Stock Assessment of Pink Shrimp (*Farfantepenaeus duorarum*)
in the U.S. Gulf of Mexico for 2011

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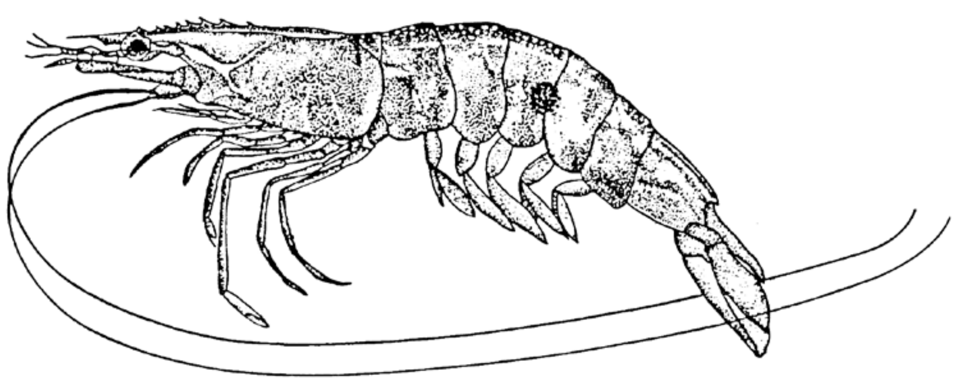

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
Galveston Laboratory
4700 Avenue U
Galveston, Texas 77551

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Rick A. Hart
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE
Southeast Fisheries Science Center
Galveston Laboratory
4700 Avenue U
Galveston, TX 77557

U. S. DEPARTMENT OF COMMERCE
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Rick A. Hart
National Marine Fisheries Service
Galveston Laboratory
4700 Avenue U
Galveston, TX 77551

National Technical Information Center
5825 Port Royal
Springfield, VA 22161
(800) 553-6847 or
(703) 605- 6000
http://www.ntis.gov/numbers.htm

1. ABSTRACT

This assessment examined the pink shrimp (*Farfantepenaeus duorarum*) population behavior when parameterized with over 25 years of commercial pink shrimp data from 1984 - 2011. In the model runs, CPUE estimates, size selectivity, spawning biomass, and numbers of recruits were generated. In addition, the incorporation of direct fishery independent surveys of shrimp abundance into the model greatly improves the precision (i.e., tuning) of this and future assessments.

The new Stock Synthesis based shrimp stock assessment model generates spawning stock biomass outputs in terms of pounds of spawning biomass, the number of recruits, and fishing mortality (F) values. Spawning biomass and recruitment for the 2011 biological year fishing season were 23,929 metric tons and 1.6 billion individuals respectively. Note that the 2011 biological year only includes 6 months of data, so the biological year 2010 should be considered as well. Spawning biomass and recruitment for the 2010 season were 46,250 metric tons and 5.1 billion individuals respectively. Fishing mortality has been decreasing in recent years, with biological year, monthly weighted apical F of 0.02 being estimated for the 2011 fishing season. Using these results, there is no evidence that the Gulf of Mexico *F. duorarum* stocks are overfished or undergoing overfishing.

2. INTRODUCTION

Historically the National Marine Fisheries Service (NMFS) applied a Virtual Population Analysis (VPA) developed by Nichols (1984) to assess the status of the Gulf of Mexico (GOM) penaeid shrimp stocks. While this model has been used since the mid-1980s, in 2008 it had been shown to not adequately track the pink shrimp (*Farfantepenaeus duorarum*) population (Hart and Nance 2010). Upon reviewing the VPA assessment, a NMFS stock assessment panel concluded that the *F. duorarum* VPA assessment was not suitable for making a status determination for the Gulf pink shrimp stocks and also concluded that new fisheries models need to be investigated for future assessments (see Appendix 1 in Hart and Nance 2010).

Therefore, the NMFS is now assessing the GOM *F. duorarum* stock with Stock Synthesis (SS-3), a widely used, peer reviewed stock assessment model, (Methot 2009; Schirripa et al. 2009, Methot and Wetzel 2012). In addition, this new modeling approach allows for the inclusion of fisheries independent data into the stock assessment. Southeast Area Monitoring and Assessment Program (SEAMAP) data, consisting of Federal and State survey data were also included in this new model to tune recruitment parameters.

This report describes the stock assessment of *F. duorarum* developed as a product of several Gulf of Mexico Fisheries Management Council SSC Meetings convened in 2011 and 2012, and an SSC Shrimp Assessment workshop held in 2012. This assessment model was chosen as the best available science to model the population dynamics of northern Gulf of Mexico *F. duorarum*. The modeling methodology uses a generalized stock assessment model, Stock Synthesis (SS-3), developed by Richard Methot (Methot 2009), and is parameterized with fishery data from 1984-2011.

3. METHODS

3.1. Model Overview

A Stock Synthesis (SS-3) model (Methot 2009, Schirripa et al, 2009) was parameterized, with time varying selectivity with a block approach, and a random walk of the Q parameter during select time periods of the fishery's history. This model data and settings are noted in subsequent sections noted below.

3.2. Data Sources

This model was parameterized in biological years, with the models starting in July 1984 and continuing through December 2011. Two years of "dummy" data were entered before July 1984 for a model burn-in period. This burn in period allowed for recruitment deviations or cycles to begin before the actual starting year data were called into the model.

The model structure included 1 fleet:

1) Commercial Shrimp Inshore and Offshore Catch Combined (1984-2011; statistical zones 1-11)

and 2 indices of abundance:

1) SEAMAP Summer Groundfish Trawls (Fisheries-independent; 1987-2011)
2) SEAMAP Fall Groundfish Trawls (Fisheries-independent; 1987- 2011)

3.2.1. Commercial Catch Statistics — Scientists have subdivided the U.S. Gulf of Mexico into 21 statistical sub-areas (Patella 1975) used by port agents and the state trip ticket system to assign the location of catches and fishing effort expended by the shrimp fleet on a trip by trip basis. The *F. duorarum* fishing grounds are located primarily within sub-areas 1-11. Port agents randomly visit fishing ports throughout the GOM to interview fishing captains and/or crews and record data pertaining to trawling activity (effort). These data include; 1) the location and depth fished by statistical sub-area; and 2) the species-specific pounds and sizes of shrimp landed for each individual trip that a vessel has completed (Nance et al. 1989).

The Stock Synthesis assessment model was parameterized with *F. duorarum* commercial catch data including; directed fishing effort by year and month, i.e., effort for those trips where >90 percent of the catch were pink 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 1-11 from January 1984 through December 2011.

To calculate catch and 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 are used to supplement the effort and location data collected by NMFS port agents and state trip tickets.

Total catch in pounds of shrimp tails by month was a primary input. Eleven count categories from 1984 to 2011 were used. Prior to 1984, shrimp catch was recorded in the 8 standard count categories. 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 one small-sized category into four additional count categories, therefore having finer resolution for these smaller sized shrimp. 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 1984-2011.

3.2.2. Growth curve and other population level rates – I used growth parameters k and linf derived and reported by Phares (1981), with variability around the growth curve set to a coefficient of variation (CV) equal to 0.07 (Berry 1967). Data inputs included a growth curve for each gender; natural mortality rate (0.3 per month as previously used in the historical VPA); and conversion factors to go from total length to the poundage breaks between the catch count categories. These data were entered as parameters in the models. Stock Synthesis estimated steepness in the spawner-recruit function and linf., with a starting size of 10 mm at age 1 month through age 20 months.

3.2.3. Size Selectivity - A dome shaped (double normal) selectivity pattern with 4 estimated parameters was used, providing a good fit to the data. In addition, since SS-3 is an annual model; individual months were modeled as years (336 “years”). Selectivity was modeled to fluctuate in 12 “1-year” blocks beginning in July. This approach is equivalent to an annual model with July through June biological year fluctuations.

3.2.4. Catchability Q – Catchability was set as a random walk in the model, with Q allowed to randomly vary during January 2005 through October 2008. These select years correspond to those years when a large increase in CPUE is evident in the time series.

3.2.5. SEAMAP Data – SEAMAP data collected by NOAA Fisheries research vessels and State Fisheries agencies were used in the Stock Synthesis model. These SEAMAP sampling data were collected primarily from statistical zones 7-11. SEAMAP shrimp abundance indices using the delta log normal index from 2008-2011 and nominal CPUE data from 1987-2011 were model inputs. Size compositions for pink shrimp collected and measured in 1987-2011 during summer and fall cruises were also data inputs.

During the February SSC 2012 workshop some members expressed concern that the SEAMAP data were collected from areas outside of the main pink shrimp fishing grounds (Figure 3.2.1). Their concerns were that these data would have undo weight in the model estimates. To address this concern, I lowered the weight or degree of influence held by the survey data in these model runs by setting the SEAMAP lamda value to 0.1.

3.3. Model Configuration and Population Dynamics

3.3.1. Selectivity, Fishing Mortality, and Natural Mortality

For the commercial fishing fleet selectivity I used a double normal setup with selectivity modeled to fluctuate in 12 “1-year” blocks beginning in July. I used a constant natural mortality (M) setup (M=0.30) for the model. 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 (2012).

3.3.2. Time-Varying Parameters

The Stock Synthesis modeling framework allows time varying fleet-specific selectivity and catchability parameters. A blocking technique was employed to allow time varying selectivity in blocks of 12 months so changes in selectivity can occur each year (or block). As noted previously, Q was also allowed to vary through a random walk technique in the model. Similarly, R_0 (unfished recruitment) was allowed to be estimated while recruitment was modeled with monthly deviations.

3.3.3. Parameter Estimation

Stock Synthesis requires the model to be initialized with approximations for certain parameters (e.g., $S_{g,a}$, $F_{g,1}$, $Q_{u,1}$, steepness) 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 (F deviations, recruitment deviations, selectivity deviations, etc.).

4. RESULTS

4.1. Parameter Estimates and Model Setups

Table 4.1.1 shows the model setup in terms of selectivity, Q settings, SEAMAP emphasis settings, and steepness estimate.

4.2. Fishery Catch Rates (CPUE)

The fit of observed and expected catch rates demonstrates how Stock Synthesis models the changes in catch rates over time. Catch rates have shown an increasing trend over the last several years. Fluctuations both within and between years were revealed, with a close fit of expected to observed catch rates. The model fits to the fishery CPUEs are illustrated in figure 4.2.1. The model allowed a random walk of Q beginning in January 2005 through October 2008. The increase in Q occurred during those years when CPUE was showing an increasing trend towards record high levels. This is due in part because the model is compensating for the high catch rates by increasing catchability. Allowing Q to increase this way accounted for some of the uncertainty in the signal in the increasing CPUE versus the model compensating by only increasing biomass. The increase in Q during this time period is also supported by the trend in CPUE measured in the fishery independent SEAMAP data.

4.3. Generalized Size Comps

The model was fit to the size composition of the catch in the model. Because the pink shrimp stock is modeled with months as "years" each month for the 26 year time period has a fit to the size composition data. Figure 4.3.1 illustrates the fit of the size composition aggregated across years. Overall, fits to catch at size was also good with no obvious patterns in the residuals evident (Figure 4.3.2).

4.4. Fishery Selectivity

The Stock Synthesis model results indicate that fishery selectivity tends to decline as shrimp get larger. This selectivity pattern matches the observed low occurrence of shrimp in the smallest count category, i.e., the largest sized shrimp. Figure 4.4.1 illustrates the size selectivity using the blocking approach.

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, thus allowing us to better tune the model's recruitment parameters. The summer and fall SEAMAP cruises reveal a pattern in CPUE similar to the commercial fishery (Figures 4.5.1). Figure 4.5.2 shows the fit to the size composition data for 1987-2011 for summer and fall survey data with size composition data fits aggregated across all years. Pearson's residuals for these fits are shown in figures 4.5.3 and 4.5.4. Size selectivity curves for the SEAMAP surveys are shown in figure 4.5.5.

4.6. Fishing Mortality

Stock Synthesis reports fishing mortality rates by age and month. These rates were discussed at length during the SSC Shrimp Stock Assessment workshop. While Stock Synthesis reports annual Fs by age the pink shrimp model is parameterized with monthly data which SS-3 treats as years. Consequently Stock Synthesis outputs F values by age and month, e.g., for 2011 the number of F values is 12 months x 19 ages = 228 F values.

To deal with this large number of F's per year, the consensus of the working group was to calculate the F rates in the following manner:

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

The implementation of equation 1 resulted in the calculation of one weighted, i.e., numbers of shrimp at age, F-value per month; the weighted average monthly F across all ages. Fishing mortality rates have been decreasing, with the apical weighted monthly F for biological year 2011 equaling 0.02 (Figure 4.6.1).

4.7. Spawning Biomass and Recruitment

Spawning biomass and recruitment for the 2011 biological year fishing season were 23,929 metric tons and 1.6 billion individuals respectively (Figures 4.7.1 and 4.7.2). Note the 2011 biological year only includes 6 months of data, therefore, biological year 2010 (July 2010-June 2011) should be considered as well. Steepness for the spawner-recruit curve was estimated at 0.81. Spawning biomass and recruitment for the 2010 season were 46,250 metric tons and 5.1 billion individuals respectively.

5. CONCLUSIONS

The Stock Synthesis model developed provides outputs for new overfished and overfishing definitions for the Gulf of Mexico *F. duorarum* fishery. The stock has been showing an increasing trend in spawning biomass and recruitment in recent years, and a decreasing trend in fishing mortality, F. No indications of overfishing or of the fishery being in an overfished condition are evident.

6. REFERENCES

Berry, R. J. 1967. Dynamics of the Tortugas (Florida) pink shrimp population. Ph.D. dissertation, University Microfilms, Ann Arbor, MI. 177 p.

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.

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., 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 p.

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. 2012. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fisheries Research in Press.

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.

Nance, J. M., E. F. Klima, and T. E. Czapla. 1989. Gulf of Mexico shrimp stock assessment workshop. NOAA Technical Memorandum NMFS-SEFSC-239, 41p.

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.

Patella, F. 1975. Water surface area within statistical subareas used in reporting gulf coast shrimp data. Mar. Fish. Rev. 37(12):22–24.

Phares, P.L. 1981. Paper presented to the Workshop on the Scientific Basis for Management of Penaeid Shrimp. Key West, FL.

Schirripa, M. J., C. P. Goodyear, and R. D. Methot. 2009. Testing different methods of incorporating climate data into the assessment of US West Coast sablefish. ICES Journal of Marine Science: Journal du Conseil 2009 66(7):1605-1613.

Table 4.1.1. 2012 pink shrimp Stock Synthesis stock assessment model configuration and parameter overview.

Model Number	Selectivity Setup	Q Setup	Seamap Settings	Control File Name
3	Blocks	Random Walk	De-Emphasis lamba 0.1	Pink_2011_9c.ctl

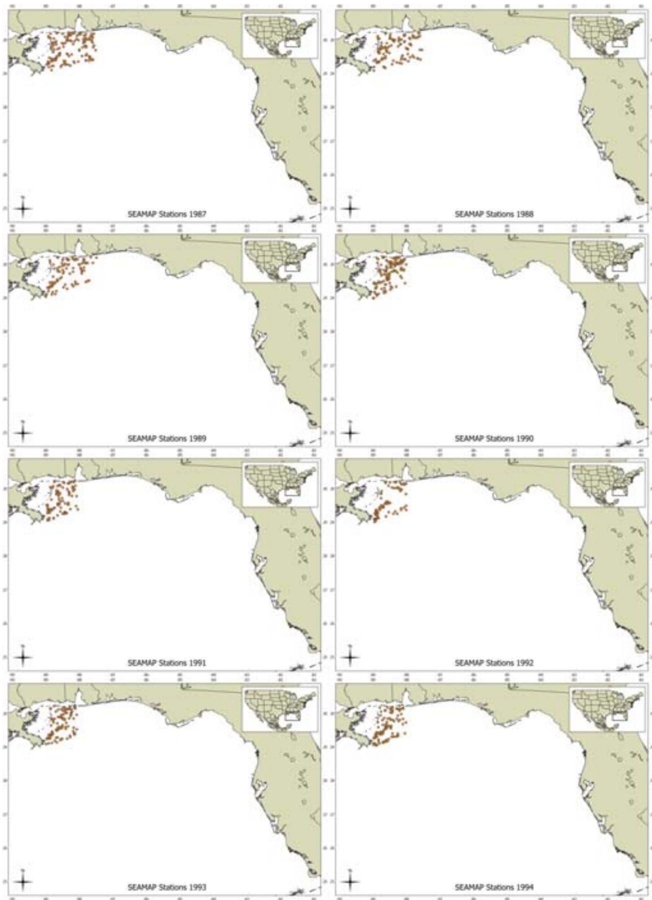

Figure 3.2.1 a. Pink shrimp SEAMAP sampling locations, 1987-1994.

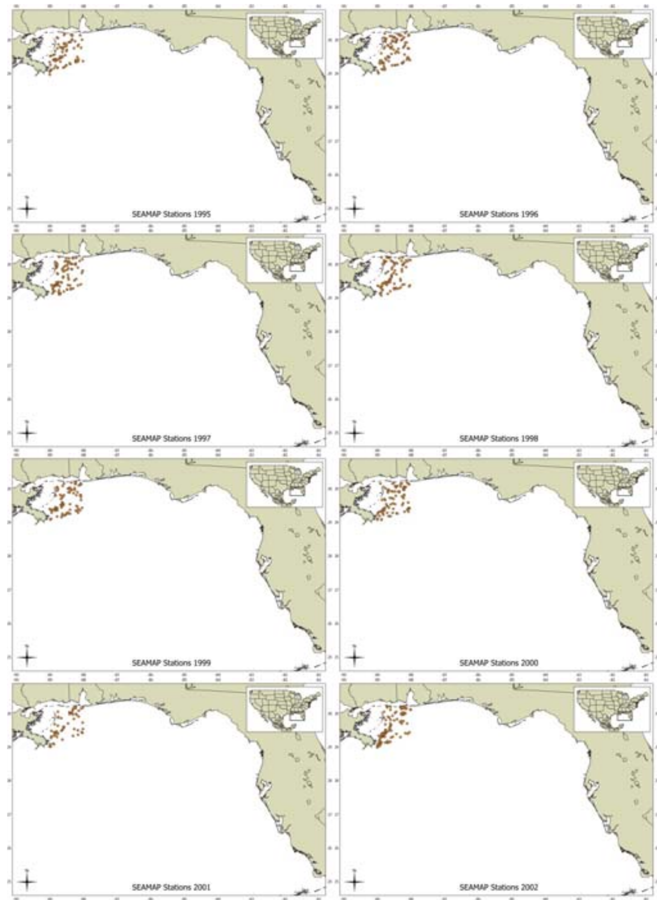

Figure 3.2.1 b. Pink shrimp SEAMAP sampling locations, 1995-2002.

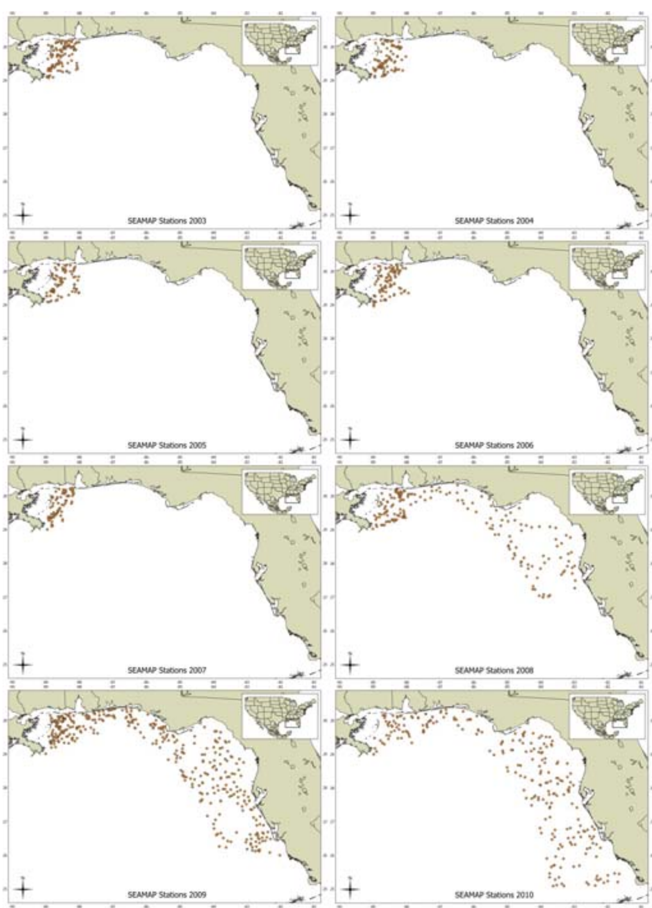

Figure 3.2.1 c. Pink shrimp SEAMAP sampling locations, 2003-2010.

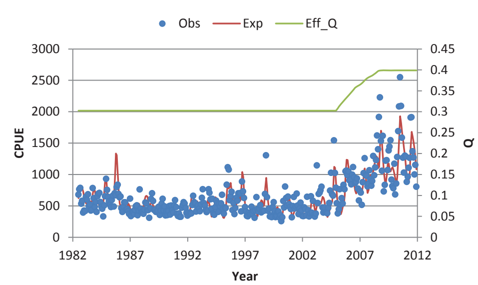

Figure 4.2.1. Pink shrimp CPUE and Q model fits.

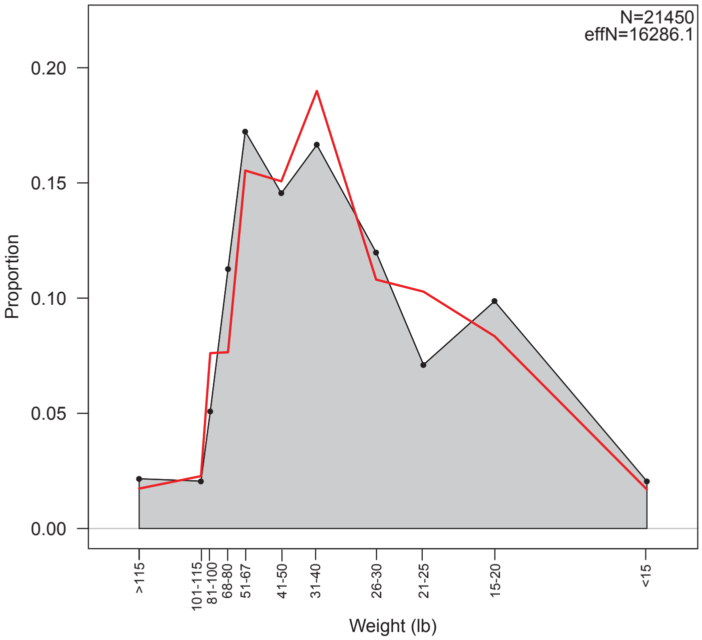

Figure 4.3.1. Size composition fits for the commercial pink shrimp fishery, 1984-2011.

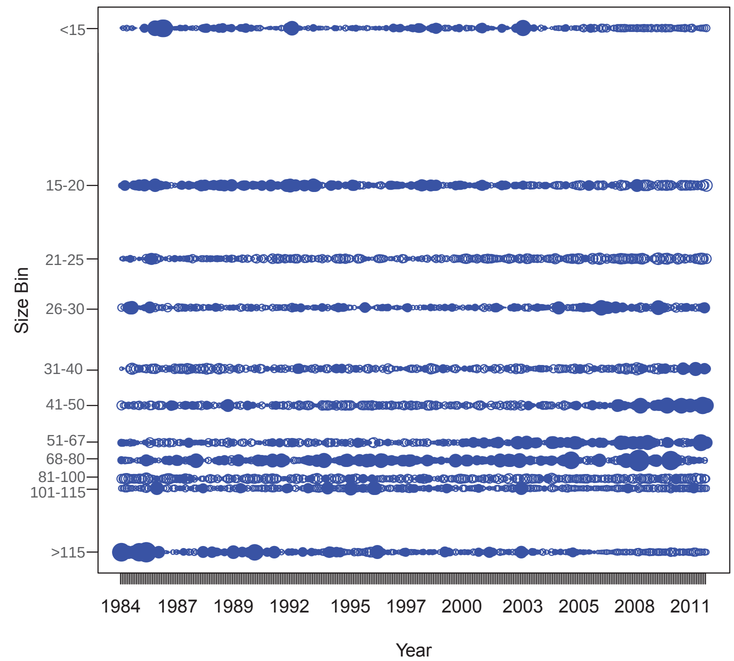

Figure 4.3.2. Residual fits for the commercial pink shrimp fishery, 1984-2011.

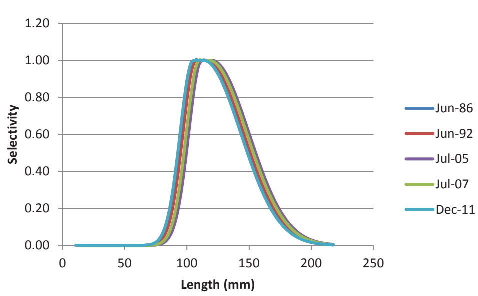

Figure 4.4.1. Pink shrimp commercial fleet size selectivity. Example years depicting the block setup.

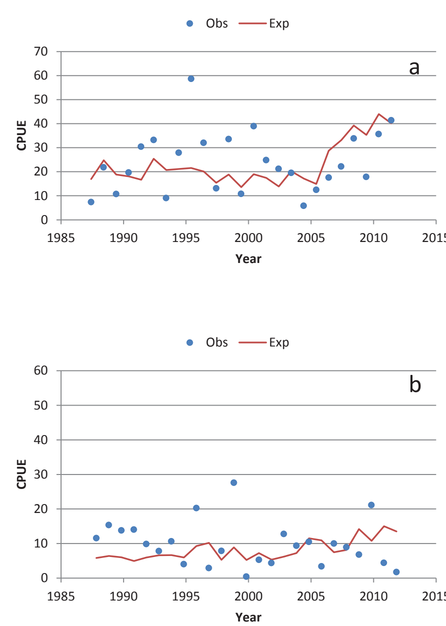

Figure 4.5.1. Pink shrimp survey fits for the Summer and Fall SEAMAP surveys, 1987-2011. Plot a is summer and plot b is fall surveys.

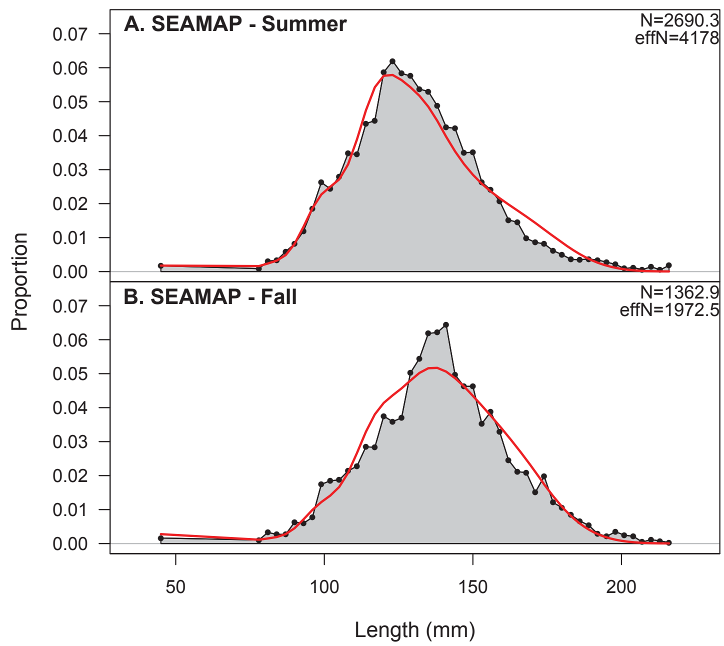

Figure 4.5.2. Size composition fits for the summer and fall SEAMAP surveys, 1987-2011.

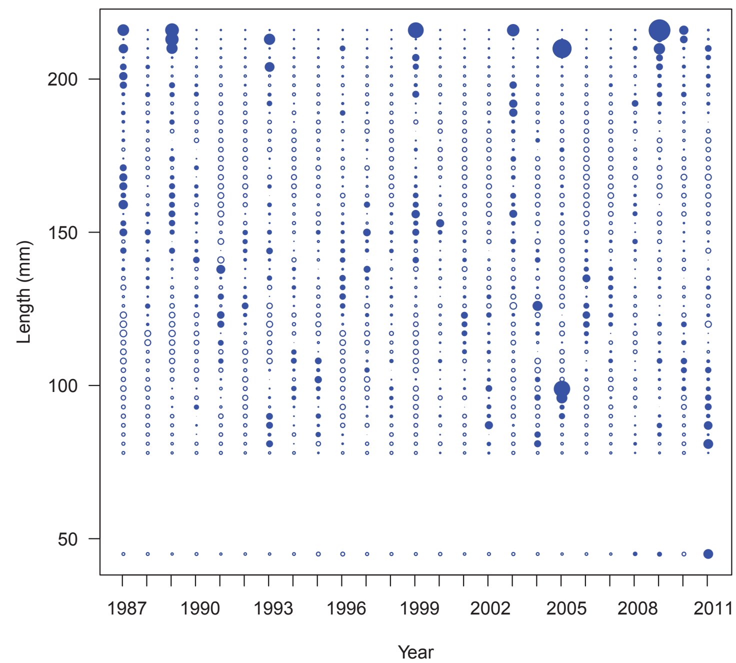

Figure 4.5.3. Residual fits for the summer SEAMAP survey, 1987-2011.

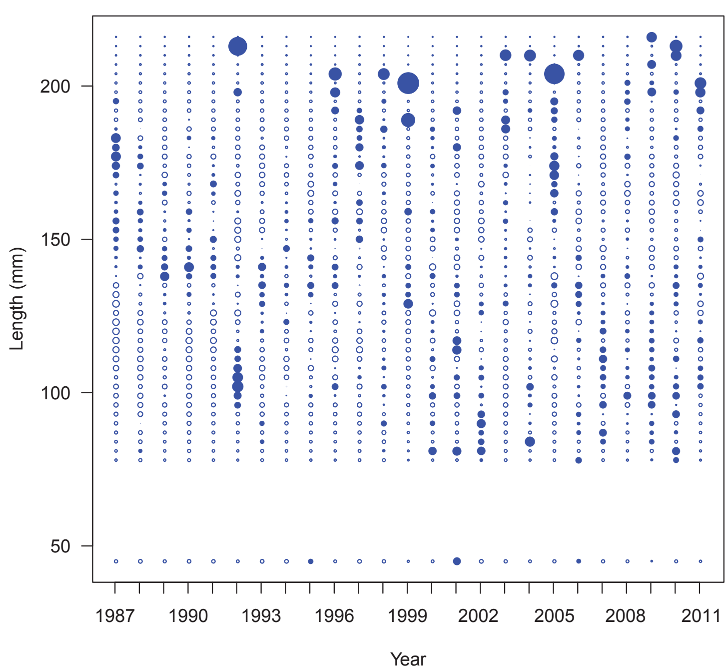

Figure 4.5.4. Residual fits for the fall SEAMAP survey, 1987-2011.

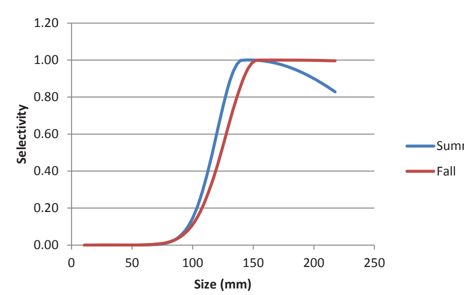

Figure 4.5.5. Pink shrimp size selectivity for the Summer and Fall SEAMAP surveys, 1987-2011.

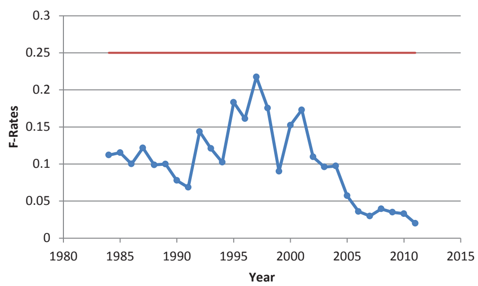

Figure 4.6.1. Pink shrimp weighted monthly apical F-values across ages 1-19 for 1984-2011.

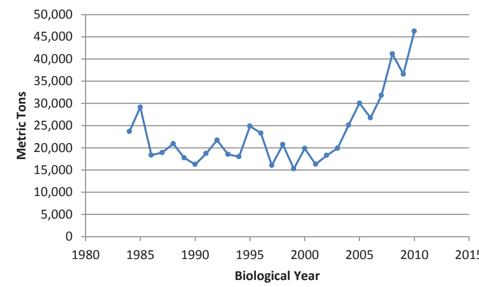

Figure 4.7.1. Pink shrimp spawning biomass estimates.

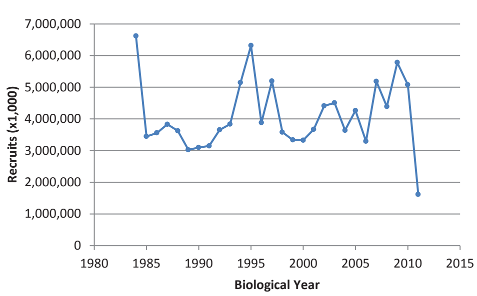

Figure 4.7.2. Pink shrimp biological year recruitment estimates. Note that biological year 2011 only includes 6 months of recruitment data, hence the low value seen in the figure.