Tab D, No. 5(b)

Stock Assessment Update for White Shrimp (*Litopenaeus setiferus*) in the U.S. Gulf of Mexico for 2014

Rick A. Hart

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NOAA Fisheries
Southeast Fisheries Science Center
Galveston Laboratory
Galveston, TX 77551
rick.hart@noaa.gov

1. ABSTRACT

This assessment examined the US Gulf of Mexico white shrimp (*Litopenaeus setiferus*) population behavior when parameterized with over 25 years of commercial white shrimp data from 1984 - 2014. 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 1.34 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 2014 fishing season. Spawning biomass and recruitment for the 2014 fishing season were 612.6 million pounds and 17.8 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. They also recommended that a shrimp MSY workshop be held to develop MSY based reference points for inclusion in Shrimp Amendment 15 of the GMFMC Shrimp Fishery Management Plan (FMP).

A SSC webinar workshop was held on August 2014 to discuss the Gulf of Mexico (GOM) penaeid shrimp MSY and ABC control rule based benchmarks. The group was presented the most recent shrimp stock assessment and the calculation of MSY for these stocks. In addition the group "discussed that MSY needs to be in terms of what the annual harvest- essentially a sum of yields- and it should be calculated from the monthly inputs and the monthly Fs, rather than the summaries and apical Fs that are currently reported from the model."

The group also discussed the tasks and logistics of an in-person MSY workshop to determine MSY based reference points. The GMFMC SSC shrimp MSY workshop was held on October 7, 2014. During this workshop MSY based reference points were presented and accepted by the SSC. These reference points were then presented to members of the Special Shrimp SSC during their March 2015 meeting. Discussions regarding the MSY estimates and the MSY based reference points centered on the differences within reference points between stocks. As excerpted from the meeting minutes, "…it was explained that the exploitation rates, i.e., F, could be similar because of harvesting many more small individuals, but yield does not increase due to harvesting smaller animals. Additionally, the models were parameterized differently for each of the shrimp species to account for differences in life history and differences in the way each fishery is prosecuted. Pink shrimp has primarily an offshore fishery, while white shrimp has primarily an inshore fishery and brown shrimp has both an inshore and offshore fishery. It was also explained that each state manages its shrimp fishery differently…" Members of the SSC voted unanimously to accept the MSY based reference points as the best available science and found them suitable for management advice.

Following the MSY workshop, the results were presented at the April 2015 GMFMC Shrimp Committee. Outside of, and before this meeting convened, the Standing SSC Chairman noted that using MSY for an overfished reference point would be incorrect as it is a rate, and hence an overfishing metric. He stated that SSBmsy would be appropriate and recommended that this be used for the overfished reference point. This information was discussed with NMFS shrimp stock assessment scientists and the Shrimp Committee Chairman. Therefore, the SSC Chair did not present the MSY estimates. Instead the committee discussed the use of SSBmsy for the overfished reference point. Using the SSBmsy would be appropriate and follows the spirit of the SSC charge of using MSY based values for the overfished and overfishing indices. Therefore, the Shrimp Committee and the Full Council granted Council staff editorial license to refine Alternative 1.3 to reflect that the overfished reference point is SSBmsy.

The acceptance and subsequent adoption of Amendment 15 of the GOM Shrimp FMP defines the overfished and overfishing reference points for penaeid shrimp. To measure if overfished and overfishing is occurring the Stock Synthesis based stock assessment models estimate a MSY and corresponding SSB at MSY and F at MSY for the terminal "year" of the stock assessment model. For the pink and white shrimp assessments the 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. The brown shrimp model is parameterized as an annual model. Therefore the models forecast SSBmsy and Fmsy can be directly compared to the annual SSB and F estimates generated in the assessments.

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 1984-2014. The model incorporates selectivity with seasonal changes (May-July) using an environmental offset approach, estimated steepness, and R_0 values.

Amendment 15 of the Gulf of Mexico Fisheries Management Plan (FMP) (GMFMC 2015) 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 165.9 metric tons 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 2014. 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; 1987-2014)
2. SEAMAP Fall Groundfish Trawls (Fisheries-independent; 1987-2014)
3. Louisiana Monthly Shrimp Trawl Surveys (Fisheries-independent; Western Subset of surveys, 1984-2014)

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 2014 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; 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 2014 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 1984-2014.

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 (372 “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 2004-2014.

3.2.5. Louisiana Monthly Shrimp Survey Data – Shrimp data collected by the State of Louisiana from 1984–2014 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 1987-2014 were survey model inputs. Size compositions for white shrimp collected and measured from 1987-2014 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 cruises reveal a recent increase in CPUE (Figure 4.5.1) similar to the commercial fishery. Figures 4.5.2 show the good model fit to the size composition data for 1987-2014 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 2014 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:

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

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 2014 F equaled 0.27 (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 2014 fishing season. Spawning biomass increased compared to last year with an overall increase in the recent years of the time series (Figure 4.7.1). Spawning biomass for the 2014 season was equal to 612.6 million pounds. Recruitment also showed an increasing trend in recent years (Figure 4.7.2). The number of recruits for 2014 equaled 17.8 billion individuals.

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 reveal increasing spawning biomass and recruitment in recent years, and a decreasing trend 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 stocks are not overfished or undergoing overfishing.

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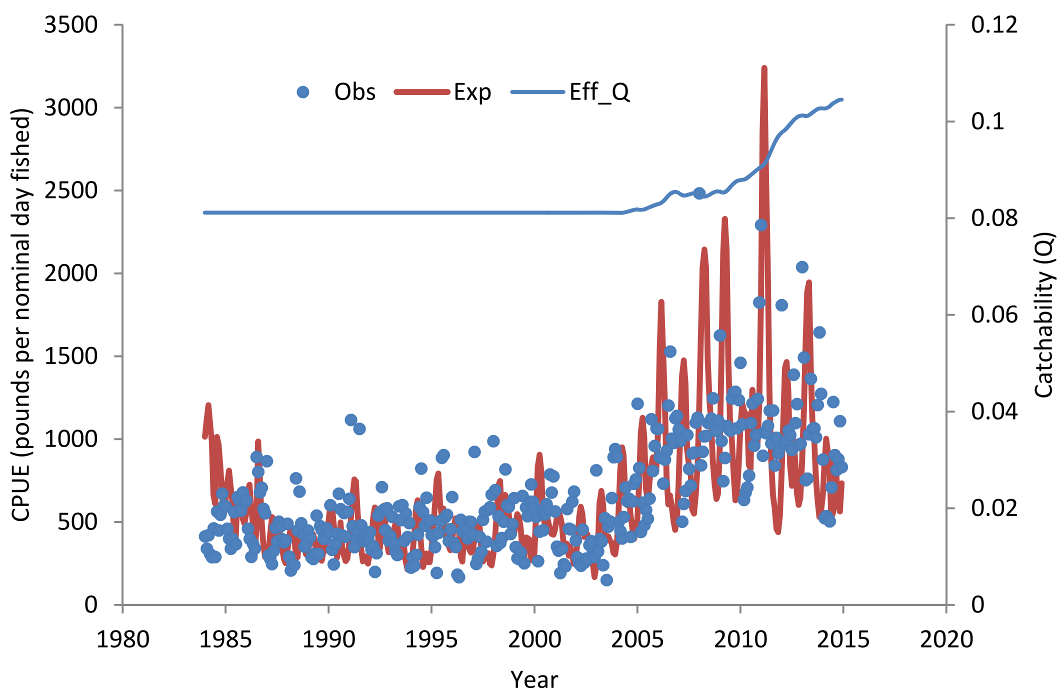

Figure 4.2.1. White shrimp commercial fishery CPUE and Q fits, 1984-2014.

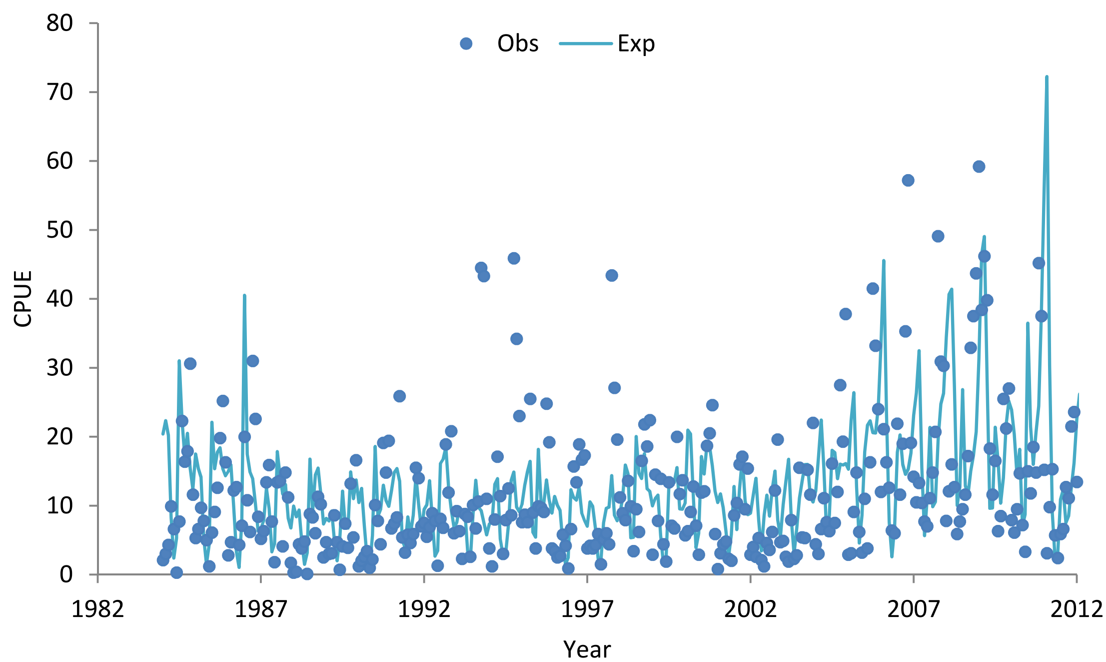

Figure 4.2.2. Louisiana survey CPUE fits 1984-2014.

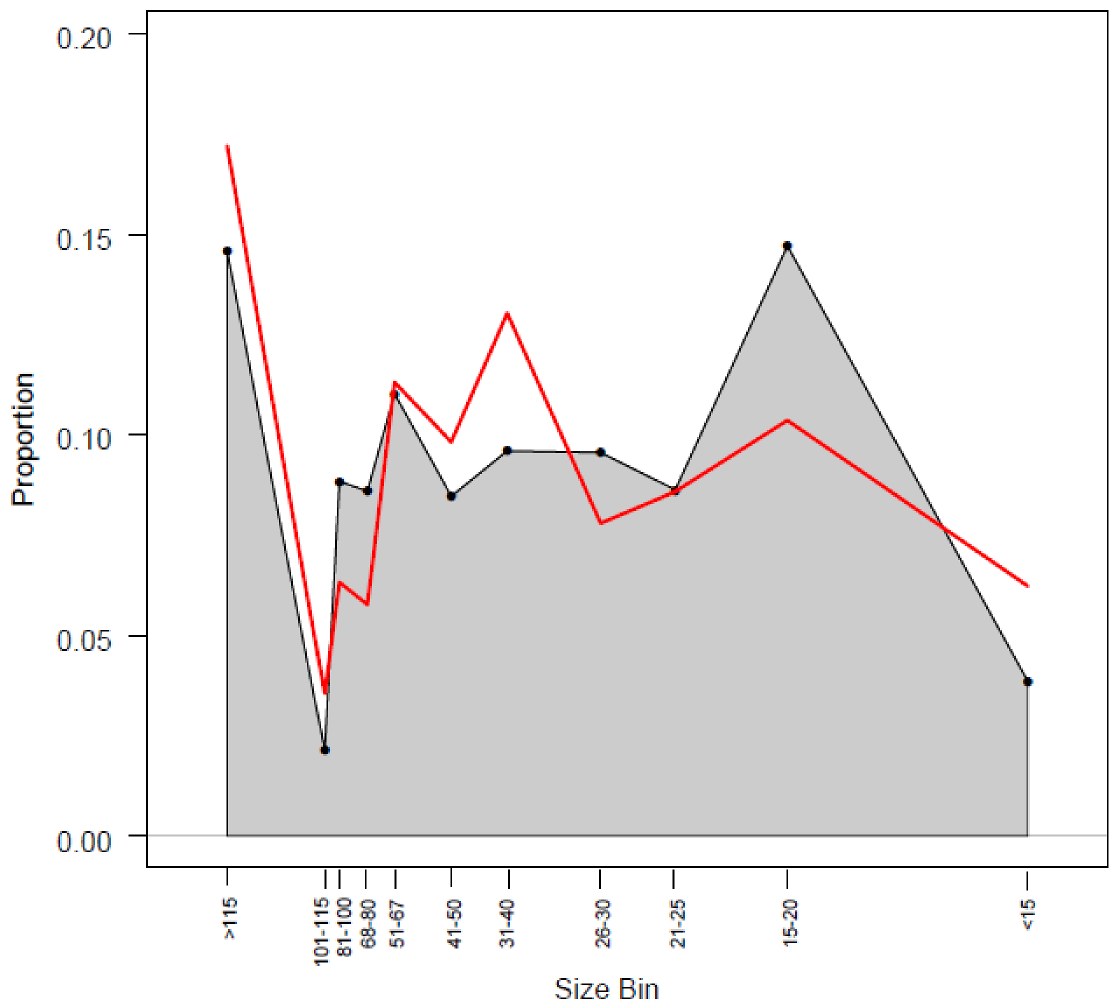

Figure 4.3.1. White shrimp commercial fishery size composition fits, 1984-2014.

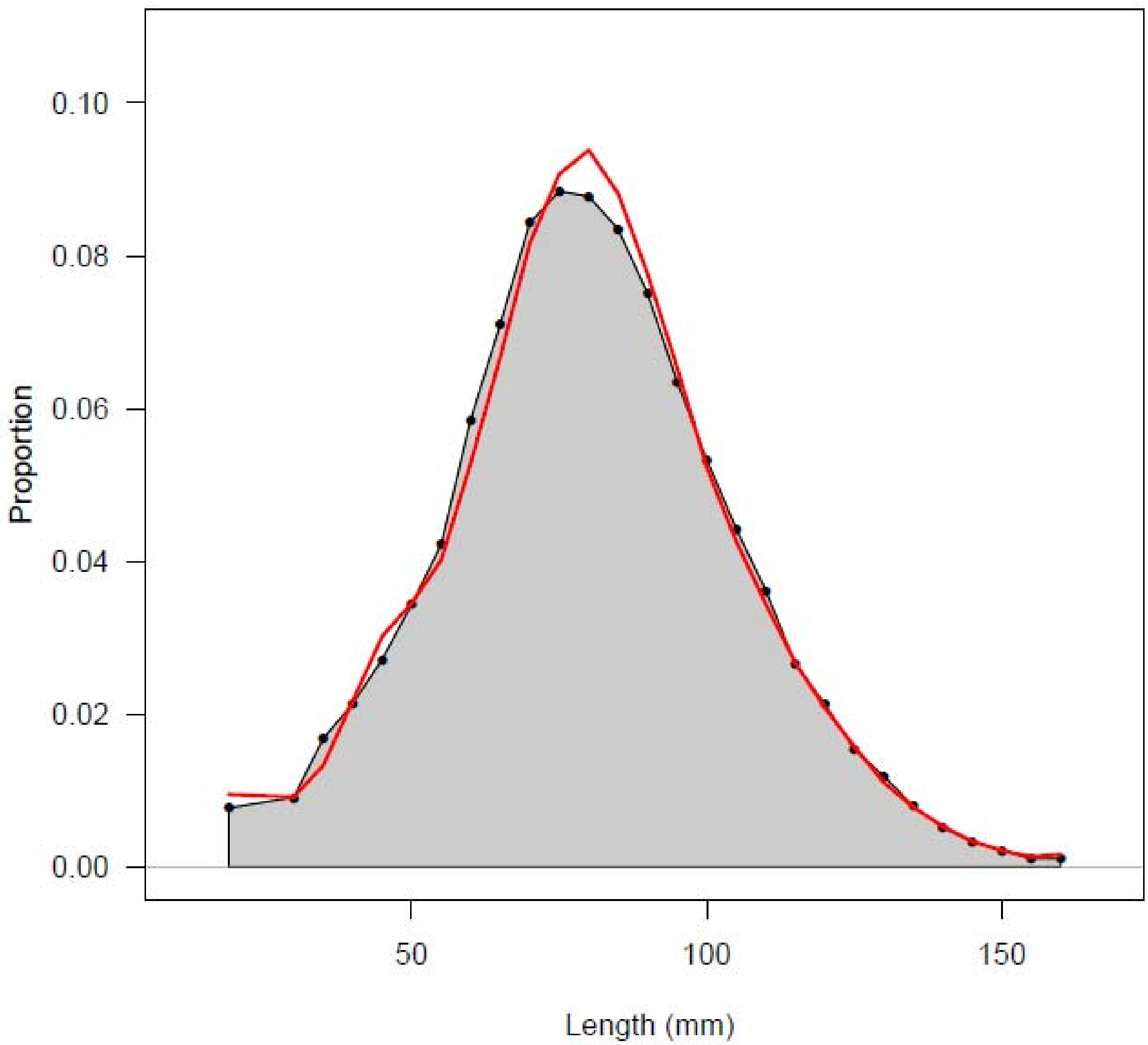

Figure 4.3.2. White shrimp Louisiana survey size composition fits, 1984-2014.

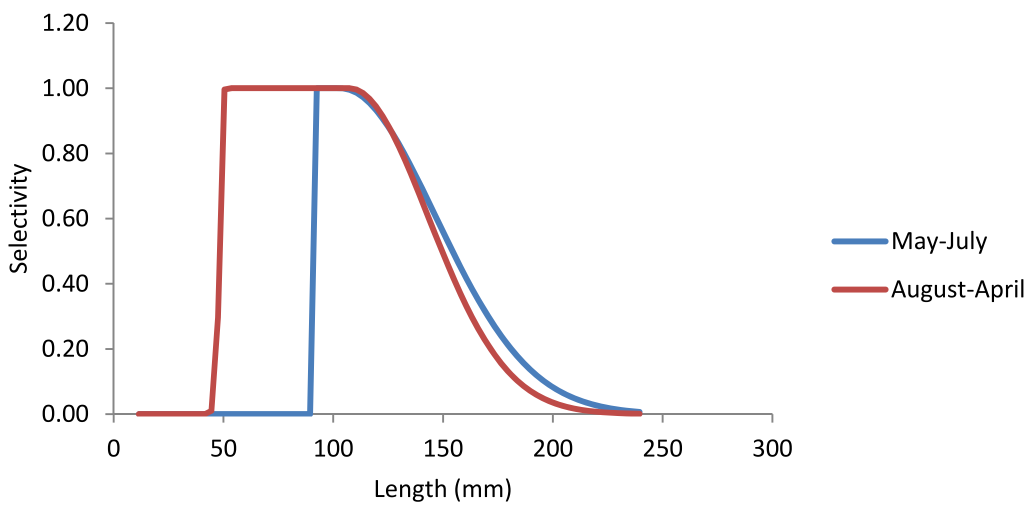

Figure 4.4.1. 2014 white shrimp commercial fishery size selectivity.

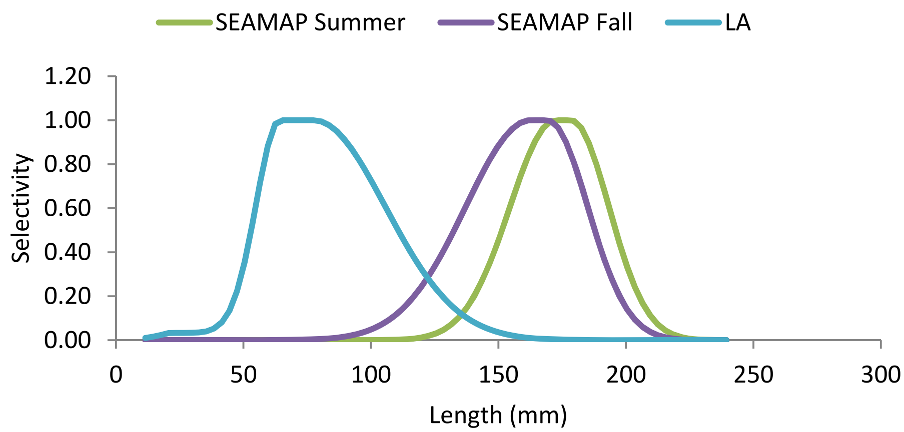

Figure 4.4.2. 2014 white shrimp Louisiana and Summer and Fall SEAMAP survey's size selectivity.

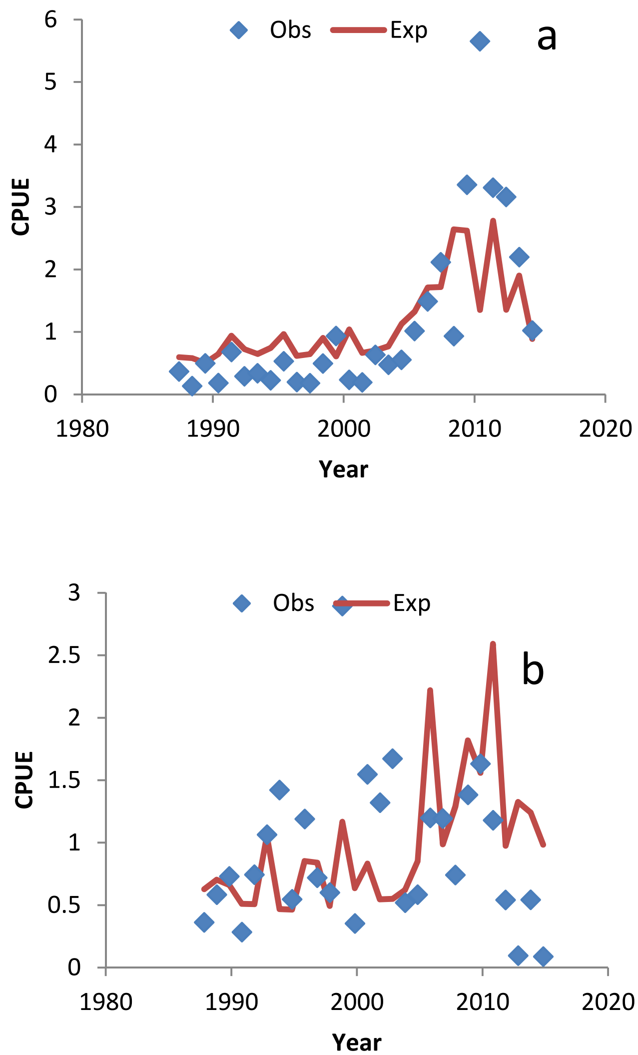

Figure 4.5.1. White shrimp SEAMAP survey CPUE. Panel a is Summer and panel b is Fall CPUE fits, 1987-2014.

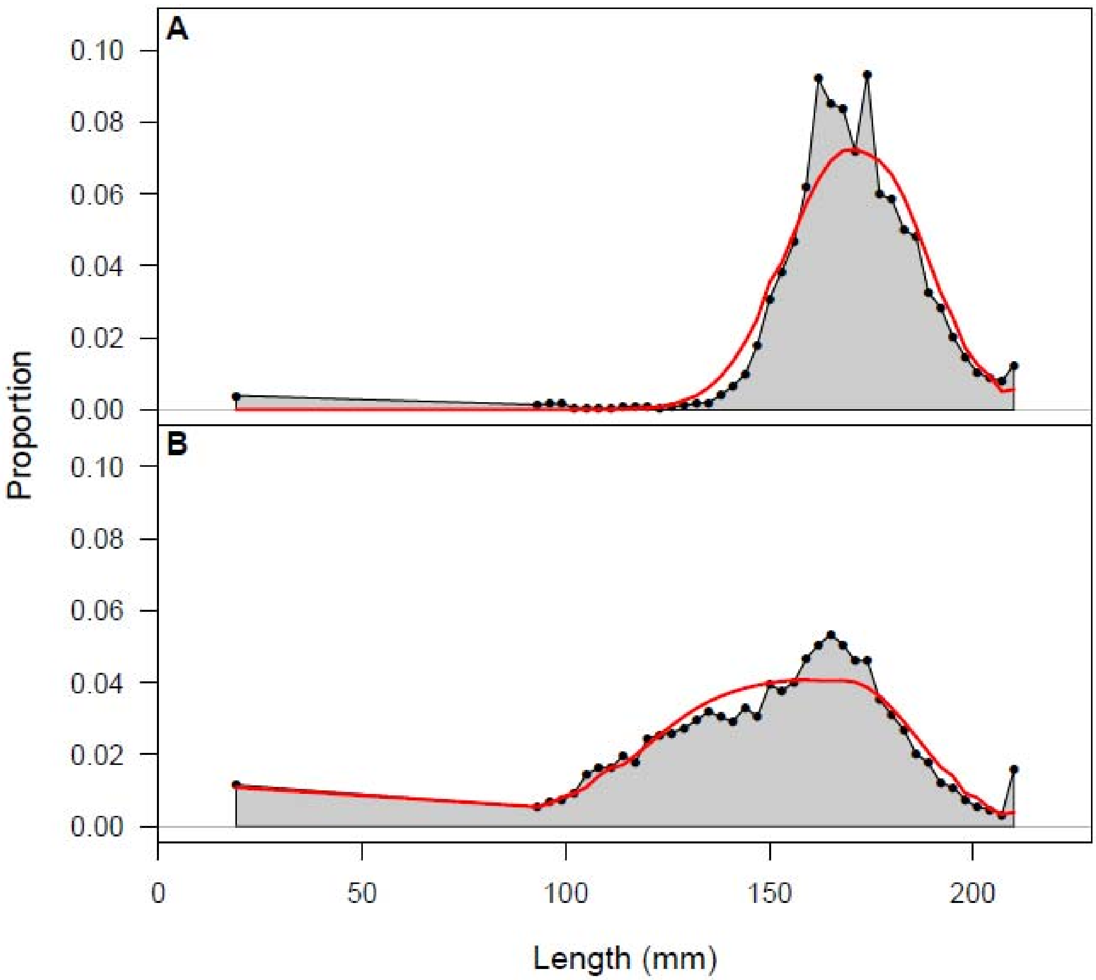

Figure 4.5.2. White shrimp SEAMAP survey size composition fits. Panel a is Summer and panel b is Fall CPUE fits, 1987-2014.

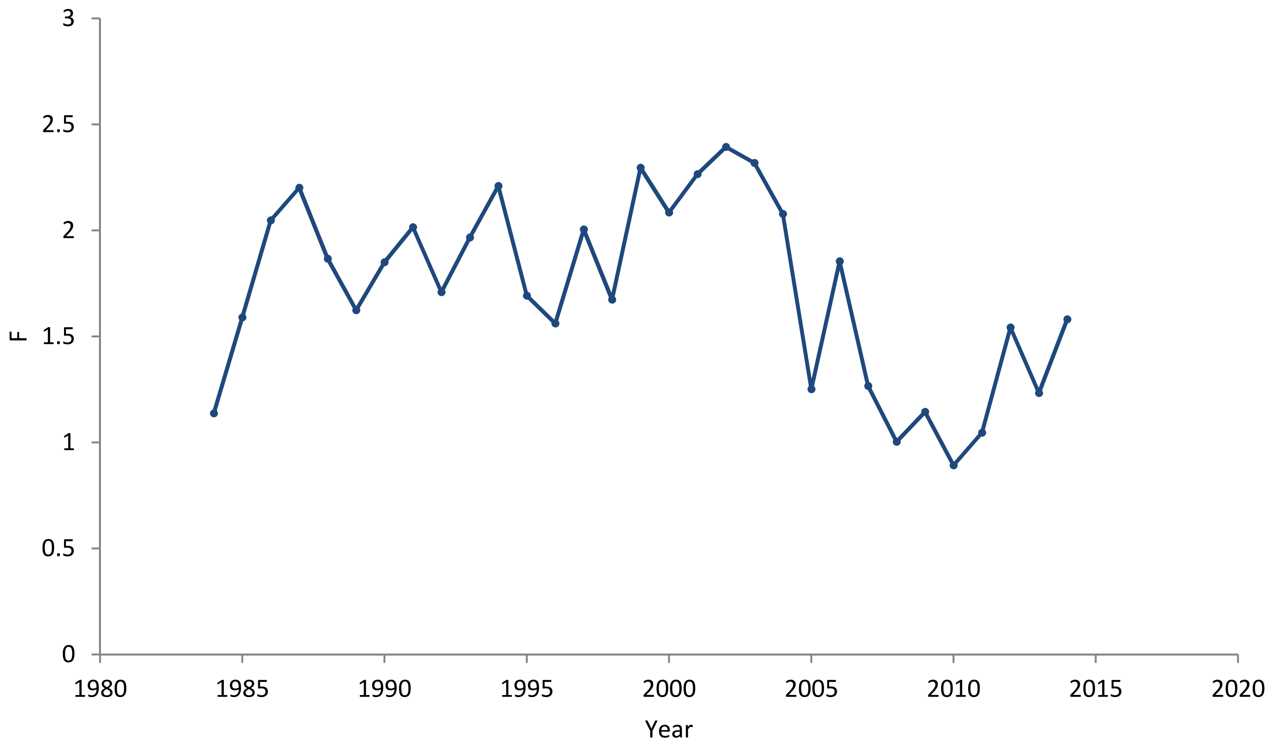

Figure 4.6.1. White shrimp weighted annual F-values across ages for 1984-2014.
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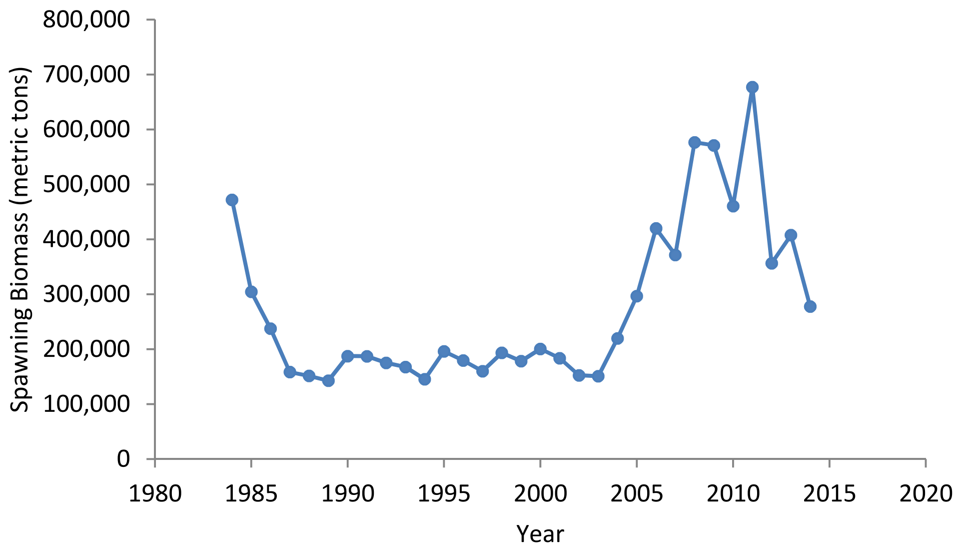

Figure 4.7.1. White shrimp spawning biomass estimates, 1984-2014.

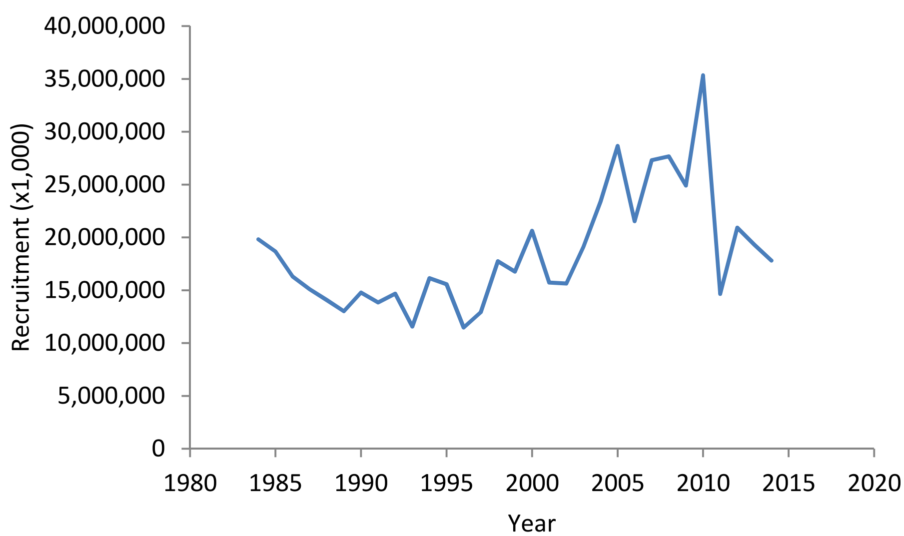

Figure 4.7.2. White shrimp recruitment model estimates, 1984-2014.