

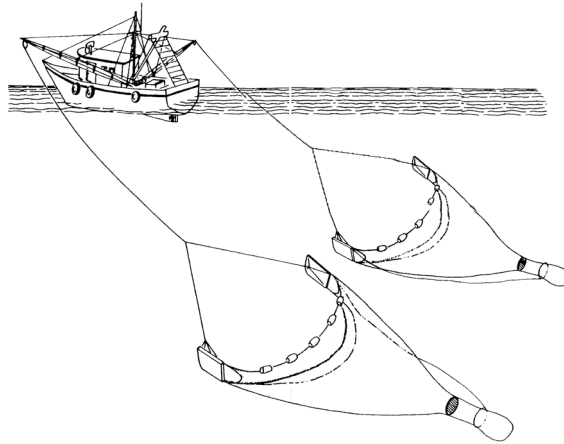


NOAA Technical Memorandum NMFS-SEFSC-604

Gulf of Mexico Pink Shrimp Assessment Modeling Update From a Static VPA to an Integrated Assessment Model Stock Synthesis

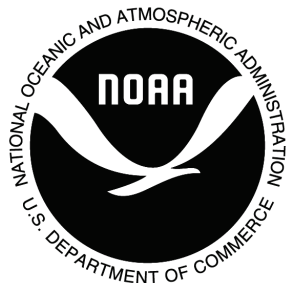
By

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Introduction

The Gulf of Mexico (GOM) pink shrimp stocks were deemed undergoing overfishing in 2008 at the conclusion of the 2007 fishing season (National Marine Fisheries Service 2009). This designation was made because the SEFSC, Galveston Laboratory's Virtual Population Analysis (VPA) results indicated the 2007 pink shrimp spawning stocks, *i.e.*, the number of parents, fell below the overfishing limit. However, because other fishery indicators, *e.g.*, catch per unit effort (CPUE), did not corroborate this finding, SEFSC staff recommended maintaining the current stock status designation until the VPA model could be thoroughly reviewed to determine if it is accurately modeling the GOM pink shrimp population's behavior, and hence, if this designation should be supported.

Consequently, in June, 2009 an internal NMFS review panel was convened and tasked with critically reviewing the VPA. The terms of reference established by the SEFSC were for the review panel to:

1. Review and characterize the current VPA model configuration and CPUE methodology.
2. Review the capability of the current VPA model to adequately monitor the shrimp populations.
3. Review and evaluate the use of number of parents as relevant recruitment overfishing and overfished parameters.
4. Provide recommendations as to the proper choice of models for assessment of shrimp populations.

In brief, the review panel concluded that the pink shrimp VPA assessment is not suitable for making a status determination for the Gulf pink shrimp stocks (Appendix 1). Further, the panel noted that the calibration of the VPA model had not been updated since its inception in the early 1980s. Currently fishing effort is below those levels during which the model was originally developed and calibrated. In his description of the VPA currently in use, Nichols (1984) forewarned that, because the fishery at the time of model development did not have enough variability, the estimated parameters, and hence VPA results, may not be reliable for fishery intensity outside of the calibrated levels. Currently the

fishery is operating far below the calibration levels for which Nichols (1984) developed the model, and we are now extrapolating, potentially beyond the models capability. Directed fishing effort, as well as landings, during the 2007 fishing season were a near record low level, and are far outside of the range of previously observed values (Figure 1). These aforementioned problems with current VPA are more thoroughly documented and discussed in the review panels report (Appendix 1). A main conclusion of the review panel was that new fisheries models should be investigated for future assessments. One of these suggested models is Stock Synthesis (SS-3), a widely used, peer reviewed assessment model, (Methot 2009; Schirripa, Goodyear, and Methot 2009) which can integrate the fishery data currently collected from the pink shrimp fishery. Because Stock Synthesis emerged as the most promising application for the development of a new pink shrimp model, and because it is accepted as a robust, reliable assessment model by the Alaska, Northwest, Northeast, Southeast, and Southwest Fisheries Science Centers (and their respective Fisheries Management Councils) for assessing other valuable fisheries, we followed the Review Panel's advice and migrated the pink shrimp data into Stock Synthesis. To date we have developed a preliminary model in Stock Synthesis, and have made several modeling runs incorporating commercial pink shrimp data from 1960 - 2008. This report is intended as a template to document and outline the steps taken to update the SEFSC shrimp stock assessment models.

Migration of the Commercial Pink Shrimp Data into Stock Synthesis

A pink shrimp model was implemented in the Stock Synthesis model developed by Richard Methot (NWFSC). Several model runs using various parameter inputs were conducted. The model inputs included:

A. Model Inputs:

1. Data sets were for 1960-2008. Catch by size, *i.e.*, composition data by month and year, directed fishing effort by month and year, and CPUE by month and year were all primary model inputs.
2. Total catch by month beginning in January 1960 through December 2008, converted to metric tons of shrimp tails.
3. Size composition of the catch. These data are entered as pounds in each of the standard eight shrimp count categories.
4. Monthly CPUE data. The coefficient of variation of these data points was typically in the range of 0.05 to 0.25. In final model runs, these CVs were increased by 0.10 in order to better conform to the average degree of difference between the data points and the model estimates.
5. Growth curve and other population level rates. The model initially used growth parameters k and l_{inf} derived and reported by Phares (1981). We allowed Stock Synthesis to estimate l_{inf} (in some runs); a growth curve for each gender; natural mortality rate (0.3 per month as previously used in the VPA); and conversion factors to go from total length to the poundage breaks between the catch count categories.

6. The shrimp population was started as 10 mm at age 1 month through age 20 months. Note these ages are offset 3 months from the age range modeled in the VPA (Table 1).

B. Size Selectivity

1. We initially used a logistic shaped size selectivity relationship; however this did not seem to fit the data well. The larger sized shrimp were not being harvested at a high enough rate, and spawning biomass increased too much. This was due to all of the large sized shrimp surviving at the end of each year. A dome shaped (double normal) selectivity pattern with 4 estimated parameters was subsequently used, providing a better fit to the data.

2. Selectivity is affected by how the fishery is being executed. During periods of the fishery, price differentials between small and large sized shrimp were greater than they currently are. The selectivity may be able to be tuned to this potential targeting of different sized shrimp. Selectivity was allowed to fluctuate, allowing the model to track changes in size composition data. Since we are modeling months as years, selectivity was set to fluctuate in 12 year increments, *i.e.*, annual fluctuations.

C. Number of Fleets:

1. Initial runs were done with 2 fleets. These fleets consisted of the catch, effort, and CPUE data partitioned into two zones, zone 1 (stat areas 1-3), and zone 2 (stat areas 4-11) (see Kutkuhn 1962 for a complete description of the Gulf of Mexico statistical areas). After several model runs it was apparent that both fleets were behaving similarly so we decided to retain the original data composition of one fleet (stat areas 1-11).

D. Growth Curve Variance:

1. Variance around the growth curve was initially set to a coefficient of variation (CV) of 0.05. In later model runs the variance was set to 0.07, which was the CV of the size distribution of the larger sized shrimp presented in Berry (1967).

Stock Synthesis Modeling Results, Potential Issues, and Recommendations

We tested the applicability of Stock Synthesis to the Gulf of Mexico commercial pink shrimp data using a preliminary model setup of just one random year of data (1976). In addition to the one year of weight composition data, the age composition data by month was also provided to the SS model. In this test configuration, SS was able to fit both the weight composition data and the age composition data. The flow chart depicted in figure 2 illustrates the basic procedural steps Stock Synthesis undergoes to arrive at the expected catch by count category. Beginning at the top of the figure 2, the steps for estimating catch by count begin with recruitment and follow the logical steps, the first of which is illustrated in figure 3, of the one-year model run showing how estimated catch-weight at size is ultimately parsed into the eight standard count bins. Figure 3 shows the test configuration growth curves using parameters reported by Berry (1967) and Phares (1981). The next modeling step is the calculation of the size distribution at age (Fig 4). Using the known size bin structure and the lower edge of these bins (Table 2) the expected poundage within each size bin can then be calculated (Fig 5). A careful examination of figure 5 also reveals how the largest sized shrimp contribute more to the total poundage, with the largest shrimp moving into the next size bin near l_{inf} . The next procedural step is the calculation of population numbers at length and size-selectivity estimates (Fig 6) Selectivity is applied in figure 7, with catch in numbers at length being estimated, followed by the estimate of catch weight in tails per pound by body size (Fig 8). Catch weight in tails per pound by body weight is then integrated to estimate the observed and expected fraction of catch by shrimp tails per pound within the standard count categories (Fig 9).

This result also demonstrates that the modeling process in Stock Synthesis, which converted catch at age to the weight composition of the catch, is comparable to the procedures used by Nichols (1984) to calculate the catch at

age from the observed weight composition of the catch. It should be noted however that Stock Synthesis works in the opposite direction of the VPA. The VPA begins with the data in the 8 count categories, while Stock Synthesis begins with recruitment and models toward the eight standard count categories (Fig 2). However, in this test configuration it was necessary to set up the SS model to use no variability around the growth curve. This apparently conforms to the previous VPA procedure, but does not use the more complete description of growth which includes variability around the growth curve. Unlike the VPA and the one year test run, in the subsequent full model runs we used a CV of 0.07 around the growth curve. The Stock Synthesis model results indicate that fishery selectivity tends to decline as shrimp get larger in order to match the observed relative low occurrence of shrimp in the greatest count category. These model runs also reveal how the largest shrimp move to the largest bin near length infinity (linf). This result, however, is sensitive to the level of natural mortality and the linf of shrimp and should be further investigated as part of a full assessment. Also revealed was how during various time periods of the fishery selectivity was high for small shrimp (Fig 10). This high level of selectivity is possibly a reflection of market conditions.

As noted by the Review Panel, there is a lack of strong correlation between catch and CPUE, with CPUE not declining during periods of higher catch. CPUE has increased recently as catch has declined to historically low levels. As long as CPUE is a good measure of relative abundance of shrimp, the low, or lack of, responsiveness of CPUE to catch is an indication that the shrimp population has remained large enough to not be dramatically affected by the catch. This situation will affect all possible assessment models of shrimp. The previous VPA linked the effort ($=\text{catch}/\text{CPUE}$) to the F at age 15 months (age 18 months in the Stock Synthesis implementation). The model in its current configuration, cannot be, nor should it be, configured to replicate this approach and instead used CPUE (which is mostly responsive to the more dominant younger shrimp) as an indicator of total fishable abundance. Because CPUE is not showing

responsiveness to high and low catch periods, Stock Synthesis (as well as all other models) cannot be expected to produce precise results. However, the Stock Synthesis model's ability to fit the expected and observed values of CPUE are shown in figure 11 and illustrate the applicability of this model to these data. In addition, the incorporation of direct fishery independent surveys of shrimp abundance into the model would greatly improve the precision (*i.e.*, tuning) of this and future assessments.

In the full time series model runs, spawning biomass and numbers of recruits, as well as the cpue estimates, were also generated (Fig 12). While the spawning biomass is not directly comparable to the VPA number of parents index, the numbers of recruits estimated in Stock Synthesis does appear to be relatively close to previous estimates. Note that the current Gulf of Mexico Shrimp Fishery Management Plan (FMP) overfishing limits are in terms of numbers of parents, however, Stock Synthesis generates spawning biomass outputs in terms of pounds of spawners. The aforementioned results were subsequently presented to the Gulf of Mexico Council's SSC at a January, 2010 meeting. The SSC concurred with our findings and passed a motion, requesting the Council accept our new modeling framework. The Gulf Council also concurred, requesting we update our stock assessment methodology by continuing to move the pink shrimp, as well as brown and white shrimp, data into the Stock Synthesis model.

One additional modeling possibility we will explore is beginning the model runs in 1984 versus 1960. The main reason for beginning model runs in 1984 is the landings data from 1960-1983 were recorded only in the standard eight market count categories. Beginning in 1984, landings are more precisely partitioned into the actual size categories in which they were landed, and are not arbitrarily assigned to standard size bins. Therefore, the use of only these later years of data (1984 to current) will result in a finer resolution of the size distributions input into the stock assessment model.

Unfortunately, as also noted by Nichols (1984), we do not have good documentation of the natural mortality rate M , and the catchability coefficient q , used in these models, and the growth curve data we are using as inputs. The M value is from a forty year old mark-recapture study, while the growth curve data were collected from a limited number and size range of shrimp over 25 years ago. Further research into an updated value for M is warranted. According to our dissection of the Nichols' VPA, this early model retained a static value for q of 3.0 for all sizes of shrimp. Within Stock Synthesis we allowed for age varying q , but not for time varying. The effect of this treatment of q , as well as the sensitivity to changes in the value of M , will be further explored in subsequent Stock Synthesis model development and runs.

Conclusion

We were successful in implementing the new Stock Synthesis assessment model for Gulf of Mexico pink shrimp stocks. This model migration from a static VPA has not only been looked at as a chance to upgrade the current assessment methodology to a peer reviewed model, but also as an opportunity to recalibrate the overfishing limits and refine the data inputs. We will continue to refine the pink shrimp Stock Synthesis based assessment and upon completion, the Gulf Council SSC will reconvene to address the recalibration of new overfishing limits. The new pink shrimp SS-3 model will also be modified to accept environmental parameters, tuning the CPUE indices. We will also begin to migrate the brown and white shrimp data into this new modeling framework, thus updating all of the SEFSC penaeid shrimp assessments.

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Table 1. Stock Synthesis and VPA models age and size comparisons.

Stock Synthesis Age (months)	VPA Age (months)	Size (mm)
0	N/A	1
1	N/A	10
4	1	~45
20	17	≥220

Table 2. Pink shrimp size bin structure.

	Size Bin							
	1	2	3	4	5	6	7	8
Shrimp/lb	>67	51-67	41-50	31-40	26-30	21-25	15-20	<15
Lower edge of size bin in lbs.	1E-06 1E-06	1/67 0.015	1/50 0.020	1/40 0.025	1/30 0.033	1/25 0.040	1/20 0.050	1/14 0.071

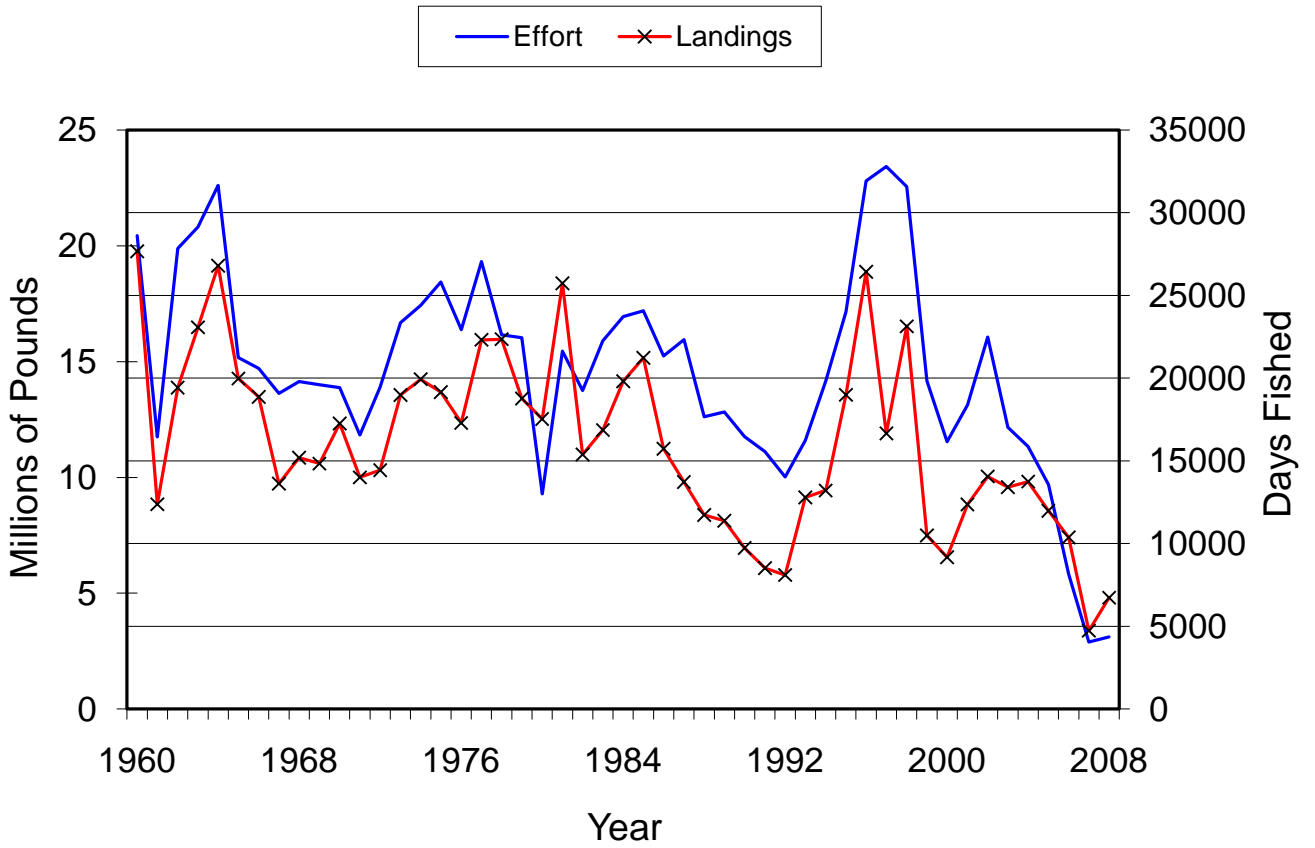


Figure 1. Pink shrimp directed effort and landings, 1960 - 2008

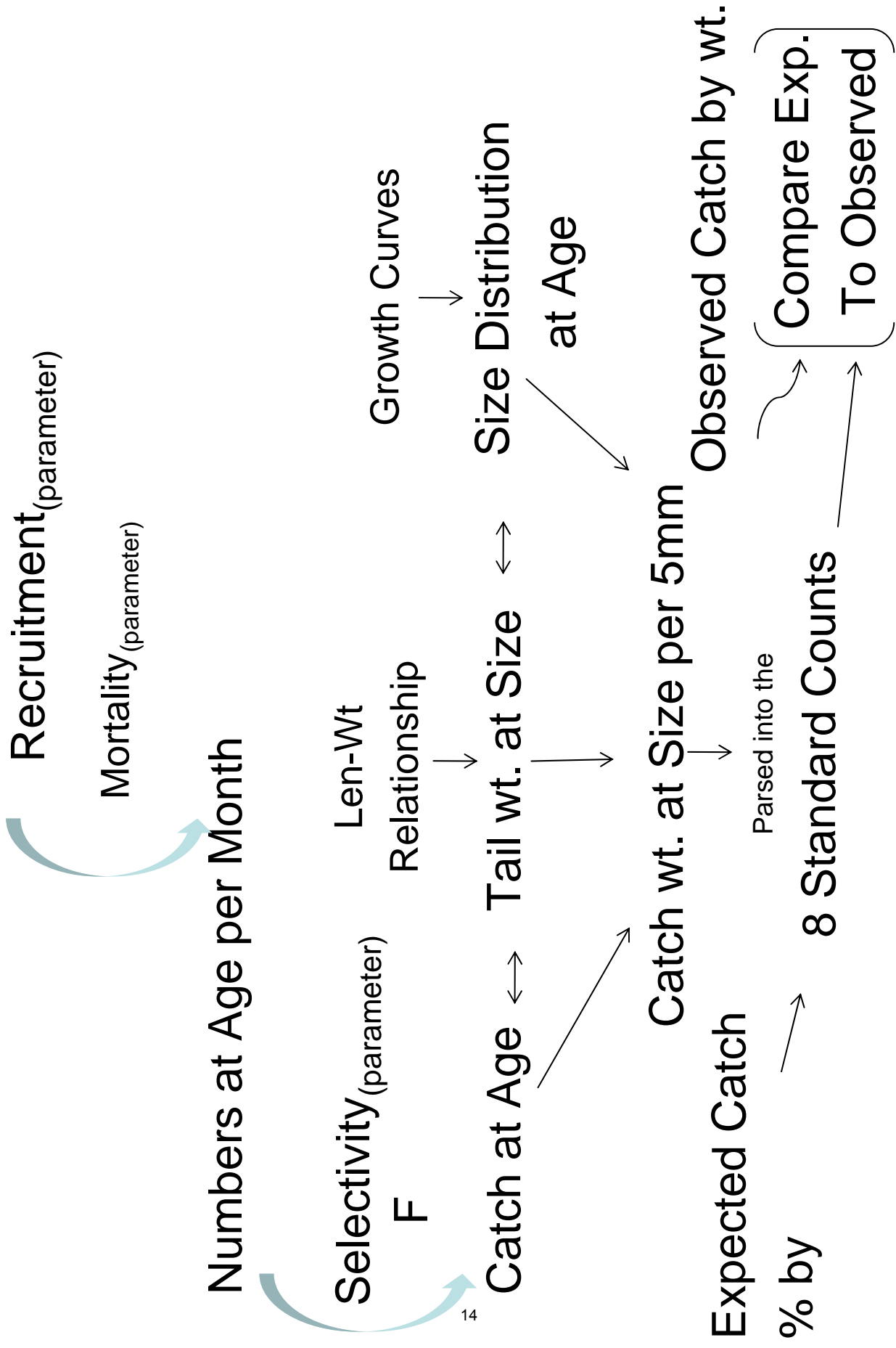


Figure 2. Stock Synthesis flow chart; calculation of catch at age by count category.

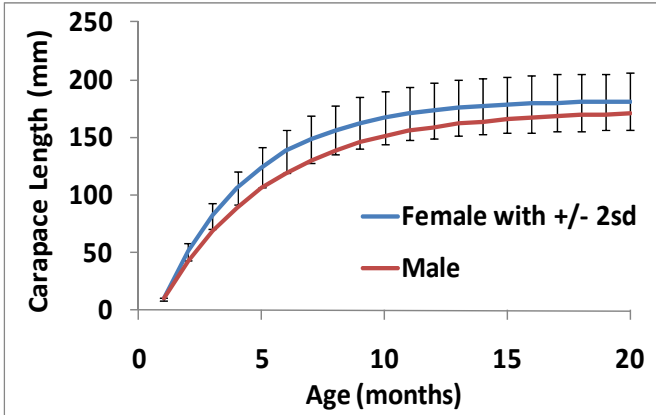


Figure 3. Pink shrimp growth curve by sex.

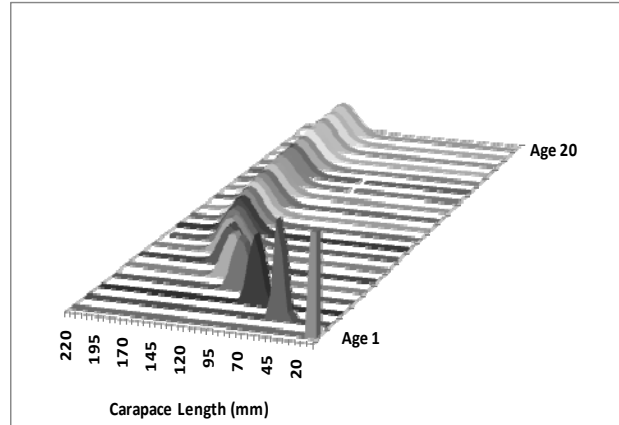


Figure 4. Pink shrimp size distribution by age.

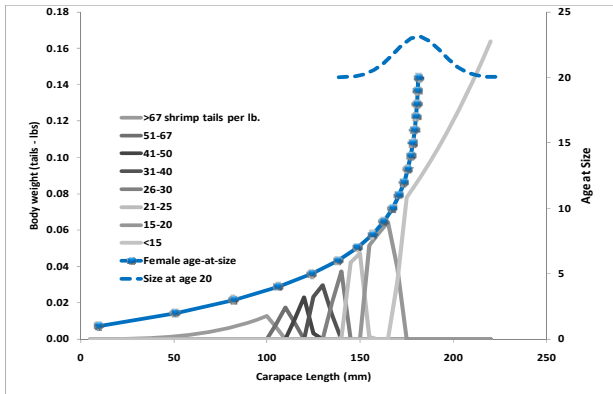


Figure 5. Pink shrimp expected biomass within size bins.

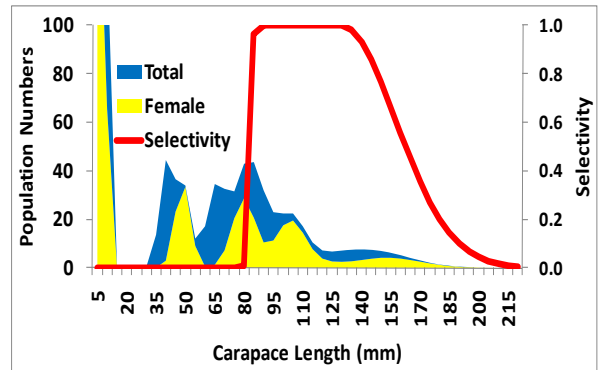


Figure 6. Pink shrimp population by length and selectivity.

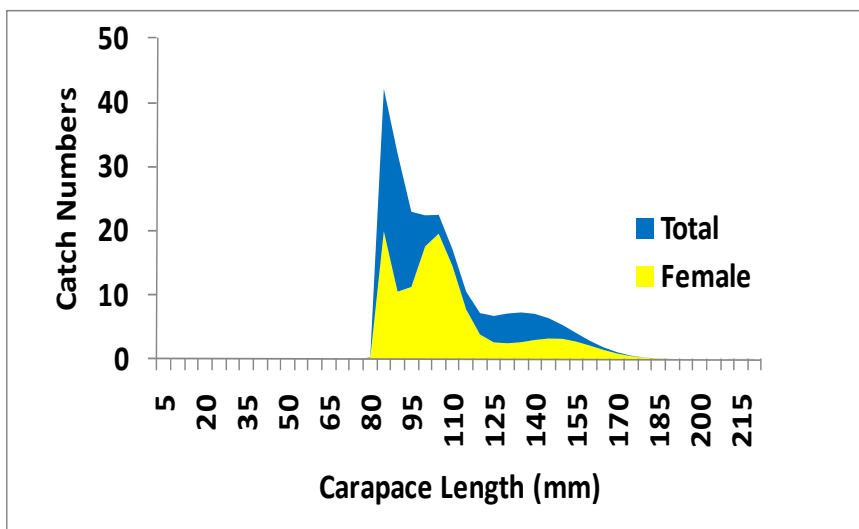


Figure 7. Pink shrimp catch numbers by size.

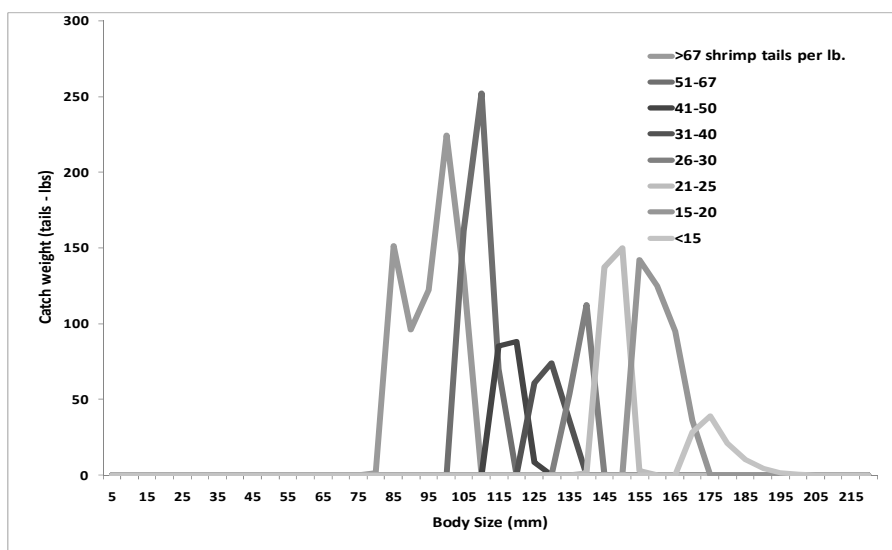


Figure 8. Pink shrimp catch weight by size.

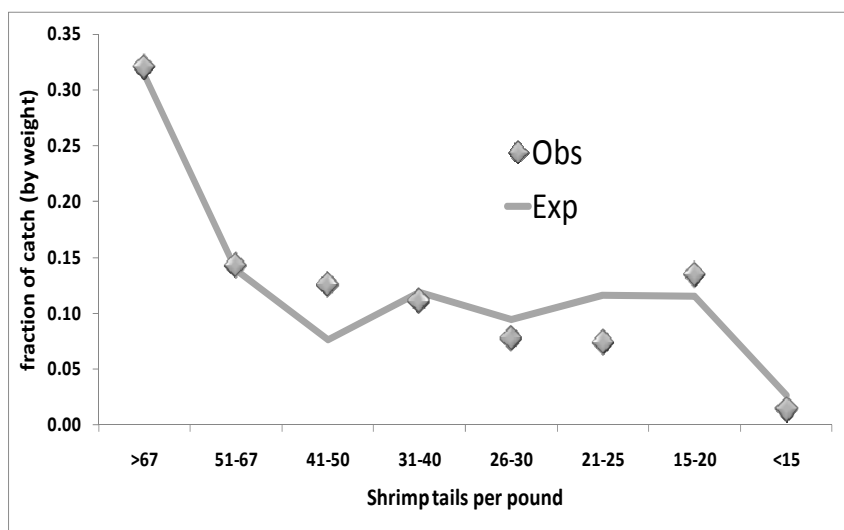


Figure 9. Pink shrimp observed vs. expected catch by count.

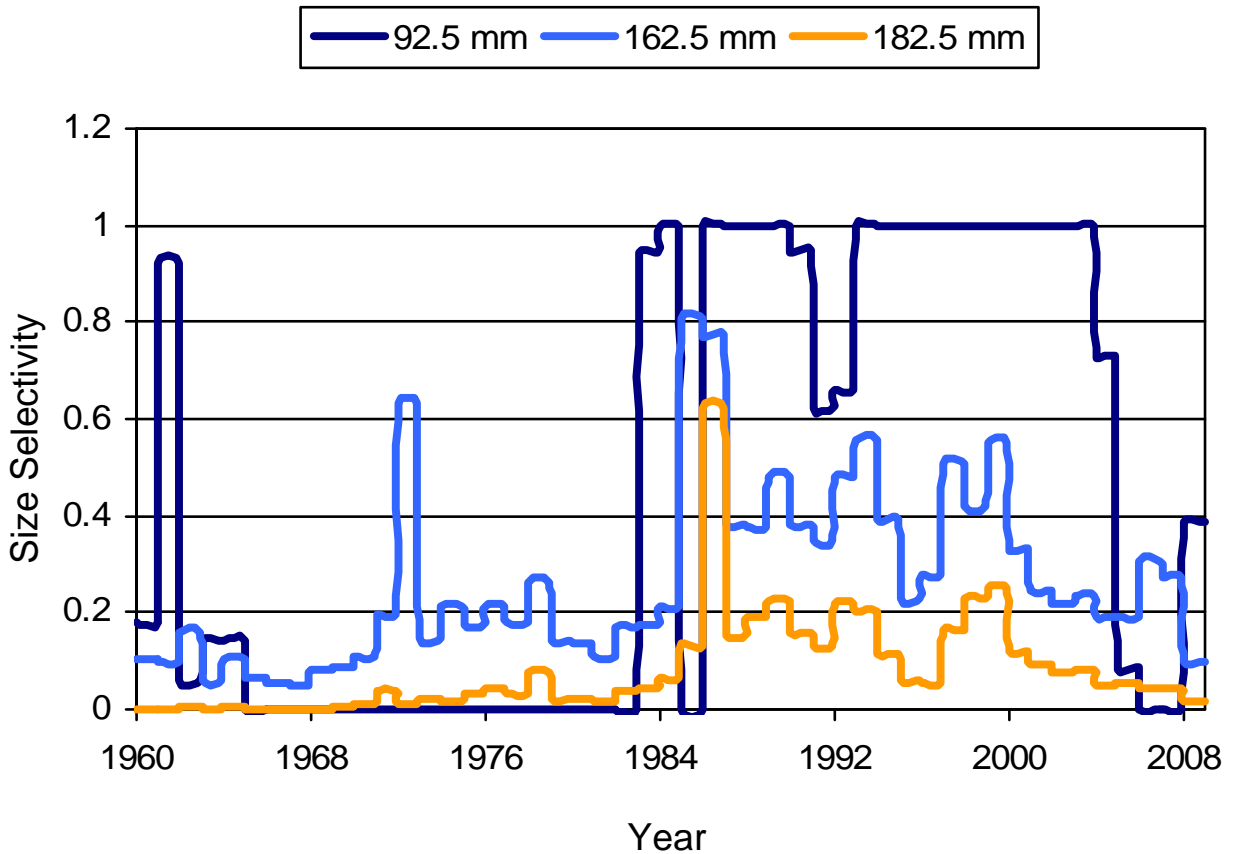


Figure 10. Modeled size selectivity of three size bins of shrimp; small 92.5 mm, medium 162.5 mm, and large 182.5 mm. Shrimp sizes are carapace lengths (millimeters).

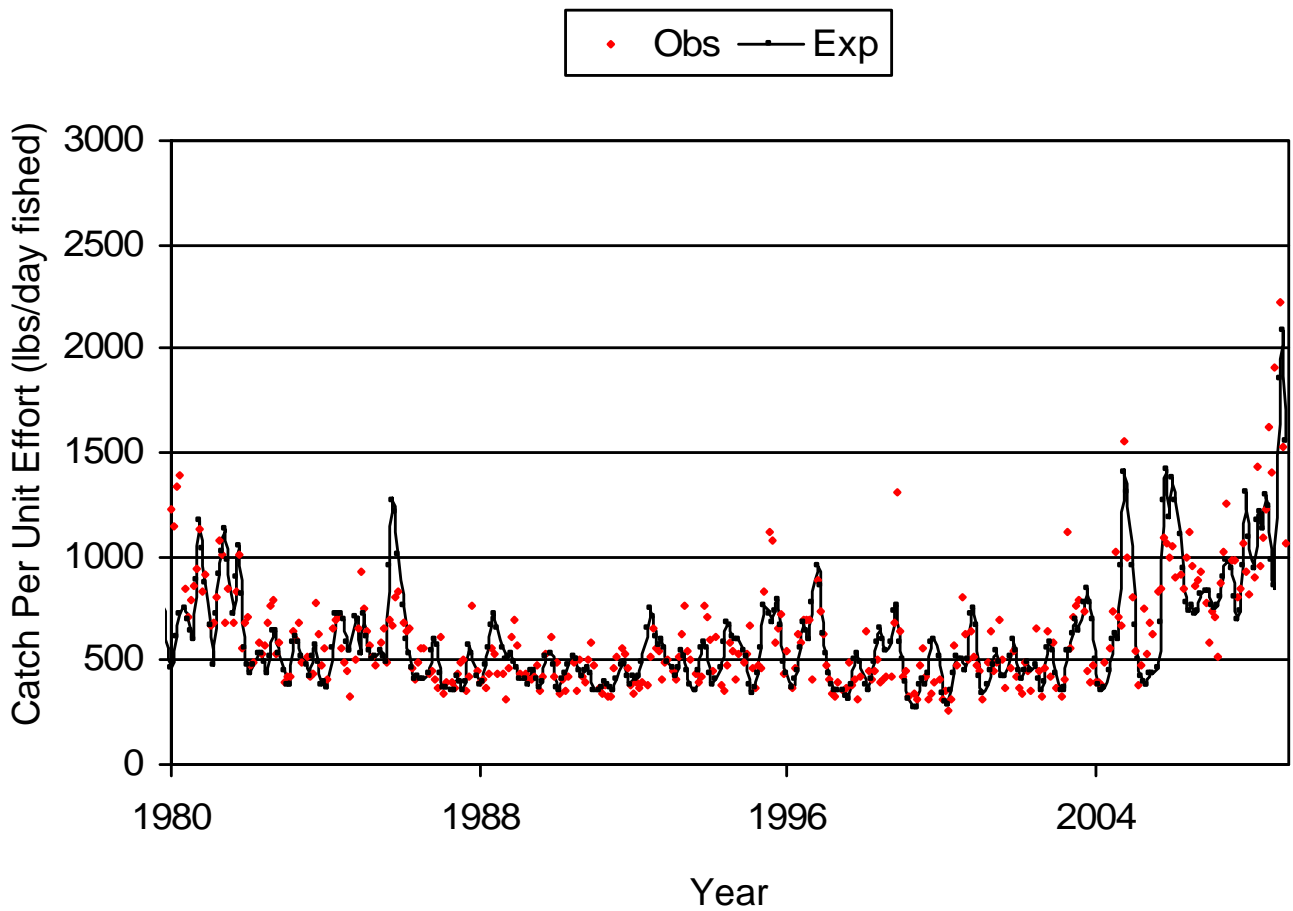


Figure 11. Pink shrimp observed vs. expected catch per unit effort (CPUE).

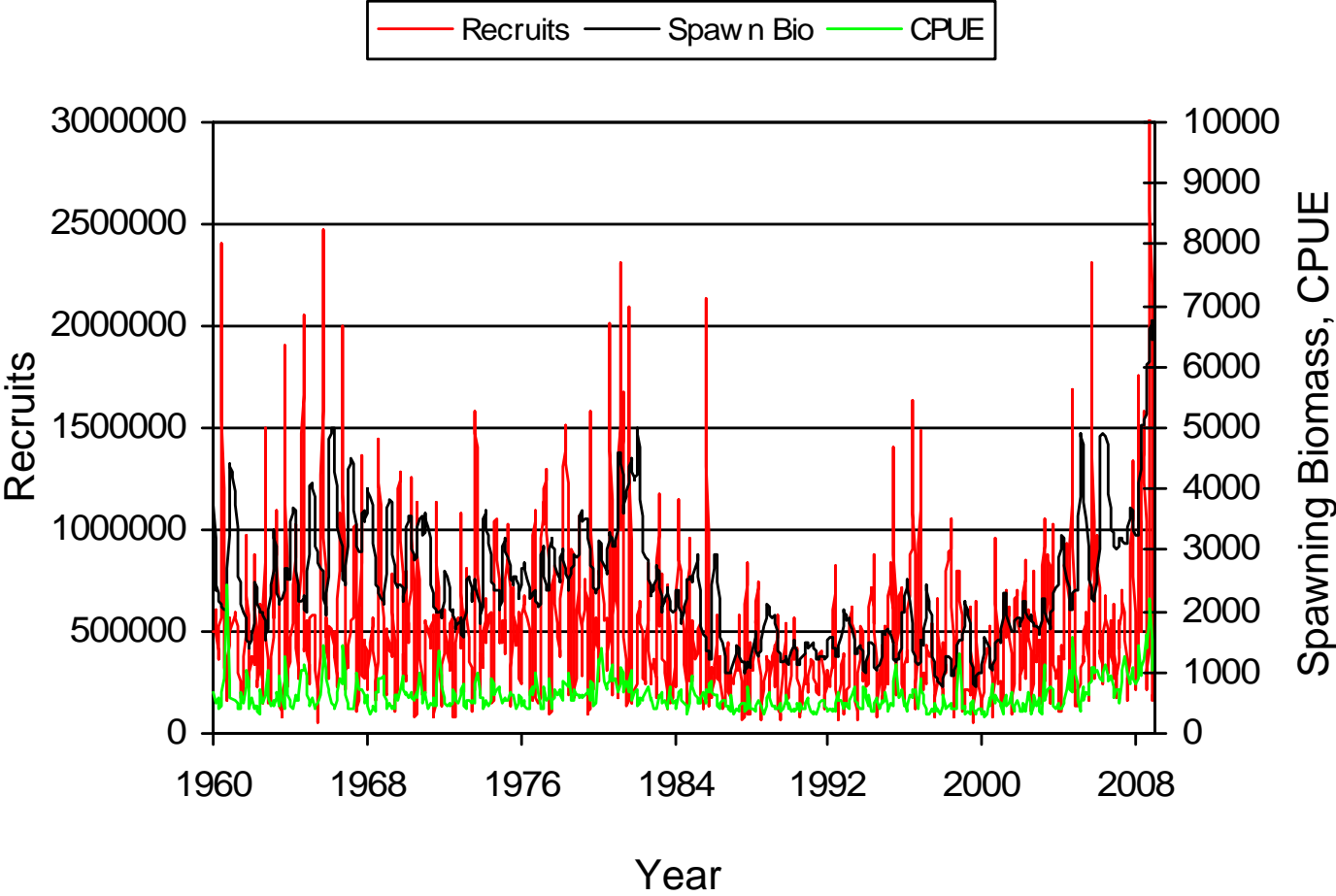


Figure 12. Pink shrimp predicted recruits x1,000, spawning biomass in metric tons, and catch per unit effort in pounds per day fished.

Appendix 1. Internal Review of the 2007 Assessment of Pink Shrimp in the Gulf of Mexico

July 10, 2009

Pink shrimp in the Gulf of Mexico are assessed annually using a virtual population analysis model (Nichols, 1984; Nance, 2008). After decades of relatively stable levels of catch, effort and estimated shrimp abundance, the level of catch declined dramatically beginning in 2006. VPA estimates of pink shrimp abundance estimated using this catch also declined. The decline in catch was expected due to recent shifts in economic conditions of the shrimp fishery. However, the decline in estimated abundance was paradoxical because shrimp catch per unit of effort (CPUE), which can be an indicator of shrimp abundance, had not declined. Consequently, the SEFSC requested an internal review of the shrimp assessment method before it is considered as the basis for evaluation of the status of this stock.

The terms of reference established by the SEFSC were to:

1. Review and characterize the current VPA model configuration and CPUE methodology.
2. Review the capability of the current VPA model to adequately monitor the shrimp populations.
3. Review and evaluate the use of number of parents as relevant recruitment overfishing and overfished parameters.
4. Provide recommendations as to the proper choice of models for assessment of shrimp populations.

The Review committee consisted of:

- Dr. Richard Methot (NMFS Office of Science and Technology; Seattle, WA) (chair)
- Dr. Jon Brodziak (NMFS Pacific Islands Fisheries Science Center; Honolulu, HI)
- Dr. Paul Spencer (NMFS Alaska Fisheries Science Center, Seattle, WA).

The Committee met via conference call with the assessment team three times in late June 2009. The assessment team was extremely cooperative and helpful in providing the committee with documents and model outputs.

TOR 1: Review and characterize the current VPA model configuration and CPUE methodology.

The Gulf of Mexico pink shrimp is assessed using virtual population analysis (VPA) model with monthly time steps. In this case, there are no relative abundance indices to “tune” or scale estimates of shrimp abundance. Instead, the VPA estimate of abundance is initiated using an estimate of the fishing mortality rate (F) on age 15 month shrimp. This terminal F is obtained from the product of monthly fishing effort (E) and an estimate of catchability (q) for age 15 shrimp. The level of effort is calculated as the ratio of catch (C) divided by standardized catch-per-unit-effort (CPUE) within each geographic zone each month, then summed over zones to get E .

The calculated abundance of each monthly cohort is then calculated using VPA which basically sums the catches for that cohort while taking into account the numbers dying from natural mortality. First, the terminal F is used to compute pink shrimp numbers at age in month 15 from the catch at age and M as

$$\text{Eq. 1} \quad N_A(T) = \frac{F_A(T) + M}{F_A(T)} \cdot \frac{C_A(T)}{(1 - e^{-F_A(T) - M})}$$

Where $T = 15$ months.

The VPA process of backcalculating the pink shrimp numbers at age matrix through time for months prior to T employs equation (1) along with the steps of computing $F_{A-1}(T-1)$ as the solution of the equation

$$\text{Eq. 2} \quad \frac{N_A(T)}{C_{A-1}(T-1)} = \frac{(F_{A-1}(T-1) + M) \cdot \exp(-F_{A-1}(T-1) - M)}{F_{A-1}(T-1)(1 - \exp(-F_{A-1}(T-1) - M))}$$

and then using the calculated value of $F_{A-1}(T-1)$ to determine $N_{A-1}(T-1)$ via

$$\text{Eq. 3} \quad N_{A-1}(T-1) = N_A(T) \cdot \exp(F_{A-1}(T-1) + M)$$

The above method was initially calibrated for pink shrimp in 1982 (Nichols, 1984). In this calibration he developed values for natural mortality, M , and the catchability, q , were calculated as follows:

- Regress monthly CPUE for each cohort on time to get estimate of the cohort’s total mortality rate (Z)
- Regress Z on effort to get M from the intercept and q from the slope of the regression.

Although the above approach was successful for brown and white shrimp, it did not provide meaningful values for pink shrimp. Instead, Nichols obtained an estimate of $M = 0.3$ from older mark-recapture studies. He also developed a q value of 3.0, but documentation of his calculations to derive this value are not available.

These values of M and q developed over 25 years ago have been used in each subsequent pink shrimp assessment. Even if these values had been estimated precisely and accurately in 1982, the values could have shifted over time. M is a model parameter that could respond to shifting habitat and ecosystem

conditions and the value of M could be different today than it was in the early 1980s. The value of q is based on a simple linear relationship between effort and fishing mortality. Although there is no direct evidence of a nonlinear relationship between E and F for pink shrimp, such relationships are not uncommon in other fisheries. The SEDAR workshop in 2008 on fishery catchability supports the possibility of changes over time. Further, and perhaps most importantly, the q relationship was obtained in the 1980s when both the level of shrimp fishing effort and the level of catch were higher than in 2006. As the fishery has retracted, there is plenty of potential for shifting patterns in fishing practices and changes in the geographical distribution of fishing effort to have changed the q value.

In addition, the VPA method was developed when shrimp fishing mortality rates were relatively high. When the F is 2-3 times higher than M , more shrimp are dying from fishing than from natural causes and the VPA method is less sensitive to the exact values of M and q . However, as F has declined to now be less than M , the calculation of shrimp abundance is more sensitive to the exact value of M and q .

TOR 2: Review the capability of the current VPA model to adequately monitor the shrimp populations

The Committee concludes that the current VPA model cannot be considered to produce a reliable indicator of current shrimp abundance. There are two principal factors supporting this conclusion.

1. The estimates of M and q are over 25 years old, were not confidently calculated at that time, and have not been updated since then. An evaluation of these values needs to occur before accepting a new assessment and periodic updates of such important factors should occur.
2. Catch has declined substantially beginning in 2006 (Figure 1). CPUE has remained relatively constant (Figure 2), and effort (which is catch/CPUE) has declined. This reduced fishery increases the possibility that the q value today differs from the historical value. Figure 4 shows monthly F at age 15 for the average monthly cohort during the 1990s and for the monthly cohorts alive in 2007. There is little overlap between the historical and current range of monthly effort. The straight line relationship is due to the use of a constant q to calculate F . If the actual relationship between F and effort is curved, then the linear extrapolation to calculate values for 2007 could easily be biased either high or low.

A VPA model possibly could provide an adequate technical basis for monitoring shrimp in the future if its calibration is investigated and updated (also see response to TOR 4). However, other methods identified in TOR 4 may be superior given the low level of F that appears to be occurring today.

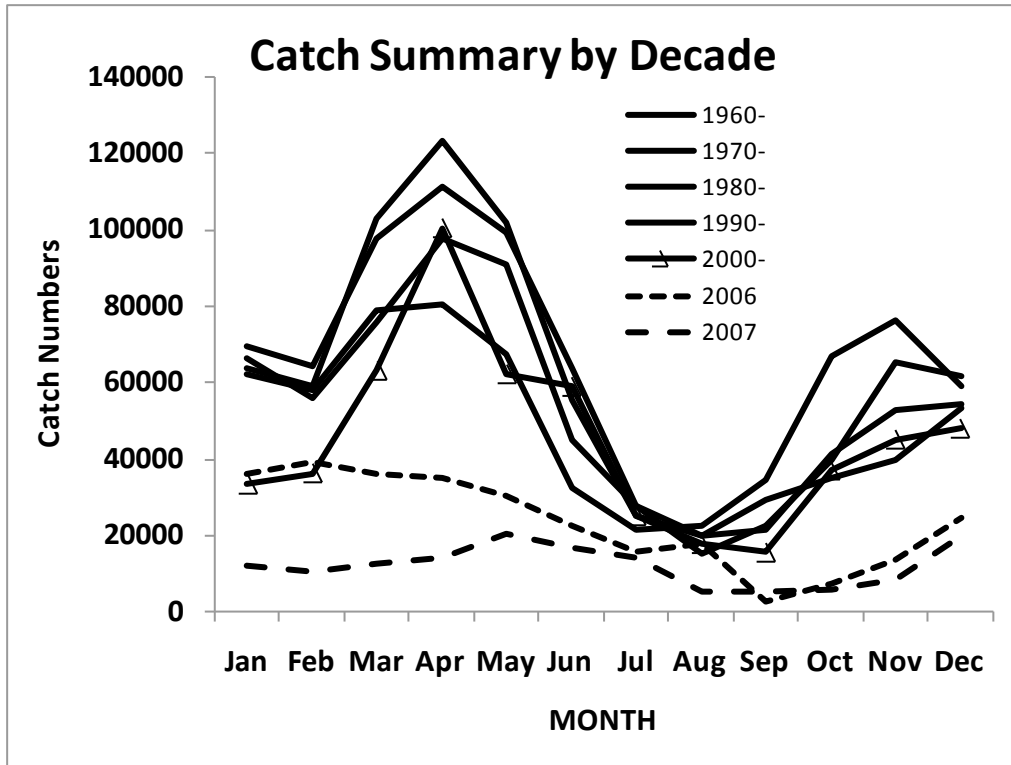


Figure 1 Average catch (in numbers) for four decades beginning in 1960, 2000-2005, and for the individual years 2006 and 2007. The four decadal lines are shown in the same format to emphasize the similarity of their pattern and level.

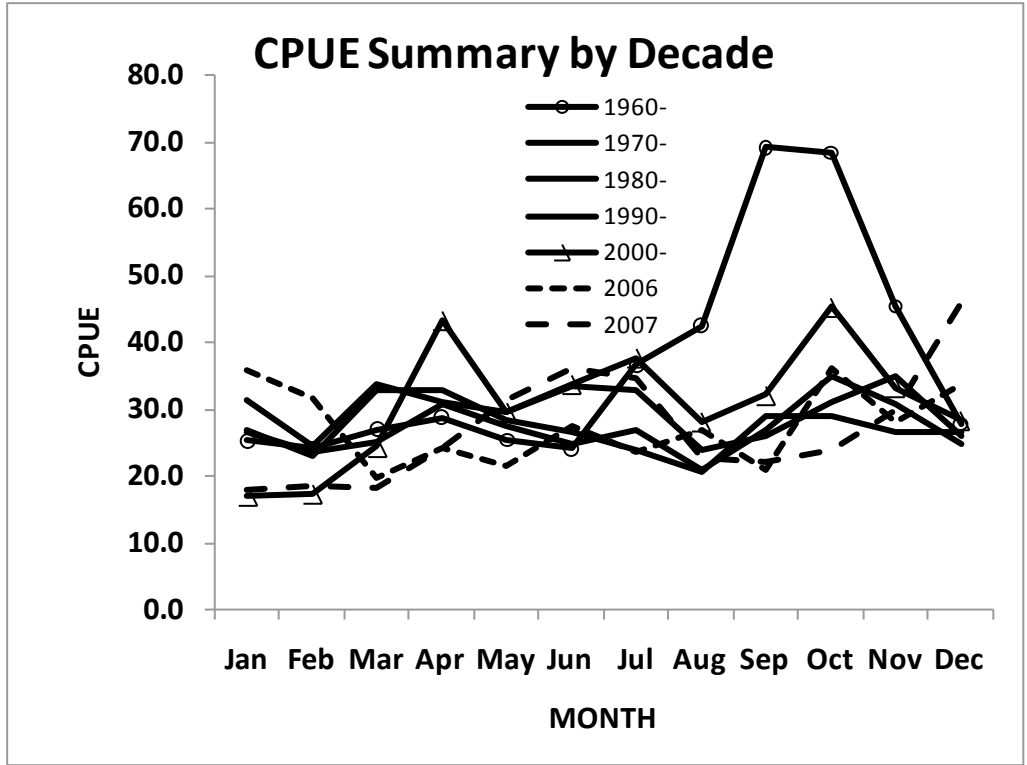


Figure 2 Average catch in numbers per day for each month averaged over four decades beginning with 1960. Since the 1960s, the monthly pattern and level has shown no long-term changes.

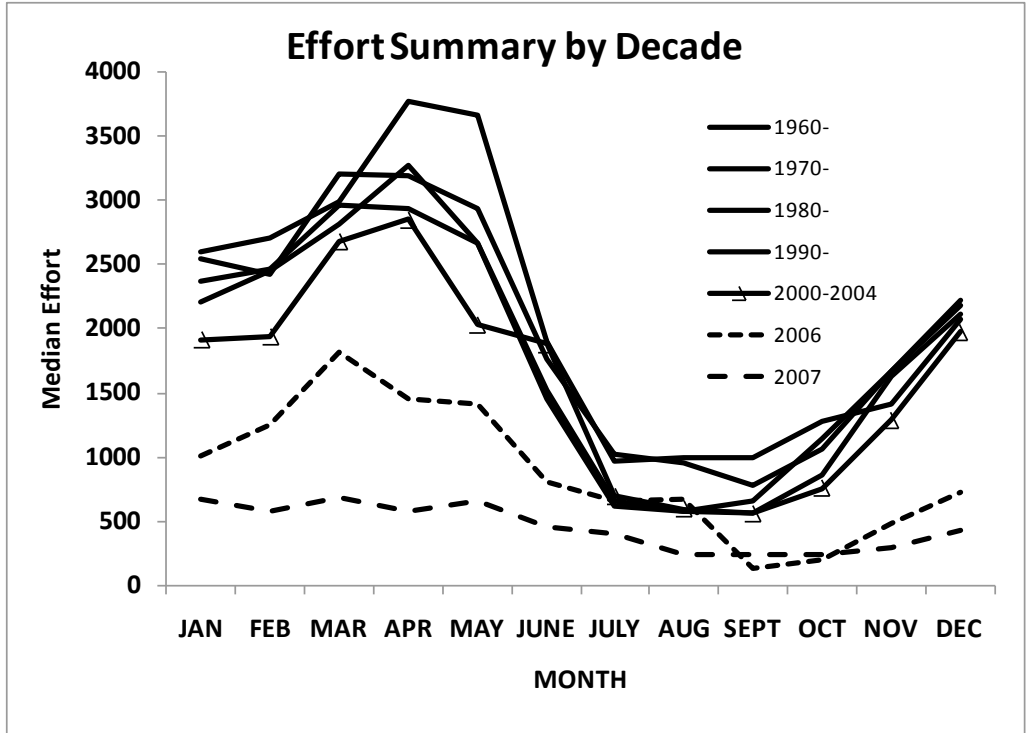


Figure 3 Average effort by month averaged over decades. Effort is calculated within each geographic stratum as catch divided by CPUE, so long-term patterns in effort basically follow the long-term patterns in catch.

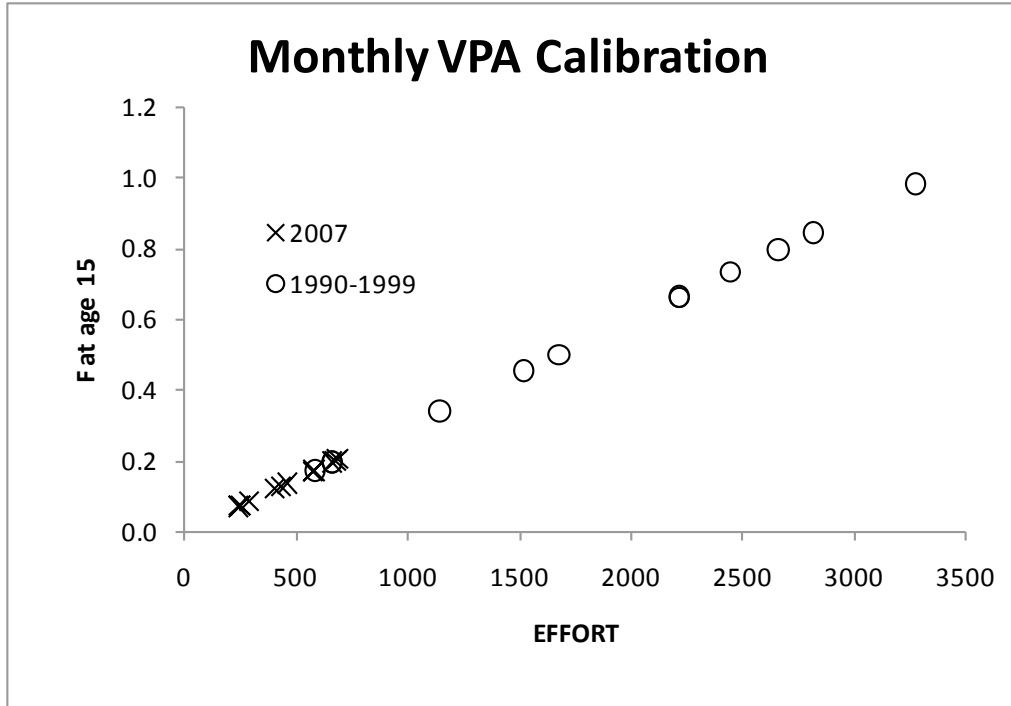


Figure 4 A comparison of the calculated F at age 15 for each month in 2007 and calculated F values for the decade of the 1990s. The straight line relationship is due to fact that F is calculated as proportional to effort. Because effort in 2007 has declined much below historical values, the calculated F values are now extrapolations outside the range in which the relationship was developed. Note that 2 months in 2007 with anomalous F values are not shown here.

TOR 3: Review and evaluate the use of number of parents as relevant recruitment overfishing and overfished parameters.

Given the concerns identified under TOR 2, the committee concludes that it is not presently possible to reach a conclusion regarding the abundance of shrimp relative to overfishing levels. Although the assessment report published in 2008 indicated that parent abundance had declined below the overfished level, we recommend that this conclusion be put on hold until the assessment can be updated to more confidently evaluate current shrimp abundance. The observation that shrimp CPUE has not declined is a provisional indicator that no dramatic decline in shrimp abundance has occurred.

TOR 4: Provide recommendations as to the proper choice of models for assessment of shrimp populations.

The committee's response to this TOR covers two general categories. The first is with regard the calibration of the catchability, q , parameter. The second category covers alternative assessment models that could be used for this assessment.

In recent years, the fishing effort has declined dramatically and is outside of the range of previously observed values, suggesting that the current fishery is in a new era in which the value of q may be different from previous periods. The value of q should be recalibrated periodically to evaluate temporal changes in q as fishing gear and/or fishing locations change over time. The first step could be simply an update of the original Nichols analysis using more recent data. In addition, a mechanistic explanation for why q may have changed in recent years may be obtained from the spatial data on catch and effort. A new analysis could investigate how the recent reductions in effort affected the spatial footprint of the fishery. Relative to the historical fishing grounds, do the areas that are being currently fished represent high density areas, or areas in which the fishing gear may have increased effectiveness? In addition, the unit of effort is 24 hours of fishing, thus may not be very responsive to shrimp boat captains' skill at searching out areas with desirable catch rates. A new study of shrimp fishing effort should explore options for measuring fishing effort in units that are as responsive as feasible to changing levels of fishing mortality.

The current model uses a linear relationship between F and fishing mortality. Some assessment models can accommodate temporal changes in q as non-linear density-dependent process or as a random walk over time. The recent SEDAR report on fishery catchability provides a good overview of the possibilities.

One alternative to using the un-tuned VPA would be to formulate the pink shrimp assessment as a tuned VPA as in the NOAA Fisheries Toolbox VPA module (see <http://nft.nefsc.noaa.gov/VPA.html>). In this case, the tuning indices would be derived from the time series of monthly commercial catch per unit effort by monthly cohort, i.e., $CPUE_A(t)$ for $t=1,2,\dots, T$. The natural mortality value, maturity ogive, and weight at age data could remain the same. The input catch at age data would also remain the same. The only difference would be the inclusion of CPUE tuning indices for monthly cohorts. This approach would provide a straightforward bridge between the current assessment and a more flexible VPA model that can be tuned to commercial CPUE series and also be configured to handle split CPUE tuning series with differing catchabilities if needed.

Another alternative assessment approach would be use a dynamic production model such as ASPIC which is part of the NOAA Fisheries Toolbox (see <http://nft.nefsc.noaa.gov/ASPIC.html>). In this approach, biomass-based relative abundance indices for pink shrimp could be developed for the exploitable population from the age-specific CPUE time series. This would require the development of an input catch biomass series as well. This is can be a straightforward modeling approach and ASPIC has been used in the assessment of Northern shrimp in the Gulf of Maine (see <http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0716/a.pdf>) and could readily be adapted to the Gulf of Mexico pink shrimp assessment. If an ASPIC formulation had numerical convergence problems

due to flat CPUE indices or a lack of information on population biomass scaling, it may also be useful to consider a Bayesian production model formulation with priors to inform the likely scale of catchability, intrinsic growth rate, and other parameters.

Another alternative would be to apply a Collie-Sissenwine analysis (CSA, see <http://nft.nefsc.noaa.gov/CSA.html>) to estimate numerical abundance of recruits and pre-recruited pink shrimp. This would require the development of relative abundance indices of recruits and pre-recruits (shrimp that would be recruited to the fishery in the next time period). Such indices could be based on the commercial CPUE time series for monthly cohorts. This approach is used to assess the Northern shrimp stock in the Gulf of Maine and accounts for the variability in cohort strength and growth through time.

Integrated assessment models written in ADMB, such as Stock Synthesis (see <http://nft.nefsc.noaa.gov/SS3.html>), could be configured for application to Gulf of Mexico pink shrimp. Such models can use the available information on population dynamics, catch, size composition, environmental forcing and CPUE trends. They can operate on monthly time steps and can incorporate features such as differential growth between males and females and between spring and autumn. The current pink shrimp assessment procedure which models male and female growth in order to derive catch-at-monthly age from the available data on shrimp counts per weight category is quite comparable to the internal procedures used in models like Stock Synthesis.

Documents Provided to Review Team

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Nance, J. M. 2008. Review of the status and health of the shrimp stocks for 2007. Report to the Gulf of Mexico Fishery Management Council, August 2008, 6 pp.

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Output tables from VPA assessment conducted in 2008.