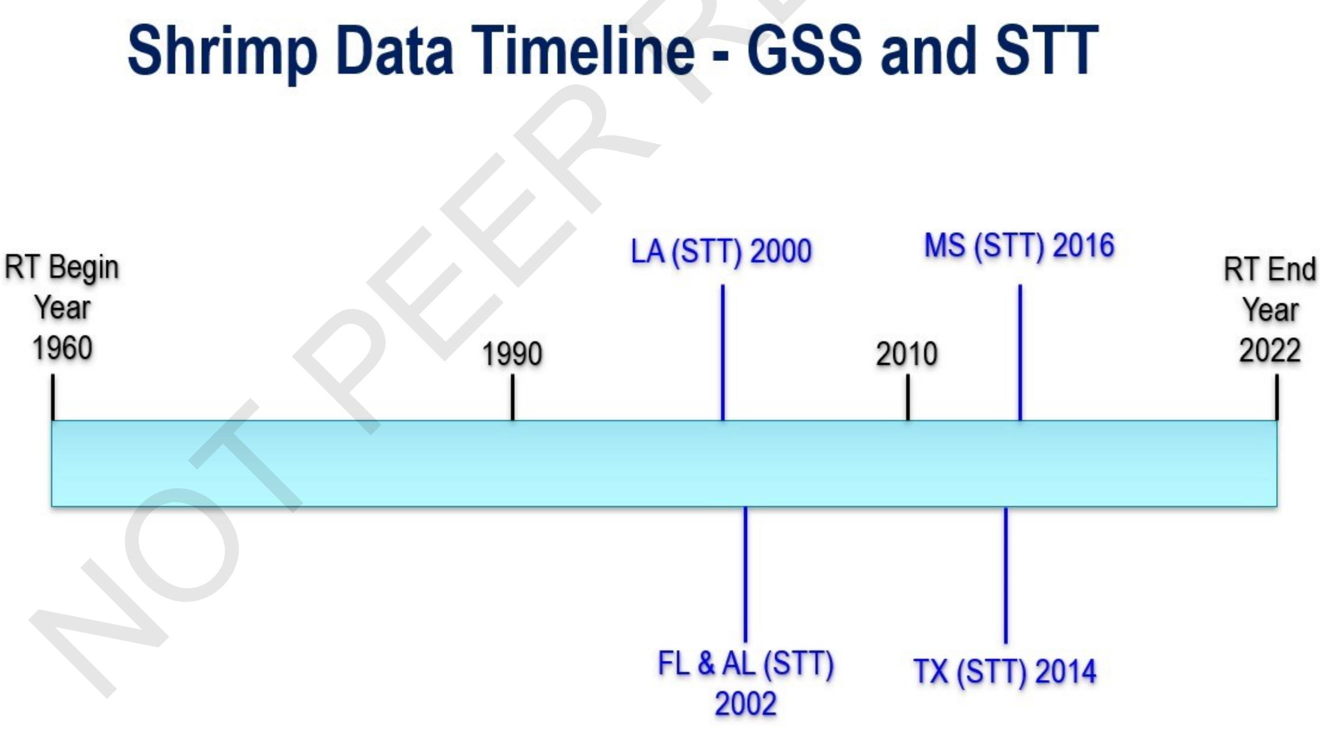
The landings for this research track did not include unreported/recreational landings. Based on the inconsistency in state data collection and reporting programs regarding the inclusion of bait shrimp, and to be consistent with previous assessments, the decision of the Commercial Workgroup was to only consider “table” or “food shrimp” and to exclude bait shrimp from the landings data. Peddling (or direct sales to the consumer without submission of a dealer report/trip ticket) and recreational landings have not been estimated.

Issue:
Transition from GSS to State Trip Tickets. Landings data are available in both the GSS and STT databases, with some or complete overlap between the data for some states and some years. For each state, the Workgroup needed to identify the best year to transition from GSS to STT

reporting. The main consideration was when the individual state reported that their STT system was mature and reliable to be the primary source for shrimp landings. However, other considerations were made for completeness of the trip ticket data (e.g., not all dealers reporting to the STT program, key variables with a high percentage of missing values, etc.) and reliability of the processing procedure of GSS. Each state system became reliable at different points between 2001 and 2016. The Workgroup needed to identify the most appropriate start date for use of state trip ticket data by state.

The September 2023 data workshop identified transition dates for each state, but subsequent forensic comparisons between GSS and STT data called some of these initial conclusions into question. A detailed examination of the rationale for the transition year for each state is presented in SEDAR 87 Working Paper 6 and was presented at the May 2024 webinar. That analysis is not repeated here except for the conclusion.

Recommendation:
The start dates for each state trip ticket system were assessed by data providers and data analysts to determine the first full year when consistent data were provided by all dealers within a state. The Workgroup recommends using data from the GSS database up until the point where each state's STT data are deemed reliable, and then using data from the STT programs beginning in the specific years listed below for each Gulf state.



(where RT refers to a "research track" stock assessment)

Texas
- GSS from 1960-2013

- STT from 2014-2022

Louisiana
- GSS from 1960-1999
- STT ticket from 2000-2022

Mississippi
- GSS from 1960-2015
- STT from 2016-2022

Alabama
- GS from 1960-2001
- STT from 2002-2022

Florida West Coast
- GSS from 1960-2001
- STT from 2002-2022

Issue:
Conversion factors: The GSMFC completed a study in 2020 to update the conversion factors used to transform weights for head-on versus headless shrimp landings for brown, white, and pink shrimp landed in the Gulf of Mexico (GSMFC 2023). The Commercial Landings and Effort Workgroup discussed the suitability of using the new conversion factors for all non-whole shrimp landings and to determine the time periods when these conversions should be applied (percent changes between conversion factors for each species are presented in Table 1). The discussion centered on the question of whether there was an actual biological change over time in the whole weight to heads off ratio for the three Penaeid species, or whether these were simply better measurements of the "true" conversion factors. The former would favor an approach where the conversion factors are "phased in" over the time period, whereas the latter would support adopting the newer time conversion factors for the entire time series. The Workgroup originally recommended adopting the new conversion factors for the entire landings time series, 1960-2022.

However, in subsequent discussions it was realized that when applying the new conversion factors, the entire "heads-off" dataset, regardless of original condition type, was converted to "heads-on" and back to "heads-off", unnecessarily introducing error to the data originally landed "heads-off". Therefore, SEFSC needed to determine which of the shrimp landings had actually been converted and which were originally reported as "heads-off". Upon a close examination of the data, identifying the original condition type of the landings became problematic for the early portion of the time series (1960-1983), where some mixed condition type landings had been converted and stored as a single value, not allowing these data to be converted back to their original units. Beginning in 1984, SEFSC were able to reliably determine the original condition of landing from the GSS and STT data. Therefore, the original recommendation was modified to begin the use of the new GSMFC conversion factors beginning in 1984. Only landings originally reported in heads-on weight needed to be revised. Those already reported in heads-off weight were not adjusted.

Revised Recommendation (May 2024 webinar):

The Workgroup recommends providing final landings data that utilizes the revised GSMFC conversion factors for shrimp landings reported in "heads-on" weight for the portion of the time series (1984-2022) where it could be reliably determined if the landing amount had been converted from heads-on to heads-off.

Issue:

Stock boundary: Historically, area reporting under the GSS did not exactly conform to the boundary between the Gulf of Mexico Fishery Management Council and the South Atlantic Fishery Management Council (SAFMC). Refer to Working Paper 6 (Atkinson et al 2024) for a detailed examination of this issue. The GSS included all shrimp caught in Areas 1-21, which includes small areas under SAFMC jurisdiction. For consistency with GSS and previous assessments and amendments, and due to inconsistency in area reporting under Florida trip tickets in the Florida Keys, the recommendation was to include all shrimp caught in Areas 1-21 and the Panel concurred with this recommendation at the May 2024 webinar.

Recommendation (May 2024 webinar):

The Workgroup recommends including all shrimp caught in Areas 1-21.

Data processing steps discussed at the Post-Data Workshop Webinars:

SEDAR 87 Working Paper 6 (Atkinson et al. 2024) provides additional details regarding data processing steps that were undertaken between the Data Workshop and the post-Data Workshop webinars.

Data aggregation: The details of the data aggregation procedures outlined during the Data Scoping call are described below.

- Fishing areas 1-21 were aggregated into three areas where areas 1-10, 11-17, and 18-21 were combined.
- Landings were categorized by inshore and offshore using definitions used in the Dettloff (2023) effort algorithm.
- Shrimp market sizes were grouped into three "market size bins" of small (more than 67 shrimp tails per pound), medium (between 31 and 67 shrimp tails per pound), and large (fewer than 31 shrimp tails per pound). Eight industry standard size bins (Table 2) were aggregated into these three bins.
- Landings were aggregated into three seasons, January to April (JFMA), May to August (MJJA), and September to December (SOND).

Imputation of missing data: Missing values for value, area, and market size bins were imputed using procedures outlined in the SEDAR 87 Working Paper 6 (Atkinson et al. 2024).

Recommendation (May 2024 webinar):

The Workgroup recommends using the landings dataset that includes all modifications discussed above. Landings by year for 1960-2022 are summarized in Table 3.

Characterization of uncertainty: SEDAR 87 Working Paper 6 (Atkinson et al. 2024) presents uncertainty estimates by state and time period, where data compiled by NMFS Headquarters (pre-1984) is assigned a 20 percent uncertainty estimate, post-1984 GSS data is assigned a 10 percent uncertainty, and STT data is assigned 5 percent uncertainty. This is meant to reflect the maturity of the STT programs.

2.8 MAPS

Figures 2 and 3 below are examples of maps generated for the effort and landings. For a complete set of these figures for 1960-2022, please refer to SEDAR 87 Working Paper 16 (Williams 2024).

2.9 COMMENTS ON ADEQUACY OF DATA FOR ANALYSIS

The effort estimates described here are only as good as the data they depend on. Figure 4 below demonstrates the time series of species-specific effort estimates grouped by historical area. Even with the advantage of fine-scale cELB pings, incomplete data (e.g., boxes not functioning or not turned on for complete trips) or missing/inaccurate landings reports have the potential to create bias in estimates. Because data collection from 2021 to present has been dependent on the receipt of physical memory chips twice annually, this creates additional potential for incomplete vessel position data to be received, thereby potentially biasing effort estimates downward. Figure 5 illustrates a decline in the proportion of overall landings covered by vessels with cELB units in recent years.

Completely missing chips are not necessarily a problem in terms of bias, because if there are no landings associated with them, it is assumed they did not fish, and if there are landings associated with them those landings will contribute to the scaling of the total effort estimate as if they were a vessel that did not have a chip. The twice per year retrieval becomes a problem only if partial-year data is received, since the corresponding vessel would be considered an "ELB" vessel in terms of the landings' scalar, but potentially only half of their actual effort is being scaled. This problem is mitigated in the latest version of the effort estimation program by accounting for vessels that report landings for the entire year but only effort for one half of the year and adjusting the scalars accordingly. An updated version of the working paper which details this change (Dettloff 2024) will be submitted.

Additionally, the new effort estimation method is strongly dependent on the other assumptions outlined in the working paper, including representativeness of vessels with cELB units both in terms of spatial fishing behavior and CPUE. It is uncertain whether these assumptions are satisfied through time given the static selection of vessels that were required to use a cELB (selection completed in 2014 and not subsequently updated). Limitations with estimating inshore effort were discussed. But since we do not have an inshore survey, we are limited to assuming there is no difference between inshore and offshore CPUE, and applying the offshore CPUEs to inshore landings to estimate inshore effort.

Landings estimates recommended here are based on the best information available, and the assumptions and decisions outlined in this document are more fully elaborated in SEDAR 87 Working Paper 6. The SEFSC plans to continue its investigation of the historical data collection, compilation, and analysis processes in hopes of resolving remaining differences between the different data streams, including unresolved differences in pink shrimp landings between the SEDAR 87 dataset and previously published estimates, as detailed in Working Paper 6. This historical data reconciliation process has been hindered by the lack of sufficient documentation and staff turnover, but we plan to continue these efforts. It should be noted that perfect correspondence should not be expected, and thus we have carefully laid out the rationale for the decisions made. Going forward we expect to use the standard methodology outlined here.

2.10 RESEARCH RECOMMENDATIONS

- Continue investigations into the methodology of the GSS to better understand differences between GSS and STT programs where they overlap.
- Improve effort data collection for inshore shrimping trips.
- Develop a method to quantify under-reporting of landings in the shrimp fishery, perhaps through the use of separate socio-economic surveys.
- Quantify the prevalence of misidentification of "hopper" brown shrimp within each Gulf state.
- Continue investigations into estimation of species-specific effort.

2.11 LITERATURE CITED

Atkinson, S., Lowther, A., Dettloff, K., Smith, S. 2024. Gulf of Mexico Commercial Brown, Pink and White Shrimp Landings. SEDAR87-DW-06. SEDAR, North Charleston, SC. 38 pp.

Dettloff, K. 2023. Estimation of Commercial Shrimp Effort in the Gulf of Mexico. SEDAR87-DW-01. SEDAR, North Charleston, SC. 23 pp.

Fissel, B, Kitts, A., Dalton, M., Kosaka, R., Krigbaum, M., Marvasti, A., Squires, D., Thunberg, E., Travis, M., and Walden, J. 2023. Characteristics of the U.S. Seafood Trade Deficit. Marine Fisheries Review, 84(1-2), p. 1-60.

GSMFC. 2023. Final Report: U.S. Gulf of Mexico Commercial Shrimp Conversion Factors Validation 2020. SEDAR87-RD-09. SEDAR, North Charleston, SC. 11 pp.

Lowther, A. 2023. Shrimp Import Data. SEDAR87-DW-10. SEDAR, North Charleston, SC. 2 pp.

Lowther, A. 2023. Summary of the Gulf of Mexico Shrimp Effort Data Collection. SEDAR87-DW-14. SEDAR, North Charleston, SC. 5 pp.

Nance, J.M., E.F. Klima, and T.E. Czapla 1989. Gulf of Mexico Shrimp Stock Assessment Workshop. NOAA Technical Memorandum, NMFS-SEFC-239.

Nichols, S. 1984. Updated Assessments of Brown, White, and Pink Shrimp in the U.S. Gulf of Mexico. NMFS-SEFSC SAW/84/SHR/2. 28 pp.

Smith, R., Lowther, A., Williams, J. 2023. Commercial Landings of Gulf of Mexico Shrimp from Self-Reported Landings Survey 2005-2020. SEDAR87-DW-03. SEDAR, Miami, FL. 11 pp.

Smith, R., Lowther, A., Williams, J. 2023. Vessel and Gear Characterization of Gulf of Mexico Shrimp Self-Reported Survey 2005-2020. SEDAR87-DW-04. SEDAR, Miami, FL. 26 pp.

2.12 TABLES

Table 1. The previously used conversion factor compared to the 2020 conversion factor recommended by the Gulf States Marine Fisheries Commission (GSMFC). These conversion factors convert heads-off weight to heads-on weight for brown, pink, and white shrimp.

Species	Old Factor	New GSMFC Factor	Percent Change
Brown shrimp	1.61	1.548	-3.9%
White shrimp	1.54	1.568	1.8%
Pink shrimp	1.60	1.565	-2.2%

Table 2. Size code categories used by the Industry from 1963-1983.

SIZE CODE	SIZE 1/SIZE2
1	01/14
2	15/20
3	21/25
4	26/30
5	31/40
6	41/50
7	51/66
8	>67

Table 3. Gulf of Mexico annual landings (1960-2022) of brown, pink, and white shrimp (heads-off pounds).

Year	Brown Shrimp	Pink Shrimp	White Shrimp
1960	61,787,343	20,658,592	28,128,567
1961	29,337,308	9,457,389	13,286,812
1962	26,620,055	15,329,969	18,376,826
1963	44,595,570	17,998,991	37,911,412
1964	33,170,644	20,986,099	35,949,464
1965	49,586,453	14,106,139	26,353,833
1966	50,881,790	12,986,068	23,698,216
1967	83,993,526	8,972,168	19,877,150
1968	63,881,322	10,168,061	26,363,949
1969	56,516,843	9,891,776	39,441,753
1970	68,679,925	11,929,699	40,579,303
1971	75,525,205	10,124,270	38,176,369
1972	75,945,771	10,811,607	32,809,222
1973	47,873,467	13,992,645	30,722,335
1974	50,759,468	14,374,393	26,874,478
1975	48,279,340	13,747,431	25,742,846
1976	77,863,267	13,021,513	36,518,116
1977	96,919,453	16,204,603	46,209,815
1978	87,508,037	16,011,393	48,036,180
1979	71,403,312	13,846,691	34,856,133
1980	68,269,927	12,877,492	42,705,545
1981	99,508,484	18,773,126	46,108,156
1982	74,804,488	11,644,028	39,219,608
1983	61,352,577	12,628,671	42,189,194
1984	82,204,088	14,698,527	55,958,235
1985	87,155,338	15,930,980	58,854,018
1986	100,564,407	11,723,343	70,052,138
1987	94,070,956	10,486,082	52,833,598
1988	82,840,325	9,135,939	44,638,937
1989	96,348,265	8,622,144	36,117,305
1990	105,912,096	7,454,083	43,701,940
1991	89,467,559	6,790,159	45,244,280
1992	70,831,209	6,341,170	47,342,282
1993	69,832,922	9,488,603	38,577,835
1994	68,881,037	10,088,773	45,334,632
1995	78,839,517	14,058,321	48,662,618
1996	76,339,327	19,341,126	35,430,587
1997	68,274,442	12,688,112	38,566,210
1998	81,615,721	17,164,094	54,187,635
1999	83,684,364	8,029,582	54,098,203
2000	98,932,949	7,447,382	70,635,889
2001	91,692,069	9,697,033	53,882,461
2002	77,478,385	8,055,429	52,647,979

2003	87,295,206	8,072,700	60,080,446
2004	76,981,943	8,613,703	66,674,049
2005	60,218,104	7,270,807	63,825,452

Table 3. Continued

Year	Brown Shrimp	Pink Shrimp	White Shrimp
2006	90,114,767	6,474,199	85,117,985
2007	73,833,069	3,461,935	65,033,011
2008	52,776,230	4,874,778	64,908,634
2009	77,549,679	4,028,248	73,683,853
2010	45,815,047	5,434,330	57,987,614
2011	74,496,273	4,551,515	56,981,681
2012	66,147,560	3,829,903	66,355,424
2013	67,611,609	4,029,532	55,550,691
2014	68,075,256	6,404,250	60,054,484
2015	64,960,821	5,536,597	53,687,668
2016	49,575,404	5,243,166	69,073,085
2017	57,019,097	11,394,487	68,765,459
2018	71,207,036	12,989,394	51,608,632
2019	41,008,599	7,755,248	65,769,998
2020	41,602,300	7,729,692	58,843,276
2021	43,048,733	7,930,843	62,806,461
2022	32,461,721	9,975,079	68,189,356

2.13 FIGURES

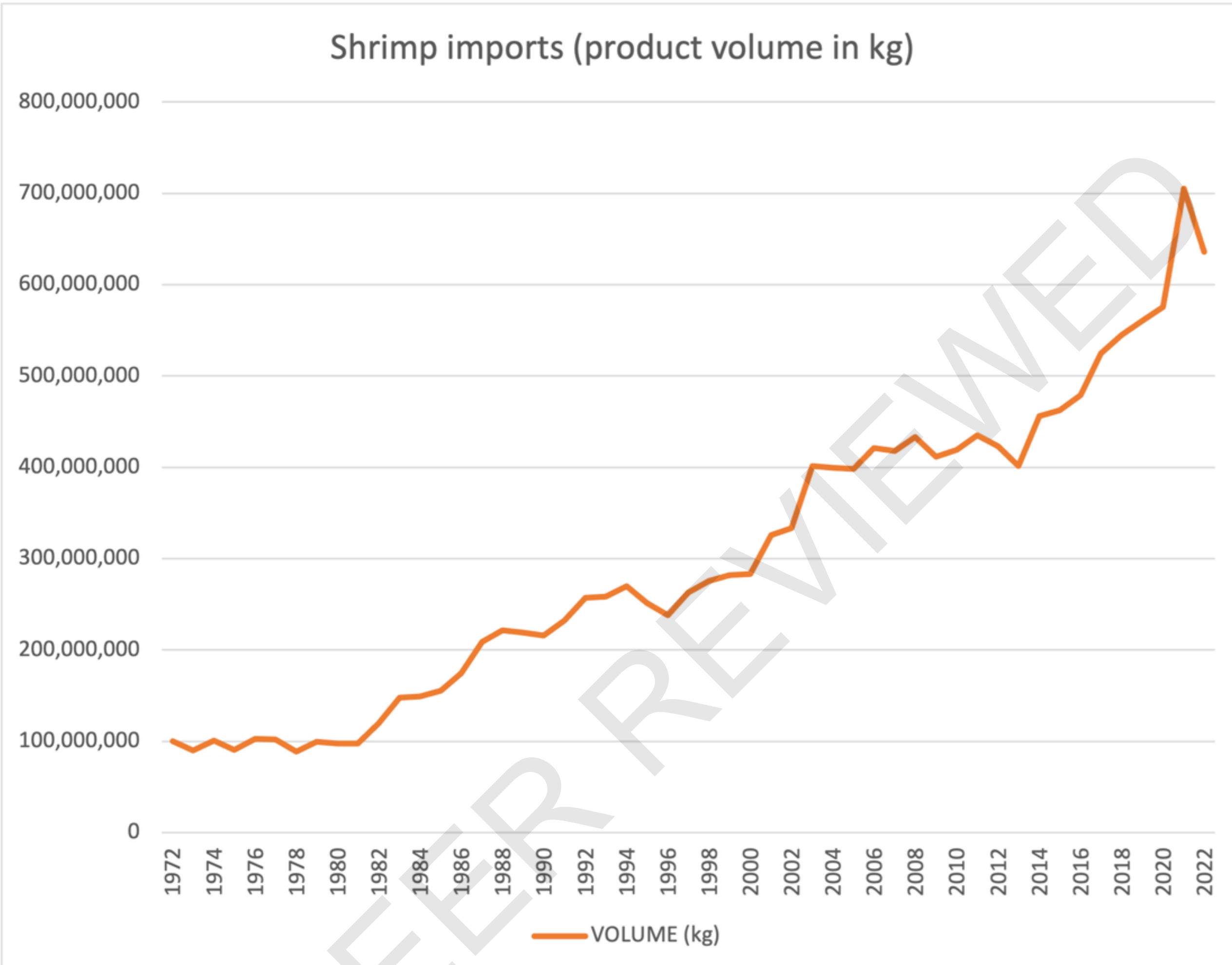


Figure 1. Total kg of shrimp imports, 1972-2022.

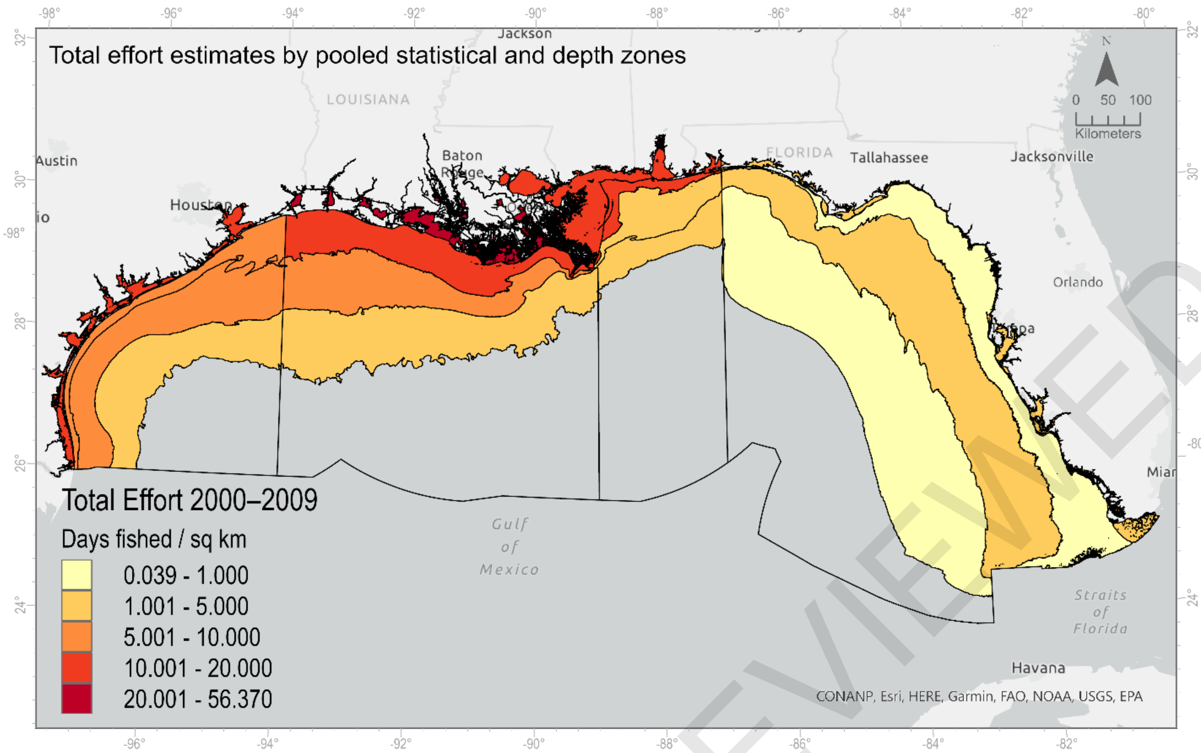


Figure 2. Total effort estimates for aggregated statistical and depth zones, 2000-2009 (Figure 31 in WP-16).

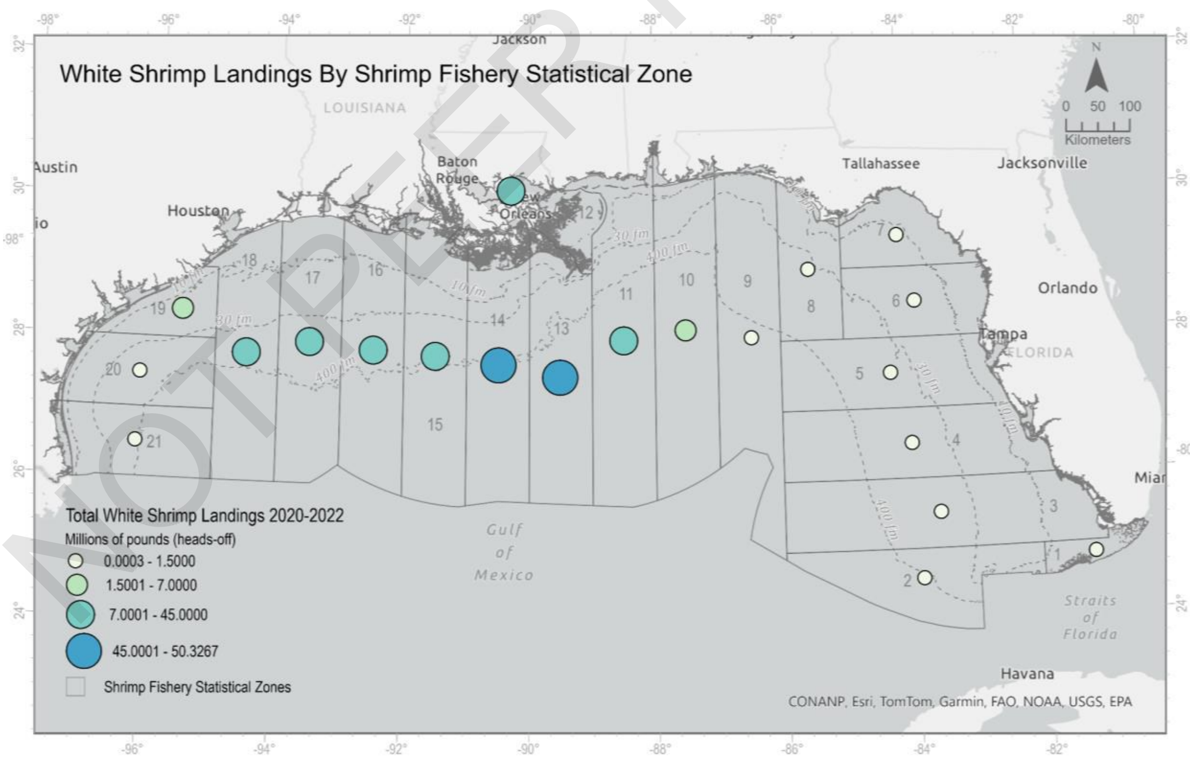


Figure 3. Total heads-off pounds landed of white shrimp in the U.S. Gulf of Mexico from 2020-2022, by statistical zone (Figure 52 in WP-16).

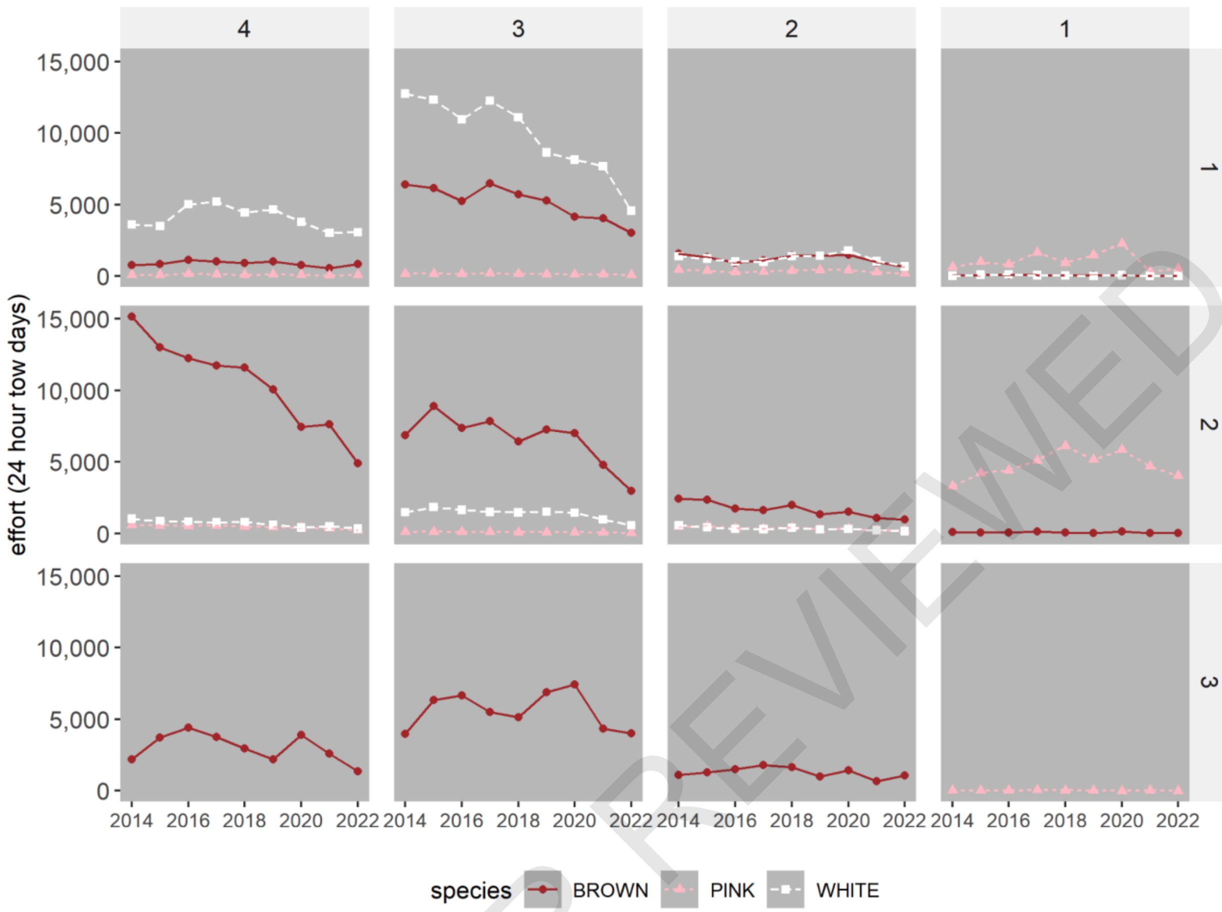


Figure 4. Time series of species-specific effort estimates grouped by historical area (horizontal axis, 1 = stat zones 1-9, 2 = 10-12, 3 = 13-17, 4 = 18-21) and depth zone (vertical axis; 1 = 0-10 fm, 2 = 10-30 fm, 3 = 30+ fm).

Figure 5. cELB coverage of offshore Penaeid landings by stratum over time as of November 2023. Panels represent areas and lines represent quadrimesters.

3 ENVIRONMENTAL DRIVERS/INDUSTRY REPORT

3.1 OVERVIEW

3.1.1 Group Membership

Cassidy Peterson, Holden Harris, Don Behringer, Mandy Karnauskas, Kevin Craig, Matt McPherson, and Jim Nance.

3.2 TERM OF REEFERENCE 3

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

We held a listening session for industry and state representatives on Wednesday, September 20, 2023. The goal of the listening session was: "to generate local ecological knowledge on the Gulf of Mexico shrimp fishery." The meeting objectives were as follows:

Listening Session Objectives:

- Obtain an oral history of the Gulf of Mexico shrimp fishery to inform the ongoing SEDAR87 Research Track Assessment (see also https://voices.nmfs.noaa.gov/search?search_api_fulltext=shrimp)
- Identify stakeholder-defined conceptual management objectives
- Identify uncertainties that might impact our ability to understand the fishery or stock
- Obtain stakeholder feedback on management approaches that would be successful for this fishery
- Collect local ecological knowledge for shrimp and associated fishery
- Identify drivers that impact the stock and fishery
- Inform a conceptual map/model that describes the stock and fishery

This is the first in a series of planned listening sessions to occur in 2024. The primary drivers impacting the shrimp fishery identified at the session were:

1. Increased importing. The large amount of farmed shrimp imports is driving down the cost of locally caught wild shrimp, and this substantially decreases the profitability of fishing.
2. Increased operating costs. The primary driver identified was the increased cost of diesel fuel. Increased labor costs were also discussed.
3. Habitat availability and environmental quality. Shrimp are impacted by freshwater input, which is changing along the coast as estuaries are replumbed and other water management protocols change.

Following the remaining listening sessions, a conceptual map will be generated to summarize the factors that impact shrimp in the Gulf of Mexico.

3.3 TERM OF REFERENCE 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.

3.3.1 Life history and seasonality

Penaeid shrimp in the Gulf of Mexico are a short-lived species whose productivity is largely environmentally driven. Brown, white, and pink shrimp follow a similar ontogeny wherein adults spawn offshore, and their planktonic larvae disperse into nearshore estuarine habitat. This nearshore marsh habitat serves as a nursery area for several months until the subadults migrate offshore (**Fig. 1**). Because of this life history, there is a particularly weak relationship between the number of adult spawners and the number of postlarvae that enter the estuary. It is consequently proposed that the juvenile and subadult life stages, wherein shrimp reside within nearshore estuarine habitats, are the stages in which density dependence occurs. Notably, these are also the areas in which environmental drivers of shrimp have been primarily studied; much less is known about how environmental drivers impact shrimp in federal waters. *Therefore, we propose that the environmental drivers that will have the greatest impact on brown, white, and pink shrimp productivity will be from the nearshore environmental conditions that impact the juvenile and subadult life stages.*

Species-specific environmental preferences shape habitat utilization in the Gulf of Mexico (**Fig. 2**, **Fig. 3**, Table 1; e.g., Turner and Brody 1983, see discussion throughout). Pink shrimp, for example, are relatively more tropical and generally inhabit saline waters with sandy bottoms; their distribution is largely concentrated in coastal Florida and southern Texas in waters from 0 to approximately 70 m (Renfro and Brusher 1982; pers. comm. J. Nance, NOAA Fisheries, james.m.nance@noaa.gov). Adult pink shrimp bury in bottom substrate during the day in salty offshore waters, and smaller pink shrimp that overwinter within estuaries bury themselves in colder temperatures for protection. Adult white shrimp prefer fresher waters and inhabit coastal waters. White shrimp are in the same region as brown shrimp, but are in relatively fresher (less saline) and shallower waters of 0 to about 35 m; (Renfro and Brusher 1982; pers. comm. J. Nance). Adult brown shrimp appear to have broader environmental tolerances and inhabit intermediate salinity and relatively deeper depths (27 - 73 m, up to 183 m; J. Nance). Like white shrimp, adult brown shrimp inhabit muddy bottoms, primarily residing along the northwest edge of the Gulf of Mexico (**Fig. 2**). Adult brown shrimp were found to be more abundant at shallower depths (14-27 m) in the summer and early fall, and deeper (≥ 46 m) in the fall and winter (Renfro and Brusher 1982). Adult brown shrimp bury during the day and swim into the water column at night, while adult white shrimp are present in the water column during the day; this leads to differential fishery targeting practices by species, despite the spatial overlap in habitat.

For the juveniles and subadults, seasonal estuary residence times differ by species (**Table 2**). Brown shrimp are harvested all year and reportedly spawn year-round with peaks in the winter (December - January, J. Nance; late winter along the northwest coast of Florida, Christmas and Eztold 1977), fall (October-December, Cook and Lindner, 1970; September-November in the northwest Gulf of Mexico; Temple and Fischer 1968), and/or in the spring and summer (May and September, Renfro and Brusher 1982; March - May, Cook and Lindner 1970; fisheries.noaa.gov/species/brown-shrimp). Brown shrimp spawning activity appears to be depth-dependent (Cook and Lindner 1970). Renfro and Brusher (1982) reported that spawning occurs year-round at deeper depths (64-110 m) and peaks during late spring and in the fall at shallower depths (27-46 m). Brown shrimp enter estuaries in the spring (February - March, J. Nance, fisheries.noaa.gov/species/brown-shrimp) peaking in March - May in Galveston Bay, Baxter 1966; Baxter and Renfro 1967) or late winter-to-spring (Christmas and Eztold 1977; January-June with peaks from February-April in Louisiana; George 1962; Gaidry and White 1973; White and Boudreaux 1977). Juveniles utilize tidal wetlands as nurseries from March - November for approximately two months (Zimmerman and Nance 2000). Brown shrimp reportedly emigrate from inshore nursery areas in late spring (e.g., May, Renfro and Brusher 1982; J. Nance). As such, *spring environmental drivers have historically shown to have the greatest impact on brown shrimp abundance and productivity*. Li and Clarke (2005) found that brown shrimp abundance was positively correlated with April - May sea surface temperature averaged across the continental shelf.

White shrimp spawn in the spring spanning through the fall (March - April, J. Nance; March - September; fisheries.noaa.gov/species/white-shrimp; April - October with a peak in May - June, Renfro and Brusher 1982; March - November with a peak in June - July, Lindner and Anderson 1965; April - August, Temple and Fischer 1968; as early as February to as late as October, Bryan and Cody 1975), with a peak in June - July corresponding to warm water temperatures (Bryan and Cody 1975; Lindner and Anderson 1956). They enter estuaries in the summer (July - August, J. Nance; April - early May, fisheries.noaa.gov/species/white-shrimp) before emigrating back offshore in the fall as water temperature declines (September - November, J. Nance; September-December, Lindner and Cook 1970; Renfro and Brusher 1982). Juveniles inhabit nursery areas from May - November (Zimmerman and Nance 2000) and are most abundant in nurseries in Louisiana from June - September (Gaidry and White 1973). *Estuarine conditions in late summer and early fall are thus most likely to impact white shrimp abundance and productivity.*

Pink shrimp are located in more tropical conditions and spawn throughout the year, with spawning peaking in spring or summer in the warmest months (April - July; Christmas and Eztold 1977, fisheries.noaa.gov/species/pink-shrimp). Juvenile and subadult pink shrimp then primarily inhabit estuarine nursery areas from summer (June - October; Costello et al. 1986) through the winter and emigrate offshore in the spring (Christmas and Eztold 1977; fisheries.noaa.gov/species/pink-shrimp). Early recruits emigrate in the fall and later recruits overwinter in estuaries and migrate offshore in the spring (Copy of Brown, white, pink life history.pptx). Criales et al. (2015) found through oceanographic transport modeling that larvae released during the summer months near Marquesas had the highest larval settlement rates, while winter settlement rates were five times lower. Thus, *estuarine conditions in summer through fall or winter will most likely impact pink shrimp abundance and productivity*.

3.3.2 Environmental drivers

We discussed potential environmental drivers that could impact penaeid shrimp within the context of several modeling frameworks:

- Vector Autoregressive Spatio-Temporal (VAST) modeling is a statistical framework used for analyzing spatio-temporal data, and will be used to estimate abundance, density, and distribution of species over space and time. VAST is particularly useful for fisheries and environmental science, since it can account for both observation and process error.
- Empirical Dynamic Modeling (EDM) includes a suite of non-parametric modeling methods for analyzing time series data based on state-space reconstruction for modeling complex, nonlinear dynamic systems in ecology.
- Bayesian frameworks, including JABBA (Just Another Bayesian Biomass Assessment), may be used to assess the biomass of population stocks over time in situations where traditional, data-intensive stock assessment methods are not feasible due to the scarcity of data.

The mechanisms driving the relationships between environmental conditions and larval/postlarval/juvenile shrimp population dynamics are poorly understood, and even less so for adult shrimp. Environmental drivers have been suggested to influence migratory and nursery emigration patterns, growth, spawning behavior, catchability, and we discuss these mechanistic hypotheses throughout. Consequently, we prioritize and identify relatively easily measurable variables that may correlate with shrimp productivity. While the relative importance of each environmental driver may vary by species, we highlight that the temporal period over which the environmental variable is summarized or collected may have a greater impact on the strength of the resulting relationship. *Further analyses, like general additive modeling, are likely required to identify which environmental drivers most influence each shrimp species.* We reference Turner and Brody (1983) for habitat suitability indices for postlarval and juvenile life stages of white and brown shrimp in estuarine nurseries. We note that environmental relationships are often correlated with space and thus environmental covariates may explain little additional variability in the data when added to spatial variables within a model (e.g., VAST).

There is a distinction between environmental drivers affecting species distribution and catchability and those impacting stock abundance and productivity. The VAST modeling framework can distinguish between covariates influencing catchability versus those that impact habitat. For EDM and JABBA models, it is likely more meaningful to identify drivers that will impact stock productivity and abundance. For surplus production models (e.g., JABBA), the likely mechanism for incorporating environmental drivers would be through a time-varying population growth rate and/or time-varying carrying capacity (Thiaw et al 2009). While meaningful correlations between environmental drivers and stock productivity can be observed at a point in time, it is important to consider that the environment is nonstationary and that these relationships may change over time.

When discussing available data, we considered the spatiotemporal scale of available data and whether the data could be hindcasted and forecasted. We prepared two tables to summarize available data from myriad sources. **Table 3** identifies online data portals with relevant environmental data, and **Table 4** details fisheries independent monitoring programs from federal and Gulf states natural resource agencies.

3.3.3 Salinity

Each shrimp species has a slightly different salinity preference, and accordingly, changes in salinity will have species-specific effects (**Figure 3**). Juvenile brown shrimp were found to be most abundant in estuaries where salinity ranged from 10-20 ppt, and accordingly, Gunter et al. (1964) hypothesized that salinity would be a key environmental driver for brown shrimp. White shrimp have been shown to inhabit a wide range of salinities ranging from <1 ppt to >40 ppt (https://www.fao.org/3/ac765t/AC765T13.htm), and Gunter et al. (1964) reported that white shrimp prefer salinities less than 10 ppt. Gunter and Edwards (https://www.fao.org/3/ac741t/AC741T20.htm) reported a significant positive correlation between 2-year lagged annual rainfall and white shrimp catch in Texas, suggesting that rainfall could be a key driver of shrimp abundance.

For brown shrimp, which prefer higher salinity, extreme rain events that result in low-salinity estuary conditions will likely negatively affect their populations. These rain events may cause cohorts of sub-adult shrimp to “flush out” of estuaries early and result in higher natural mortality rates, both from lower salinity tolerance and increased predation offshore. These early emigrations following large freshwater inflows have been observed in North Carolina (Hunt et al. 1980; Jones and Sholar 1981, Laney and Copeland 1981). Freshwater diversions may also affect the ability of juvenile brown shrimp to feed and thus growth rates and survival (Rozas and Minello 2011). It is notable that salinity in some areas (as well as other environmental conditions) can be dramatically altered due to large-scale environmental engineering projects—in particular, the recent and planned diversions of the Mississippi River (https://www.wired.com/story/the-controversial-plan-to-unleash-the-mississippi-river/). It's also hypothesized that the recent large-scale environmental engineering changes in the Everglades and Florida Bay have resulted in higher salinity and driven increased catch rates of pink shrimp (Browder and Robblee 2009). Salinity has been proposed to be an important driver of recruitment in pink shrimp (Criales et al. 2015).

Salinity is a relatively easily measurable variable and correlates with many other environmental conditions, including precipitation, river discharge, and variations in mixed layer depth. Data sources for monitoring salinity include measures for precipitation, river discharge, inshore sampling, and ocean modeling products. Precipitation records are available from NOAA National Marine Weather Service climate data products (e.g., for coastal Texas, weather.gov/wrh/climate?wfo=hgx). The RC4USCoast data set provides monthly time series as well as long-term averaged monthly climatological patterns for twenty-one variables, including alkalinity and dissolved inorganic carbon concentration. Surface, bottom, and averaged daily spatial-temporal salinity data is available from HYCOM (SEDAR87-DW-09). The HYCOM (Hybrid Coordinate Ocean Model; hycom.org) is a numerical ocean model that integrates satellite observations, in situ measurements, and oceanographic data to simulate and forecast ocean currents, temperature, salinity, and other oceanographic variables with high spatial and temporal resolution. Although HYCOM boasts high spatial and temporal resolutions, the model might not capture high resolution freshwater inputs, such as from the Mississippi River, to accurately represent freshwater plumes. State sampling programs typically collect data on salinity (**Table 4**), or states may collect salinity through local environmental monitoring programs.

3.3.4 Temperature

Extreme temperatures in estuary conditions can impact behavior and mortality rates of shrimp. For inshore post-larval shrimps, temperatures approximately 15°C mark their lower tolerance limit. Prolonged exposure to low temperatures reduces feeding and growth rates, which can potentially cause mortality in severe events (J. Nance). A lower bound on temperature preference for brown and white shrimp of approximately 15°C/59°F was observed in estuaries and the lab (Venkataramaiah 1971). Temperatures below 4.4°C and above 32.2°C can cause mass mortality and/or physiological stress (Gunter and Hildebrand 1951 and Kutkuhn 1966, respectively). Temperature has also been shown or hypothesized to influence individual growth rate (Christmas and Eztold 1977 and references therein), spawning activity (Linder and Anderson 1956; Perez-Farfante 1969), recruitment (Baxter and Renfro 1967). Conversely, elevated temperatures can result in reduced oxygen levels, cause direct temperature stress, increase consumption rates, and facilitate proliferation of certain pathogens and diseases. Temperature (**Figure 3**) may thus be correlated with other meaningful variables (e.g., disease) that are challenging to monitor. Li and

Clarke (2005) found links between annual sea surface temperature during April and May and brown shrimp abundance in Alabama, Mississippi, Louisiana, and Texas.

Data sources for temperature include water quality measurements from all of the Gulf states' inshore sampling programs (**Table 4**) and ocean modeling products. HYCOM derived bottom seawater temperature is available and viewable at the following repository links: high-resolution and processed low-resolution (SEDAR87-DW-09).

3.3.5 Dissolved oxygen

White and brown shrimp both inhabit areas affected by the Gulf of Mexico hypoxic zone. Changes in dissolved oxygen (DO) may affect the distribution, migration, and catchability of early life stages (megalopae and juveniles) within estuarine and nearshore habitats, as well as offshore adult populations, likely due to avoidance behavior (Zimmerman and Nance 2001). Reduced DO may further result in mechanistic impacts, including through increased mortality or reductions in growth and reproduction through impacts on shrimp metabolism and bioenergetics (Zimmerman and Nance 2001). Zimmerman and Nance (2001) reported a negative correlation between hypoxia and catch of brown shrimp, though this relationship was not significant for white shrimp, likely due to their lesser reliance on offshore habitat. Changes in DO are driven by changes in water temperature and biological metabolism throughout the water column (Kemp and Boynton 1980). The biological responses from DO reductions might not be instantaneous; rather, cumulative exposure can result in a lagged decrease in fishery landings (Huang et al. 2010). Considering the interaction between temperature, DO, and shrimp bioenergetics, it is important to carefully consider the relationship between environmental and shrimp monitoring data from FIM efforts in each of the GOM states.

Dissolved oxygen data can be obtained from nearshore state FIM sampling or other state coastal monitoring programs (**Table 4**). While this information is collected from the SEAMAP survey, these observations are made 1-2 m above the sea floor and may not be indicative of oxygen available for shrimp on the benthos. Overall, we consider that DO is relatively challenging to measure and cannot be spatially extrapolated with confidence.

3.3.6 Larval and postlarval transport

Shrimp eggs and larvae are dependent on atmospheric and oceanographic dynamics to ensure transport into the nursery estuaries (Criales et al. 2015; FAO Fish Synop). Inshore transport is driven by larval and postlarval behavior (e.g., diel vertical migration), flood tide transport, wind-forcing, storms, and marine inundations. Consequently, wind, current, and physical oceanographic processes may impact shrimp abundance and productivity.

Data sources to inform environmental indices for larval and postlarval transport include a hurricane index that calculates accumulated cyclone energy, tidal and wind records, and NOAA buoy data (**Table 3**).

3.3.7 Nutrients and primary production

Nutrient delivery into the estuary and near-shore marine environment drives the ecosystem's primary production. The three shrimp species represent relatively low-trophic groups in the marine food web, and may thus be controlled by bottom-up environmental and biological processes. Nutrient delivery is largely driven by river discharge into the Gulf of Mexico and interacts with other environmental variables such as dissolved oxygen, salinity, and temperature. The Mississippi River Basin contributes approximately 70-80% of the total nitrogen load and about 90% of the total phosphorus load to the Gulf of Mexico (Dunn 1996). High nutrient inputs are largely responsible for the seasonal hypoxia from nutrient-fueled algal blooms that, upon decomposition, consume available oxygen (Rabalais et al. 2022).

Sources for these data include river discharge from the RC4USCoast river chemistry dataset. Spatial-temporal maps for nutrients and primary production are readily available for this assessment from the MODIS satellite-based sensor that provides high-resolution oceanographic imaging available from 2003-2022 (SEDAR87-DW-09). Specifically, MODIS data is available for chlorophyll-a, normalized carbon fluorescence, and particulate organic carbon. GOM state monitoring programs also collect nearshore water quality data separately from their FIM survey programs that includes measures such as chlorophyll-a, turbidity, and light attenuation (**Table 4**).

3.3.8 Habitat quality and availability

Shrimp rely on marshes, mangroves, and seagrass beds as a nursery areas, which have been proposed as the environmental bottlenecks to shrimp productivity. These nursery habitats serve as sources of food and refuge from predators. Vegetation structure (spartina or mangrove) habitat increases post-larval settlement and production (Turner and Brody 1983 and references therein); some species may preferentially benefit from mangrove habitat due to the added complexity. Seagrass is particularly important for pink shrimp. Shrimp particularly benefit from marsh edge habitat (Minello et al. 1994), which increases and then decreases as marsh deteriorates or is physically broken through anthropogenic impacts. Further, substrate type may influence the distribution of shrimp, since substrate preferences vary by species (Turner and Brody 1983 and references therein).

Data to inform this driver includes the NOAA NERRs marsh elevation data (**Table 3**). Some states also collect this information (**Table 4**).

3.4 Episodic events

Episodic events may have meaningful impacts on the productivity of shrimp. For example, given the importance of physical oceanographic processes for larval transport and survival, it has been anecdotally reported that “the next year after hurricanes are the best catches,” suggesting that hurricanes may “stir up” or “flesh out” any nutrients or other physical water properties that impact shrimp. Hurricane activity may serve as a proxy for changes to winds, salinity, temperature, or other related environmental drivers that may impact larval transport (e.g., Criales et al. 2010). Other potentially influential events include red tide, oil spills, changes in state water management (e.g., Mississippi River diversions), disease outbreaks, and decadal climatic indices, such as the El Nino Southern Oscillation (ENSO).

Importantly, the timing of these events will strongly influence the magnitude of the impact felt on each species. For example, a strong rain event in April or May in Louisiana would significantly impact brown shrimp when juveniles and subadults inhabit estuaries. In contrast, an event of similar magnitude in June or July would have a significantly reduced impact on brown shrimp.

It may also be worth considering that any of the above-listed environmental drivers may not influence the distribution or productivity of shrimp until the driver hits a threshold level. For example, temperature may not impact shrimp below a maximum temperature, but if waters exceed a threshold temperature, the stock would be adversely impacted (e.g., see FAO Fish Synopses for brown, white, and pink shrimp). Preliminary exploratory analyses (e.g., GAMs) may be able to address the observation of environmental thresholds.

Information on these processes may come from the hurricane intensity index, Florida HAB monitoring index, state records on water management, or a climatic index (e.g., ENSO) (**Table 3**).

3.5 Inshore Environmental Data from Fisheries and State Water Quality Monitoring Programs

We inventoried environmental data collected by Gulf states and federal fisheries independent monitoring programs in **Table 4**. These sampling programs generally measure temperature and salinity (via conductivity). Most also measure turbidity and DO, and some measure pH. Habitat data is collected by the Florida and Texas monitoring programs. Acquiring the data generally requires directly contacting the resource management agent, and we detail information for the point of contact for each data set.

Sampling designs include random and fixed schemes. Stratified random sampling designs (Florida and Texas) are consistent with the assumptions of most statistical methodologies by allowing all sampling units a non-zero probability of being selected (Gruss et al. 2018). Fixed-station sampling methods (Alabama and Mississippi) visit the same locations repeatedly to track changes over time. Five Gulf-wide programs are conducted under SEAMAP and SEFSC, including summer/fall trawls, spring/summer/fall and annual longline surveys, and fall/spring plankton sampling.

It has been recommended that state fisheries independent monitoring surveys could be analyzed to identify the timing that small shrimp appear in coastal and estuarine waters. These areas and time periods should be prioritized for extracting meaningful environmental data that may impact the productivity of shrimp.

3.6 Environmental Drivers Conclusions

We highlight salinity or some metric of freshwater input as the primary or most influential environmental driver of overall productivity for all three shrimp species; secondarily, we propose exploring the impacts of temperature on shrimp dynamics. Both salinity and temperature were selected because of their link to habitat preferences and distribution, as well as their correlation with other potentially important processes (e.g., freshwater input) and the existence and ease of data accessibility, use, and manipulation to fit a variety of modeling structures.

We hypothesize that these drivers will have the greatest impact on shrimp while they inhabit their nearshore, estuarine nursery habitat, as this is where density dependence is expected to occur. We recommend that these drivers match shrimp usage temporally; in particular, brown, white, and pink shrimp environmental drivers should be measured from the spring, late summer and early fall, and summer through fall, respectively.

3.7 DATA GAPS AND ADDITIONAL RESEARCH RECOMMENDATIONS

We highlight data gaps and research recommendations that will improve understanding of environmental impacts on shrimp.

Updated life history information – Much of the life history obtained for shrimp was conducted in the 1960-1970s. Given the short generation time of shrimp, high environmental influence on productivity, and nonstationary environmental dynamics, life history dynamics have likely changed, and these parameters should be updated (e.g., SEDAR87-DW-05).

Density dependence - The suggestion to prioritize environmental impacts on the estuarine stages of shrimp relies on the assumption that this is the region in which density dependence occurs. Expert guidance has suggested that there is no relationship between post larvae entering the estuary and the number of spawning adults in the population (J Nance). While previous efforts suggest that density dependence occurs during estuary residence (e.g., Galveston Bay sub-adult survey to predict brown fishery dynamics for the upcoming year), further research to support this assumption would further validate the assumptions made herein.

Population connectivity models for brown and white shrimp – Research linking spawning adults to their nursery estuary may provide guidance on which estuarine habitats are most productive. Priority could then be given to these most influential nursery habitats for research and conservation.

Mechanistic environmental relationships – Hypothesized environmental drivers presented in this report are correlative only and do not attempt to identify the mechanistic relationship underlying these correlations. Further research identifying the exact driver and the organismal and stock-wide response to these drivers would improve this effort. Updated environmental relationships should be generated or explored.

State FIM data standardization - Additional research should be conducted to standardize and calibrate state-by-state surveys.

Role of shrimp as key forage species - As forage species, shrimp play a key role in the ecosystem. Additional research may clarify linkages between shrimp and predator species and better clarify the extent of predator-induced mortality (e.g., Fujiwara et al. 2016). These linkages may inform how these interrelated species should be managed from an ecosystem-based perspective.

3.8 LITERATURE CITED

Baxter, K. N. and W. C. Renfro, Seasonal occurrence and size distribution of postlarval brown and white shrimp near Galveston, Texas with notes on species identification, U.S. Fish Wildl. Serv., Fish. Bull., 66, 149-158, 1967.

Browder, J.A. and Robblee, M.B., 2009. Pink shrimp as an indicator for restoration of everglades ecosystems. Ecological Indicators, 9(6), pp.S17-S28.

Bryan, C. E. and T. J. Cody, A study of commercial shrimp, rock shrimp and potentially commercial finfish 1973-1975, in Part I. White Shrimp, *Penaeus setiferus* (Linn.), Spawning in the Gulf of Mexico off Texas Coast, Fish. Branch, Texas Parks and Wildl. Dept., P.L. 88- 309 Proj. 2-202-R:1-29, 1975.

Christmas, J. Y. and D. J. Etzold, The shrimp fishery of the Gulf of Mexico United States: a regional management plan. Tech. Rep. No. 2, Gulf Coast Research Laboratory, Ocean Springs, Mississippi, 1977.

Cook, H. L. and M. J. Lindner, Synopsis of biological data on the brown shrimp *Penaeus aztecus* Ives, 1891, FAO Fish. Rep. (57) 4, 1471-1497, 1970.

Costello, T. J., D. M. Allen, AND J. H. Hudson. 1986. Distribution, seasonal abundance, and ecology of juvenile northern pink shrimp, *Penaeus duorarum*, in the Florida Bay area. National Oceanic and Atmospheric Administration Technical Memorandum NMFS-SEFC-161. June 1986. United States Department of Commerce, Miami, Florida.

Criales, M.M., Cherubin, L.M. and Browder, J.A., 2015. Modeling larval transport and settlement of pink shrimp in South Florida: dynamics of behavior and tides. *Marine and Coastal Fisheries*, *7*(1), pp.148-176.

Criales, M.M., Robblee, M. B., Browder, J. A., Cardenas, H., and T. Jackson. 2010. Nearshore concentration of pink shrimp *Farfantepenaeus duorarum* postlarvae in northern Florida Bay in relation to the nocturnal flood tide. Bulletin of Marine Science 86: 51–72.

Dunn, D.D., 1996. Trends in nutrient inflows to the Gulf of Mexico from streams draining the conterminous United States, 1972-93 (Vol. 96, No. 4113). US Department of the Interior, US Geological Survey.

FAO Species Synopsis for Brown shrimp: https://www.fao.org/3/ac765t/AC765T14.htm

FAO Species Synopsis for Pink shrimp: https://www.fao.org/3/ac765t/AC765T15.htm

FAO Species Synopsis for White shrimp: https://www.fao.org/3/ac765t/AC765T13.htm

Fujiwara, M., Zhou, C., Acres, C., Martinez-Andrade, F. 2016. Interaction between Penaeid shrimp and fish populations in the Gulf of Mexico: importance of shrimp as forage species. PLoS ONE: 11(11): e0166479.

Gaidry, W.J., III, White C.J. 1973. Investigations of commercially important penaeid shrimp in Louisiana estuaries. La. Wildl. Fish. Comm. Tech. Bull. 8. 154 pp.

George, M.J. 1962. Preliminary observations of the recruitment of postlarvae and growth of juveniles of the brown shrimp, *Penaeus aztecus* Ives, in Barataria Bay. La. Wild. Fish. Comm. 9the Biennial Rep., 1960-1961: 160-163.

Grüss, A., Perryman, H.A., Babcock, E.A., Sagarese, S.R., Thorson, J.T., Ainsworth, C.H., Anderson, E.J., Brennan, K., Campbell, M.D., Christman, M.C. and Cross, S., 2018. Monitoring programs of the US Gulf of Mexico: inventory, development and use of a large monitoring database to map fish and invertebrate spatial distributions. *Reviews in Fish Biology and Fisheries*, 28, pp.667-691.

Gunter, G., J.Y. Christmas and R.K. Killebrew, 1964 Some relations of salinity to population distributions of motile estuarine organisms, with special reference to penaeid shrimp. Ecology, 45(1):181–5

Gunter, G. and H.H. Hildebrand, 1954 The relation of total rainfall of the State and catch on the marine shrimp (*Penaeus setiferus*) in Texas waters. Bull.mar.Sci. Gulf Caribb., 4(2):95–103

Gunter, G., Edwards, J.C. 1969. The relation of rainfall and fresh water drainage to the production of penaeid shrimp (*Penaeus flubiatilis* Say and *Penaeus aztecus* Ives) in Texas and Louisiana waters. FAO Fish. Rep. 57: 875-892.

Harris, H. 2023. Gulf of Mexico Spatial-Temporal Environmental Data. SEDAR87-DW-09. SEDAR, North Charleston, SC. 8 pp.

Hunt, J.H., Carroll, R.J., Chinchilli, V., Frankenburg, D. 1980. Relationship between environmental factors and brown shrimp production in Pamlico Sound, North Carolina. N.C. Dep. Nat. Resour. Comm. Devel., Div. Mar. Fish., Spec. Sci. Rep. 33: 1-29.

Huang, L., Smith, M.D. and Craig, J.K., 2010. Quantifying the economic effects of hypoxia on a fishery for brown shrimp *Farfantepenaeus aztecus*. Marine and Coastal Fisheries, 2(1), pp.232-248.

Kemp, W.M. and Boynton, W.R., 1980. Influence of biological and physical processes on dissolved oxygen dynamics in an estuarine system: Implications for measurement of community metabolism. Estuarine and Coastal Marine Science, 11(4), pp.407-431.

Jones, R.A., Sholar, T.M. 1981. The effects of freshwater discharge on estuarine nursery areas of Pamlico Sound, North Carolina. N.C. Dep. Nat. Resour. Comm. Devel., Div. Mar. Fish., Completion Rep., Proj. CEIP 79-11. 60 pp.

Kesner-Reyes, K., Segschneider, J., Garilao, C., Schneider, B., Rius-Barile, J., Kaschner, K., & Froese, R. (2019, October). AquaMaps Environmental Dataset: Half-Degree Cells Authority File (HCAF ver.7, 10/2019). Retrieved from https://www.aquamaps.org/main/envt_data.php.

Kutkuhn, J.H. 1966. The role of estuaries in the development and perpetuation of commercial shrimp resources. Pp 16-36 in R.F. Smith, A.H. Swartz, and W. H. Massmann, eds. A symposium on estuarine fisheries. Am. Fish. Soc. Spec. Publ. 3.

Laney, R.W., Copeland, B.J. 1981. Population dynamics of penaeid shrimp in two North Carolina tidal creeks. Rep. 81-1 to Carolina Power and Light Company, Raleigh, N.C. 161 pp.

Li, J., Clarke, A.J. 2005. Sea surface temperature and the brown shrimp (*Farfantepenaeus aztecus*) population on the Alabama, Mississippi, Louisiana and Texas continental shelves. Estuar. Coast. Shelf Sci., 64: 261-266, 10.1016/j.ecss.2005.02.019

Lindner, M. J. and W.W. Anderson, Growth, migrations, spawning and size distribution of shrimp, *Penaeus setiferus*, U.S. Fish Wildl. Serv., Fish Bull., 106, 554-645, 1956.

Lindner, M. J. and H. L. Cook, Synopsis of biological data on the white shrimp *Penaeus setiferus* (Linn.), 1767, FAO Fish. Rep., 57, 1439-1469, 1970.

Minello, T.J., Zimmerman, R.J., Medina, R., 1994. The importance of edge for natant macrofauna in a created salt marsh. *Wetlands*, 14, pp. 184-198.

Ogburn, M.B., Criales, M.M., Thompson, R.T. and Browder, J.A., 2013. Endogenous swimming activity rhythms of postlarvae and juveniles of the penaeid shrimp *Farfantepenaeus aztecus, Farfantepenaeus duorarum*, and *Litopenaeus setiferus*. *Journal of Experimental Marine Biology and Ecology*, *440*, pp.149-155.

Palomares, M.L.D. and D. Pauly. Editors. 2023. SeaLifeBase. World Wide Web electronic publication. https://www.sealifebase.ca (11/2023).

Perez-Farfante, I. 1969. Western Atlantic shrimp of the genus *Penaeus*. U.S. Fish Wildl. Serv. Fish. Bull. 67: 461-591.

Rabalais, N.N., Turner, R.E. and Scavia, D., 2002. Beyond Science into Policy: Gulf of Mexico Hypoxia and the Mississippi River: Nutrient policy development for the Mississippi River watershed reflects the accumulated scientific evidence that the increase in nitrogen loading is the primary factor in the worsening of hypoxia in the northern Gulf of Mexico. BioScience, 52(2), pp.129-142.

Renfro, W.C., Brusher H.A. 1982. Seasonal Abundance, Size Distribution, and Spawning of Three Shrimps (*Penaeus aztecus, P. setiferus,* and *P. duorarum*) in the Northwestern Gulf ofMexico, 1961-1962. NOAA Technical Memorandum NMFS-SEFC-94. 47 pp.

Rozas, L.P., Minello, T.J. 2011. Variation in penaeid shrimp growth rates along an estuarine salinity gradient: implications for managing river diversions. J. Exp. Mar. Biol. Ecol., 397(2): 196-207.

Temple, R.F. and C.C. Fischer, 1968 Seasonal distribution and relative abundance of planktonic-stage shrimp (*Penaeus spp.*) in the northwestern Gulf of Mexico, 1961. Fishery Bull.U.S. Fish Wildl. Serv., 66(2):323–34

Thiaw, M., Gascuel, D., Jouffre, D., Thiaw, O.T., 2009. A surplus production model including environmental effects: Application to the Senegalese white shrimp stocks. *Progress in Oceanography*, 83, pp. 351-360.

Turner, R.E., Brody, M.S. 1983. Habitat suitability index models: northern Gulf of Mexico brown shrimp and white shrimp. U.S. Dept. of Int. Fish Wildl. Serv. FWS/0BS-82/10.54. 24pp.

Venkataramaiah, A. 1971. Study of the salinity relationship of the commercial shrimp (Family Penaeidae) in estuarine waters. Contract No. DACW39-71-C-008. (Prog. Rep. June 1971-August 1971). U.S. Army.

White, C.J., Boudreaux, C. J. 1977. Development of an areal management concept for gulf penaeid shrimp. La. Wildl. Fish. Comm. Tech. Bull. 22. 77 pp.

Zimmerman, R.J. and Nance, J.M. (2001). Effects of Hypoxia on the Shrimp Fishery of Louisiana and Texas. In Coastal Hypoxia: Consequences for Living Resources and Ecosystems (eds N.N. Rabalais and R.E. Turner). https://doi.org/10.1029/CE058p0293

3.9 TABLES

Table 1

Environmental preference data for brown, white, and pink shrimp. Preference parameters for depth, temperature, salinity, primary production, oxygen concentration, distance from land, and area bounding box are provided by AquaMaps (Kesner-Reyes et al. 2019) and SeaLifeBase (Palomares et al. 2023). Data were queried for the environmental envelope preferences, representing the absolute and preferred ranges. The absolute minima (first column) represents the minimum in extracted data or 25th percentile - 1.5 × interquartile (whichever is lesser). The preferred minima (second column) represents the 10th percentile of the observed variation in the environmental predictor, and the preferred maxima (third column) represents the 90th percentile. The absolute maxima (last column) represents the maximum in extracted data or 75th percentile + 1.5 × interquartile (whichever is greater).

Brown shrimp			
DepthMin (m)	DepthPrefMin (m)	DepthPrefMax (m)	DepthMax (m)
0	27	54	160
TempMin (°C)	TempPrefMin (°C)	TempPrefMax (°C)	TempMax (°C)
12.2	17.6	28.1	32.3
SalinityMin (ppt)	SalinityPrefMin (ppt)	SalinityPrefMax (ppt)	SalinityMax (ppt)
19	28.5	36.1	36.6
PrimProdMin (mgC·m^{-3}·day^{-1})	PrimProdPrefMin (mgC·m^{-3}·day^{-1})	PrimProdPrefMax (mgC·m^{-3}·day^{-1})	
0	0.5	18.8	
OxyMin (mmol·m^{-3})	OxyPrefMin (mmol·m^{-3})	OxyPrefMax (mmol·m^{-3})	OxyMax (mmol·m^{-3})
145.5	177.2	227.4	268.9
LandDistMin (km)	LandDistPrefMin (km)	LandDistPrefMax (km)	LandDistMax (km)
0	8	153	385
NMostLat (°)	SMostLat (°)	WMostLong (°)	EMostLong (°)
39	8	-98	-60

Notes: found throughout the Gulf of Mexico, but they’re abundant from AL->Mexico (north-western Gulf of Mexico), at depths of 4–160 m, with highest densities at 27–54 m. From sealifebase: Penaeus aztecus - Benthic; depth range 0 - 200 m (Ref. 356), usually 27 - 54 m. https://www.sealifebase.ca/summary/Penaeus-subtilis.html			
White shrimp			
DepthMin (m)	DepthPrefMin (m)	DepthPrefMax (m)	DepthMax (m)
0	8	36	55
TempMin (°C)	TempPrefMin (°C)	TempPrefMax (°C)	TempMax (°C)
14.6	16.4	27	31.2
SalinityMin (ppt)	SalinityPrefMin (ppt)	SalinityPrefMax (ppt)	SalinityMax (ppt)
19	26.5	36.2	36.7
PrimProdMin ($mgC \cdot m^{-3} \cdot day^{-1}$)	PrimProdPrefMin ($mgC \cdot m^{-3} \cdot day^{-1}$)	PrimProdPrefMax ($mgC \cdot m^{-3} \cdot day^{-1}$)	
-0.2	0.8	33.3	
OxyMin ($mmol \cdot m^{-3}$)	OxyPrefMin ($mmol \cdot m^{-3}$)	OxyPrefMax ($mmol \cdot m^{-3}$)	OxyMax ($mmol \cdot m^{-3}$)
126.6	178.6	243.4	277
LandDistMin (km)	LandDistPrefMin (km)	LandDistPrefMax (km)	LandDistMax (km)
0	8	149	385
NMostLat (°)	SMostLat (°)	WMostLong (°)	EMostLong (°)
42	-36	-98	-34
Notes: Found throughout the Gulf of Mexico, but they’re most abundance from AL->Mexico (north-western Gulf of Mexico), at depths of 8 – 55 m, with highest densities at 11 – 36 m (shallower depths than brown shrimp). Live in mud, silt, and sandy bottoms.			
Pink shrimp			
DepthMin (m)	DepthPrefMin (m)	DepthPrefMax (m)	DepthMax (m)
0	4	48	137
TempMin (°C)	TempPrefMin (°C)	TempPrefMax (°C)	TempMax (°C)

16	22.4	28	32.2
SalinityMin (ppt)	SalinityPrefMin (ppt)	SalinityPrefMax (ppt)	SalinityMax (ppt)
22.1	32.6	36.2	38.1
PrimProdMin ($mgC \cdot m^{-3} \cdot day^{-1}$)	PrimProdPrefMin ($mgC \cdot m^{-3} \cdot day^{-1}$)	PrimProdPrefMax ($mgC \cdot m^{-3} \cdot day^{-1}$)	
0.2	1.4	31.6	
OxyMin ($mmol \cdot m^{-3}$)	OxyPrefMin ($mmol \cdot m^{-3}$)	OxyPrefMax ($mmol \cdot m^{-3}$)	OxyMax ($mmol \cdot m^{-3}$)
145.7	200.5	248.7	269.7
LandDistMin (km)	LandDistPrefMin (km)	LandDistPrefMax (km)	LandDistMax (km)
1	4	118	478
NMostLat (°)	SMostLat (°)	WMostLong (°)	EMostLong (°)
40	18	-97	-74
Notes: Occur offshore Costello et al 1986; at depths of 4 – 48 m, but adults are found as deep as 137 m			

Table 2

Overview of life-history timing for Gulf of Mexico shrimp species. Activities are occurring in all colored months, while darker colors represent timing of peak estuarine usage or spawning. Timing was compiled from expert experience (J. Nance), SEFSC shrimp outreach presentation materials (Copy of Brown, white, pink life history (1).pptx), and publicly available species report pages from NOAA Fisheries (https://www.fisheries.noaa.gov/species/brown-shrimp, https://www.fisheries.noaa.gov/species/white-shrimp, https://www.fisheries.noaa.gov/species/pink-shrimp). Additional refinement of this table may be warranted.

Estuarine Usage timing												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Brown												
White												
Pink*												
Spawning timing												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Brown												
White												
Pink*												

Table 3

Online environmental data resources. (Google sheet.)

process	data source	link	spatial resolution	temporal resolution	caveats
Riverine inputs	RC4USCoast: A river chemistry dataset	https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:0260455			
Hurricane index	accumulated cyclone energy calculation	https://github.com/SEFSC/IEA-GWEM-DataSynth/tree/main/Ecospace-environmental-drivers	6-hourly storm tracks, can be subset at any spatial or temporal scale	can create index at monthly, yearly, or other scale	
Salinity (surface, bottom, averaged)	HYCOM ocean model	https://github.com/SEFSC/IEA-GWEM-DataSynth/tree/main/Ecospace-environmental-drivers	Gulf of Mexico	1993-2022	Consideration needed for high-resolution insure use
Temperature (surface, bottom, averaged)	HYCOM ocean model	https://github.com/SEFSC/IEA-GWEM-DataSynth/tree/main/Ecospace-environmental-drivers	Gulf of Mexico	1993-2022	Consideration needed for high-resolution insure use
Chlorophyll-A	MODIS satellite imagery	https://github.com/SEFSC/IEA-GWEM-DataSynth/tree/main/Ecospace-environmental-drivers	Gulf of Mexico	2003-present	
Normalized carbon fluorescence	MODIS satellite imagery	https://github.com/SEFSC/IEA-GWEM-DataSynth/tree/main/Ecospace-environmental-drivers	Gulf of Mexico	2003-present	
Particulate organic carbon	MODIS satellite imagery	https://github.com/SEFSC/IEA-GWEM-DataSynth/tree/main/Ecospace-environmental-drivers	Gulf of Mexico	2003-present	

Marsh elevation	NOAA NERRS system	https://www.fisheries.noaa.gov/inport/item/47712	Apalachicola Bay and Mission Aransas NERRs	Ap. Bay 2014-2022; Mission Aransas 20111 only	
Florida HAB monitoring	FWC	https://myfwc.com/research/redtide/monitoring/database/	SW Florida	1953-present	To request data, email: HABdata@MyFWC.com.
Water height	NOAA tides & currents	https://tidesandcurrents.noaa.gov/products.html			
Rainfall	NOAA NWS	https://www.weather.gov/wrh/climate?wfo=hgx			
Remote sensing	USF virtual buoys	https://optics.marine.usf.edu/projects/vbs.html	Central west Florida and West Florida Shelf	2014-present	
USGS National Water Information System	Water quality sondes	https://waterdata.usgs.gov/monitoring-location/301429089145600/#parameterCode=00065&period=P7D&showMedian=true	National monitoring	Varies by station	

Table 4

Inventory of inshore environmental data from Gulf state fisheries independent monitoring programs conducted in Texas, Louisiana, Texas, Mississippi, Alabama, and Florida.

State	Organization and sampling program(s)	Design	Biological sampling (overview)	Habitat data collected	Water quality data collected	Spatial coverage	#	Format	POC	Caveats and notes
Florida	Florida Fish and Wildlife Conservation Commission (FWC) Fish and Wildlife Research Institute (FWRI) Fisheries independent monitoring (FIM)	Monthly stratified random sampling	Two seine types and trawls	Substrate types (i.e., habitat type, e.g., mud, sand, oyster); SAV: visual estimation of percent cover and percent composition by species; Shoreline type (collected by matrix, e.g., black / red / white mangrove) but is generally collapsed for analyses, e.g., "mangrove / terrestrial structure" for a site with multiple mangrove species and rip-rap.	Temperature, DO (mg/L), conductivity / salinity (ppt), pH. Measurements collected at surface and every meter and at bottom. Can get surface, averaged, or bottom.	Data goes back 1998 on monthly for four estuaries: Charlotte Harbor, Tampa Bay, Cedar Key, and Apalachicola Bay. Also have spotty, “one-off” sampled areas.	Monthly; 1998-present for the four LTM estuaries.	CSV files	meagan.schrandt@myfwc.com	There's. data sheet of reference codes (e.g., ‘M’ for mud). Sampling records bycatch, including drift algae, which may be consequential for juvenile shrimp.
Alabama	Alabama Department of Conservation Natural Resources (DCNR) Marine Resources Division (MRD)	Monthly fixed stations	Trawls, seines, "hydros" reef sites, gill nets	Depth for trawls.	Temperature, DO, and salinity. Measurements taken at bottom for trawls, midwater for seines, bottom for hydros.	24 trawl sites, 10 seines, and 9 hydros in coastal Miss. waters. Seines and hydros are inshore. Trawl sites are inshore or close to shore if in the Gulf	Sampling began in 1981 but not all stations are continuous. Continuous trawl monitoring started in 1992.	All data on a single, huge, exclamation-point delimited text file. >1M rows and 12	General: jessica.marchant@dcnr.alabama.gov | Gillnet data: chase.katechis@dcnr.alabama.gov | Hydro stations data: jason.hermann@dcnr.alabama.gov. Office phone: 251-861-2882	DISL will have buoys and monitoring programs. Continuous monitoring water quality multiparameter sondes and long-term weather data.

									columns .		
Mississippi	Mississippi Department of Marine Resources Fisheries Independent Monitoring (MDMR)	Monthly fixed stations	16 foot trawls	Depth. Most of the bottom would be mud. A few would be sand.	Temperature, DO, salinity, turbidity (always with secchi, now also with FMU), recently pH Surface and bottom measurements.	Mississippi sound, Biloxi Bay, St. Louis Bay	4 sites from 1974, hiatus 1980-1983, returns in 1984. 1996 expanded to 6 sites. 2009 increased to 12 sites. 2019 increased to 20.	CSV and Excel	Jason Saucier, jason.saucier@dmr.ms.gov	
Mississippi	Mississippi Department of Marine Resources Fisheries Independent Monitoring (MDMR)	Fixed WQ sondes	Sondes	None	Temperature and salinity, some with DO	11 sites. Mississippi sound and in estuaries	2008 to present	CSV download	Darrell Lambeth, Supervisory Hydrologist, dlambeth@usgs.gov | https://dmr.ms.gov/hydrological-monitoring/	Some data can be taken of the site for QA/QC
Louisiana	Louisiana Department of Wildlife and Fisheries (LDWF)	Six foot trawls stratified (Mar-Jul). Finfish fixed and stratified. Trawl sites are fixed.	Bio sampling: Offshore trawls, inshore trawls (6' and 16'), trammel nets, gill nets, oyster dredges. Constant recorder devices in the water. POC Nicole Smith nsmith@wlf.la.gov	Depth, bottom type, proximity to marsh	Temperature, DO, conductivity, salinity, turbidity. Top and bottom.	Spread over coastal LA.	Monthly or bi-monthly. Data back to 1965. Standardized in 1978. Environmental data more limited in early sampling.	Can be exported as CSV or Excel. Large files.	Michael Harden, mharden@wlf.la.gov. 225-765-2371 ext 1747.	Rainfall data can be pulled from LSU climatology. Mississippi flow has been shown to correlate with Brown shrimp success. Other LA state agencies: CPRA, DNR,

										and DEQ.
Texas	Texas Parks and Wildlife Department	Monthly stratified random sampling	Bag seins, bay trawls, gill nets, oyster dredges, and Gulf trawls	Qualitative. Bottom type. Habitat information mainly associated with bag seins. Recent effort to supplement habitat information.	Temperature, salinity, DO, turbidity. Bag sein and gill net will be surface collection. Trawl will be bottom collection.	9 major bays.	Monthly. Data starts in most bays in 1982. All of the Bays by 1986. 20 sampling sites for each bay per month.	Can be provided in CSV or Excel.	Mark Fisher, Science Director, Mark.Fisher@tpwd.state.tx.us. Habitat information from Emma Clarkson; Emma.Clarkson@tpwd.texas.gov 361-694-0226.	Comprehensive sampling. All gears have year-around coverage, except gill nets are conducted spring and fall. Only data gap is April-May 2020.
Gulf-wide	NOAA Southeast Area Monitoring and Assessment Program (SEAMAP) groundfish survey	Seasonal (summer / fall) stratified random	Trawls	Recently started doing camera drops on some surveys	Temperature, DO, salinity, turbidity, fluorescence. From CTD. Have altimeter (or an altitude meter) to assess how far off the bottom	Brownsville, TX to Florida Keys. 9-110 m depth.	Summer and fall cruises. Measurements for full time series (1987). Reliably from 2001. Sampling 911 CTD.	Access or CSV through data portal	Adam Pollack and Jeff Rester. Data portal: https://seamap.gsmfc.org/	Temperature and salinity is reliable back to the start of the timeseries. DO is less reliable until the early-2000s, then becomes reliable.
Gulf-wide	SEAMAP longline survey	Seasonal (spring/summer/fall) stratified random	Longline	None	Likely temperature, salinity, DO. Unsure of others.	Texas to Alabama. Out to 10 m.	Seasonal sampling. Started around 2007.	Access or CSV through data portal	Jeff Rester, Gulf States Marine Fisheries Commission. Data portal: https://seamap.gsmfc.org/	Inshore state sampling.
Gulf-wide	NMFS SEFSC longline	Annual (summer) stratified	Longline	Recently started doing camera drops on some surveys	Temperature, DO, salinity, turbidity, fluorescence. From	Gulf-wide. 9-366 m depth	Started 1995 to present.	Data dump. Access	Adam Pollack. adam.pollack@noaa.gov	DO more reliable after early-2000s

	survey	random			CTD.			or CSV.		
Gulf-wide	NMFS SEFSC Fall Plankton Survey	Annual fixed stations	Plankton tows	None	Temperature, DO, salinity, turbidity, fluorescence. From CTD.	Gulf-wide. 9 to several hundred meters	1982 to present	Data dump. Access or CSV.	David Hanisko. david.s.hanisko@noaa.gov	DO more reliable after early-2000s
Gulf-wide	NMFS SEFSC Spring Plankton Survey	Annual fixed stations	Plankton tows	None	Temperature, DO, salinity, turbidity, fluorescence. From CTD.	Gulf-wide. Off-shelf. Deep.	1982 to present	Data dump. Access or CSV.	David Hanisko. david.s.hanisko@noaa.gov	DO more reliable after early-2000s

3.11 FIGURES

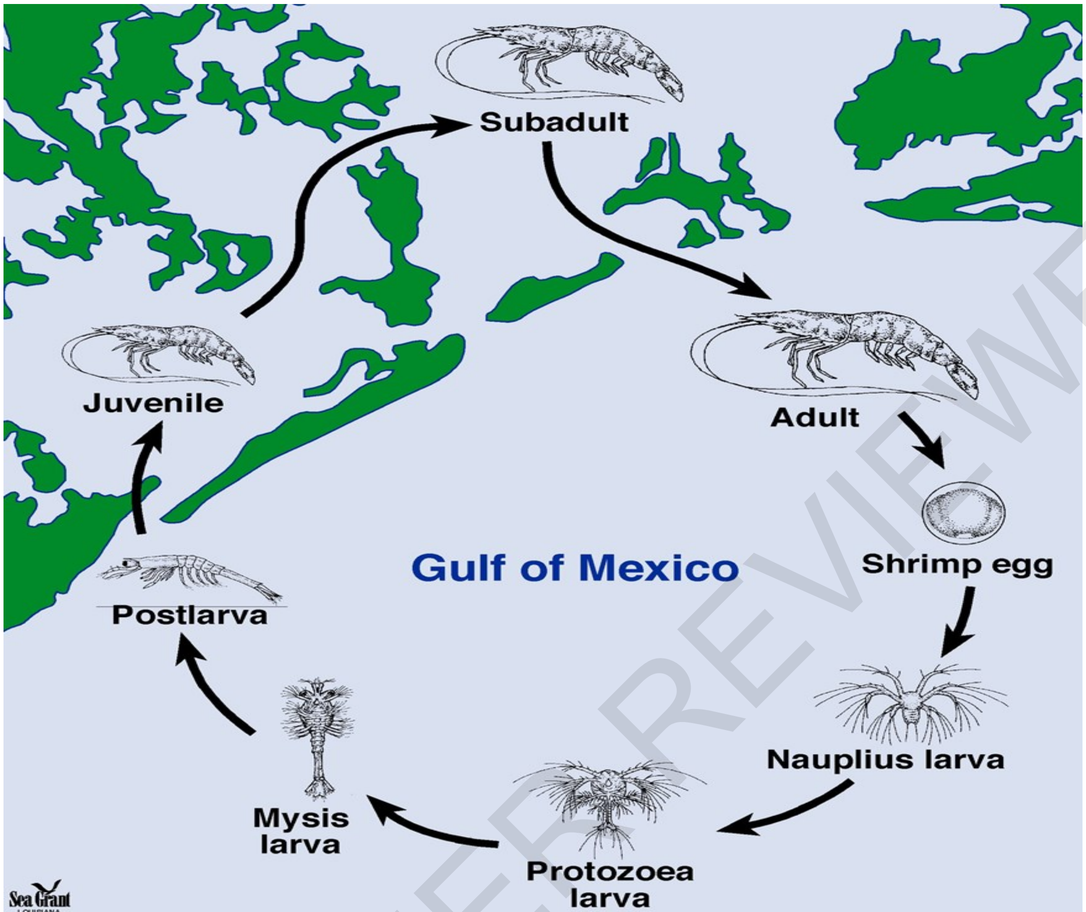


Figure 1

Representative life cycle for brown, white, and pink shrimp. Schematic from Florida Sea Grant.

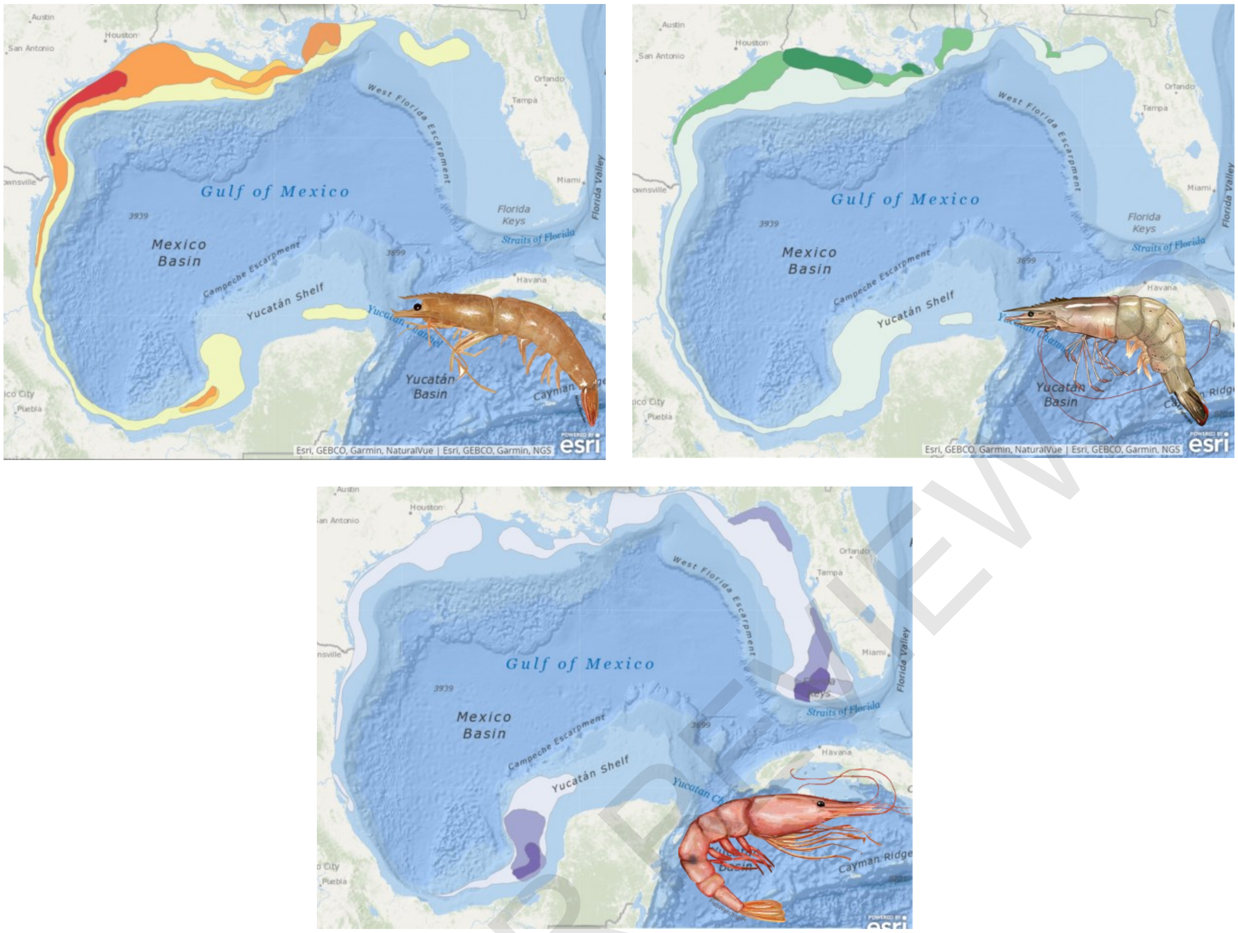


Figure 2

Distribution of shrimp catch by species. Maps were adapted from the [Gulf of Mexico shrimp fishery story map](). Species shown clockwise beginning in the top left are brown, white, and pink shrimp.

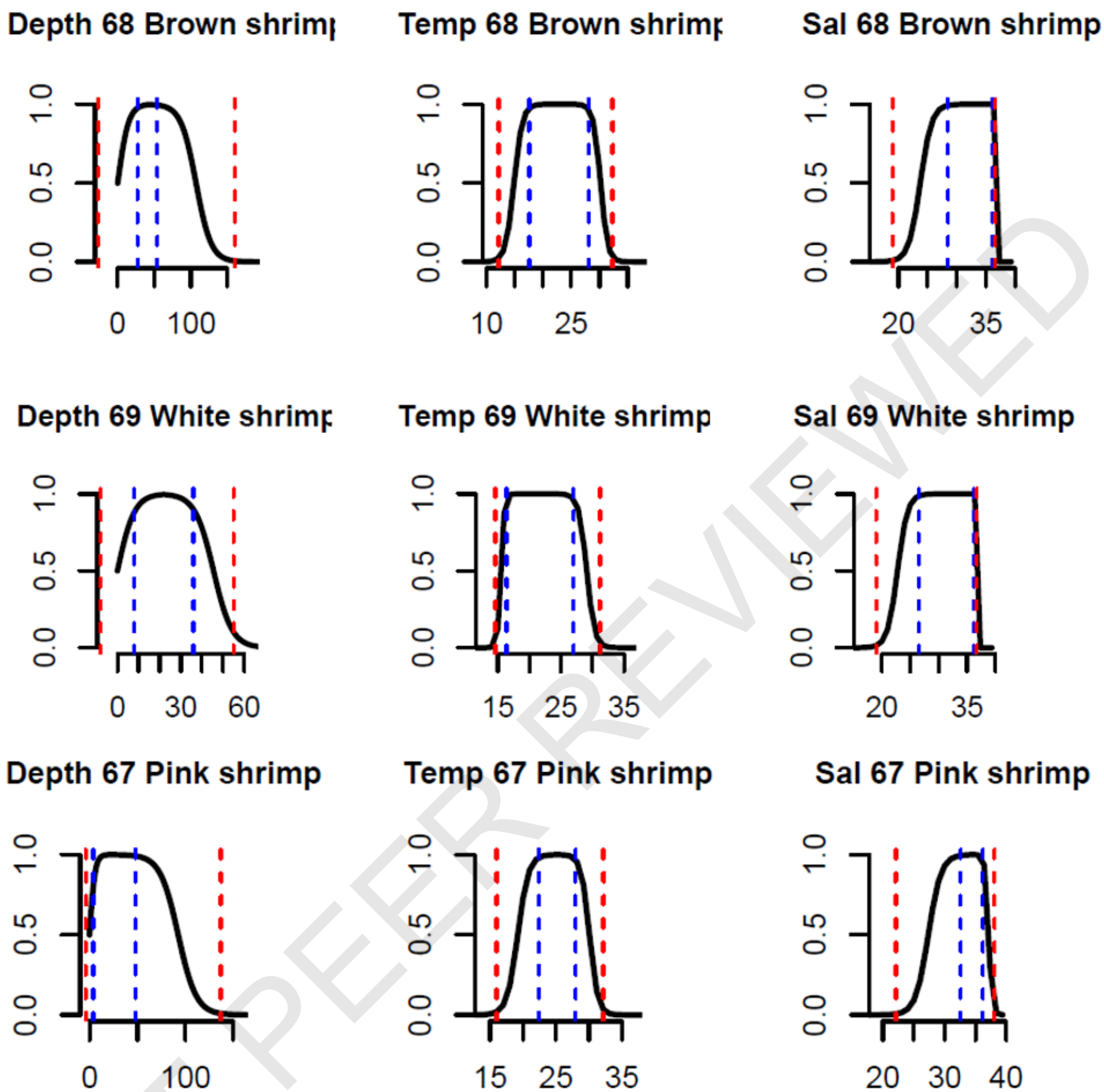


Figure 3

Depth (left), temperature (middle), and salinity (right) environmental preference envelopes for brown (top), white (middle), and pink (bottom) shrimp from an Ecopath with Ecosim and Ecospace model for the Gulf of Mexico, courtesy of Holden Harris. The units for depth are m, temperature is degrees C, and salinity is in ppt. Environmental preference functions were calculated with a double-logistic equation with four preference parameters: absolute minima and maxima (inner dashed blue lines) and preferred minima (outer dashed red lines)

4 INDICES OF POPULATION ABUNDANCE

4.1 OVERVIEW

The Index Working Group (IWG) was tasked with reviewing raw data and indices of abundance from surveys associated with sampling programs from the five Gulf States (Texas, Louisiana, Mississippi, Alabama, and Florida) and the Southeast Area Monitoring and Assessment Program (SEAMAP). Data for brown shrimp, white shrimp and pink shrimp were reviewed independently for small, medium, and large size categories (Table 1) across three discrete spatial areas in the northern Gulf of Mexico (Figure 1). Section 2 lists the contributed working papers containing the full descriptions of the sampling programs, individual surveys, datasets, analytical methods, and model diagnostics, reviewed by the IWG. All sampling programs, surveys, and associated data (nominal time series, abundance indices, etc.) were evaluated following the criteria listed in Section 3. Rationalizations for the recommendation or exclusion of a survey and/or data are given in the 'Comments on Adequacy for Assessment' in their respective sections.

4.1.1 Terms of Reference

The IWG was tasked with the following Terms of Reference

- 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.

4.1.2 Group membership

Members of the IWG included: Adam Pollack (co-workgroup lead), David Hanisko (co-workgroup lead), Peyton Cagle, Dwayne Edwards, Jessica Marchant, Fernando Martinez-Andrade, Michelle Masi, Jason Saucier, Meagan Schrandt, Katie Siegfried, Ted Switzer, and James Tolan.

There were also several members of the Assessment Development Team and Workshop Panel that sat in on several workgroup sessions.

4.2 REVIEW OF WORKING PAPERS

The IWG reviewed the following working papers:

SEDAR87-DW-05	-	Gulf of Mexico Brown, Pink, and White Shrimp Weight-Length Regression using SEAMAP Data
SEDAR87-DW-11	-	Indices of relative abundance for Pink, Brown, and White Shrimp from surveys conducted in several Florida Gulf coast estuaries
SEDAR87-DW-12	-	Inshore brown and white shrimp relative abundance in Louisiana
SEDAR87-DW-13	-	Brown, White and Pink Shrimp Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico
SEDAR87-RD01	-	SEAMAP Trawl Shrimp Data and Index Estimation Work Group Report
SEDAR87-RD03	-	Mississippi Department of Marine Resources and University of Southern Mississippi Gulf Coast Research Laboratory Inshore Trawl Monitoring Programs: Sampling and Lab Protocols
SEDAR87-RD04	-	Marine Fisheries Crustacean Section - Independent Sampling Activities: Field Manual
SEDAR87-RD05	-	AL MRD Fisheries Assessment and Monitoring Program (FAMP)
SEDAR87-RD06	-	AL MRD FAMP Assessment Sampling - Standard Operating Procedures
SEDAR87-RD07	-	TPWD’s Gulf Trawl Sample Design

4.3 SURVEY EVALUATIONS

All surveys and associated data presented to the IWG were evaluated based on the following criteria:

- Temporal range
- Spatial range
- Consistent survey design (e.g. fixed sampling sites, stratified random etc.)
- Standardized sampling methodology (e.g. gear, vessels, effort, etc.)
- Ages and/or sizes represented
- Appropriate analytical methods

Surveys within each sampling program were independently evaluated based on the criteria listed above and deemed to be either Suitable or Not Suitable. The surveys then entered the second stage of review to determine whether or not their data would be recommended for use in the assessment. Based on the two determinations, surveys were assigned one of the following categories by the IWG:

- Suitable and Recommended: Based on the criteria listed above, the survey met the minimum requirements for being considered for use in the assessment and was deemed to be a representative example of the population trends for a given area.
- Suitable and Not Recommended: Based on the criteria listed above, the survey met the minimum requirements for being considered for use in the assessment and was deemed not to be a representative example of the population trends for a given area.
- Not Suitable (Not Recommended): Based on the criteria listed above, the survey did not meet the minimum requirements for being considered for use in the assessment

Evaluation of abundance indices used the same criteria listed above for the surveys and were deemed to be either Representative or Not Representative.

4.4 FISHERY-INDEPENDENT INDICES

4.4.1 SEAMAP

The Southeast Area Monitoring and Assessment Program (SEAMAP) is a collaborative effort between federal, state and university programs, designed to collect, manage and distribute fishery independent data throughout the region. The Summer and Fall Groundfish surveys initially covered an area between Brownville, TX and Mobile Bay, AL. It should be noted that shrimp statistical zone (SSZ) 10 was dropped from the survey universe in 1989 because of the increased number of hangs in the area as Alabama expanded their artificial reef permit area.

Beginning in 1987, the SEAMAP summer and fall groundfish surveys adopted a unified sample design. Strata were still defined by area and depth zone, but with an additional stratum based on time of day (day and night) incorporated into the design. Towing time was variable during the survey, ranging from 10 (min) to 55 (max) minutes, and was dependent on the time required to completely tow through a depth zone. If the depth zone could not be covered in 55 minutes, multiple tows were made at the station. The survey gear consists of a 12.8 m (42 ft) semi-balloon shrimp trawl with a 12.8 m headrope and does not contain a turtle excluder device (TED) or any bycatch reduction devices (BRD).

Major changes in the SEAMAP sample design occurred between the 2008 summer and fall surveys. Stratification by time of day was dropped, tow time was standardized to 30 minutes, and sampling effort allocated proportionally by the spatial area represented by each shrimp statistical zone and depth zone combination. Minor changes to depth zones were made during subsequent years with the current design utilizing two depth zones, which have been consistent since 2013. While the change in sample design occurred in 2008, it is important to note that the state partners did not adopt the new sample design until 2010.

In 2008, SEAMAP received supplemental funding that provided the opportunity to conduct experimental bottom trawl surveys on the West Florida Shelf. Based on the success of the experimental trawl surveys by the state of Florida, the surveys were fully expanded in 2010 to include the area from Mobile Bay, AL to Key West, FL using identical gear as the historical SEAMAP survey.

Methods of Estimation:

Working Paper Number: SEDAR87-DW-13

Data Type: Fishery Independent

Time Series: 1987-2022

Standardization: Delta-lognormal (Lo et al. 1992)

Submodel Variables: Year, time of day, statistical zone, depth

Abundance Indices: Tables 7 to 32 in working paper

Comments on Adequacy for Assessment:

Sampling Program:

SEAMAP, consisting of the Summer and Fall Groundfish Surveys, was deemed an appropriate sampling program for brown shrimp, white shrimp, and pink shrimp. This program represents a long-term fishery independent survey that successfully captures the target shrimp species across the northern Gulf of Mexico. Representation of the three size classes was species dependent, however the underrepresented size category data could be combined with the other size categories if needed.

Index of Abundance:

Brown shrimp:

The IWG reviewed and evaluated 30 brown shrimp abundance indices and/or data series with the final decision for inclusion shown in Table 3. In general, all size classes across statistical zones 18-21 and 11-17 and both survey designs (1987-2008 and 2009-2022) were deemed ‘Representative’. For statistical zones 8-10, no indices were able to be constructed for the Summer Groundfish Survey due to the low catch rates for all size categories. For the Fall Groundfish Survey, abundance indices were calculated for only the large and medium size classes, but deemed to be ‘Not Representative’, mainly due to the low catch rates.

White shrimp:

The IWG reviewed and evaluated 30 white shrimp abundance indices and/or data series with the final decision for inclusion shown in Table 4. For the Summer Groundfish Survey, only the abundance indices for the large size category were deemed to be ‘Representative’ for statistical zones 18-21 and 17-11. The abundance index for the medium size category was deemed ‘Not Representative’, and an abundance index was not able to be produced for the small size category due to low catches. In addition, no abundance indices were able to be produced for statistical zones 8-10.

Pink shrimp:

The IWG reviewed and evaluated 6 pink shrimp abundance indices and/or data series with the final decision for inclusion shown in Table 5. For the Summer Groundfish Survey, the abundance indices for the large and medium size classes were deemed 'Representative', while the index for the small size category was deemed 'Not Representative'. For the Fall Groundfish Survey, all the abundance indices were deemed 'Not Representative' due to issues with spatial coverage during the early part of the time series and that it is potentially indexing the same portion of the population as the Summer Groundfish Survey.

4.4.2 TEXAS

Gulf Trawl:

The Texas Parks and Wildlife – Coastal Fisheries Division samples five Gulf areas within the Texas Territorial Sea (shoreline to nine nautical miles offshore), where 16 samples are collected every month in each area (80 samples per month in total).

Data are collected as a stratified cluster sampling design; each Gulf area serves as non-overlapping strata with a fixed number of samples per month. A cluster sample is defined as a type of probability sample where each sample unit is a collection, or cluster, of elements. Specifically, locations are sampled and include every organism encountered at that location as part of the sample.

Gulf trawl sample locations are randomly selected from grids (1-minute latitude by 1-minute longitude) within the Texas Territorial Sea that contain water >1.8 m deep in at least ⅓ of the grid and are known to be free of obstructions. One half of the samples in each area are collected during each half (days 1-15 and 16-31) of the month to ensure good temporal distribution of samples.

Trawls are 6.1 m (20 ft) wide otter trawls with 38 mm (1.5 in) stretched nylon multifilament mesh throughout. Trawl doors are 1.2 m (48 in) long and 0.5 m (20 in) wide; and constructed of 13 mm (0.5 in) plywood with angle iron framework and iron runners. Trawls are towed linearly, parallel to the fathom curve; direction of tow (north or south) is randomly chosen for the initial tow and alternated on subsequent tows. All tow times are 10 minutes in duration. No grid is sampled more than once per month. Sampling takes place during daytime, from 1/2 hour before sunrise to 1/2 hour after sunset.

Organisms greater than 5 mm total length, captured in the trawl or stranded on the boat deck, are identified to the lowest possible phylogenetic unit (genus and species preferred). Up to 50 randomly selected shrimp of each commercial species (brown, white and pink) are measured. Sex and female maturity stage are determined for up to 50 white shrimp.

Water quality parameters of bottom salinity (ppt), water temperature (°C), dissolved oxygen (ppm) and turbidity [Nephelometric Units (NTU)] are measured prior to each Gulf trawl sample.

<u>Methods of Estimation:</u>

Working Paper Number:

Data Type: Fishery Independent

Time Series: 1987-2022

Standardization: Nominal Index combined for all areas sampled across all years.

Submodel Variables: N/A

Abundance Indices: N/A

Comments on Adequacy for Assessment:

Sampling Program:

The IWG recommends using the 20-foot Gulf trawl survey data for shrimp abundance index development beginning in 1987. This survey captures a wide range of size classes and is conducted throughout the year with samples collected monthly at randomly chosen stations. Despite representing a smaller spatial extent than the SEAMAP survey and limited spatial overlap, these data represent a larger temporal series for shrimp abundance

Index of Abundance:

The IWG reviewed nominal CPUE time series for small, medium and large size categories of brown shrimp and white shrimp. The time series for the small size category of brown shrimp and white shrimp were deemed 'Representative', while the medium and large size category were deemed 'Not Representative' due to the low catch rates in those size categories.

Bay Trawl:

The Texas Parks and Wildlife – Coastal Fisheries Division samples nine major bay systems along the Texas coast, where 20 bay trawl samples are collected every month in larger bays (Galveston Bay, Matagorda Bay, San Antonio Bay, Aransas Bay, Corpus Christi Bay) and 10 bay trawl samples are collected every month in smaller bays (Sabine Lake, East Matagorda Bay, upper Laguna Madre, lower Laguna Madre). A total of 140 bay trawl samples are collected every month.

Data are collected as a stratified cluster sampling design; each bay serves as non-overlapping strata with a fixed number of samples per month. A cluster sample is defined as a type of probability sample where each sample unit is a collection, or cluster, of elements. Specifically, locations are sampled and include every organism encountered at that location as part of the sample.

Bay trawl sample locations are randomly selected from grids (1-minute latitude by 1-minute longitude) within each bay system that contain water >1 m deep at mean low tide in at least ⅓ of the grid and are known to be free of obstructions. One half of the samples in each bay are collected during each half (days 1-15 and 16-31) of the month to ensure good temporal distribution of samples.

Trawls are 6.1 m (20 ft) wide otter trawls with 38 mm (1.5 in) stretched nylon multifilament mesh throughout. Trawl doors are 1.2 m (48 in) long and 0.5 m (20 in) wide; and constructed of 13 mm (0.5 in) plywood with angle iron framework and iron runners.

Trawls are towed at 3 mph in a circular manner, tow times are 10 minutes in duration. No grid is sampled more than once per month. Sampling takes place during daytime, from 1/2 hour before sunrise to 1/2 hour after sunset.

Organisms greater than 5 mm total length, captured in the trawl or stranded on the boat deck, are identified to the lowest possible phylogenetic unit (genus and species preferred). Up to 50 randomly selected shrimp of each commercial species (brown, white and pink) are measured.

Water quality parameters of bottom salinity (ppt), water temperature (°C), dissolved oxygen (ppm) and turbidity [Nephelometric Units (NTU)] are measured prior to each Gulf trawl sample.

Methods of Estimation:

Working Paper Number:

Data Type: Fishery Independent

Time Series: 1987-2022

Standardization: Nominal Index combined for all areas sampled across all years.

Submodel Variables: N/A

Abundance Indices: N/A

Comments on Adequacy for Assessment:

Sampling Program:

TPWD recommends using the 20-foot bay trawl survey data for shrimp abundance index development beginning in 1987. This survey captures a wide range of size classes and is conducted throughout the year with samples collected monthly at randomly chosen stations

Index of Abundance:

The IWG reviewed nominal CPUE time series for small, medium and large size categories of brown shrimp and white shrimp. The time series for the small size category of brown shrimp and white shrimp were deemed ‘Representative’, while the medium and large size category were deemed ‘Not Representative’ due to the low catch rates in those size categories.

4.4.3 LOUISIANA

The Marine Fisheries Division develops management recommendations for Louisiana’s shrimp resources through an ongoing systematic sampling and monitoring program which utilizes a variety of gear types designed to provide technical data on shrimp population dynamics and associated hydrological and environmental conditions and has resulted in the most extensive and continuous coast wide data set among the Gulf states which dates to the early 1960's.

This fisheries-independent (FI) monitoring program is largely based upon methodology developed during the Cooperative Gulf of Mexico Estuarine Inventory and Study (GMEI; Perret et al. 1971). That project was conducted in cooperation with the Gulf States Marine Fisheries Commission (GSMFC), the states of Alabama and Mississippi, and the National Marine Fisheries Service (NMFS) laboratories at Galveston, Texas and St. Petersburg, Florida.

Standardized sampling methods and procedures used in the GMEI were developed by the Technical Coordinating Committee of the GSMFC.

The FI 4.9 m (16 ft) trawl survey database dates back to 1965 for some areas in Louisiana. The program utilizes a 4.9 m (16 ft) otter trawl in state inshore waters to sample and monitor the abundance, size, and distribution of penaeid shrimp, blue crab, and groundfish in the larger inshore bays, waterways, and passes. Sampling and station selection for the 4.9 m (16 ft) trawl survey were standardized by the late 1970's, which is why an index time series beginning in 1980 is recommended. Enhanced monitoring was initiated in late 2010 by adding stations to increase the spatial coverage of the survey within each Coastal Study Area. For each 4.9 m (16 ft) trawl sample, the net is towed for ten minutes (timed when the trawl first begins to move forward to when it stops forward movement) at a constant speed and in a sinusoidal pattern to avoid prop wash in shallow waters. This survey also provides data for indices of abundance for use in stock assessment for blue crab and some finfish species.

For additional details of the 16-foot inshore otter trawl, see SEDAR 87 RD04: Marine Fisheries Crustacean Section – Independent Sampling Activities: Field Manual.

In addition to the 4.9 m (16 ft) trawl gear, the FI monitoring program also utilizes a 1.8 m (6 ft) trawl in state inshore nurseries and a 6.1 m (20 ft) trawl in state outside waters. The 1.8m (6 ft) trawl survey dates back to the late 1960s and is designed to monitor shrimp recruitment. This trawl survey changes over time from established standardized sample locations to stratified random in 2013. The 6.1 m (20 ft) trawl survey began with standardized sample locations in 2013.

Methods of Estimation:

Working Paper Number: SEDAR 87 DW-12: Inshore brown and white shrimp relative abundance in Louisiana

Data Type: Fishery Independent

Time Series: 1980-2022

Standardization: Delta-lognormal (Lo et al 1992 sans bias correction)

Submodel Variables: N/A

Abundance Indices: N/A

Comments on Adequacy for Assessment

Sampling Program:

LDWF recommends using the FI 16-foot trawl survey data for shrimp abundance index development beginning in 1980. This survey captures a wide range of size classes and is conducted throughout the year with samples collected monthly at each station.

For brown shrimp, LDWF recommends developing an index of abundance from 1980-2022 for the months of March-June only. These months cover the primary period that brown shrimp recruit into estuarine waters and when developing sub-adults leave.

For white shrimp, LDWF recommends developing an index of abundance from 1980-2022 for all months of the year. White shrimp are present in inshore waters throughout the year as overwintering adults in spring months and as new recruits in summer months, giving the best option for an abundance index that includes all size classes.

LDWF does not recommend using the 6-foot trawl data because this data does not give good representation of all class sizes; this gear is primarily sampled in interior marshes looking for recruitment abundance and average size. The 20-foot offshore trawl data was expanded in 2010 using the 16-foot trawl, but later transitioned into a larger 20-foot balloon trawl in 2013. Because of this short time series, the 20-foot offshore data is not recommended.

Index of Abundance:

Brown shrimp:

The IWG reviewed annual abundance indices for brown shrimp developed for three size categories using samples from the months of March – June only. The three size categories for the brown shrimp indices are small (TL <115.6mm), medium (TL ≥115.6 - ≤151.8mm), and large (TL ≥151.8mm). The small and medium size categories of brown shrimp were deemed 'Representative', while the large size category was deemed 'Not Representative' due to the low catch rates.

White shrimp:

The IWG reviewed annual abundance indices for white shrimp developed for three size categories using samples from all months of the year. The three size categories for the white shrimp indices are small (TL <108.1mm), medium (TL ≥108.1 - ≤144.3mm), and large (TL >144.3mm). All size categories of white shrimp were deemed 'Representative'.

See SEDAR 87 DW-12: Inshore brown and white shrimp relative abundance in Louisiana for details on indices.

4.4.4 MISSISSIPPI

MS Long-term Monitoring Program:

Long-term trawl monitoring for shrimp and other species began in Mississippi in 1973. The program provides ongoing monitoring and assessment of commercially and recreationally important fish and shellfish species in Mississippi territorial waters to provide fisheries managers with current biological data required for management decisions. The trawl monitoring program also provides a long-term database to profile inshore species abundance through time to detect long-term changes in abundance.

Sampling is conducted using a 19 mm (.75 in) bar mesh 4.9 m (16 ft) (headrope measurement) otter trawl and with a 6 mm (.25 in) liner in the cod end. All trawls are towed at a constant speed for 10 minutes. The standard (rostrum to telson) length (mm), and individual weight (g) of up to 20 individuals are recorded and the total weight (g) is recorded for all penaeid shrimp species by station.

Mississippi's long-term trawl monitoring program originally included four fixed stations located along a transect in the Mississippi Sound, Back Bay of Biloxi and Bernard Bayou (Biloxi Transect). The Biloxi Transect was expanded in 2009 to include two additional stations in the

Mississippi Sound located inside Horn Island and at Dog Keys Pass. Six trawl sites were also added in 2009 along a transect in the western Mississippi Sound, St. Louis Bay and the Jourdan River (Western Sound). In 2019 following an historic opening of the Bonnet Carré Spillway, eight trawl sites were added in the western Mississippi Sound to monitor the long-term effects of freshwater from the spillway's operation and to monitor baseline conditions.

Biloxi Transect monitoring work was completed by University of Southern Mississippi, Gulf Coast Research Laboratory (GCRL) from 1973-2017, and by Mississippi Department of Marine Resources (MDMR) from 2018-2022. Western Sound trawl monitoring was completed by MDMR from 2009-2017, and by GCRL from 2019-2022. Expanded Western Sound monitoring was completed by MDMR from 2019-2022.

MS Shrimp Monitoring Program:

The objective of Mississippi's shrimp monitoring program is to monitor size and seaward migration of shrimp within the Mississippi Sound. Historically, sampling was conducted only from April to June twice per week to collect brown shrimp lengths. Average shrimp size is determined and daily growth rates are estimated to project when shrimp could reach legal size. This monitoring program historically included nine fixed sample stations and a 10th station was added in 2016. The program was expanded to include monthly, year-round sampling in 2019 so that shrimp sizes could be monitored year-round and to ensure that existing management strategies such as seasonal area closures are still appropriate to protect subsequent shrimp crops.

The shrimp monitoring program is conducted using a 19 mm (.75 in) bar mesh 4.9 m (16 foot) (headrope measurement) otter trawl. All trawls are towed at a constant speed for 10 minutes. Penaeid shrimp and identified to species. The standard (rostrum to telson) length (mm) of up to 50 individuals are recorded and the total weight (g) and total number are recorded for all penaeid shrimp species by station.

<u>Methods of Estimation:</u>

Working Paper Number: SEDAR 87 RD03

Data Type: Fishery Independent

Time Series: 1984-2022

Standardization: Delta-lognormal (Lo et al 1992 sans bias correction)

Submodel Variables: N/A

Abundance Indices: N/A

<u>Comments on Adequacy for Assessment:</u>

Sampling Program:

MS Long-Term Monitoring Program:

- Length data of penaeid shrimp is not available for samples collected from 1973-1983 so only 1984-2022 data was recommended for consideration in establishing an index.

- Due to variability between habitat type between the long-term original four sites and the sites which were added in 2009 and 2019 only the original four sites were recommended for consideration in establishing an index.
- Peak abundance of juvenile and subadult Brown Shrimp within the survey area occurs from March to June. Due to the lack of Brown Shrimp in other months the MDMR recommended that only March to June data be considered for establishing an index.

Shrimp Monitoring Program:

Due to seasonality of data collection - samples collected April - June only from 2008-2018, the lack of individual weights, and the difference in gear from the long-term monitoring program - unlined trawl vs. liner trawl - this data is not recommended for consideration in establishing an index.

Index of Abundance:

Nominal indices based on the Mississippi trawl data were provided to the working group for White and Brown shrimp. Mississippi data was also combined with Louisiana and Alabama data and combined indices for White and Brown shrimp were presented to the group.

4.4.5 ALABAMA

The fisheries assessment and monitoring program (FAMP) is a fishery independent database that helps to determine the status of populations of marine organisms throughout Alabama coastal waters. This data is available to fisheries managers to use in the analysis of growth, seasonal and geographical distribution, changes in population structures and correlation of abundance with some abiotic factors for all Alabama marine fauna. Monthly sampling for all penaeid shrimp, *Callinectes* sp. crabs and finfish species started in October 1980. All organisms were enumerated and weighed according to SEAMAP procedures beginning in 1990. In 1998 the program shifted to an interagency program with ADEM; water quality parameters and the number of sites sampled were expanded but effort was reduced to one sampling regime per quarter. After determining that quarterly sampling did not provide enough definition to accurately observe trends, monthly sampling was resumed in October 2000. Given the revisions of the SEAMAP program and the importance for similar sample collection/processing throughout the Gulf, AMRD adjusted the FAMP program in order to produce data complementary to SEAMAP protocols beginning in May 2010. Sample sites were selected at the beginning of the program to be most representative of the marine fauna found in Alabama waters. Current sample locations and gear used at those sites in Mississippi Sound, Mobile Bay, the Perdido system, Little Lagoon and Alabama’s territorial sea can be found in Section 3 and 4 of the following working paper: SEDAR87-RD-05. Three methods of sample collection are/were employed within these areas to target a wide range of fauna throughout their life history. Seine hauls and Beam Plankton nets are/were used to target juvenile life stages utilizing shoreline habitats, and otter trawls are used to target juvenile and adult stages occurring within deeper waters. Beam-Plankton sampling was discontinued after December 2018. Due to the variability in seine and BPL sampling methods and the limited capture of species of interest, only data obtained from trawl samples is recommended for use in this assessment.

For trawl sample collection procedures, see reference document SEDAR87-RD06.

For gear specifications, see reference document SEDAR87-RD06, Appendix E.

Excluded Data:

- Trawl samples collected in the Perdido System prior to 2013 were removed from the data set due to variations in gear used.
- Size class data obtained from trawl samples collected from 1985 to 2000, as shrimp were only counted and not measured during this time frame.

Methods of Estimation:

Working Paper Number:

Data Type: Fishery Independent

Time Series:

Total abundance data: February 1981- December 2021

Size class data: February 1981- May 1985, October 2000 - December 2021

Standardization: N/A (data was not standardized)

Submodel Variables: N/A

Abundance Indices: N/A

Comments on Adequacy for Assessment:

Sampling Program:

AMRD FAMP

Due to the variability in seine and BPL sampling methods and the limited capture of species of interest, only data obtained from trawl samples is recommended for use in this assessment.

Index of Abundance:

No abundance indices were reviewed by the IWG, only nominal time series.

4.4.6 FLORIDA

The Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWC-FWRI) has conducted fisheries-independent monitoring (FIM) surveys in estuaries of Florida's Gulf Coast since 1989. Initial surveys (FWC-FWRI long-term FIM) in Charlotte Harbor, Tampa Bay, Cedar Key, and Apalachicola Bay used small-mesh seines, otter trawls, and multi-panel gillnets during a limited 10-week seasonal window in the fall and spring. In 1998, these surveys were modified to a monthly stratified-random sampling design that used a 21.3 m × 1.8 m center-bag haul seine (3.2 mm nylon mesh), a 6.1 m otter trawl (38 mm stretched mesh with a 3.2 mm nylon mesh liner in the cod end), and a 183 m × 3 m center-bag haul seine (37.5 mm stretch nylon mesh). The 21.3 m seine was deployed in shallow (≤1.5 m) shoreline and nearshore habitats (approximate area sampled = 140 m^2). The 21.3 m seine was also deployed in tidally influenced river habitats in a semi-circular set from the stern of a vessel and retrieved along the shoreline (approximate area = 68 m^2). In bay habitats, trawls were towed for 10 minutes along a path approximately 0.2 nautical miles (approximate area = 1,482 m^2). Trawls deployed in river habitats were towed for 5 minutes, traveling approximately 0.1 nautical miles (approximate area = 741 m^2). The 183 m seine was deployed along shoreline habitats (≤2.5 m), forming a rectangular shape, and sampled an approximate area of 4,120 m^2. Two sampling changes are of note for developing indices of abundance from FWC-FWRI long-term FIM data. First, bay trawl sampling was originally (1998–2004) seasonal and in 2005 became monthly, resulting in a nearly three-fold increase in annual effort for all estuaries. And second, 21.3 m seine sampling was expanded in 2016 in Charlotte Harbor to include tidal tributaries and creeks, with the intent of providing more data for juvenile Snook, resulting in a nearly five-fold increase in annual effort in Charlotte Harbor.

The FWC-FWRI-FIM program also conducts a complementary survey in polyhaline (salinity >18) seagrass areas of various Gulf Coast estuaries. In 2008, the polyhaline seagrass habitat survey was initiated to complement the existing long-term FIM surveys to better describe species assemblages associated with this under-sampled habitat within the long-term FIM survey. The polyhaline seagrass survey is conducted monthly (June–November) in St. Andrew Bay, Apalachicola Bay, the Big Bend region, Tampa Bay, and Charlotte Harbor. The survey was originally a multi-gear survey, using the same 6.1 m otter trawl and 183 m hauls seine as the long-term FIM survey. Both gear types were used to sample polyhaline seagrass habitats with ≥50% submerged aquatic vegetation cover. Haul seines were set in a rectangular shape along a shallow shoal (<0.5 m water depth) and trawls were towed in 1.0 m to 7.6 m of water depth. Each trawl was towed for 5 minutes, traveling approximately 0.1 nautical miles (approximate area sampled = 741 m^2). After evaluating the ability of the polyhaline survey to yield statistically powerful data for detecting temporal trends in species' abundance, the survey was amended in 2019 to discontinue the use of haul seines and increase the sample size (number of nets deployed) of the 6.1 m otter trawl.

<u>Methods of Estimation:</u>

Working Paper Number: SEDAR 87 DW-11

Data Type: Fishery Independent

Time Series:

- **Pink Shrimp :**1998-2022 (FWC-FWRI long-term), 2008-2022 (FWC-FWRI polyhaline seagrass)
- **Brown Shrimp:** 2001-2022 (FWC-FWRI long-term)
- **White Shrimp:** 2001-2022 (FWC-FWRI long-term)

Standardization: Generalized Linear Model (GLIMMIX, SAS Institute 2006)

Submodel Variables:

- **Pink Shrimp** (FWC-FWRI long-term): SAV percentage, Gear, Bottom type, Month, Bay, Salinity quantile, Year, Depth quantile, Temperature quant, Shore type
- **Pink Shrimp** (FWC-FWRI polyhaline seagrass): Bay, Salinity quantile, Bottom type, Year, Shore type, Month, Temperature quantile, SAV percent
- **Brown Shrimp** (FWC-FWRI long-term): Zone, Bottom type, Salinity quantile, Month, Effort (sampled area over 100m^2), SAV presence, Year, Depth quantile

- **White Shrimp** (FWC-FWRI long-term): Salinity quantile, Gear, Bottom type, Shore type, Month, Effort (sampled area over 100m^2), Year, Depth quantile, SAV presence

Abundance Indices: Tables 17 to 20 in working paper.

Comments on Adequacy for Assessment:

Sampling Program:

The FWC-FWRI Long-term FIM survey is conducted in Charlotte Harbor, Tampa Bay, Cedar Key, and Apalachicola Bay, using three primary gears: a 21.3 m center-bag haul seine (3.2 mm nylon mesh), a 6.1 m otter trawl (38 mm stretched mesh with a 3.2 mm nylon mesh liner in the cod end), and a 183- center-bag haul seine (37.5 mm stretch nylon mesh). The polyhaline seagrass survey is conducted monthly (June–November) in St. Andrew Bay, Apalachicola Bay, the Big Bend region, Tampa Bay, and Charlotte Harbor, using the 6.1 m otter trawl.

Gear:

The 21.3 m seine is recommended for use in the assessment. With a 3.2 mm mesh, this gear captures a wide size range of shrimp (Figures 2-5, SEDAR 87 DW-11) in multiple habitats. Frequency of occurrence within this gear was as high as 61% for Pink Shrimp, 10% for Brown Shrimp, and 10% for White Shrimp (Tables 1-12, SEDAR 87 DW-11).

The 6.1 m otter trawl is recommended for use in the assessment. With a 3.2 mm mesh liner, this gear captures a wide range of sizes (Figures 2-5, SEDAR 87 DW-11). This gear has frequencies of occurrence as high as 69% for Pink Shrimp, 42% for Brown Shrimp, and 40% for White Shrimp. In addition, the 6.1 m otter trawl samples habitat that is not accessible to the seine gear (Tables 1-12, SEDAR 87 DW-11).

The 183 m seine is not recommended for use in this assessment. With a stretch mesh of 37.5 mm, this gear is size-selective to the larger sub-adult or adult portion of the estuarine shrimp population. In addition to the narrow size selectivity, frequency of occurrence in this gear is generally very low for all three species.

Index of Abundance:

Indices of abundance for Pink Shrimp were developed using long-term FIM data and generalized linear models; however, all years prior to 1998 were excluded from analyses due to reduced temporal coverage during the year (Figure 20, SEDAR 87 DW-11). Analyses of Pink Shrimp abundances were further reduced to only include Charlotte Harbor and Tampa Bay because Pink Shrimp were captured much less frequently in Florida's northern Gulf Coast estuaries (Tables 1-3, SEDAR 87 DW-11). Samples collected using 183 m × 3 m center-bag haul seines were also excluded from the analyses because the seine's larger mesh size led to very low catches of Pink Shrimp. A total of three indices of abundance were explored and presented to the Index Working Group for Pink Shrimp from the FWC-FWRI long-term FIM program: 1) a full model, which included all data; 2) a reduced model that excluded the Charlotte Harbor tidal tributaries and creeks sampling expansion (2016–2022); and 3) a reduced model that excluded the Charlotte Harbor tidal tributaries and creeks (2016–2022) as well as the bay trawl expansion (2005–2022). All three indices of abundance had similar temporal trends and the third model had the lowest coefficients of variation. Therefore, the model recommended by the group was the reduced model that excluded the Charlotte Harbor tidal tributaries and creeks (2016–2022) as well as the bay trawl expansion (2005–2022). The recommended final subset model (1998-2022) included data from bay and river-deployed 21.3 m seines and river-deployed 6.1 m otter trawls.

An index of abundance for Pink Shrimp was also developed from the polyhaline seagrass survey, via generalized linear model (Figure 21, SEDAR 87 DW-11). As with long-term FIM analyses, polyhaline seagrass survey analyses of Pink Shrimp excluded northern estuaries because of low catches in the northern estuaries (Tables 4, SEDAR 87 DW-11). The index of abundance from the polyhaline seagrass survey included data from the 6.1 m otter trawls from 2008 through 2022 and is recommended.

An index of abundance was developed for Brown Shrimp via generalized linear models using data from long-term FIM data collected in Apalachicola Bay (Figure 22, SEDAR 87 DW-11). Data from all other estuaries were excluded because Brown Shrimp were either rarely collected or absent in all other Gulf estuaries (Tables 5-7, SEDAR 87 DW-11). In addition, all years prior to 2001 were excluded from analysis to conserve a time series with analogous gear use and spatial coverage. River deployments of the 21.3 m center bag seine were excluded because Brown Shrimp were rarely collected in these habitats (Tables 6, SEDAR 87 DW-11). As with the Pink Shrimp indices, the 183 m haul seines were excluded because of low catch rates in this larger mesh size gear. The developed brown shrimp index was determined to be suitable and recommended for use. The final recommended subset model (2001-2022) included data from bay-deployed 21.3 m seines and bay and river-deployed 6.1 m otter trawls.

An index of abundance was developed for White Shrimp via generalized linear models using data from long-term FIM data collected in Apalachicola Bay (Figure 23, SEDAR 87 DW-11). White Shrimp catch was limited to the northern Florida Gulf Coast estuaries, with 97% of the catch occurring in Apalachicola Bay (Tables 9-12, SEDAR 87 DW-11). As with the Brown Shrimp index, all years prior to 2001 were dropped from analysis. White Shrimp catch predominantly occurred within spatial zones that encompassed the lower reaches, and discharge plume, of the Apalachicola River; therefore, all other spatial zones were excluded from the analysis. Sampling stations deploying the 183 m seine were also removed from the analysis due to low catch rates of White Shrimp. The developed White Shrimp index was determined to be suitable and recommended for use. The final recommended subset model (2001-2022) included data from bay and river-deployed 21.3 m seine and 6.1 m otter trawls.

Indices of abundance of Brown and White Shrimp were not developed from FWC-FWRI polyhaline seagrass surveys because this survey represents a shorter time series as compared to the FIM long-term Survey. In addition to the shortened time series, catches of Brown and White Shrimp within this survey were low in frequency and overall catch (Tables 8,12, SEADAR 87-DW-11).

4.4.7 COMBINED ALABAMA, MISSISSIPPI, AND LOUISIANA INDICES

Similarities in methods exist between the FI monitoring programs in Alabama, Louisiana, and Mississippi. Based on these similarities, a combined index among the three states was initiated during the Data Workshop (see above for detailed information on each state's FI monitoring programs).

Alabama, Louisiana, and Mississippi recommended using the combined FI 16-foot trawl survey data from the individual state sampling programs as the foundation for combined shrimp abundance index development. These surveys capture a wide range of size classes and are conducted throughout the year with samples collected monthly at each station. For brown shrimp, the states recommended developing an index of abundance from a potential span of 1980-2022 for the months of March-June only. These months cover the primary period that brown shrimp recruit into estuarine waters and when developing sub-adults leave. Louisiana FI data will be used for years 1980-2022, Mississippi 1984-2022, and Alabama 2001-2021. These time frames are when FI data was gathered with the inclusion of individual lengths. For white shrimp, the states recommend developing an index of abundance with a potential span of 1980-2022 for all months of the year. White shrimp are present in inshore waters throughout the year as overwintering adults in spring months and as new recruits in summer months, giving the best option for an abundance index that includes all size classes. The same potential time series of observations by state sampling programs would be considered for this index. A combined white shrimp index removing all size classification was also discussed.

Several preliminary nominal delta-lognormal combined indices of abundance for white and brown shrimp were examined during the workshop as a focus for further discussions (Figures 3-4). The core of which focused on the overlap of sampling years and potential weighting of data from the individual state sampling programs. The combined sampling programs span 1980-2022. However, all three sampling programs only overlap from 2001 to 2021 and Mississippi and Louisiana only overlap from 1984 to 2022. Therefore, raising questions as to whether a longer time series from one or two areas vs shorter times series from all three programs was more advantageous. The spatial area of inference for each of the state sampling programs also varies significantly, with the state of Louisiana accounting for the vast majority of the area of interest. The group determined that spatial weighting of data from the individual sampling programs is likely warranted and needed to be further explored.

Given the need to further explore the times series of data to include and the need to pursue potential spatial weighting of data among the three programs, the IWG recommends that combined indices of abundance from Alabama, Mississippi and Louisiana be pursued as a research recommendation.

4.5 CONSENSUS RECOMMENDATIONS

The review of data associated with individual sampling programs conducted by the states of Texas, Louisiana, Mississippi, Alabama, and Florida and the National Marine Fisheries Service are summarized in Table 2. The spatial ranges of the individual sampling programs are in Figure 2. Recommendations regarding data sets to examine representative trends in abundance for brown, white and pink shrimp are summarized respectively in Tables 3, 4 and 5. The species summaries include recommendations for each size category and sampling region.

4.6 RESEARCH RECOMMENDATIONS

- Explore survey / gear calibration studies among state and federal sampling programs
- Perform post hoc analysis to potentially account for habitat classification variables and on indices of abundance
- Examination of whether due to zeros, indices based on monthly data may best be structured to focus on core recruitment months or accommodate in model

- Exploration of indices of abundance utilizing combined data from AL, MS, and LA 16 ft state sampling programs, including potentially including a weighting factor to account for differences in area sampled (surface area, habitat area, etc.)

4.7 LITERATURE CITED

Lo, N.C.H., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Canadian Journal of Fisheries and Aquatic Science 49:2515-2526.

4.8 TABLES

Table 1. Size categories of brown shrimp, white shrimp, and pink shrimp based on total lengths and the associated market category.

Species	Length Limits	Size Category	Market Category (tails/lb)
Brown	Total Length < 115.6	Small	> 67
	115.6 >= Total Length <=151.8	Medium	30 to 67
	151.8 > Total Length	Large	< 30
Pink	Total Length < 109.8	Small	> 67
	109.8 >= Total Length <= 144.2	Medium	30 to 67
	144.2 > Total Length	Large	< 30
White	Total Length < 108.1	Small	> 67
	108.1 >= Total Length <= 144.3	Medium	30 to 67
	144.3 > Total Length	Large	< 30

Table 2. Programmatic evaluation

Agency	Survey	Evaluation
Texas	Gulf Trawl	Suitable – Recommended
Texas	Bay Trawl	Suitable – Recommended
Louisiana	6 ft trawl	Suitable – Not recommended
Louisiana	16 ft trawl	Suitable – Recommended
Louisiana	Nearshore trawl	Suitable – Not recommended
Mississippi	Long term monitoring	Suitable – Recommended
Mississippi	Shrimp monitoring	Suitable – Not recommended
Alabama	16 ft trawl	Suitable – Recommended
Alabama	Beam - Plankton	Not suitable
Alabama	Seine	Suitable – Not recommended
Florida	6.1 m trawl	Suitable – Recommended
Florida	21.3 m seine	Suitable – Recommended
Florida	183 m seine	Suitable – Not recommended
Partner (NMFS and state agencies)	SEAMAP Summer Groundfish Survey	Suitable – Recommended
Partner (NMFS and state agencies)	SEAMAP Fall Groundfish Survey	Suitable – Recommended

Table 3. Review of abundance indices for brown shrimp

Survey	Years	Statistical Zones	Size Class	Recommendation
SEAMAP Summer Groundfish Survey	1987-2008	21-18	Large	Representative
SEAMAP Summer Groundfish Survey	1987-2008	21-18	Medium	Representative
SEAMAP Summer Groundfish Survey	1987-2008	21-18	Small	Representative
SEAMAP Summer Groundfish Survey	2009-2022	21-18	Large	Representative
SEAMAP Summer Groundfish Survey	2009-2022	21-18	Medium	Representative
SEAMAP Summer Groundfish Survey	2009-2022	21-18	Small	Representative
SEAMAP Summer Groundfish Survey	1987-2008	17-11	Large	Representative
SEAMAP Summer Groundfish Survey	1987-2008	17-11	Medium	Representative
SEAMAP Summer Groundfish Survey	1987-2008	17-11	Small	Representative
SEAMAP Summer Groundfish Survey	2009-2022	17-11	Large	Representative
SEAMAP Summer Groundfish Survey	2009-2022	17-11	Medium	Representative
SEAMAP Summer Groundfish Survey	2009-2022	17-11	Small	Representative
SEAMAP Summer Groundfish Survey	2009-2022	10-02	Large	No Index

SEAMAP Summer Groundfish Survey	2009-2022	10-02	Medium	No Index
SEAMAP Summer Groundfish Survey	2009-2022	10-02	Small	No Index
SEAMAP Fall Groundfish Survey	1987-2007	21-18	Large	Representative
SEAMAP Fall Groundfish Survey	1987-2007	21-18	Medium	Representative
SEAMAP Fall Groundfish Survey	1987-2007	21-18	Small	Representative
SEAMAP Fall Groundfish Survey	2008-2022	21-18	Large	Representative
SEAMAP Fall Groundfish Survey	2008-2022	21-18	Medium	Representative
SEAMAP Fall Groundfish Survey	2008-2022	21-18	Small	Representative
SEAMAP Fall Groundfish Survey	1987-2007	17-11	Large	Representative
SEAMAP Fall Groundfish Survey	1987-2007	17-11	Medium	Representative
SEAMAP Fall Groundfish Survey	1987-2007	17-11	Small	Representative
SEAMAP Fall Groundfish Survey	2008-2022	17-11	Large	Representative
SEAMAP Fall Groundfish Survey	2008-2022	17-11	Medium	Representative
SEAMAP Fall Groundfish Survey	2008-2022	17-11	Small	Representative
SEAMAP Fall	2008-2022	10-02	Large	Not Representative

Groundfish Survey				
SEAMAP Fall Groundfish Survey	2008-2022	10-02	Medium	Not Representative
SEAMAP Fall Groundfish Survey	2008-2022	10-02	Small	No Index
Louisiana	1980-2022	Louisiana state waters	Large	Not Representative
Louisiana	1980-2022	Louisiana state waters	Medium	Representative
Louisiana	1980-2022	Louisiana state waters	Small	Representative
Texas	1985-2022	Texas Bay	Large	Not Representative
Texas	1985-2022	Texas Bay	Medium	Not Representative
Texas	1985-2022	Texas Bay	Small	Representative
Texas	1985-2022	Texas Gulf	Large	Not Representative
Texas	1985-2022	Texas Gulf	Medium	Not Representative
Texas	1985-2022	Texas Gulf	Small	Representative
Florida	2001-2022	Florida bays	Small	Representative

Table 4. Review of abundance indices for white shrimp

Survey	Years	Area	Size Class	Recommendation
SEAMAP Summer Groundfish Survey	1987-2008	21-18	Large	Representative
SEAMAP Summer Groundfish Survey	1987-2008	21-18	Medium	Representative
SEAMAP Summer Groundfish Survey	1987-2008	21-18	Small	No Index
SEAMAP Summer Groundfish Survey	2009-2022	21-18	Large	Representative
SEAMAP Summer Groundfish Survey	2009-2022	21-18	Medium	Not Representative
SEAMAP Summer Groundfish Survey	2009-2022	21-18	Small	No Index
SEAMAP Summer Groundfish Survey	1987-2008	17-11	Large	Representative
SEAMAP Summer Groundfish Survey	1987-2008	17-11	Medium	Not Representative
SEAMAP Summer Groundfish Survey	1987-2008	17-11	Small	No Index
SEAMAP Summer Groundfish Survey	2009-2022	17-11	Large	Representative
SEAMAP Summer Groundfish Survey	2009-2022	17-11	Medium	Not Representative
SEAMAP Summer Groundfish Survey	2009-2022	17-11	Small	No Index
SEAMAP Fall Groundfish Survey	1987-2007	21-18	Large	Representative
SEAMAP Fall	1987-2007	21-18	Medium	Representative

Groundfish Survey				
SEAMAP Fall Groundfish Survey	1987-2007	21-18	Small	Not Representative
SEAMAP Fall Groundfish Survey	2008-2022	21-18	Large	Representative
SEAMAP Fall Groundfish Survey	2008-2022	21-18	Medium	Not Representative
SEAMAP Fall Groundfish Survey	2008-2022	21-18	Small	Not Representative
SEAMAP Fall Groundfish Survey	1987-2007	17-11	Large	Representative
SEAMAP Fall Groundfish Survey	1987-2007	17-11	Medium	Representative
SEAMAP Fall Groundfish Survey	1987-2007	17-11	Small	Not Representative
SEAMAP Fall Groundfish Survey	2008-2022	17-11	Large	Representative
SEAMAP Fall Groundfish Survey	2008-2022	17-11	Medium	Not Representative
SEAMAP Fall Groundfish Survey	2008-2022	17-11	Small	No Index
Louisiana	1980-2022	Louisiana state waters	Large	Representative
Louisiana	1980-2022	Louisiana state waters	Medium	Representative
Louisiana	1980-2022	Louisiana state waters	Small	Representative
Texas	1985-2022	Texas Bay	Large	Not Representative

Texas	1985-2022	Texas Bay	Medium	Not Representative
Texas	1985-2022	Texas Bay	Small	Representative
Texas	1985-2022	Texas Gulf	Large	Not Representative
Texas	1985-2022	Texas Gulf	Medium	Not Representative
Texas	1985-2022	Texas Gulf	Small	Representative
Florida	2001-2022	Florida bays	Small	Representative

Table 5. Review of abundance indices for pink shrimp

Survey	Years	Area	Size Class	Recommendation
SEAMAP Summer Groundfish Survey	2010-2022	2 -10	Large	Representative
SEAMAP Summer Groundfish Survey	2010-2022	2 -10	Medium	Representative
SEAMAP Summer Groundfish Survey	2010-2022	2 -10	Small	Not Representative
SEAMAP Fall Groundfish Survey	2010-2022	2 -10	Large	Not Representative
SEAMAP Fall Groundfish Survey	2010-2022	2 -10	Medium	Not Representative
SEAMAP Fall Groundfish Survey	2010-2022	2 -10	Small	Not Representative
Florida	1998-2022	Florida bays	Small	Representative
Florida	2008-2022	Florida bays	Small	Representative

4.9 FIGURES

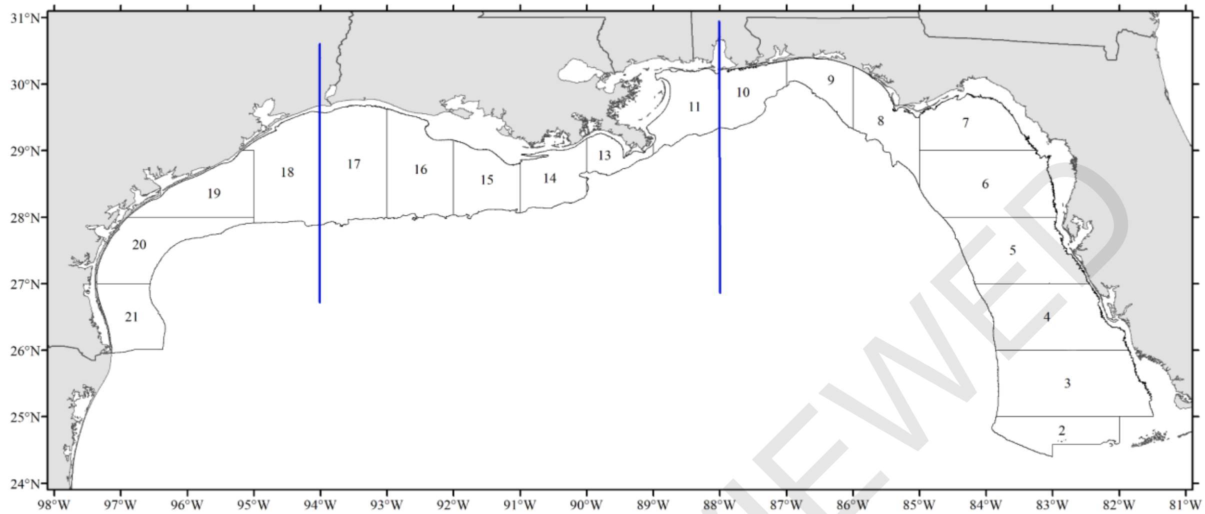


Figure 1. Gulf of Mexico statistical zones with the blue lines representing the geographical breaks used when calculating abundance indices for brown shrimp, white shrimp, and pink shrimp.

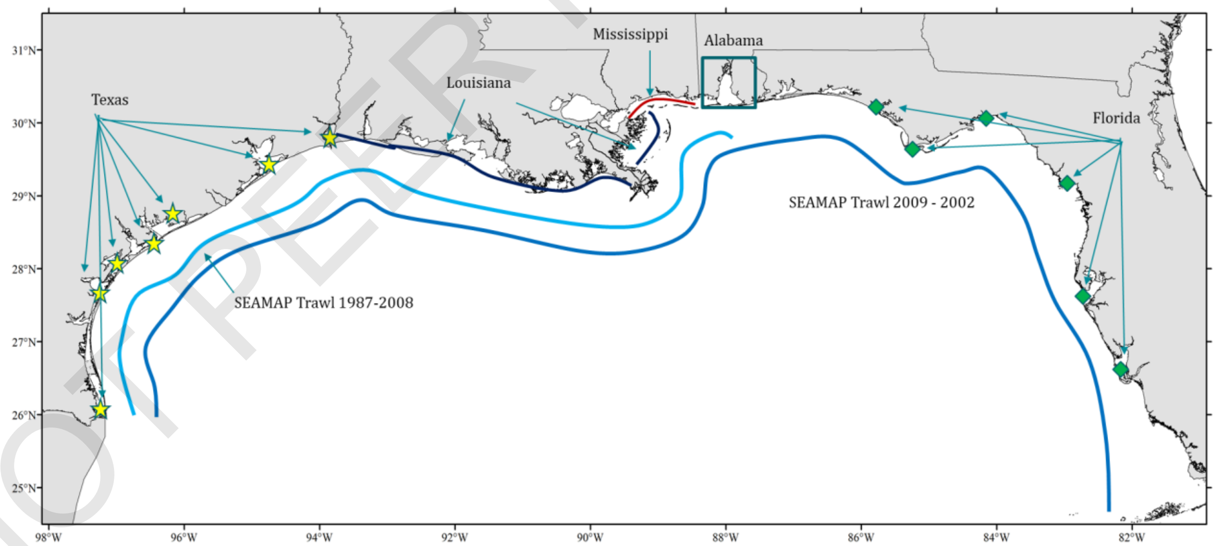
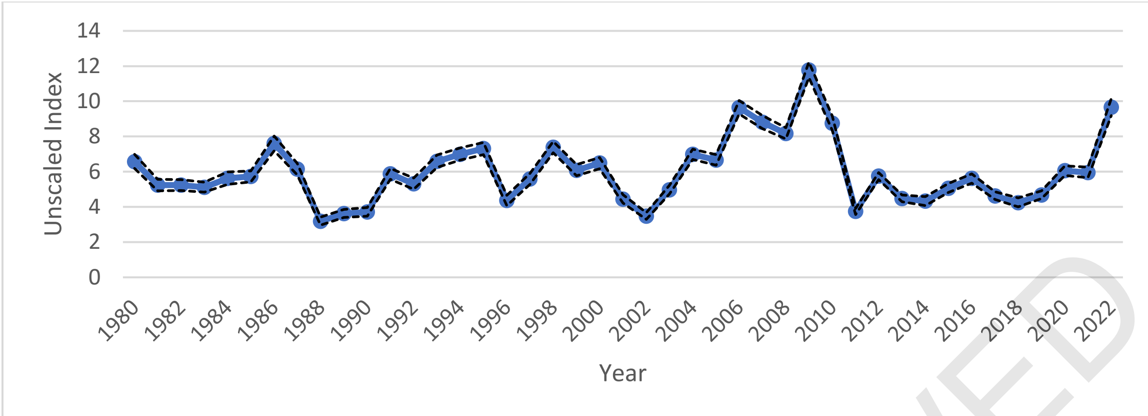
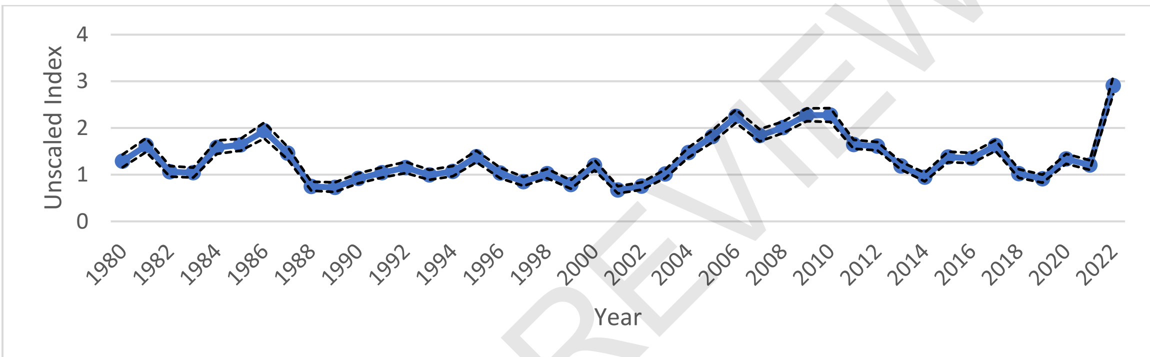


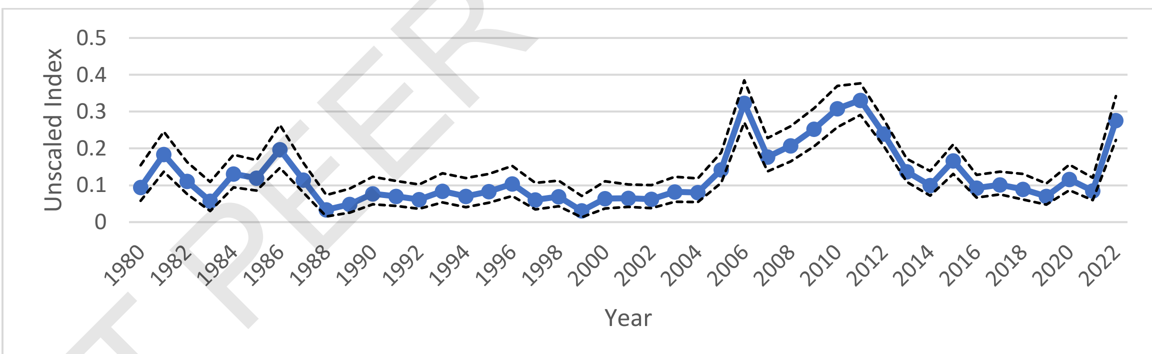
Figure 2. Generalized survey areas of federal and state sampling programs across the northern Gulf of Mexico.



a. Small

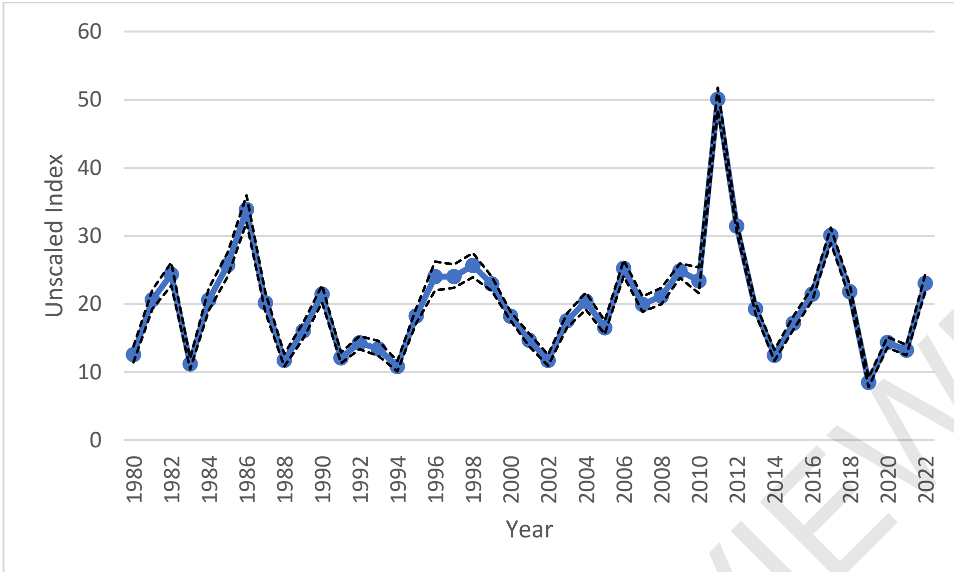


b. Medium

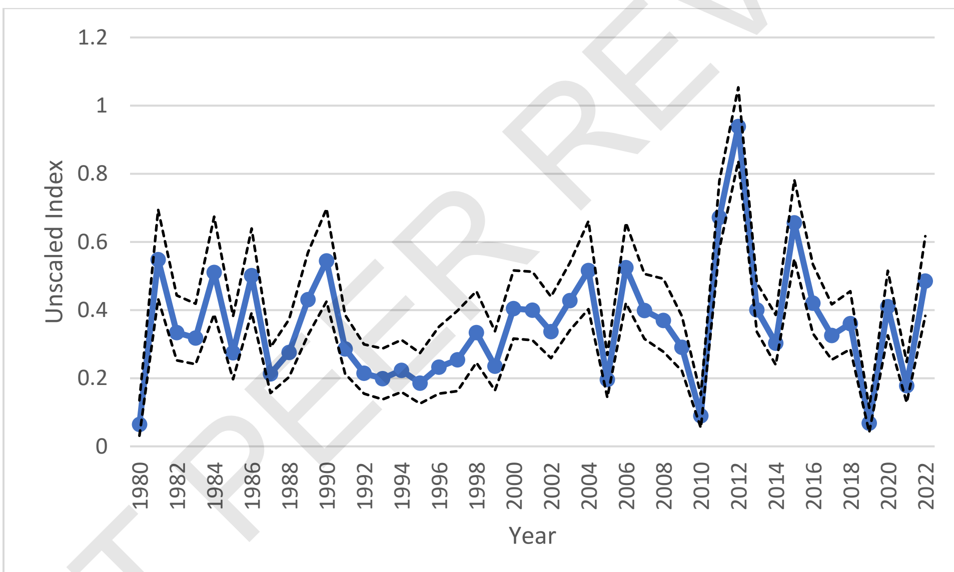


c. Large

Figure 3. Small, medium, and large white shrimp nominal indices of abundance from combined Louisiana, Mississippi, and Alabama survey data.



a. Small



b. Medium

Figure 4. Small and medium brown shrimp nominal indices of abundance from combined Louisiana, Mississippi, and Alabama survey data. There were insufficient data to generate a combined index for large brown shrimp.

5 ECONOMICS AND SOCIAL SCIENCES

5.1 OVERVIEW

Economic and social sciences were included in the Terms of Reference for the Gulf of Mexico shrimp SEDAR assessment. Incorporating social science into the stock assessment process from the start is particularly important for shrimp because they are a fluctuating annual crop where this year's harvest relates little or not to next year's recruitment or stock size. As a result, classic stock or growth overfishing are less of a concern, and other aspects of the fishery rise to prominence, including ones driven by economic or social forces, motives and behavior. Since this is the inaugural SEDAR for the Gulf of Mexico shrimp stock, it is appropriate to evaluate the full range of scientific data available. Further, this process of evaluation and documentation can inform other GOM shrimp research and management support efforts that build on or follow the stock assessment itself.

As this is the first time that data and information from economics and the social sciences are to be included in the SEDAR process, the data workshop was spent developing, in collaboration with the assessment leads, more specific and clear objectives for the workgroup to address. It was determined that a central concern of the assessment scientists is understanding---and, possibly, modeling---the economic and social drivers of the fleet's fishing effort. The science of economics helps explain the behavior of firms (in this case shrimp harvesters), with prices and markets playing a central role. As shrimp firms and production changes, the shrimpers and their communities are impacted and change as well, as the full range of social sciences document.

In the case of the GOM shrimp fishery, in broad strokes, the slow shift over 3+ decades from a scarce, high-value, wild-caught, luxury product to a high-volume, imported, farm-raised commodity led to 1) a drastic shrimp price decline; 2) a consolidation of the shrimp fleet to cut cost; 3) raised productivity (CPUE) for the remaining vessels due to less congestion on the shrimping grounds, and, finally, 4) a low-margin, "break-even" industry exposed to global shrimp and oil price fluctuations. Social consequences of these economic developments include, for example, growing reliance on (cheap) "imported" labor and reduced resilience of shrimping firms, and by extension their communities, against further shocks such as fuel price spikes, hurricane impacts, or poor shrimp recruitment years.

Available economic and social data on Gulf of Mexico shrimping vary by the time and space they cover, their correspondence across sources, and whether they are quantitative or quantifiable or primarily qualitative. Working papers provided by Liese (DW-07, DW-08) and Griffith at al. (DW-15) identify some of the factors that might be drivers of shrimping effort, including imported and GOM shrimp prices, fuel prices, and the overall economics of the harvesting industry, as well as background information on the recent history of the fishery. Qualitative social science information can assist in understanding developments in the fishery and hence validate trends, thresholds, and outliers in the quantitative fisheries data used by the assessment process.

5.1.1 Terms of Reference

The terms of reference for the SEDAR87 data workshop explicitly call for the inclusion of economics, a social science discipline:

"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”

5.1.2 Participants

Below are the workgroup participant of the economics and social science workgroup and their affiliations:

Matt Freeman, Economist, Gulf of Mexico Fishery Management Council, Tampa, FL

David Griffith, Professor of Anthropology, East Carolina University, Greenville, NC

Christopher Liese (group lead), Economist, NOAA SEFSC, Social Science Research Group, Miami, FL

David Records, Economist, NOAA SERO, Social Science Branch, St. Petersburg, FL

Mike Travis, Lead Economist, NOAA SERO, Social Science Branch, St. Petersburg, FL

5.1.3 Objectives

Narrow Goal:

Provide quantitative data as stock assessment inputs.

Provide qualitative information as background and explanation of developments over time in the fishery.

Broad Goal:

Integrate social scientists into the SEDAR process to learn from each other’s disciplines and identify future areas for collaboration.

Advise on the SEDAR’s input/model/output to facilitate future (economic and management) use of the assessment’s science.

5.2 REVIEW OF WORKING PAPERS AND CONSENSUS RECOMMENDATIIONS

The workgroup discussed and found consensus on recommendations for the fuel price index, inflation adjustment index, and the discount rate (on 9/19/2023) and, tentatively, on the approach/methodology for the shrimp price indices (Gulf of Mexico domestic and imports) and the qualitative write-up (9/20/23). The workgroup discussed and endorsed the economic survey data (economic performance) but no obvious use by the stock assessment could be established at this time (9/20/23). A lot of discussion focused on the recent history and developments in this fishery at the workshop, and these discussions were used to refine the early working paper on the social dimensions of the GOM fishery (SEDAR87-DW-02). The workgroup met by phone on 10/20/23 and revisited and finalized the Gulf of Mexico domestic and import shrimp price indices, as well as endorsed the final qualitative write-up (Griffith et al., DW-15).

The workgroup noted that while they could endorse the data sources/information in general, not all decisions can be made independent of the specifics of the final stock assessment models chosen and the purpose and method for including economic data. Further, the economic data will often not match the data/model resolution across many or even all of the stock assessment's dimensions. Economic data is more aggregate, often at an annual, overall fishery resolution.

5.3 QUANTITATIVE DATA

5.3.1 Fuel Price Index

There are several national and regional indices for fuel prices (gas, diesel, or crude oil; retail or wholesale; etc.). They have varying start dates, with many starting in the mid-1970s (after the world oil shocks). Because all these indices are ultimately tied to the global oil market, it is unsurprising that the price fluctuations within each are broadly the same. As a result, the specific choice of a fuel price index is not critical for SEDAR87, where the goal is to capture the underlying trends over time as opposed to absolute values. The workgroup endorsed using a regional index for retail diesel if a time series starting in 1995 is sufficient, as recommendation in the working paper (SEDAR87-DW-08). The exact choice, however, will depend on the needed time frame.

It should be noted that all provided indices are annual and have been adjusted for inflation. It is possible to provide monthly or seasonal price indices if this is deemed useful for the stock assessment purpose.

5.3.2 Inflation Adjustment

The workgroup discussed the best index to use for inflation adjusting dollar values across time. By consensus, the group agreed that the U.S. Bureau of Economic Analysis (BEA) GDP implicit price deflator should be used as proposed in the working paper. NOAA Fisheries' SERO and SEFSC analysts regularly use this index and keeping a consistent approach helps ensure science that is more comparable. Similar as for the fuel price indices, the specific choice of inflation index is probably not critical for SEDAR87 as they all broadly show the same devaluation of the U.S. dollar over time, especially at an annual level. More details are provided in the working paper (SEDAR87-DW-08).

Data file: shr_infladj_USBEA_2922_08182023.csv

5.3.3 Discount Rate

The workgroup discussed what discount rate should be used by the stock assessment, should future dollar values need to be expressed as, or compared to, today's values. The recommended discount rate for this SEDAR is 2.0%, as recommended by the Biden Administration for Federal agencies developing regulatory analysis. More details are provided in the working paper (SEDAR87-DW-08).

Data file: shr_discount_OMB_future_11052023.csv

5.3.4 Economic Survey Results including Economic Performance

The workgroup discussed the GOM shrimp economic survey data and results. The results are very interesting and support much of the narrative of this fishery. The workgroup endorsed the data as usable and scientifically sound. That said, the performance and derived economic measures are usually ***outcomes*** of the fishery rather than drivers. Hence it is not clear to the group if or how these economic metrics would be integrated into a stock assessment model. An example, though deemed not very likely by the group, could be the inclusion of a lagged fishery profit measure, i.e., assuming that last year's (average) profit influences fishing behavior the following year. Another example might be claims payments related to the DWH oil spill, though the fishery aggregate/average nature of the results obscures the huge variation within the fleet, i.e., the measure would be average payments per vessel per year, but some vessels received large payouts while many received nothing. The workgroup felt that it was premature to determine if and how these data/results might support the stock assessment and hence recommends keeping them for now. More details are provided in the working paper (SEDAR87-DW-07).

Data file: shr_econ_SSRG_0619_08182023 - formatted for printing_discussion.csv

5.3.5 Shrimp Price Indices

The workgroup was tasked with deriving a GOM shrimp price index and a shrimp import price index (or global price index) during the SEDAR87 data workshop. The price indices are entirely derivative of the dealer landings (SEDAR87-DW-06) and import data (SEDAR87-DW-10) provided and documented by the SEFSC Fisheries Statistics Division. However, the focus on price index creation was deemed within the expertise of the economics and social sciences workgroup.

The discussion focused initially on the central role of prices in our decentralized or market economy. In a decentralized economy, the fluctuation of prices serves as the critical signal that coordinates all economic activity, conceptually allocating scarce resources to their most efficient/valuable use. As such, the price of shrimp is the principal variable that drives shrimping effort, though, ultimately, it is the interplay of consumer demand for shrimp and global supply that sets the price.

While the shrimp price (in a given market) drives the fishery, two caveats were discussed. The first is the delineation of the shrimp market. Most of the shrimp consumed in the U.S. is imported, as domestic landings measure in 100+ millions of lbs while imports reflect many billions of lbs of shrimp biomass (imported in various product forms). As such shrimp imports dwarf the production in the GOM shrimp fishery. Published research (Asche et al. 2012) shows the GOM shrimp market is integrated with, and a "price taker" from, the global market. As a result, it is expected that the import shrimp price leads the GOM shrimp price, which in turn drives GOM shrimp effort. That said, segments of the GOM shrimp fishery, e.g., pink shrimp, sell to more local markets and could (also) be driven by more local price developments. A GOM shrimp price index can be derived from ex-vessel prices of GOM landings. Such an index is "closer to the fishery" and might contain the effects of more local and regional drivers, e.g., local product scarcity or glut (warehouse fire or capacity constraint).

A second caveat is that prices, resulting from the interaction of a myriad of independent supply and demand decisions, reflect or summarize ***all*** the information available to market participants. As such it is usually not possible to further identify the specific factors that drive prices, unless they are very dominant or persistent over time. Similarly, it is not possible to say, on a decadal scale, if the global shrimp price drop led to an increase in shrimp volume or vice versa, as these processes (supply, demand, and price) continuously interact (feedback), shaping the market together. In the case of shrimp, a once high-priced, scarce, luxury product generated profit, and thereby attracted interest and investment, which led to increased production, including the development of shrimp farms. As additional, lower-cost-of-production shrimp entered the global market, shrimp prices dropped, and (greatly) expanded the demand and hence the market for shrimp.

Another very important aspect of shrimp prices in particular is that the per pound price varies substantially for different shrimp size categories, i.e., larger shrimp demand a premium over smaller shrimp. The price for the largest shrimp can be many multiples of the price for the smallest. So while today, shrimp is traded as a commodity, this commodity is split into differently priced categories. It should be noted that the spread across shrimp prices has declined somewhat over the last decades as shrimp farmers can control the size of shrimp produced. In comparison, the specific species of shrimp has little to no impact on the price.

As eluded to earlier, two data sources could be used to generate shrimp price indices for SEDAR87. A GOM shrimp price index can be derived from ex-vessel prices of GOM landings reported by the dealers, and an import/global market price of shrimp index can be derived from import data ultimately collected by U.S. Customs and Border Protection (CBP). The GOM landings data provided the species information and only two shrimp product forms represent the vast majority of GOM landings, frozen heads-on shrimp (whole shrimp) and frozen heads-off shrimp ("tails"). The date of the dealer record corresponds roughly with the month the shrimp were caught, and these landings clearly correspond to the harvested biomass of the GOM shrimp fishery.

In contrast, the import data generally does not specify the shrimp species but does provide size categories for the frozen (plain) shrimp product form category (since 1990). Only in the last two years has CBP differentiated between wild-caught and farmed shrimp (since 2021). Further, the different "product forms" of imports---ranging from whole, frozen to heads-off/tails all the way to cooked, breaded, canned, etc.---obscure the weight of the actual shrimp input and hence the original biomass (from worldwide shrimp fisheries and aquaculture production). This makes measuring a standardized "volume of shrimp imports" difficult. Further, the variety of product forms also complicates the use of the import price data as the price reflects the overall value of the product, and it is impossible to determine which part of the price reflects the value added from the actual shrimp input (vs., e.g., the value added by bread crumbs and the act of breading).

That said, the amount of shrimp imported in simple, frozen forms is huge. Given these vast product flows, if the purpose of a price index is to integrate shrimp price fluctuations and trends into the stock assessment, using a subset of the import data is acceptable, e.g., volume or average price by year of frozen, heads-off shrimp. We could combine frozen heads-on and heads-off product using NMFS conversion factors, but given the lack of species information some approximation error is introduced.

The workgroup agreed that developing a price index is not trivial and depends a lot on its intended use. The workgroup agreed that more research is needed on prices and price indices on the dealer landings data, as everyone's experience dates back a decade or more, if any. The dealer data have undergone significant changes in that time, as has the fishery. On the other hand, the group agreed that a full research project would exceed the scope of this SEDAR (and take too long), and to stick to simple and proven methods. In light of that, it was decided that the index derived from the dealer data should mirror the one based on the import data. This decision also eliminates providing species-specific price indices (using the dealer data).

It was further discussed to what extent size should be incorporated into the index production. For instance, it would be possible to produce price indices for different size categories, but no use for such indices was found at the time. A straight average across all the applicable landings or imports, i.e., ignoring size categories, represents the actual prices paid and received in the specific year---and hence is an important measure---yet it suffers from distortions from shifting market shares of different shrimp sizes. Given that the focus of a price index is as a possible driver of effort, the workgroup decided that a size-adjusted price index would be most appropriate. The actual size categories are a given in the import data. A size-adjusted price index is produced by weighted-averaging across prices by size and where the weights are kept constant, similar to how the consumer price index is calculated using a fixed market basket of goods and services over time. The weights might be the series' average (over time) share of market for each size category. The group agreed on the methodology needed for generating price indices, and recommended using the average size distribution across the time series as the weights in the size-adjusted price indices.

Finally, it should be noted that all the GOM and import shrimp price data is nominal data and will need to be inflation adjusted before use in most analysis. Hence the price indices data provided to this SEDAR have been inflation adjusted using the GDP implicit price deflator. Any forward-looking analysis would not need inflation adjustment as dollar values will be hypothetical and can be based on the "current" price level. Note though, for other reasons, future dollar values will need to be discounted for most analysis.

In summary, given the previous discussion, the workgroup recommends using the size-adjusted import price index in any regression where a proxy for the primary driver of effort on the demand side is needed. The workgroup notes that if deemed useful or necessary for the stock assessment further indices can be generated from the data already submitted to this SEDAR. Such indices could differentiate by species (only for the GOM dealer data, though), by size category, e.g., large-medium-small, or by season or month. It was noted though that frozen imports have a very long shelf life and are routinely stored making assignment to a specific time period difficult.

5.4 QUALITATIVE INFORMATION

Apart from quantitative economic data provided for SEDAR 87 modeling efforts, economic and social science information can assist in understanding and validating developments, specifically trends, breaks, and outliers, in the quantitative data during the assessment process. The GOM shrimp fishery has been substantially influenced and changed by many global and local developments, including globalization/world trade and the extensive farming of shrimp, fuel price fluctuations, hurricanes, and the DWH oil spill. The workgroup discussed and documents many of these developments in the fishery and finalized a working paper (SEDAR87-DW-15), for the benefit of the assessment scientists and others not intricately familiar with the more recent history of the fishery. The working paper is primarily focused on developments since 2000, though some of the trends discussed have been in effect for longer. After many rounds of review and revision, the final version of the working paper was endorsed by all workgroup members and submitted to SEDAR87 on November 29, 2023.

This comment received from a shrimper on a 2007 economic survey creatively sums up the problems facing the Gulf of Mexico shrimp fishery since 2000 and especially during the 2006-2008 period which led to rapid industry consolidation and, possibly, again today (in 2023).

5.5 ECONOMIC DATA AND THE PROPOSED DATA STRATIFICATION

As mentioned before, the workgroup noted that while they could endorse the data sources/information in general, not all decisions can be made independent of the specifics of the final stock assessment models chosen and the purpose and method for including economic data. Further, some economic "data" is more akin to analysis, e.g., different price indices can be derived from the underlying data.

The economic data will often not match the data/model resolution across many or even all of the stock assessment's dimensions. Economic data is usually more aggregate, often at an annual, overall fishery resolution. On the proposed data stratification for SEDAR87, the workgroup generally found that, from a quantitative economic perspective, there is little difference between the three species. Prices are similar and the production methods, and hence costs, identical. While shrimp species abundance differ by region and season, most vessels harvest different species throughout the year, including by travelling and fishing throughout the entire (U.S.) GOM. Hence most economic work in this fishery aggregates all shrimp species into just 'shrimp'.

For the same reason, stratifying across area fished is not very meaningful from an economic perspective, and we only have annual economic data. Finally, while shrimp by size demand very different prices, shrimpers control over the sizes caught is limited to choosing the area fished, mostly the distance from shore. These decisions are so micro, that we do not have the economic data needed (trip-level costs) to differentiate.

The exception to the above is the time dimension. As described in the qualitative sections, the GOM shrimp fishery has undergone substantial changes over the last 30 years. Many of these changes are driven by---or captured in---the large variation of the prices for shrimp and for fuel over time, especially in year-to-year comparisons. If a further seasonal break-down of some price indices might explain more than an annual trend is an empirical question and could not be answered by the workgroup at this time.

5.6 LITERATURE CITED

Asche F., L.S. Bennear, Atle Oglend, and M.D. Smith. 2012. "US shrimp market integration." Marine Resource Economics, 27(2), 181-192

Griffith, D. 2023. Social Dimensions of the Gulf of Mexico Shrimp Fishery: Overview. SEDAR87-DW-02. SEDAR, North Charleston, SC.8 pp.

Griffith, David, Christopher Liese, Mike Travis, Matt Freeman, David Records 2023. Social Dimensions of Gulf of Mexico Shrimping. SEDAR87-DW-15. SEDAR, North Charleston, SC.12 pp.

Liese, C. 2023. Economics of the Federal Gulf of Mexico Shrimp Fishery. SEDAR87-DW-07. SEDAR, North Charleston, SC.3 pp.

Liese, C. 2023. General Economic Measures for Fuel Price Trend, Inflation Adjustment, and Discounting. SEDAR87-DW-08. SEDAR, North Charleston, SC. 6 pp

5.7 FIGURES

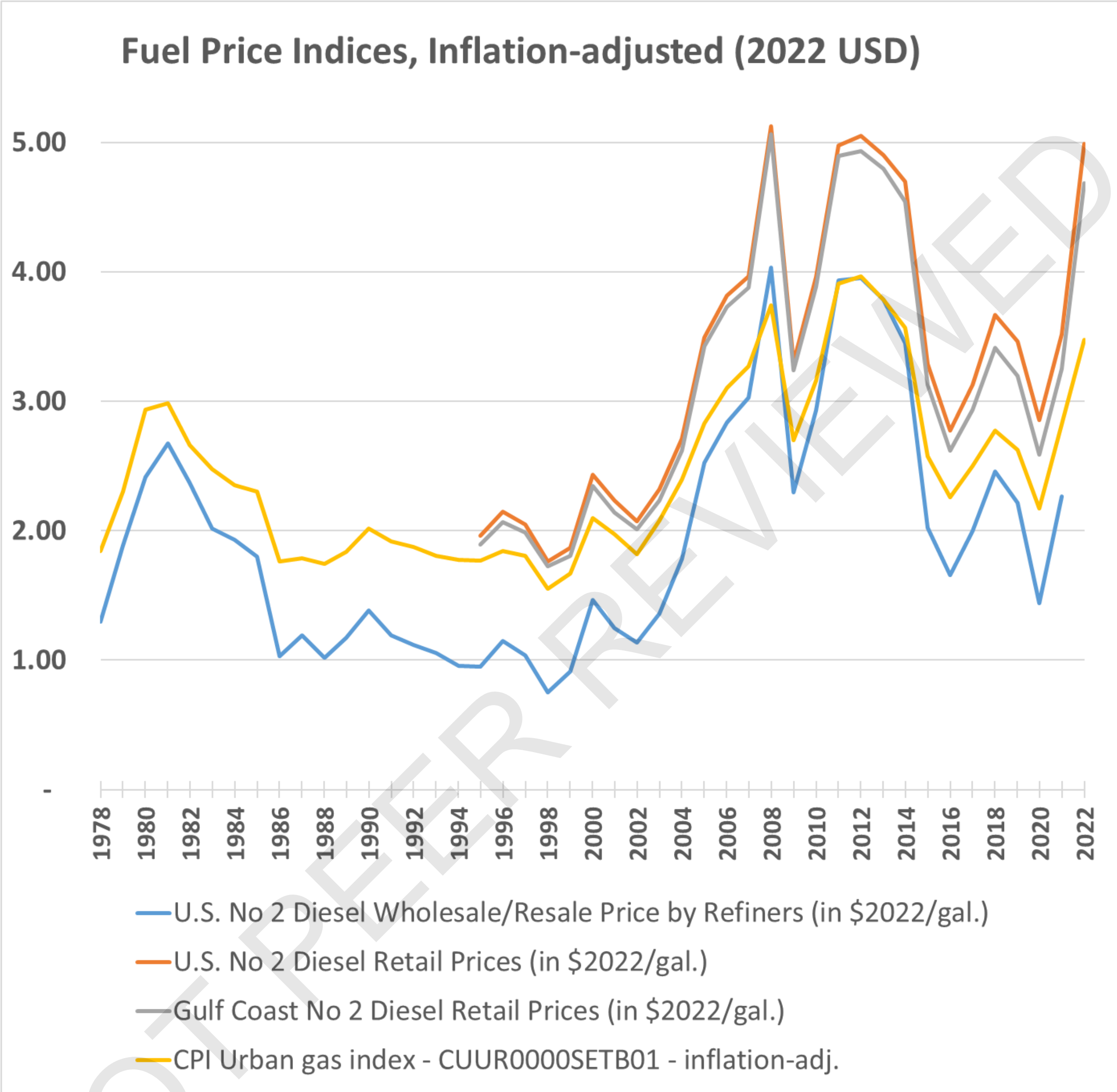


Figure 1: Data file: shr_priceIndx_SEFSC_7222_11052023.csv

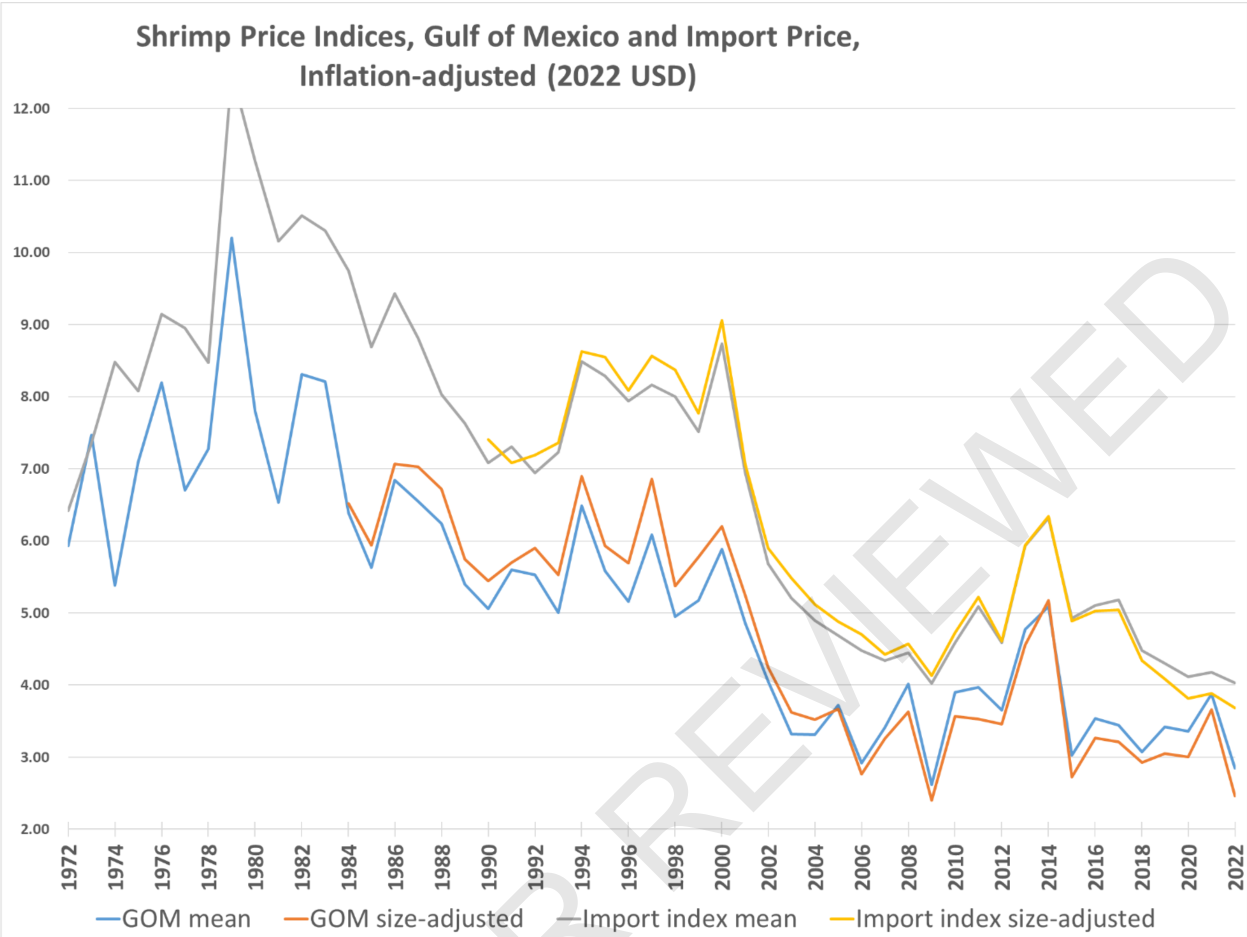


Figure 2: Data file: shr_priceIndx_SEFSC_7222_11052023.csv

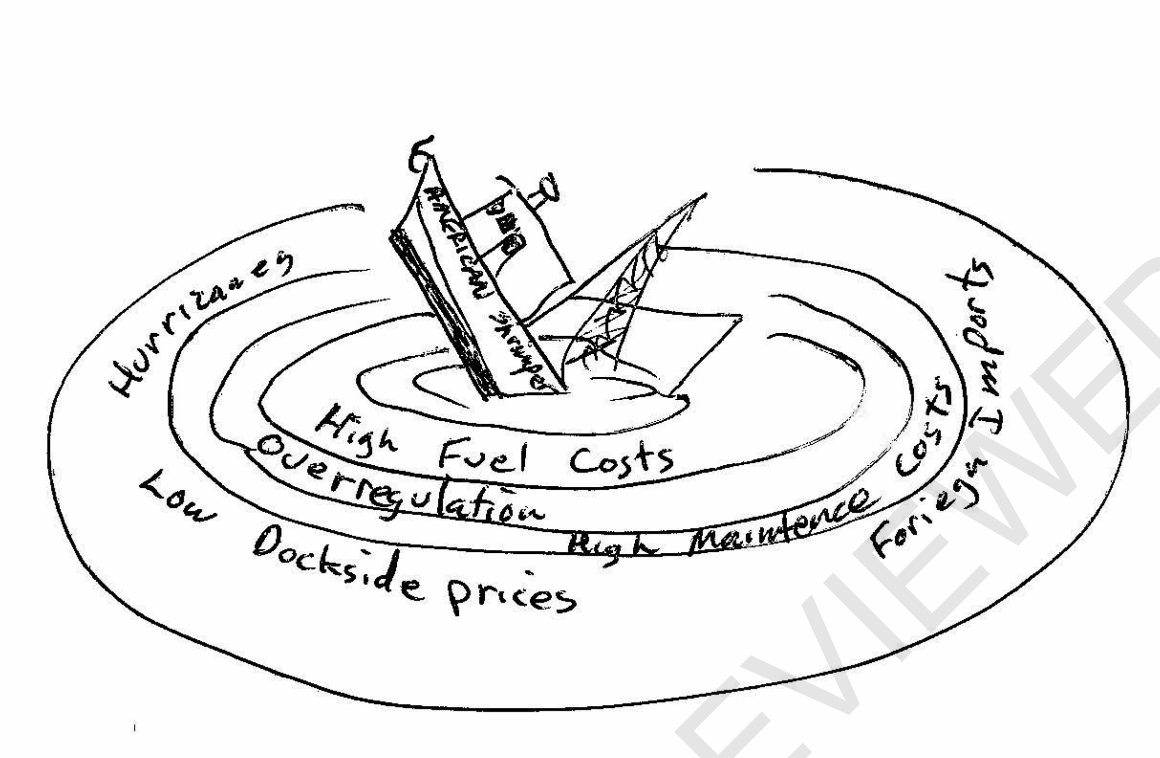


Figure 3. (source: J. D. Passwater)