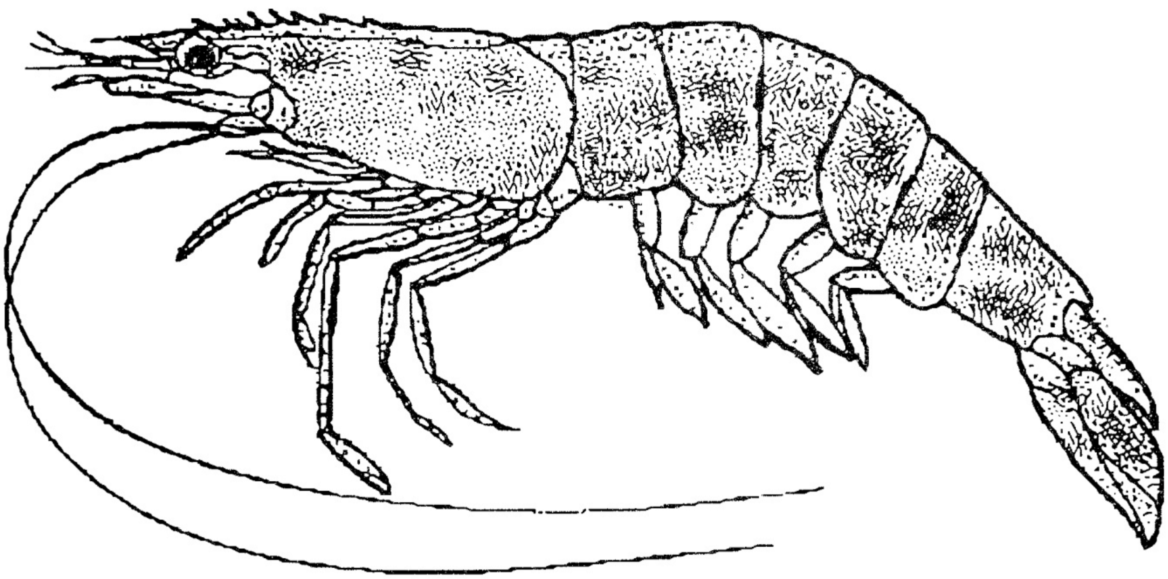
Stock Assessment Update for Brown Shrimp (*Farfantepenaeus aztecus*) in the U.S. Gulf of Mexico for 2014



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1. ABSTRACT

This report documents a stock assessment update for the Gulf of Mexico brown shrimp (*Farfantepenaeus aztecus*) for the 1984-2014 time series. In this model fits to the CPUE estimates, size selectivity, spawning biomass, numbers of recruits, and fishing mortality estimates (F) were generated. In addition, the incorporation of direct fishery independent surveys (SEAMAP and Louisiana State Shrimp Surveys) of shrimp abundance into the model greatly improves the precision (i.e., tuning) of this assessment update.

Amendment 15 of the Gulf of Mexico Fisheries Management Plan (FMP) (GMFMC 2015) set new overfishing and overfished levels generated from the bench mark stock assessment. The criteria are based on SSBmsy and Fmsy and are 6.1 million pounds of tails and 9.12 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 SSB outputs in terms of pounds of spawning biomass, and numbers of recruits. Fishing mortality (Fmsy) was estimated to be 0.897. Spawning biomass and recruitment at the end of the 2014 fishing season were 75.6 million pounds and 41.2 billion individuals respectively. Using these results, there is no evidence that the Gulf of Mexico brown shrimp stocks are overfished or undergoing overfishing.

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 a stock assessment update for brown shrimp (*Farfantepenaeus aztecus*). This modeling methodology uses a generalized stock assessment model, Stock Synthesis (SS-3) (Methot 2009), and is parameterized with fishery data from 1984-2014, incorporating non-time varying selectivity, an estimated steepness value, and non-time varying R_0.

Amendment 15 of the Gulf of Mexico Fisheries Management Plan (FMP) 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 6.1 million pounds of tails and 9.12 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

This Stock Synthesis assessment update was parameterized as an annual model, with 12 seasons. This allowed for a better fit of the highly cyclical recruitment pattern evident in the commercial and survey data. In addition, this model was parameterized with such complexities as a density dependent flexible Q, static recruitment deviations, static R_0 (unfished recruitment) and estimated steepness in the Beverton-Holt spawner-recruit.

3.2. Data Sources

The model was parameterized with data from 1984 through 2014. Two years of "dummy" data were entered into the model before the actual 1984 data to allow for a burn in period. This burn in period facilitated the development of recruitment deviations or cycles which were initiated prior to the actual starting year data being called into the model.

The Stock Synthesis model was developed using the time period 1984-2014. The model structure included 2 fleets:

1) Commercial Offshore shrimp catch statistics (statistical zones 7-21)
2) Commercial Inshore 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 brown shrimp commercial catch data including; directed fishing effort by year and month, i.e., effort for those trips where >90 percent of the catch were brown shrimp, used to calculate monthly CPUE; total catch; and catch by size, i.e., size composition data consisting of count of numbers of shrimp per pound; for statistical zones 7-21 from January 1984 through December 2014. To calculate CPUE catch 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 was a primary input. Eleven count categories from 1984 to 2012 were used. Beginning in 1984 shrimp catch data for the smallest sized shrimp, >67 count, were recorded at a finer scale, thus allowing us to partition this size category into four additional count categories, therefore having finer resolution for the smallest 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 for each of the eleven size bins for the years 1984-2014.

3.2.2. Growth Curve and other Population Level Rates - The growth parameters k and linf, derived and reported by Parrack (1981), were used as initial parameter values. Data inputs included a growth curve for each gender; natural mortality rate (3.24) per year as previously used in the historical VPA (Nichols 1984); and conversion factors to go from total length to the poundage breaks between the catch count categories (Brunenmeister 1980). These data were entered into SS-3 as parameters.

3.2.3. Size Selectivity - A dome shaped (double normal) selectivity pattern with 4 estimated parameters was used in each of the models. This resulting pattern provided a good fit to the data as will be shown in the results. In these model setups selectivity was not time varying.

3.2.4. Catchability Q – Catchability was set as a density dependent parameter in the model.

3.2.5. Louisiana Monthly Shrimp Survey Data – Shrimp data collected by the State of Louisiana from 1984 – 2014 were included in the models. These data were collected and provided by staff of the Louisiana Department of Wildlife and Fisheries (LDWF) (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 brown shrimp collected and measured in 1987-2014 during 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 each commercial fishing fleet (i.e., offshore and inshore) I used a double normal selectivity setup with the same selectivity's for all years. 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

For this model, time varying R_0 was not allowed. In addition, since recruitment is not continuous for brown shrimp as evidenced by the survey data, I allowed recruitment to occur during the months of February, April, June, July, and August. Catchability varied as a density dependent function.

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 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 catch rate model fits for each fleet and also show how the density dependent Q setups perform in the model.

The increase in the commercial fishery CPUE during the later portion of the time period evident in the commercial fishing fleet is also visible in the CPUE indices measured in the fishery independent SEAMAP and Louisiana survey data. Model fits to the Louisiana survey data are shown in Figure 4.2.2.

4.3. Generalized Size Comps

The model fit to the size composition of the catch for the commercial in- and offshore fishing fleet is shown in figure 4.3.1. These results illustrate how the inshore fleet catches predominately smaller sized shrimp compared to the offshore fleet. Fits to the size composition catch data from the Louisiana survey are shown in figure 4.3.2. These data fits are similar to the commercial inshore fleet's catch of smaller sized shrimp.

4.4. Fishery Selectivity for the Commercial Fleet and Louisiana Surveys

Selectivity curves were developed for each of the commercial fishery fleets. These curves were fit to the seasonal harvest of smaller shrimp inshore and the larger shrimp harvested offshore (Figure 4.4.1). Size selectivity fits for the Louisiana survey are shown in figure 4.4.2, illustrating the higher selectivity for those smallest sized shrimp. These curves are shown with the SEAMAP selectivity fits to better illustrate the selectivity patterns exhibited by these two different surveys.

4.5. SEAMAP Selectivity, CPUE, and Size Composition

Selectivity fits for summer and fall SEAMAP data are shown alongside of the Louisiana survey data in figure 4.4.2. The summer and fall SEAMAP cruises reveal a recent increase in CPUE, similar to the commercial fishery (Figure 4.5.1). Figure 4.5.2 shows the model fit to the size composition data for 1987-2014 for summer and fall SEAMAP surveys. The use of these fisheries independent data, in concert with the Louisiana surveys, have provided added information on some of the trends which were evident in the commercial shrimp fishery, thus allowing us to better tune the model's recruitment parameters.

4.6. Fishing Mortality

Stock Synthesis outputs F values by age and year. The model is also parameterized with two fleets, an offshore and an inshore fleet. Averaging across fleets and ages by year the 2014 F estimate is equal to 0.897/year (Figure 4.6.1).

4.7. Steepness, Spawning Biomass, and Recruitment

The model estimated a steepness value of about 0.99. The total annual spawning biomass and recruitment values have shown an increase in recent years. Spawning biomass and recruitment at the end of the 2014 fishing season were 75.6 metric tons and 41.2 billion individuals respectively (Figures 4.7.1 and 4.7.2).

5. CONCLUSIONS

The Stock Synthesis model developed provides outputs for new overfished and overfishing definitions for the Gulf of Mexico brown shrimp fishery. This assessment revealed the fishery is not overfished nor undergoing overfishing. Spawning biomass and recruitment have fluctuated in recent years. Spawning stock biomass and recruitment have decreased in recent years while fishing mortality (F) increased during the later portion of the time series.

REFERENCES

Brunenmeister, S.L. 1984. Commercial brown, white and pink shrimp size: total size conversions. NOAA Technical Memorandum NMFS-SEFSC-20, 7pp.

Gallaway, B. J., J. G. Cole L. M. Martin, J. M. Nance, and M. Longnecker. 2003a. An evaluation of an electronic logbook as a more accurate method of estimating spatial patterns of trawling effort and bycatch in the Gulf of Mexico shrimp fishery. North American Journal of Fisheries Management 23:787–809.

Gulf of Mexico fishery management council. 2015. Status Determination Criteria for Penaeid Shrimp and Adjustments to the Shrimp Framework procedure. Amendment 15 to the Fishery Management Plan for the Shrimp Fishery of the Gulf of Mexico, U.S. Waters Including Environmental Assessment, Fishery Impact Statement, Regulatory Impact Review, and Regulatory Flexibility Act Analysis. 80 p.

Gallaway, B. J., J. G. Cole, L. R. Martin, J. M. Nance, and M. Longnecker. 2003b. Description of a simple electronic logbook designed to measure effort in the Gulf of Mexico shrimp fishery. North American Journal of Fisheries Management 23:581–589.

Hart, R.A. 2012. Stock assessment of brown shrimp (Farfantepenaeus aztecus) in the U.S. Gulf of Mexico for 2011. NOAA Technical Memorandium NMFS-SEFSC-638, 37 p.

Hart, R.A., and J.M. Nance. 2010. Gulf of Mexico pink shrimp assessment modeling update: from a static VPA to an integrated assessment model, Stock Synthesis. NOAA Technical Memorandum NMFS-SEFSC-604. 32 pp.

Methot, R.D. 2009. Stock assessment: operational models in support of fisheries management. In Beamish and Rothschild (ed) Future of Fishery Science. Proceedings of the 50th Anniversary Symposium of the American Institute of Fishery Research Biologists, Seattle, WA. Springer. Fish & Fisheries Series, Vol. 31: Pg. 137-165.

Methot, R.D. and C. Wetzel. 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fisheries Research 142:86-99.

Nance, J., W. Keithly Jr., C. Caillouet Jr., J. Cole, W. Gaidry, B. Gallaway, W. Griffin, R. Hart, and M. Travis. 2008. Estimation of effort, maximum sustainable yield, and maximum economic yield in the shrimp fishery of the Gulf of Mexico. NOAA Technical Memorandum NMFS-SEFSC-570, 71 p.

Nichols, S. 1984. Updated assessments of brown, white, and pink shrimp in the U.S. Gulf of Mexico. Paper presented the Workshop on Stock Assessment. Miami, Florida, May 1984.

Parrack, M.L. 1981. Some aspects of brown shrimp exploitation in the Northern Gulf of Mexico. NMFS. 50 pp, figures, tables, and appendices.

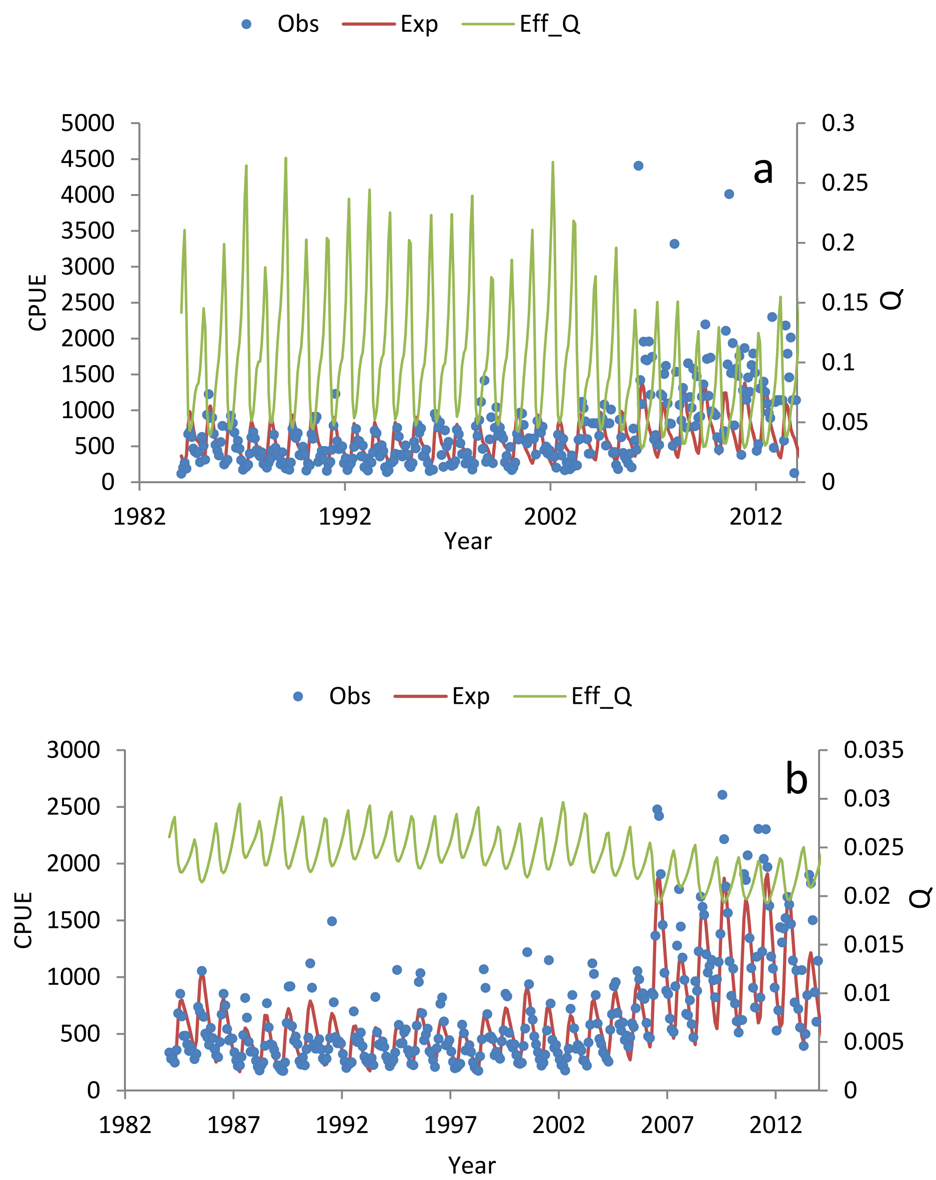

Figure 4.2.1. Brown shrimp CPUE and Q fits for Inshore and Offshore Fleets. Panel a is Inshore and panel b is Offshore.

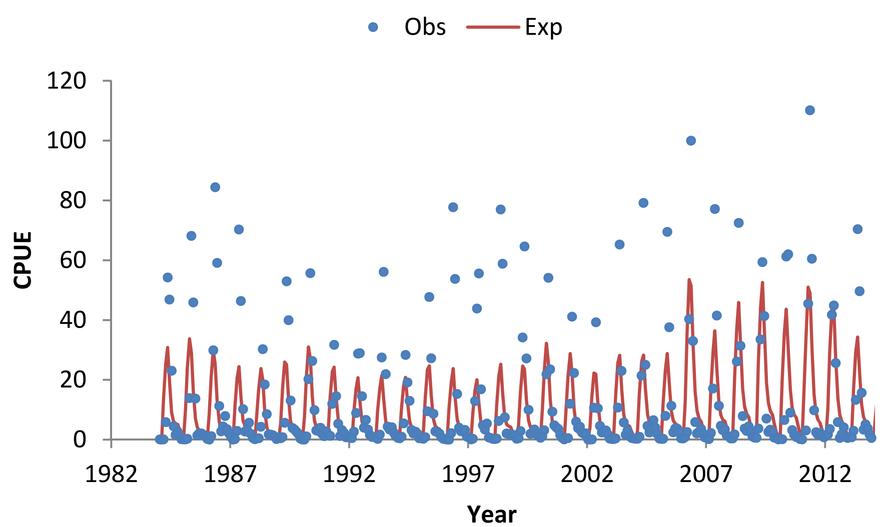

Figure 4.2.2 Brown shrimp Louisiana West Survey delta log normal CPUE fits.

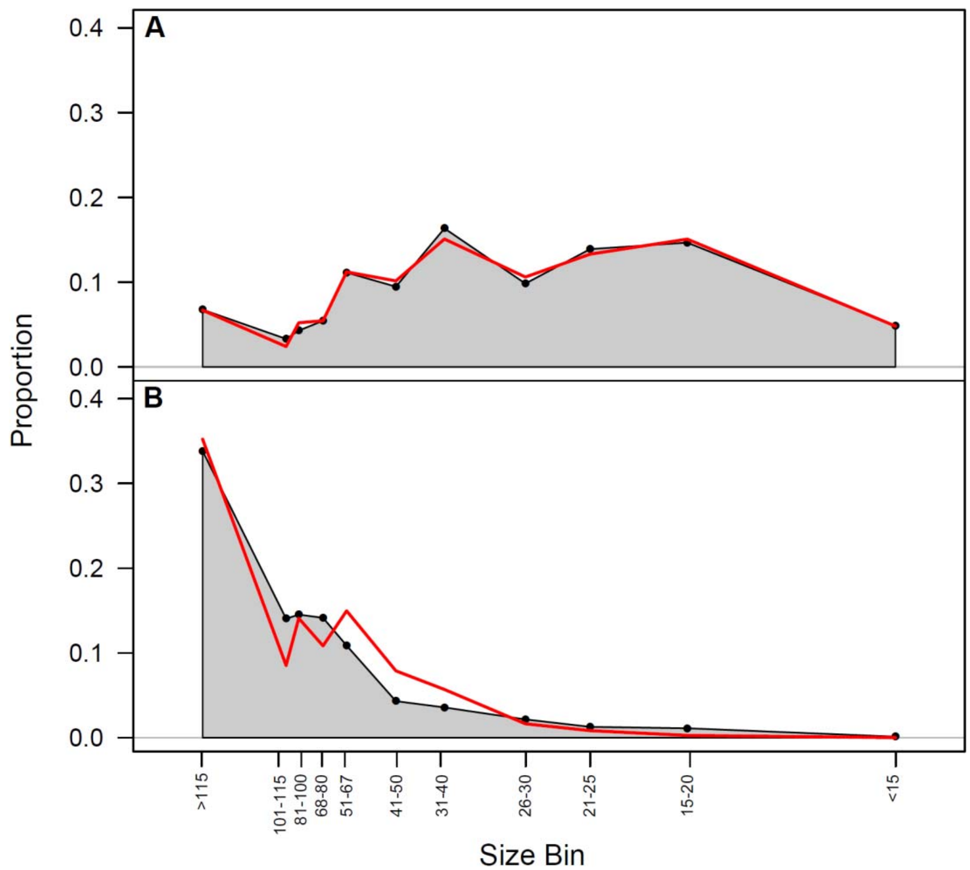

Figure 4.3.1. Brown shrimp size composition fits for Offshore and Inshore Fleets. Panel A is Offshore and panel B is Inshore.

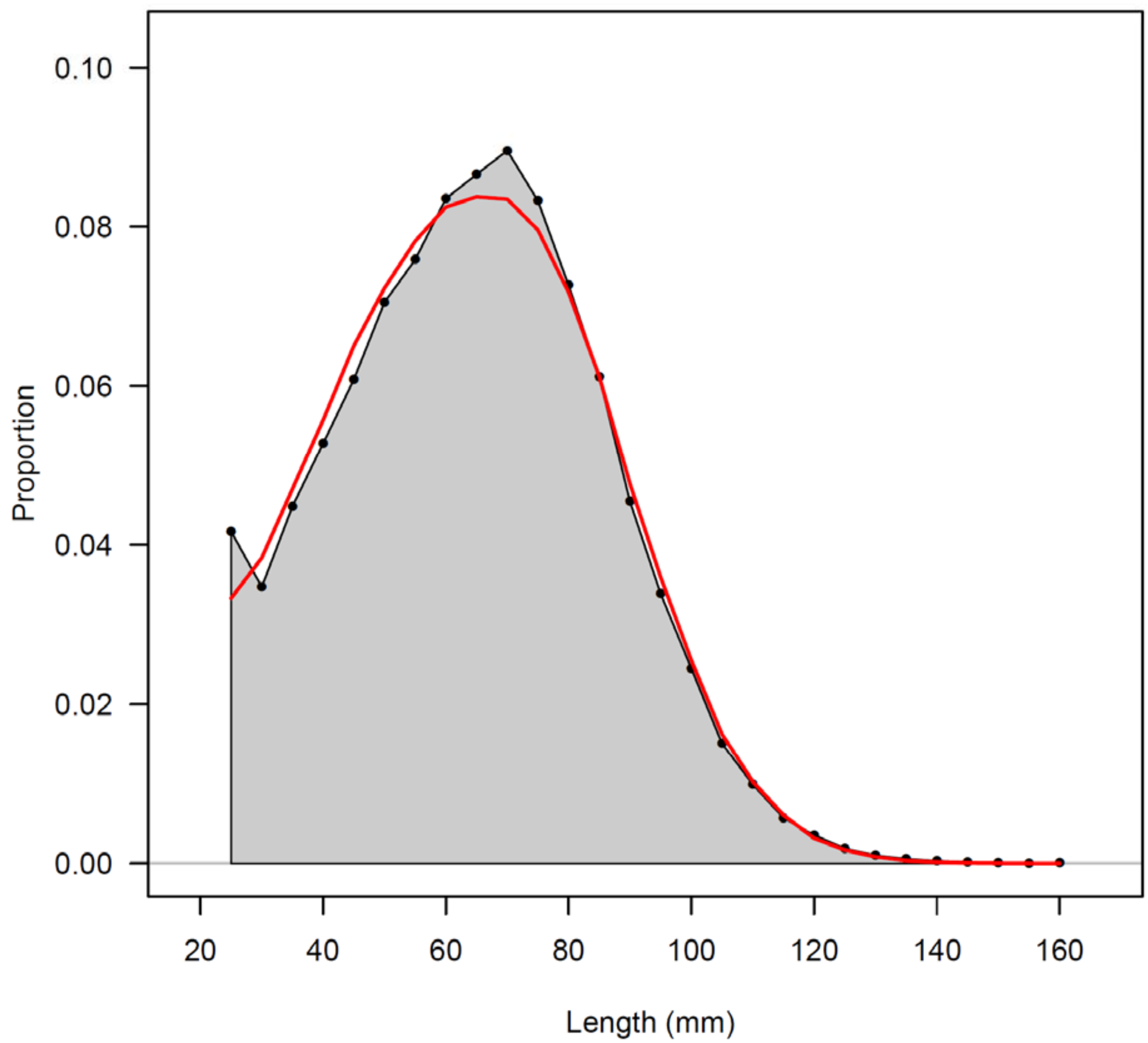

Figure 4.3.2 Brown shrimp size composition fits for Louisiana West Survey .

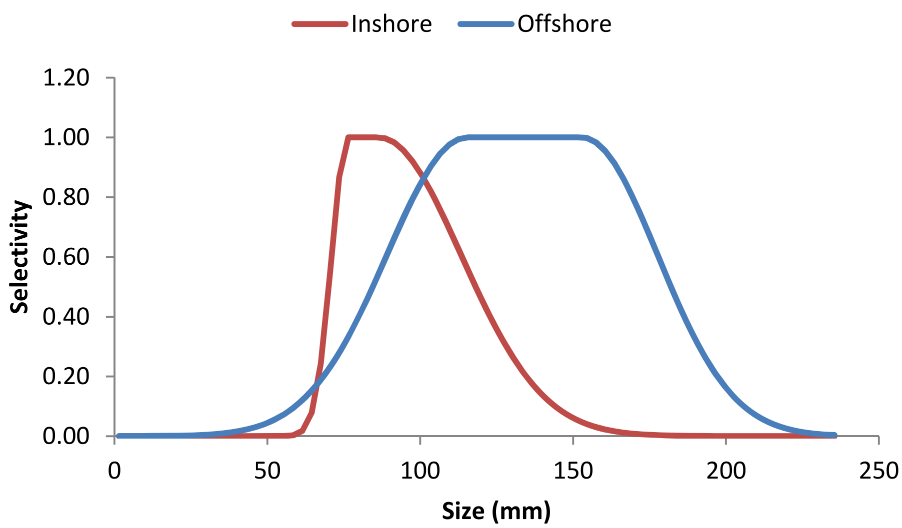

Figure 4.4.1. Brown shrimp commercial fishery size selectivity for the Inshore and Offshore fleets.

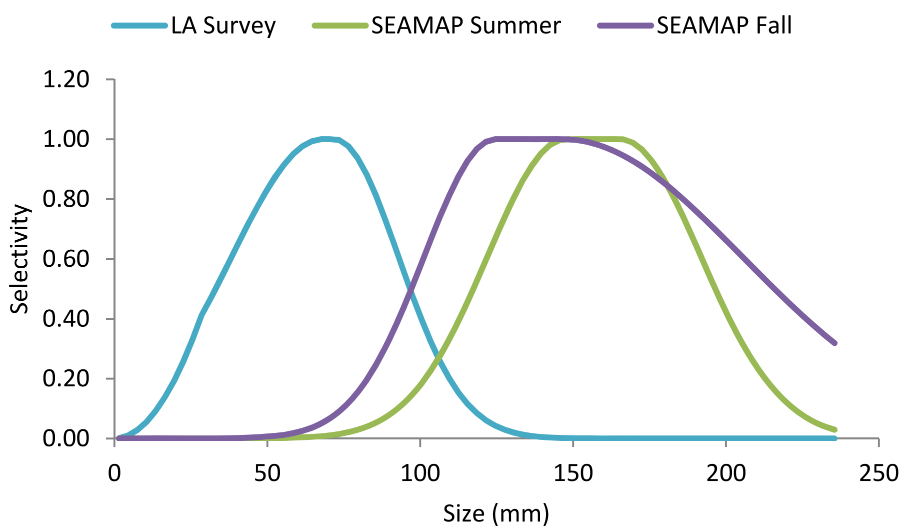

Figure 4.4.2. Brown shrimp size selectivity for Louisiana and SEAMAP surveys.

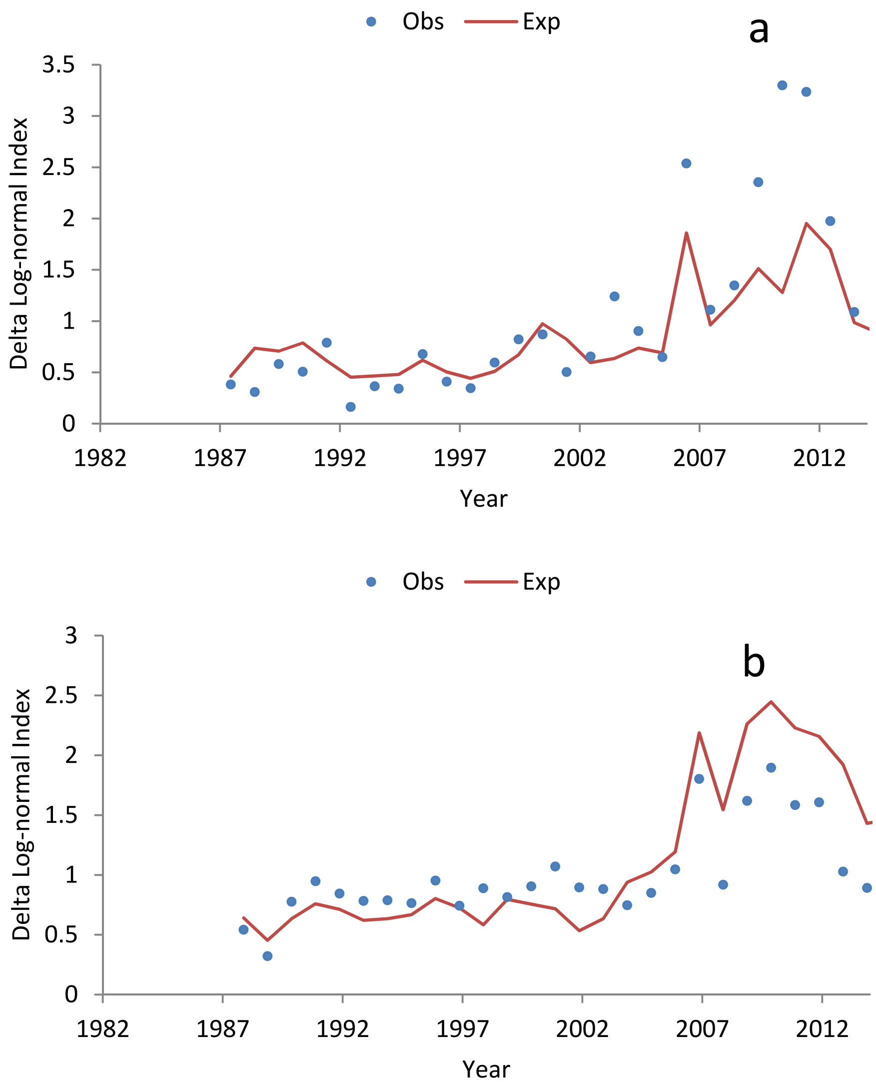

Figure 4.5.1 Brown shrimp SEAMAP Summer and Fall Survey Delta Lognormal fits. Panel a is Summer and panel b is Fall.

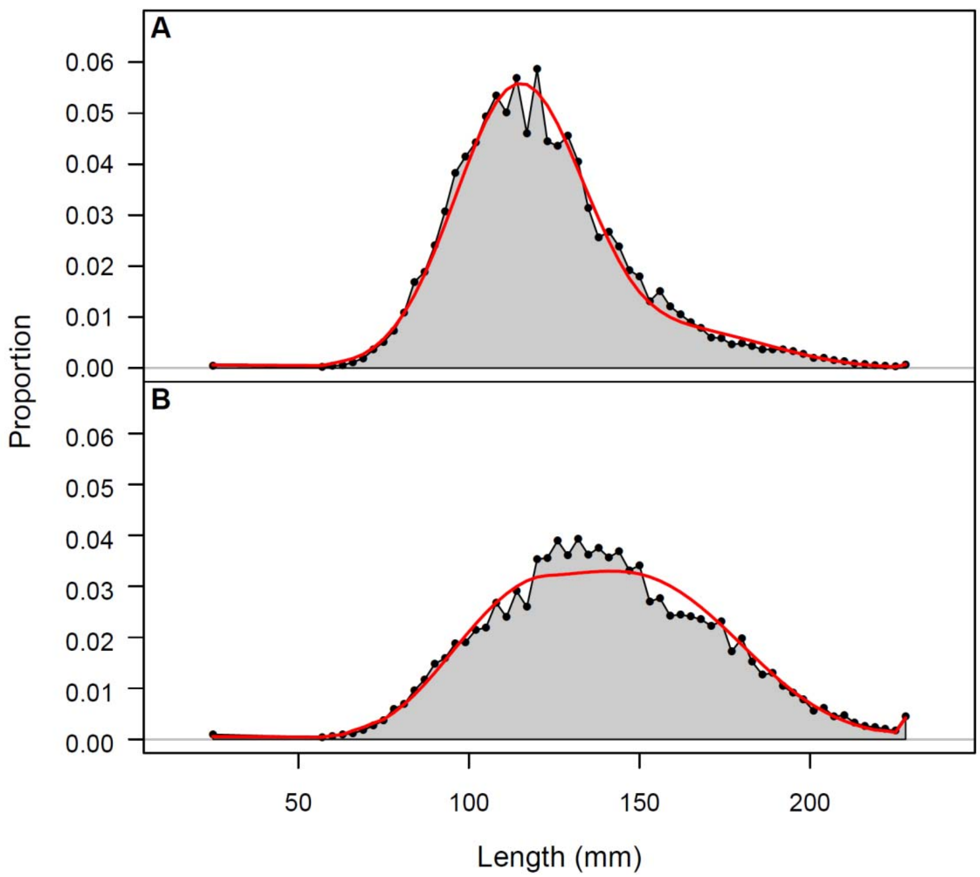

Figure 4.5.2. Brown shrimp size composition fits for the SEAMAP surveys. Panel a is Inshore and Panel b is Offshore survey fits.

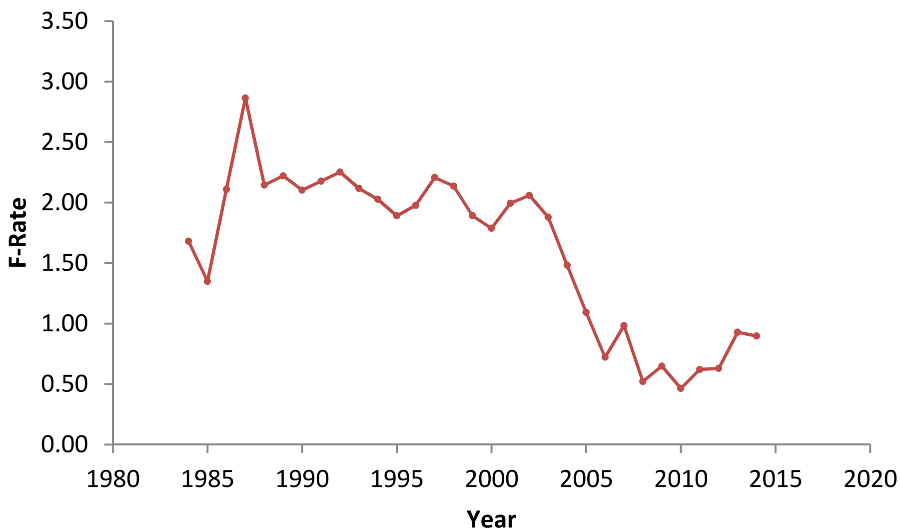

Figure 4.6.1. Brown shrimp annual F value.

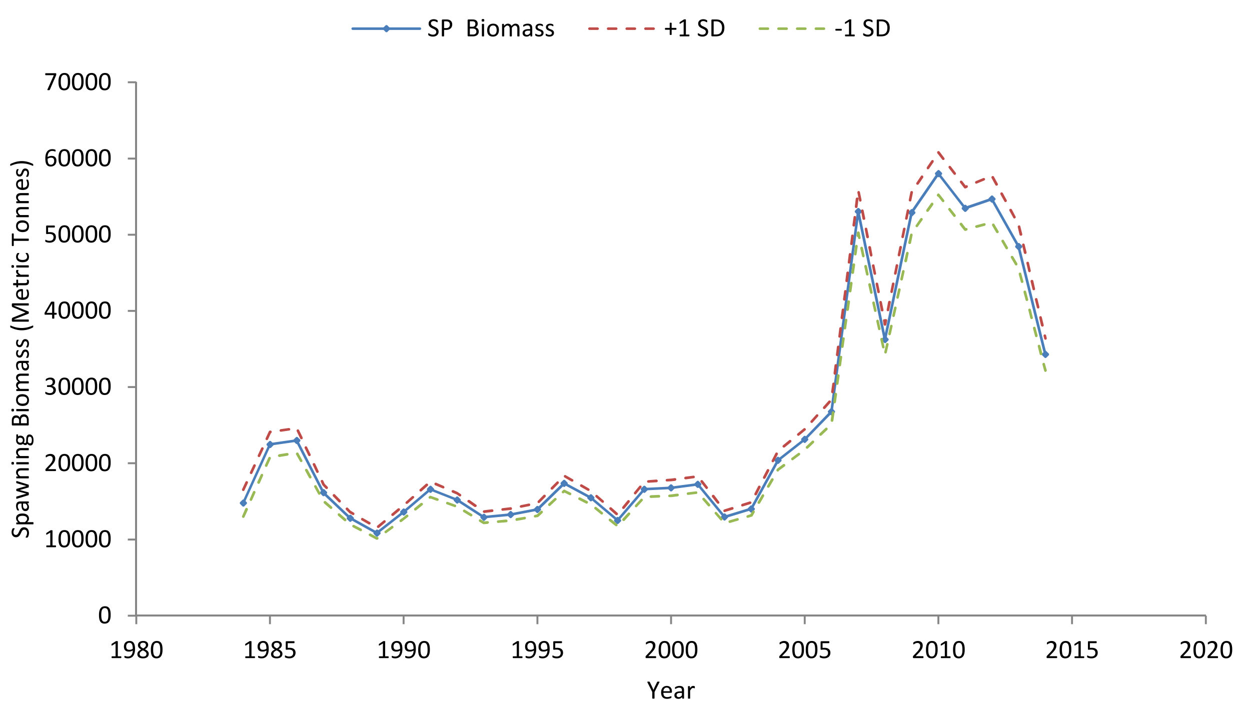

Figure 4.7.1. Brown shrimp spawning biomass estimates.

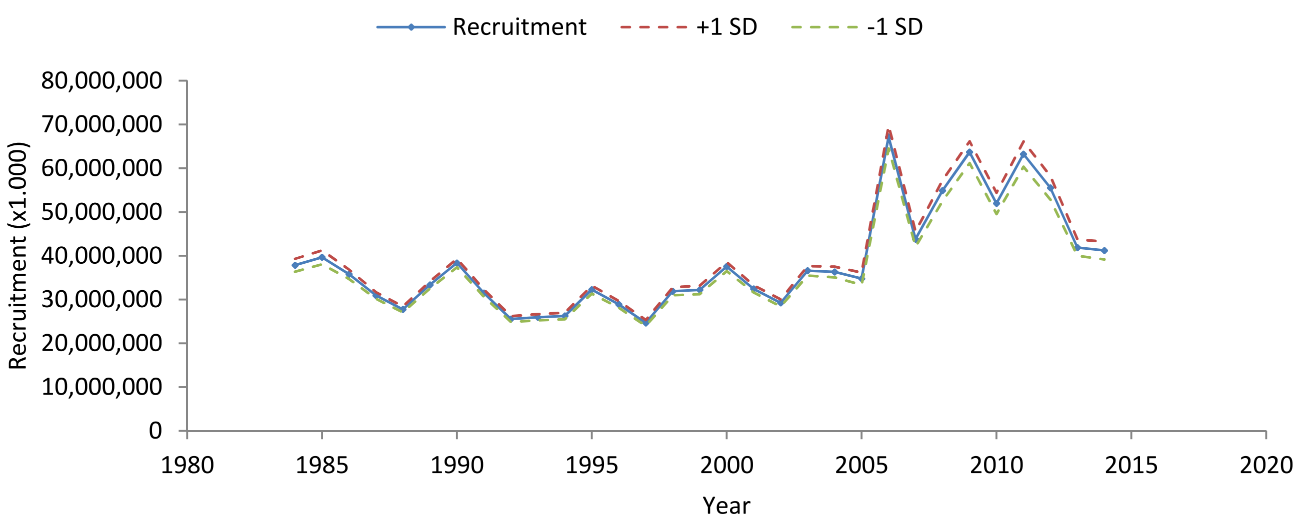

Figure 4.7.2. Brown shrimp recruitment model estimates.