Stock Assessment Update for White Shrimp (*Litopenaeus setiferus*) in the U.S. Gulf of Mexico for the 2017 Fishing Year

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December 2018

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1. ABSTRACT

This assessment update examined the US Gulf of Mexico white shrimp (*Litopenaeus setiferus*) population's behavior when parameterized with over 30 years of commercial white shrimp data from 1984 - 2017. In the full time series model run, fits to the CPUE estimates, size selectivity, spawning biomass, and numbers of recruits were generated. In addition, the incorporation of fishery independent surveys (SEAMAP and Louisiana State Shrimp Surveys) of shrimp abundance into the model greatly improves the precision (i.e., tuning) of this and future assessments.

Amendment 15 of the Gulf of Mexico Fisheries Management Plan (FMP) set new overfishing and overfished levels generated from the bench mark stock assessment. The criteria are based on SSBmsy and Fmsy and are 365.7 million pounds of tails and 3.48 per year respectively. Upon completion of the annual shrimp stock assessments the SSB and F values are compared to these management criteria.

The Stock Synthesis based shrimp stock assessment model generates fishing mortality (F) values, spawning stock biomass outputs in terms of pounds of spawning biomass, and the number of recruits. Fishing mortality had been decreasing in recent years, with annual weighted F of 1.58 being estimated for the 2017 fishing season. Spawning biomass and recruitment for the 2017 fishing season were 643.4 million pounds and 16.3 billion individuals respectively.

2. INTRODUCTION

The Gulf of Mexico penaeid shrimp stock synthesis based stock assessments have been vetted and reviewed by the Gulf of Mexico Fishery Management Council (GMFMC) Scientific and Statistical Committee (SSC) and Special Shrimp SSC since their inception in 2009. More recently the assessment's resulting reference points have been reviewed by these SSCs during several workshops. During the March 10, 2014 GMFMC special shrimp SSC meeting the group was again presented with the benchmark brown, pink, and white shrimp stock assessments. The group discussed that MSY based reference points be developed for the shrimp stocks.

The acceptance and subsequent adoption of Amendment 15 of the GOM Shrimp FMP defines the MSY based overfished and overfishing reference points for penaeid shrimp. To measure if the stock is in an overfished condition or undergoing overfishing the Stock Synthesis based stock assessment model estimate an MSY and corresponding SSB at MSY and F at MSY for the terminal "year" of the stock assessment model. The white shrimp assessment model is parameterized with months as years so the terminal SSBmsy value is for the terminal month and is multiplied by 12 to arrive at an annual SSBmsy index. This index value is then compared against the sum of the 12 monthly SSB estimates for the terminal assessment year. If the assessment year sum of SSB is greater than the index SSBmsy than the stock is not overfished. Conversely, if the assessment year sum of SSB is less than the index SSBmsy than the stock is overfished. Similar to the overfished reference point, the overfishing reference point F by month estimates are summed to an annual F estimate and are compared to the calculated annual Fmsy estimates derived by the assessment model.

This report describes the stock assessment update for white shrimp (*Litopenaeus setiferus*) using a generalized stock assessment model, Stock Synthesis (SS-3) (Methot 2009, Schirripa et al. 2009), parameterized with fishery data from 1984-2017. The model incorporates selectivity with seasonal changes (May-July) using an environmental offset approach, estimated steepness, and R_0 values.

As noted, Amendment 15 of the Gulf of Mexico Fisheries Management Plan (FMP) (GMFMC 2016) set new overfishing and overfished levels using criteria generated from the bench mark shrimp stock assessment. These new management criteria are based on SSBmsy and Fmsy and are 365.6 million pounds of tails and 3.48 per year respectively. This annual shrimp stock assessment generates estimates of SSB and F values which are compared to the aforementioned management criteria.

3. METHODS

3.1. Model Overview

To model the population dynamics of white shrimp I used a generalized stock assessment model, Stock Synthesis (SS-3) (Methot 2009). The Stock Synthesis model presented in this report was parameterized with such complexities as static mortality rates, seasonal changes in selectivity, recruitment deviations, and estimated steepness in the Beverton-Holt spawner-recruit function.

3.2. Data Sources

The model was parameterized with data from 1984 through 2017. The model structure included 1 fleet:

1) Commercial in- and offshore shrimp catch statistics (statistical zones 7-21)

and 3 indices of abundance:

1. SEAMAP Summer Groundfish Trawls (Fisheries-independent; 1987-2017)
2. SEAMAP Fall Groundfish Trawls (Fisheries-independent; 1987-2017)
3. Louisiana Monthly Shrimp Trawl Surveys (Fisheries-independent; Western Subset of surveys, 1984-2017)

3.2.1. Commercial Catch Statistics – The Stock Synthesis assessment model was parameterized with white shrimp commercial catch data from statistical zones 7-21 from January 1984 through December 2017 including: directed fishing effort by year and month, i.e., effort for those trips where >90 percent of the catch were white shrimp, used to calculate monthly CPUE. In addition, model inputs included total catch by size, i.e., size composition data consisting of count of numbers of shrimp per pound. To calculate CPUE statistics the methods outlined in Nance et al. (2008) were used. Beginning with pilot studies in 1999, an electronic logbook program (ELB) was initiated to augment shrimp fishing effort measurements. Gallaway et al. (2003a, 2003b) provides an in-depth description of this ELB data collection program and data collection procedures. These ELB data have been used to supplement the effort and location data collected by NMFS port agents and state trip tickets since 2006.

Total catch in pounds of shrimp tails by month from January 1984 through December 2017 was a primary input in the model. Beginning in 1984 shrimp catch data for the smallest sized shrimp, >67 count, were recorded at a finer scale, thus allowing the partitioning of this size category into four additional count categories, therefore having finer resolution for the smaller sized shrimp in the catch. This resulted in a total of 11 count categories for the data collected from 1984 to present; <15, 15-20, 21-25, 26-30, 31-40, 41-50, 51-67, 68-80, 81-100,101-115, and >115 (Hart and Nance 2010). These data are entered into the model as monthly catch in pounds in each of the eleven size bins for the years 1984-2017.

3.2.2. Growth Curve and other Population Level Rates - Growth parameters k and linf derived and reported by Klima (1964, 1974) were used as initial parameter values. Data inputs included a growth curve and a natural mortality rate of 0.27 per month as previously used in the historical VPA (Nichols 1984). The conversion factors developed by Brunenmeister (1980) were used to convert the data from total length to the poundage breaks between the catch count categories.

3.2.3. Size Selectivity - A dome shaped (double normal) selectivity pattern with 4 estimated parameters was used in the model. This resulting pattern provided a good fit to the data as will be shown in the results. In addition, months were modeled as years (408 “years”).

3.2.4. Catchability Q – Catchability was fixed during the early years of the time series and then set as a random walk from 2004-2017.

3.2.5. Louisiana Monthly Shrimp Survey Data – Shrimp data collected by the State of Louisiana from 1984–2017 were included in the model. These data were collected and provided by staff of the Louisiana Department of Wildlife and Fisheries (LDWF) and included size composition and indexes of abundance, see Appendix 1 in Hart (2012).

3.2.6. SEAMAP Data – SEAMAP data collected by both NOAA Fisheries research vessels and State Fisheries agency vessels were used in the Stock Synthesis model. For a complete description of the SEAMAP data collection procedures see Appendix 2 in Hart (2012). These SEAMAP sampling data inputs were collected from statistical zones 7-21. Sampling index data using the delta log normal index from 1987-2017 were survey model inputs. Size compositions for white shrimp collected and measured from 1987-2017 during the summer and fall cruises were also model inputs.

3.3. Model Configuration and Population Dynamics

3.3.1. Selectivity, Natural Mortality, and F Configurations – For the commercial fishing fleet selectivity I used a double normal setup and developed two seasonal selectivity curves; one curve for August-April, and one for the months of May–July. Natural mortality was fixed at 0.27 per month (Nichols 1984) for all shrimp ages in the model. I used the hybrid method of F approximation (Methot 2009). For a more detailed technical description of fishery selectivity, natural mortality M, and fishing mortality F settings used in Stock Synthesis, consult Methot and Wetzel (2013).

3.3.2. Time-Varying Parameters – I developed two selectivity curves, using an environmental link setup for selectivity. This allowed for potentially higher selectivity for the large shrimp which are present during the spring fishing season. In addition, R_0 (unfished recruitment) was not set as an estimated parameter. Recruitment was also modeled with monthly deviations superimposed on a 12 month cycle.

4. RESULTS

4.1. Parameter Estimates, Model Setups, and Model Fits

Stock Synthesis requires the model to be initialized with approximations for certain parameters which are then estimated by the model in preset phases. These initial approximations scale the parameters to biologically reasonable values, and facilitate the evaluation of parameters, e.g., mortality, recruitment deviations, and selectivity deviations, estimated in subsequent phases.

4.2. CPUE

Catch rate fluctuations both within and between years were revealed, with a close fit of expected to observed catch rates. Figure 4.2.1 illustrates the fit to the catch rates for this model with the random walk Q setup beginning in 2004.

The increase in the commercial fishery CPUE observed during this time period is also supported by the increasing trend in CPUE measured in the fishery independent SEAMAP and Louisiana survey data. The model fit to the Louisiana survey data is shown in Figure 4.2.2.

4.3. Generalized Size Comps

The model fit to the size composition of the catch for the commercial fishing fleet is shown in figure 4.3.1. Fits to the size composition for the Louisiana data are shown in figure 4.3.2.

4.4. Fishery Selectivity for the Commercial Fleet and Louisiana Surveys

Two seasonal selectivity curves were developed for the commercial fishery to model the seasonal harvest of large shrimp which are present in the spring fishery. The Stock Synthesis model results illustrate the fishery selectivity for the months of August-April and May-July (Figure 4.4.1). Size selectivity fits for the Louisiana survey are shown in figure 4.4.2.

4.5. SEAMAP CPUE, Size Composition, and Selectivity

The use of these fishery independent data has provided added information on some of the trends we see in the shrimp fishery. In addition these added data sources allow for better tuning of the models recruitment parameters. The summer and fall SEAMAP CPUE are shown in (Figure 4.5.1). Figures 4.5.2 show the good model fit to the size composition data for 1987-2017 for summer and fall surveys. Selectivity fits are shown for summer and fall SEAMAP data in figure 4.4.2.

4.6. Fishing Mortality

Stock Synthesis outputs F values by age and month, e.g., for 2017 the number of F values calculated is: 12 months x 24 ages = 288 F values. To synthesize this large number of Fs per year, the consensus of the 2012 SSC working group was to calculate the F rates in the following manner:

$$\text{Weighted Average Monthly F} = \frac{\sum[\mathit{Numbers\ by\ Age\ Matrix\ by\ Month}]\times[\mathit{F\ by\ Age\ Matrix\ by\ Month}]}{\sum \mathit{Numbers\ at\ Age\ by\ Month}} \qquad \text{(Eq.1)}$$

Equation 1 resulted in the calculation of weighted average monthly F values. These rates per month are then summed by year and compared to the Fmsy estimates. Fishing mortality over the last 5 years has shown a slight increase in recent years of the time series and in 2017 F equaled 1.58 (Figure 4.6.1).

4.7. Steepness, Spawning Biomass, and Recruitment

The model was set to estimate steepness for the spawner-recruit curve, with a steepness value of 0.99 estimated for the 2017 fishing season. Spawning biomass increased compared to last year and equaled 643.4 million pounds (Figure 4.7.1). Recruitment decreased with the number of recruits for 2017 equalling 16.3 billion individuals (Figure 4.7.2).

5. CONCLUSIONS

The Stock Synthesis stock assessment update provides outputs for new overfished and overfishing definitions for the Gulf of Mexico white shrimp fishery. The model update revealed an increase in spawning biomass, a decrease in recruitment, and a slight decrease in fishing mortality (F) during the later portion of the time series. This assessment update also provides evidence that the Gulf of Mexico white shrimp stock is not overfished or undergoing overfishing.

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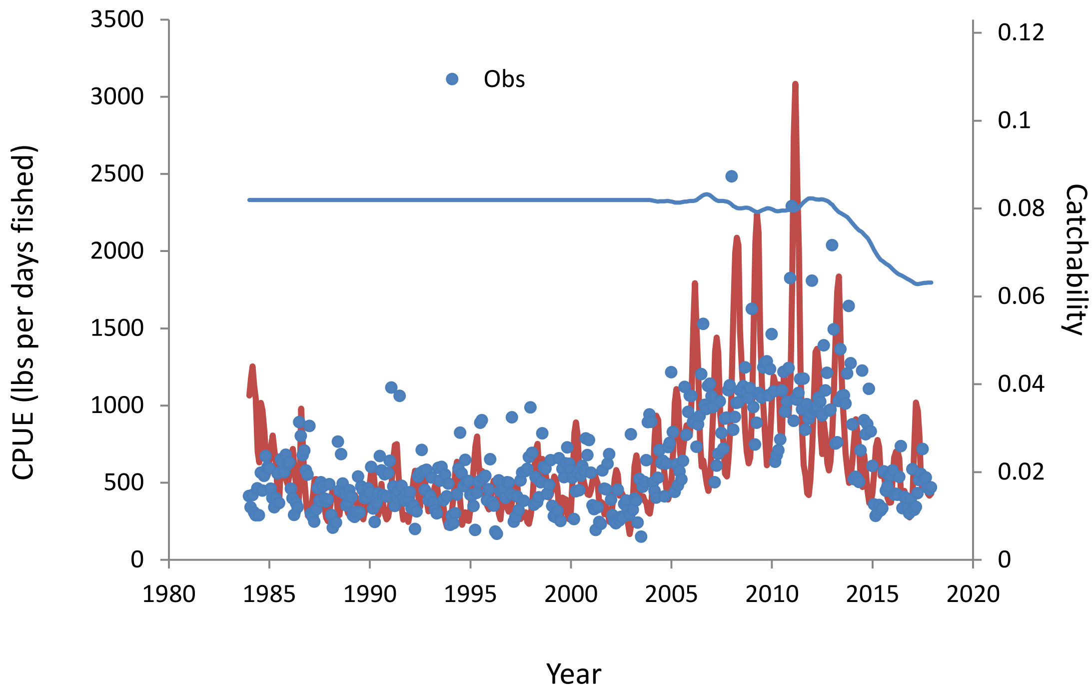


Figure 4.2.1. White shrimp commercial fishery CPUE and Q fits, 1984-2017.

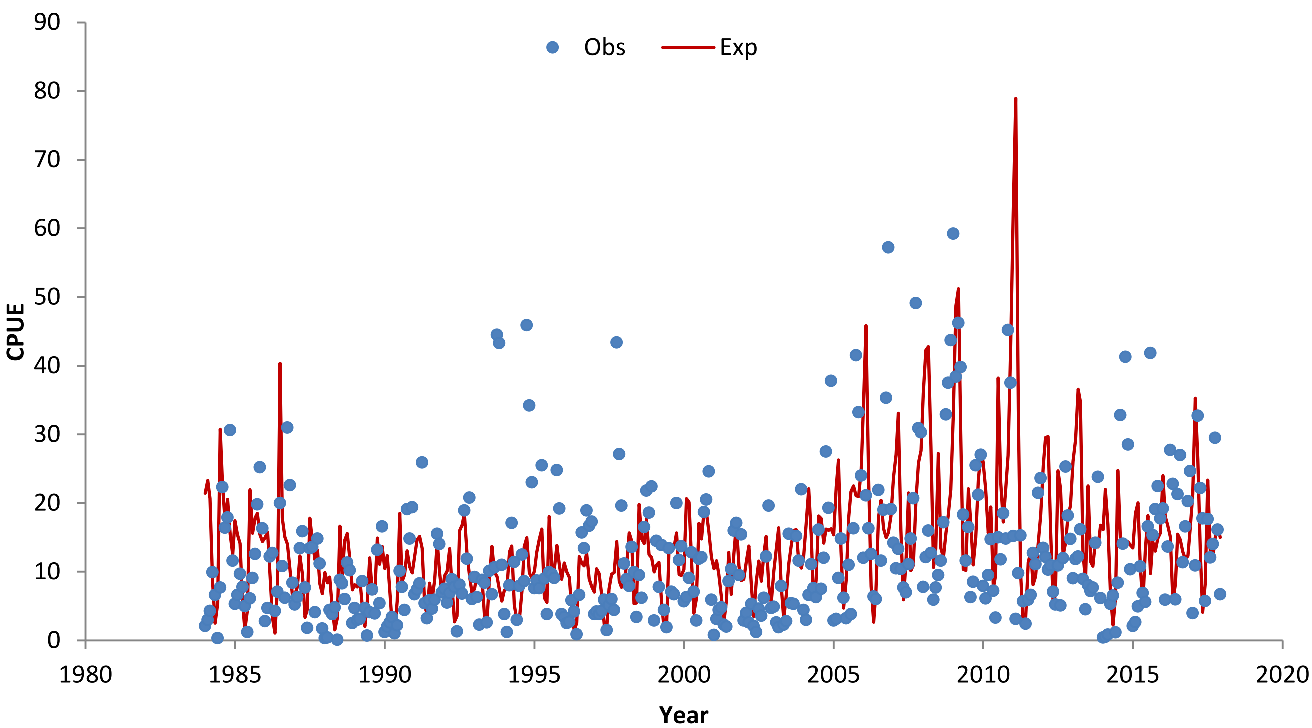


Figure 4.2.2. Louisiana survey CPUE fits 1984-2017.

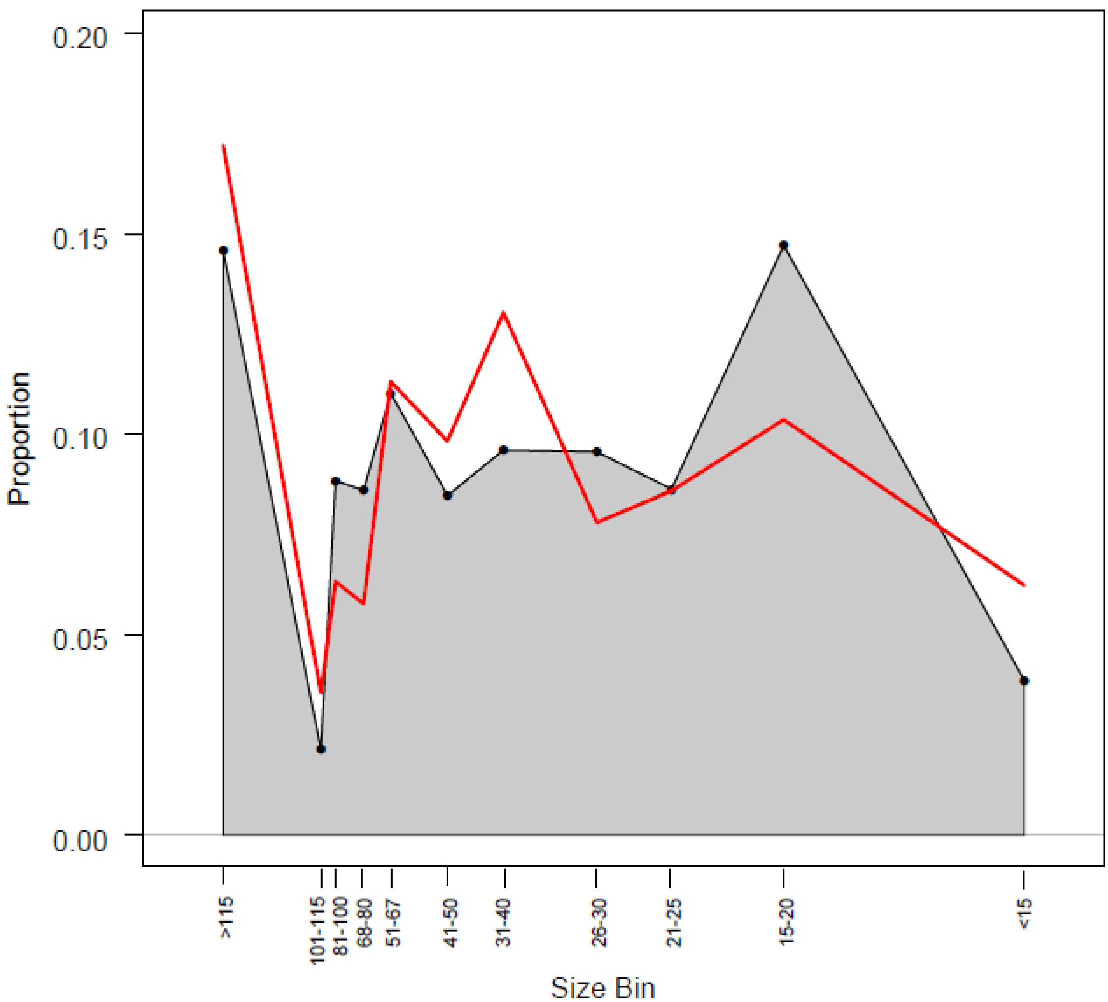


Figure 4.3.1. White shrimp commercial fishery size composition fits.

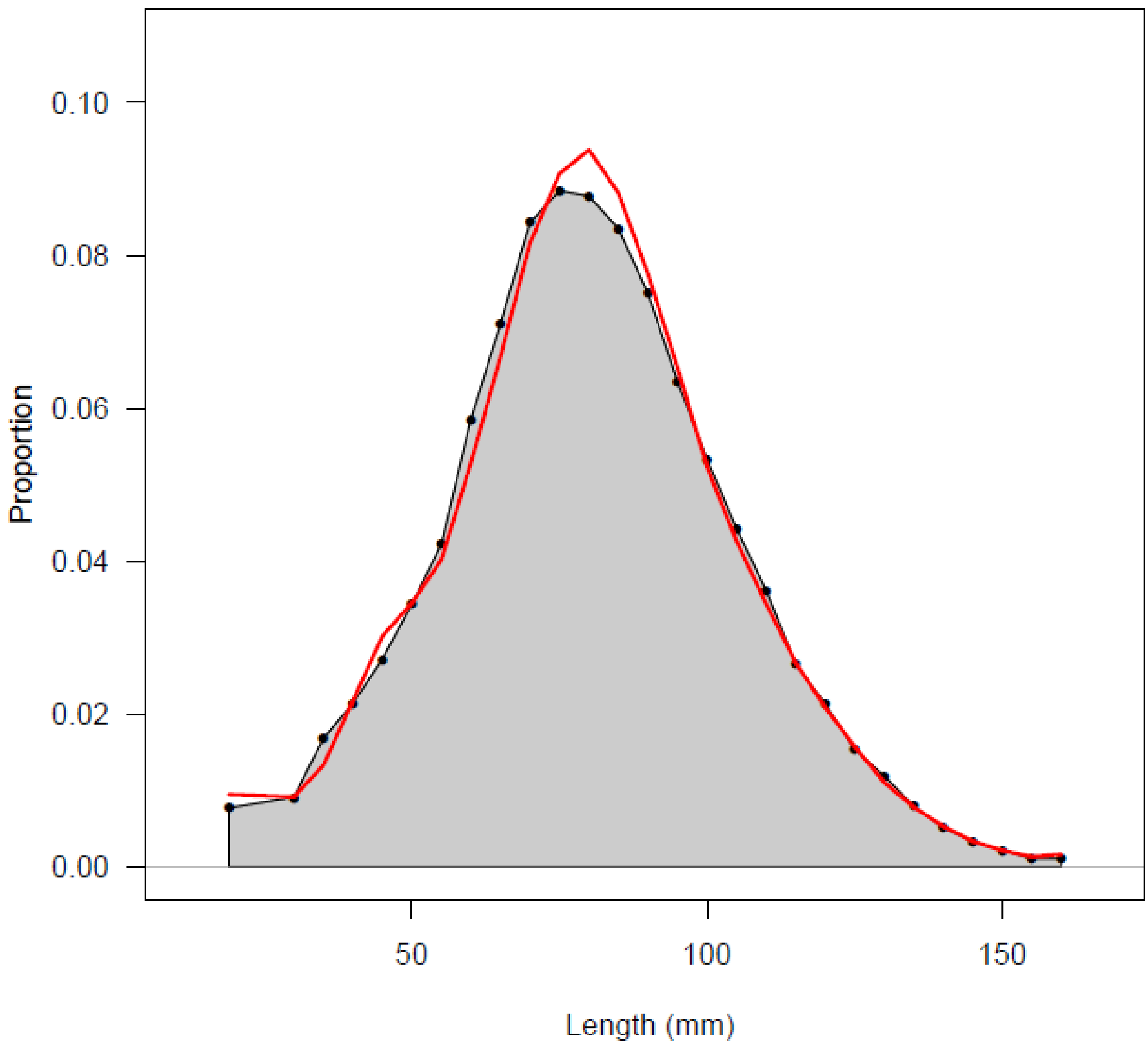


Figure 4.3.2. White shrimp Louisiana survey size composition fits.

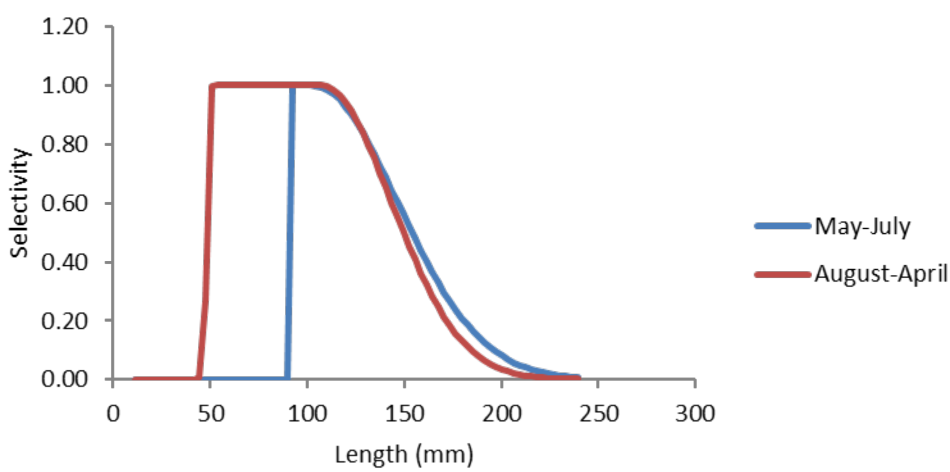


Figure 4.4.1. White shrimp commercial fishery size selectivity.

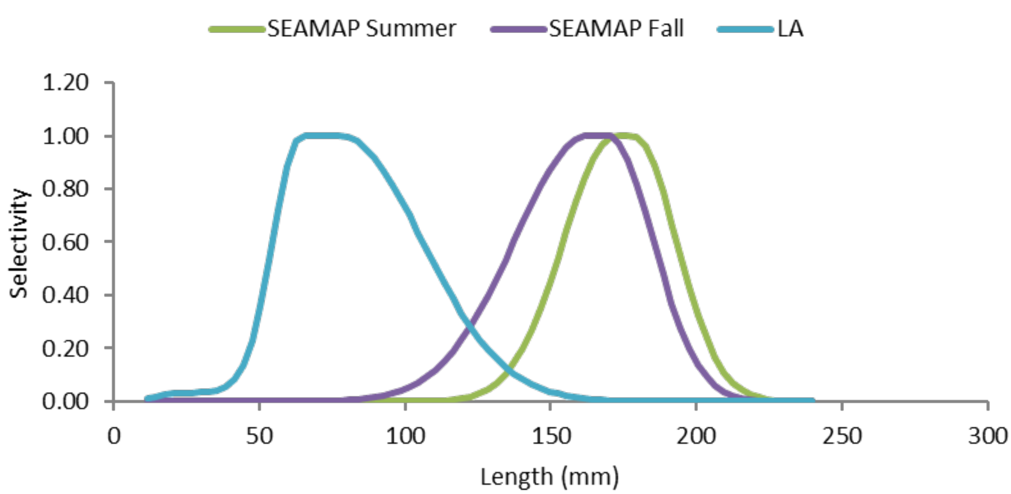
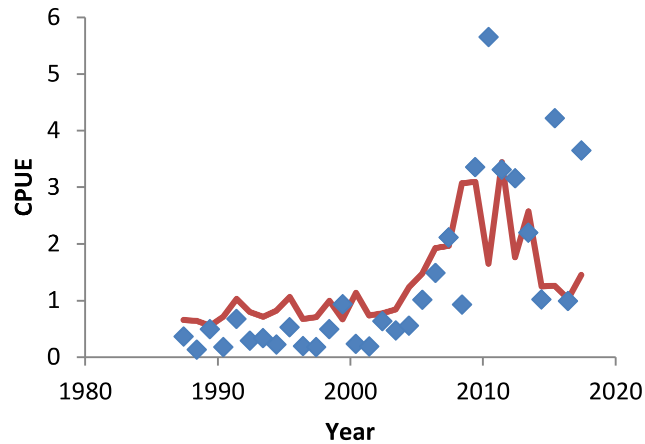


Figure 4.4.2. White shrimp Louisiana and Summer and Fall SEAMAP survey's size selectivity.

a



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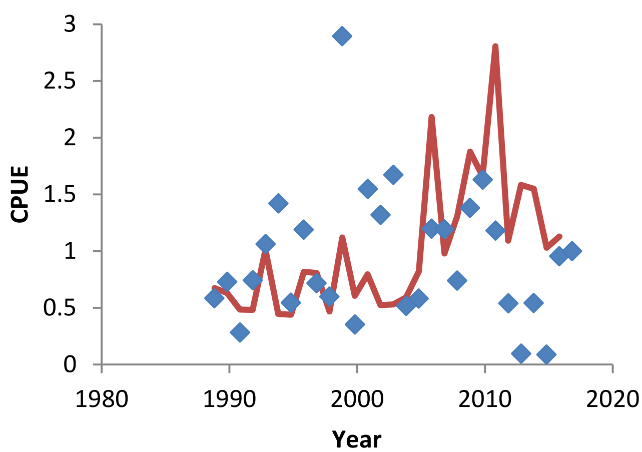

Figure 4.5.1. White shrimp SEAMAP survey CPUE. Panel a is Summer and panel b is Fall CPUE fits, 1987-2017.

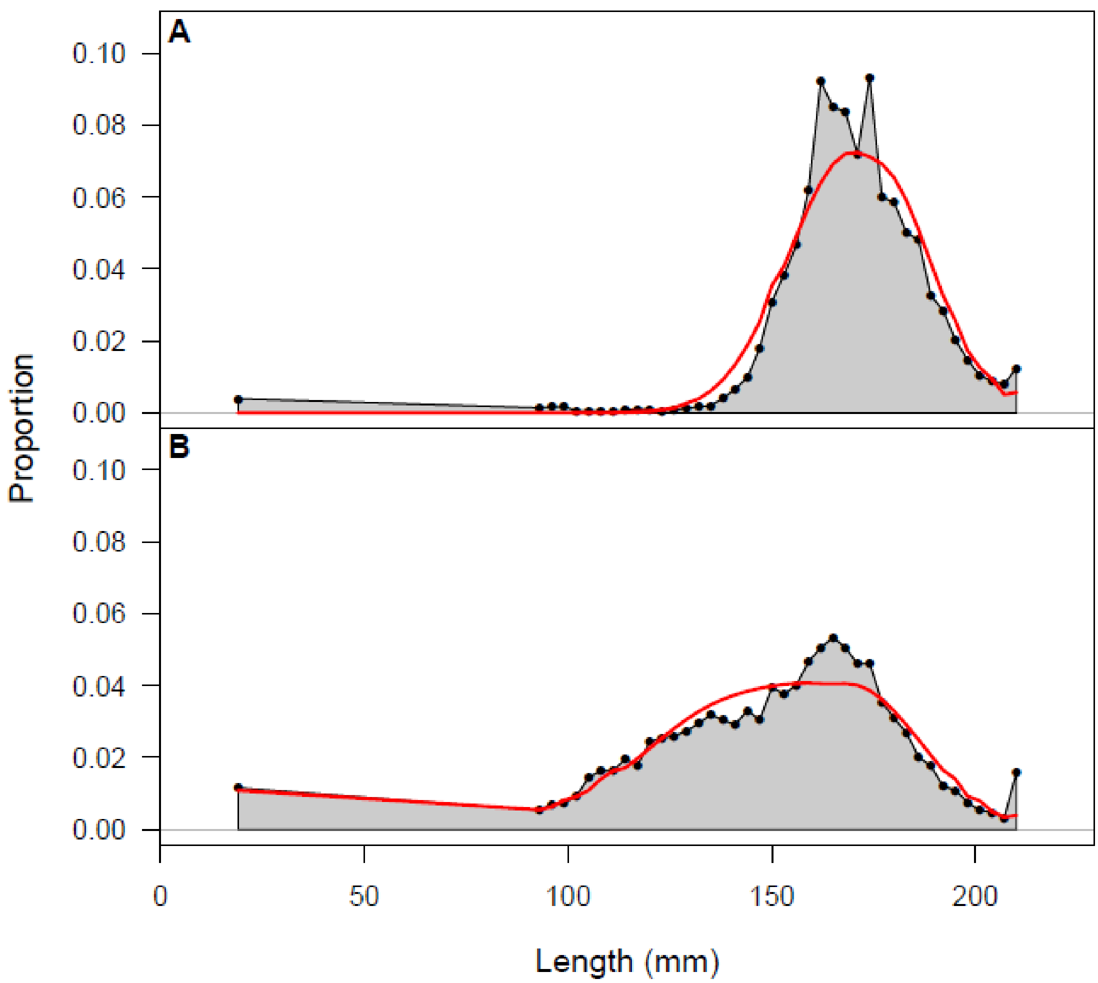

Figure 4.5.2. White shrimp SEAMAP survey size composition fits. Panel A is Summer and panel B is Fall CPUE fits.

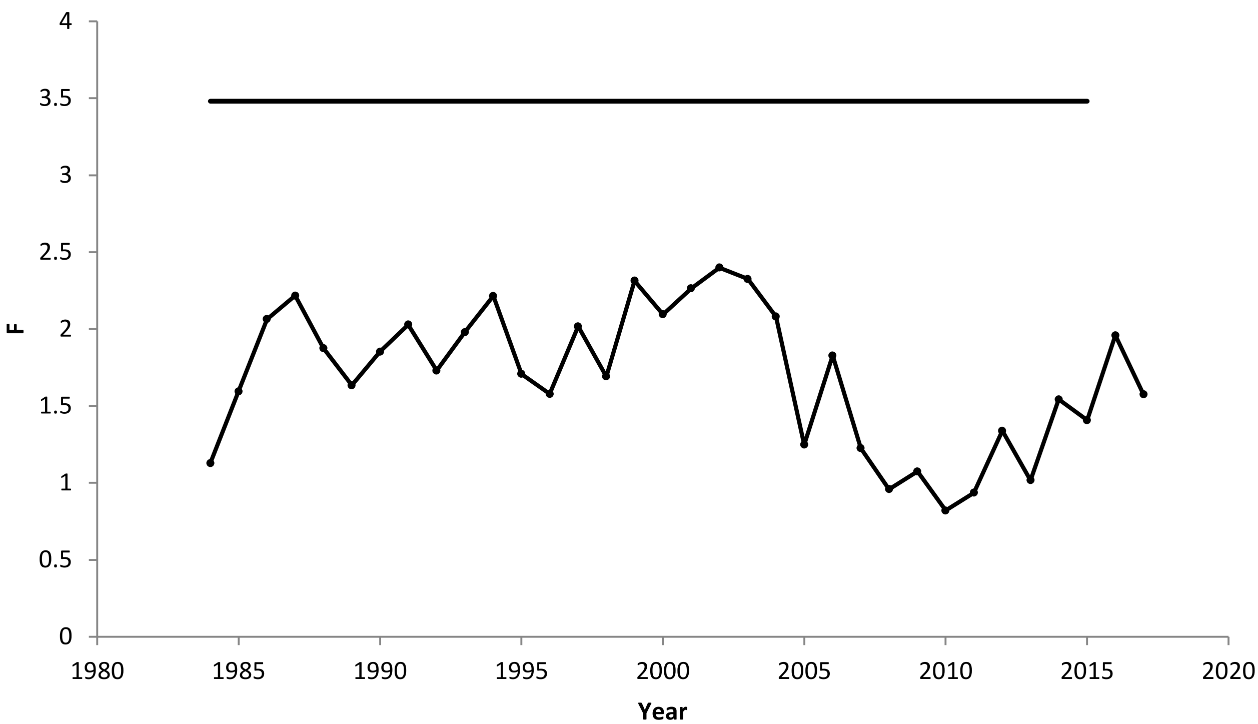

Figure 4.6.1. White shrimp weighted annual F-values across ages for 1984-2017.

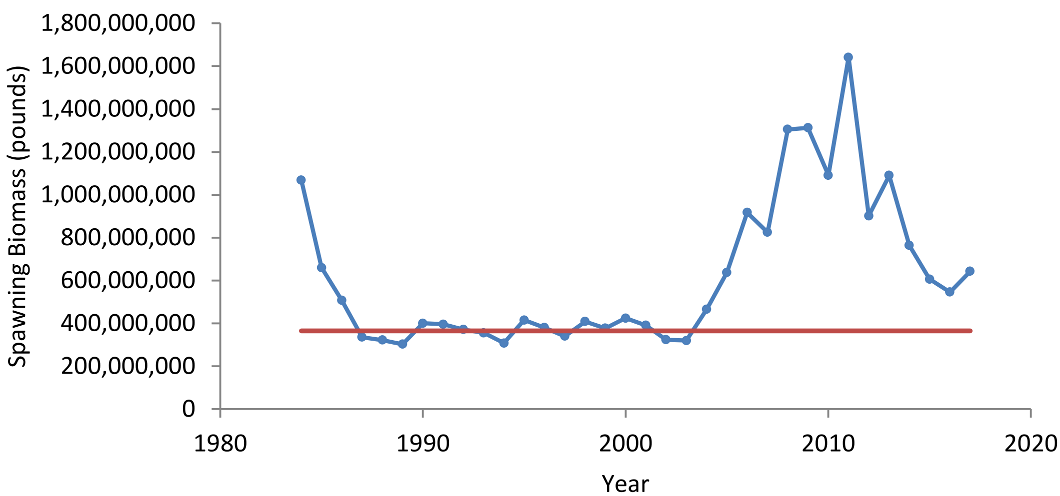

Figure 4.7.1. White shrimp spawning biomass estimates, 1984-2017.

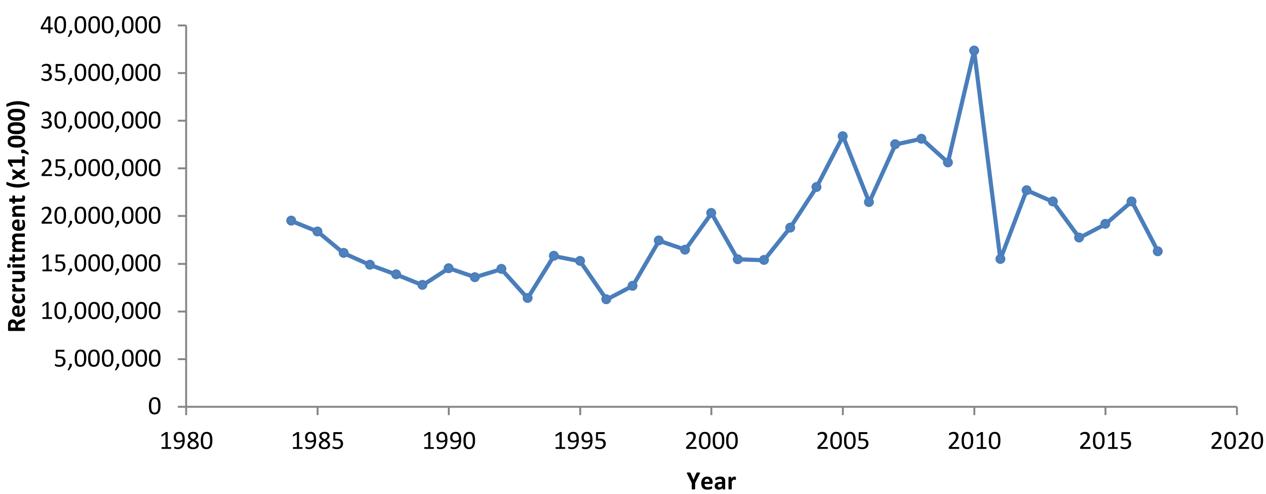

Figure 4.7.2. White shrimp recruitment model estimates, 1984-2017.