Review of the Status and Health of the Shrimp Stocks for 2008

by

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Farfantepenaeus aztecus (brown shrimp), Farfantepenaeus duorarum (pink shrimp), and Litopenaeus setiferus (white shrimp), comprising the bulk of the Gulf of Mexico shrimp fisheries, are essentially annual crops. Annual harvests vary considerably due to fluctuations in environmental conditions experienced by larvae and juveniles. Maximum sustainable yield (MSY) estimates have been reported, based on analytical models of catch and effort. Such MSY values were near observed maximum catches. However, due to the environmental fluctuations seen to date, catches above MSY, even if persisting over several years, should not by themselves be taken as evidence of overfishing.

The findings by Nance et al. (1989), Klima et al. (1990), and Nance (1993), agree that the best way to define overfishing for the three major shrimp species in the Gulf of Mexico is in terms of spawning population size. Empirical comparisons of over 40 years of landings data with the indices of spawning population size determined by VPA stock assessment were used by Nance et al. (1989), Klima et al. (1990), and Nance (1993) to define minimum levels of spawning stock believed to be compatible with maximum productivity under current environmental conditions. These values are the most meaningful proxy for MSY. Maintaining parent stock numbers above these levels should be sufficient to prevent overfishing on each of the shrimp stocks.

Parent stock is defined for brown shrimp as the number of age 7+ (months) shrimp during the November through February period, with a level of 125 million shrimp set as the lower limit. White shrimp parent stock is defined as the number of age 7+ (months) shrimp during the May through August period, with a level of 330 million shrimp set as the lower limit. Pink shrimp parent stock is defined as the number of 5+ (months) shrimp during the July through June period, with a level of 100 million shrimp set as the lower limit.

Last year the VPA analysis indicated that the parent index values for two of the three major penaeid shrimp species were above the overfishing index level. Brown and white shrimp parent levels were well above the overfishing index, while pink shrimp parent stock estimates were below the index level (Figure 1).

After decades of relatively stable levels of catch, effort and estimated shrimp abundance, the level of pink shrimp catch declined dramatically beginning in 2006. VPA estimates of pink shrimp abundance estimated using this catch data also declined. The decline in catch was expected due to recent shifts in economic conditions of the shrimp fishery. In 2007 the VPA shrimp assessment results showed that pink shrimp parent stocks dipped below the overfishing threshold limit, which in turn triggered an overfishing status determination in the Status of the Stocks Report to Congress released in May 2009.

However, the decline in estimated pink shrimp abundance from the VPA was paradoxical because shrimp catch per unit of effort (CPUE), which can be an indicator of shrimp abundance, had not declined, but continued to remain above average. Consequently, the SEFSC requested an internal review of the shrimp assessment method before it was considered as the basis for evaluation of the status of this stock. The review panel 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), and Dr. Paul Spencer (NMFS Alaska Fisheries Science Center, Seattle, WA).

Several concerns regarding the modeling input variables were noted during the review and the committee concluded that it was not possible to reach a definitive conclusion regarding the abundance of pink shrimp relative to overfishing levels using the present modeling approach (Review Panel Report attached as Appendix I).

Based on this review panel conclusion the current assessment model was not run for pink shrimp this year. We are currently investigating a new assessment approach to determine the pink shrimp stock status and will have it accomplished as soon as possible.

While it is not possible to determine the current status of the pink shrimp stocks this year, the VPA analysis was used to investigate the overfishing index limits for brown and white shrimp. Analysis indicated that the parent numbers for these two penaeid shrimp species were above the overfishing index (Figures 2 and 3). While the VPA model seems to function well for these two shrimp stocks, we are also investigating updating the current input variables and migrating the assessment analysis to the same modeling approach we will use for the pink shrimp assessment.

Besides the three major penaeid shrimp species, royal red shrimp (Hymenopenaeus robustus) is the only other commercial shrimp species in the Gulf of Mexico Shrimp Fishery Management Plan (FMP). Overfishing was defined for this species as a fishing level greater than optimal yield (OY) as defined in the FMP. OY was set at MSY (maximum sustainable yield), which was estimated to be 392,000 pounds of tails over 1,290 days fished. During 2008, a total of 138,116 pounds of royal red shrimp (tail weight) were caught in the Gulf of Mexico. This amount is under the overfishing index level set for this shrimp species (Figure 4).

Literature Cited

Klima, E., J. Nance, E. Martinez, and T. Leary. 1990. Workshop on the definition of shrimp recruitment overfishing. NOAA Technical Memorandum, NMFS-SEFC-264, 18 p.

Nance, J. 1993. Gulf of Mexico shrimp fishery recruitment overfishing definition workshop 2. NOAA Technical Memorandum, NMFS-SEFSC-323, 12 p.

Nance, J., E. Klima, and T. Czapla. 1989. Gulf of Mexico Shrimp Stock Assessment Workshop. NOAA Technical Memorandum, NMFS-SEFC-239, 43 p.

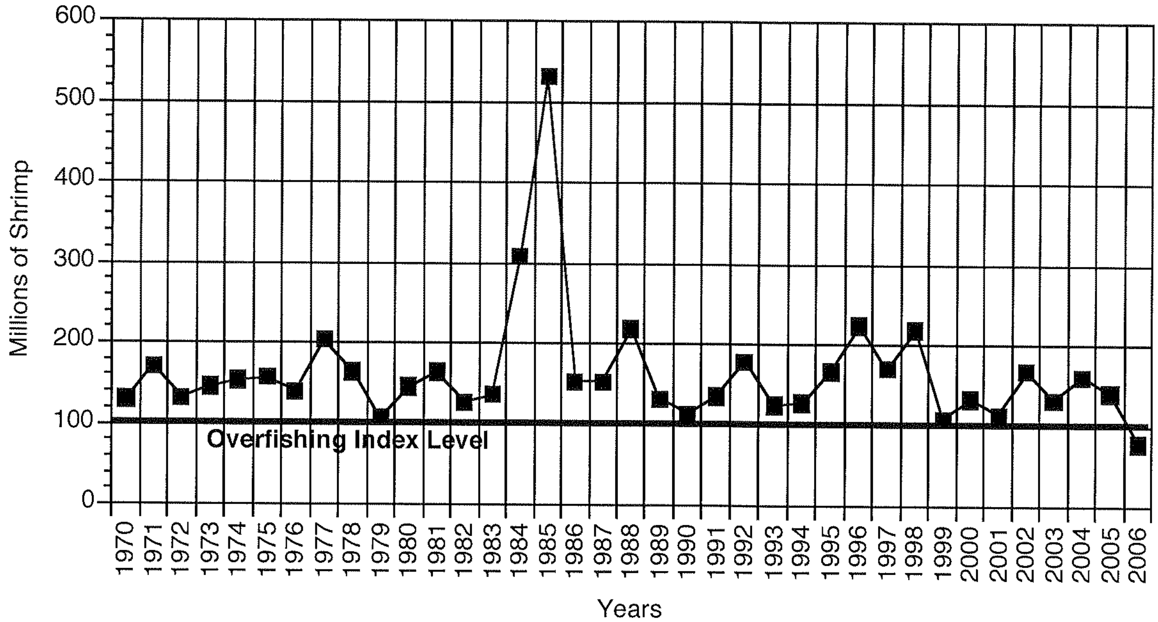

Figure 1. Pink shrimp parent stock levels over the past 37 years.

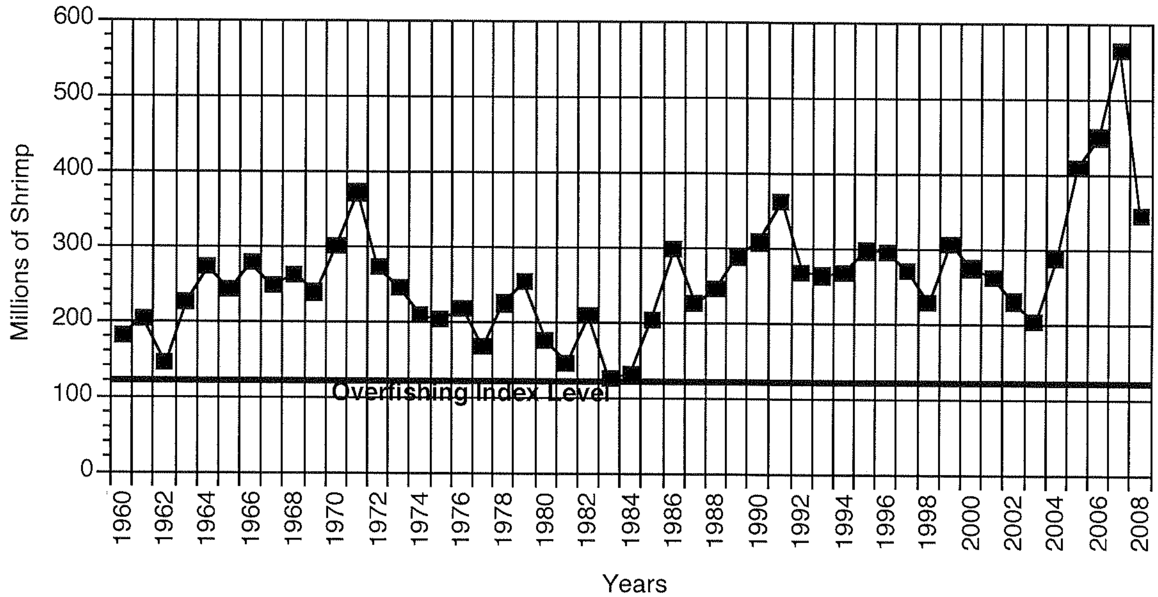

Figure 2. Brown shrimp parent stock levels over the past 49 years.

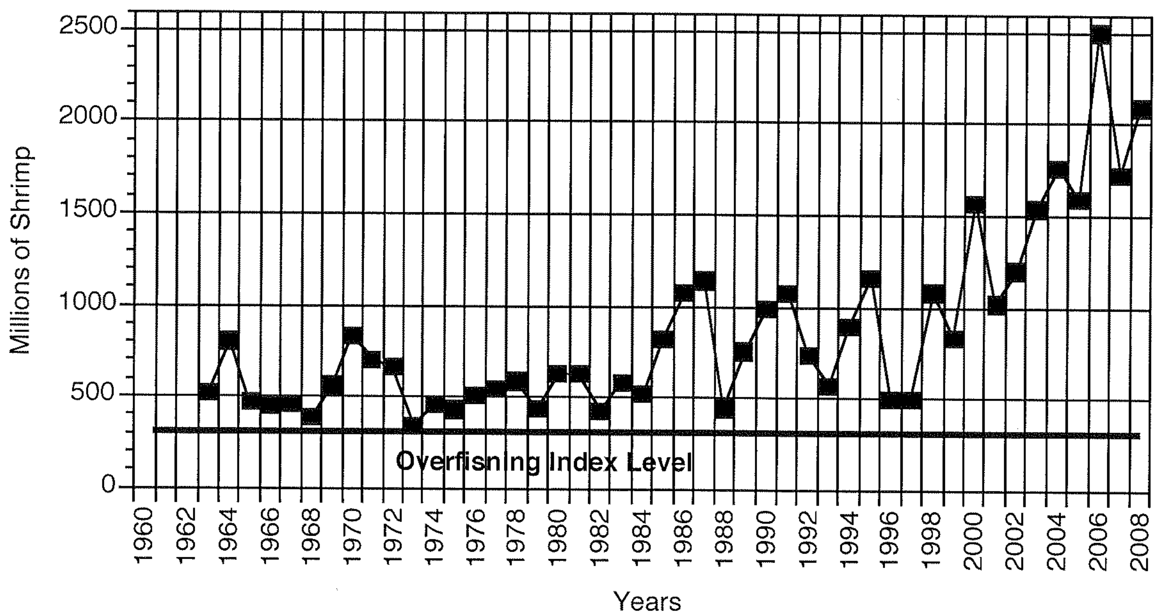

Figure 3. White shrimp parent stock levels over the past 46 years.

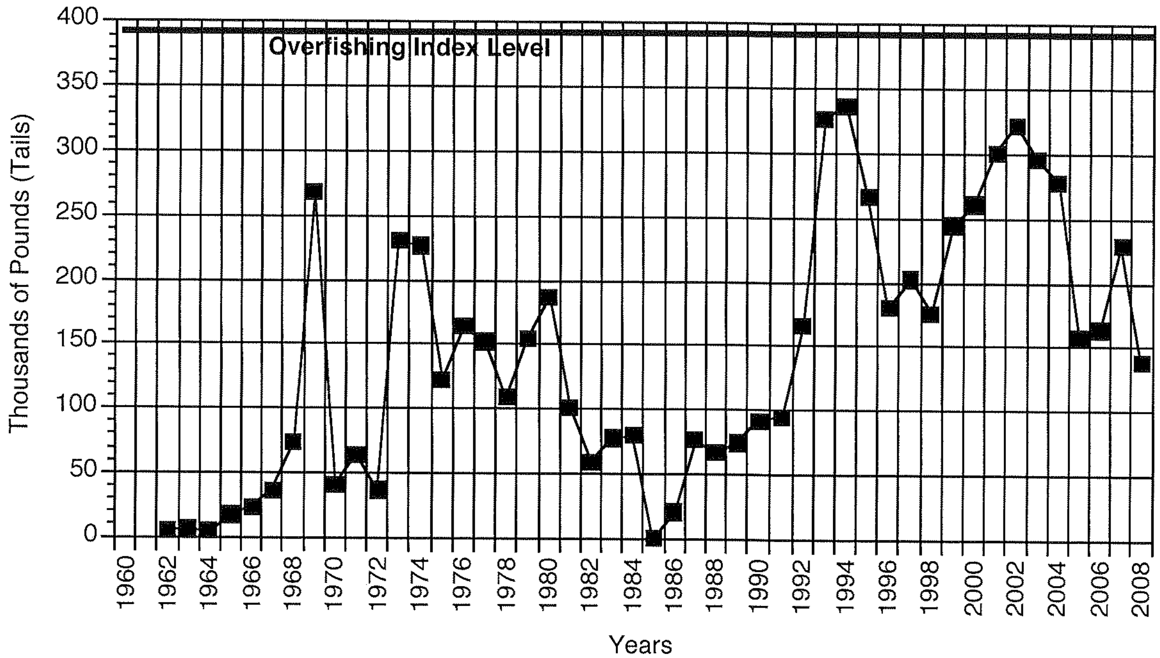

Figure 4. Royal red shrimp landing levels over the past 47 years.

Appendix I

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

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

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

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

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

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

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, using the following steps:

- 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 as 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.

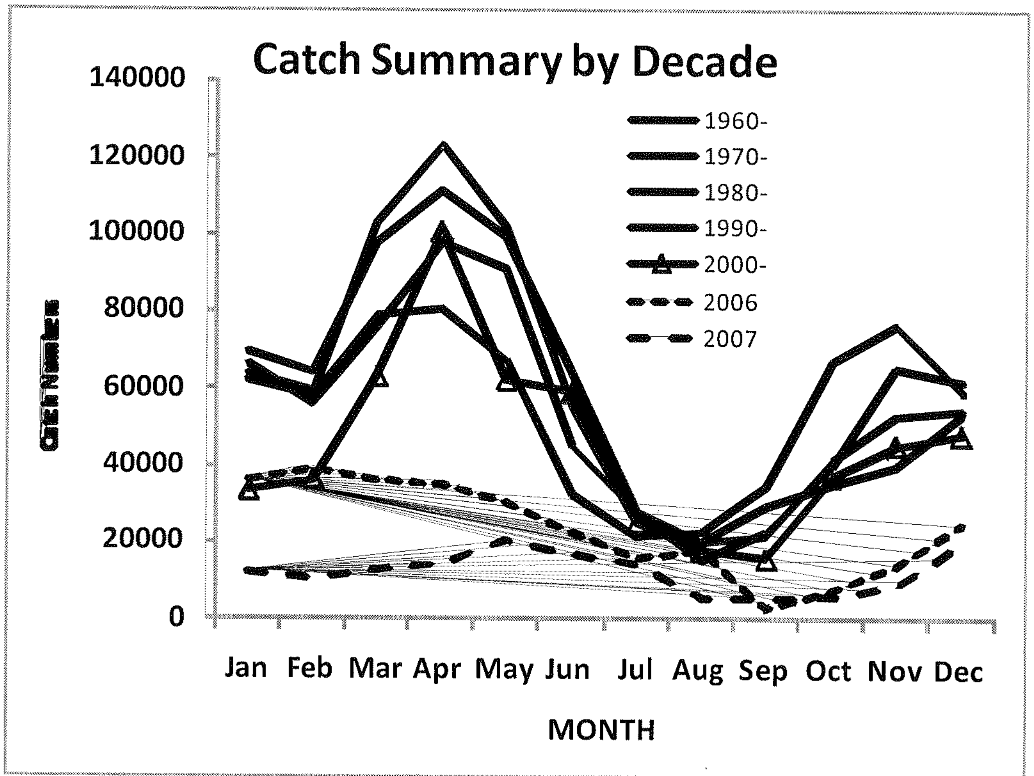

Figure 1 Average catch (in numbers) for four decades beginning in 1960, 2000-2005, and for the individual years 2006 and 2007. The four decadal lines are shown in the same format to emphasis the similarity of their pattern and level.

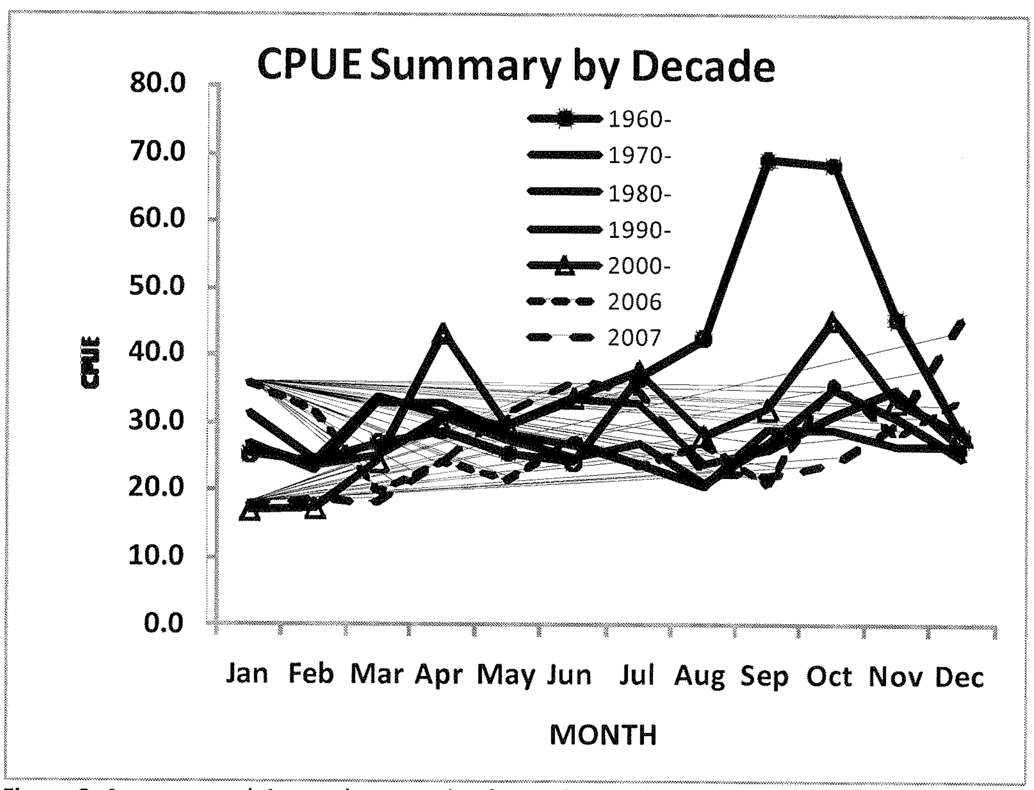

Figure 2 Average catch in numbers per day for each month averaged over four decades beginning with 1960. Since the 1960s, the monthly pattern and level has shown no long-term changes.

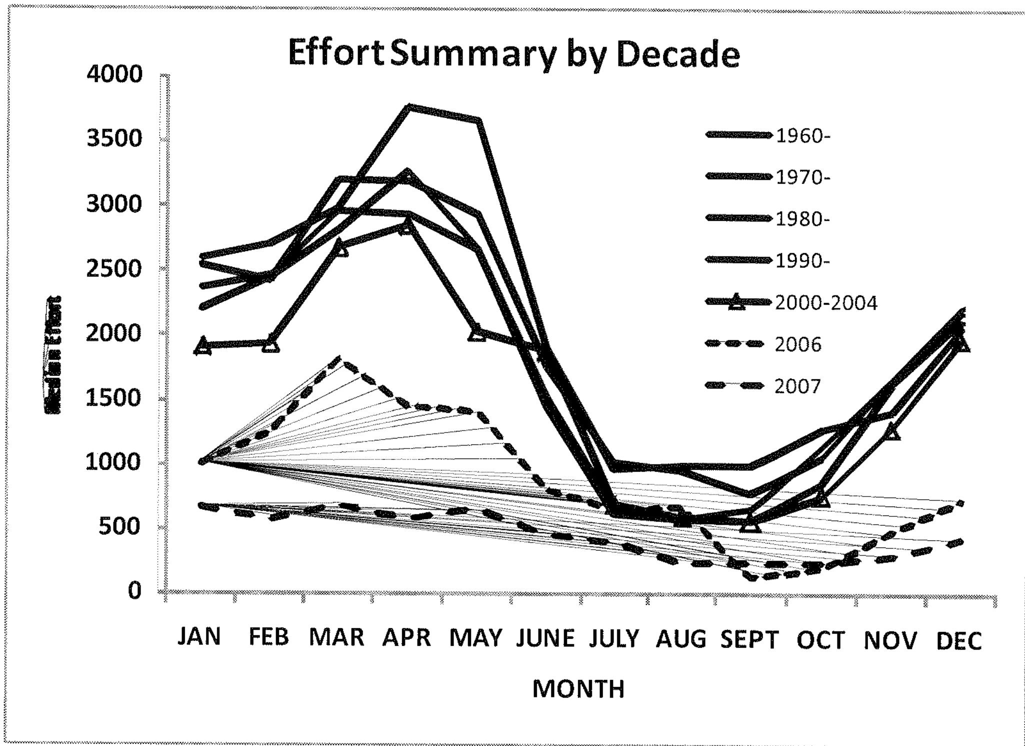

Figure 3 Average effort by month averaged over decades. Effort is calculated within each geographic stratum as catch divided by CPUE, so long-term patterns in effort basically follow the long-term patterns in catch.

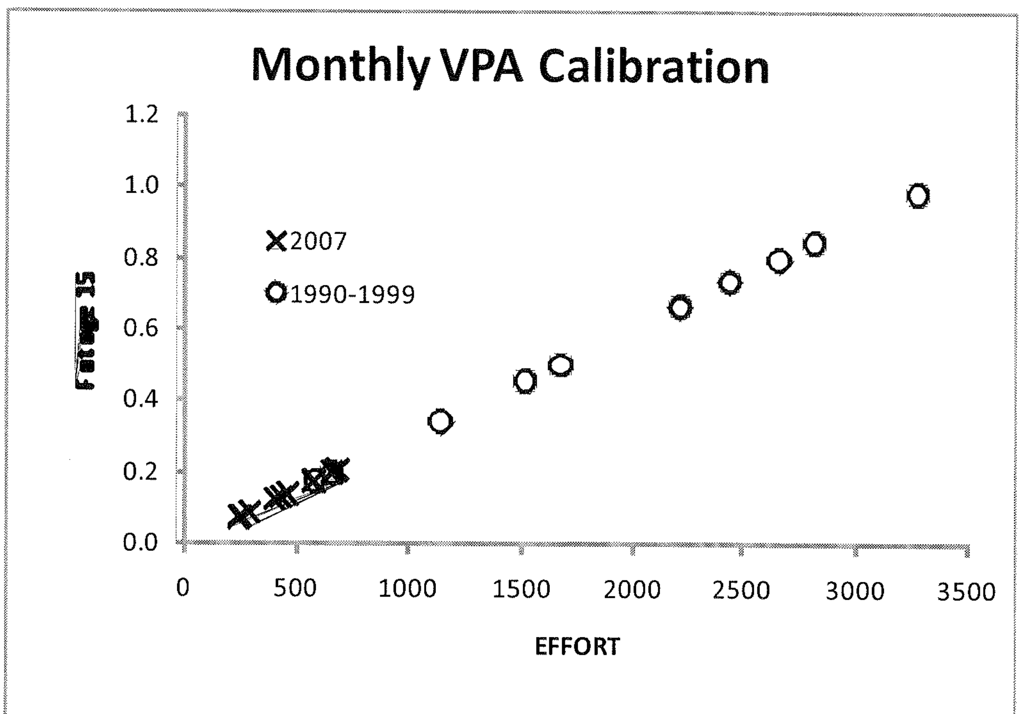

Figure 4 A comparison of the calculated F at age 15 for each month in 2007 and calculated F values for the decade of the 1990s. The straight line relationship is due to fact that F is calculated as proportional to effort. Because effort in 2007 has declined much below historical values, the calculated 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.

<u>TOR 3</u>: 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,..., 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 con 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. 1992. Estimation of effort for the Gulf of Mexico shrimp fishery. NOAA Technical Memorandum, NMFS-SEFSC-300, 12 pp.

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Output tables from VPA assessment conducted in 2008.