Stock Assessment of White Shrimp (*Litopenaeus setiferus*) in the U.S. Gulf of Mexico for 2011

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1. ABSTRACT

This assessment examined the US Gulf of Mexico white shrimp (*Litopenaeus setiferus*) population behavior when parameterized with over 25 years of commercial white shrimp data from 1984 - 2011. In the full time series model run, fits to the CPUE estimates, size selectivity, spawning biomass, and numbers of recruits were generated. In addition, the incorporation of fishery independent surveys (SEAMAP and Louisiana State Shrimp Surveys) of shrimp abundance into the model greatly improves the precision (i.e., tuning) of this and future assessments.

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 fishing season were 664,782 metric tons and 14.2 billion individuals respectively. Fishing mortality has been decreasing in recent years, with annual monthly weighted apical F of 0.22 being estimated for the 2011 fishing season. Using these results, there is no evidence that the Gulf of Mexico white shrimp 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 population (Hart and Nance 2010). Upon reviewing the VPA assessment, a NMFS stock assessment panel concluded that the pink shrimp 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 pink shrimp 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, and Louisiana Inshore Shrimp Survey data were also included in this new model to tune recruitment parameters. Due to the concerns and problems with the pink shrimp VPA it was decided that NMFS should also migrate the white shrimp assessments into the SS-3 framework. Therefore, SS-3 is now being used to assess the GOM white shrimp stocks.

This report describes the stock assessment of white shrimp (*Litopenaeus setiferus*) 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 white shrimp. 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, incorporating selectivity with seasonal changes (May-July) using an environmental offset approach, and estimated steepness and R_0 values.

3. METHODS

3.1. Model Overview

To model the population dynamics of white shrimp I used a generalized stock assessment model, Stock Synthesis (SS-3) developed by Richard Methot (Methot 2009). The Stock Synthesis model presented in this report was parameterized with such complexities as static mortality rates, seasonal changes in selectivity, recruitment deviations, and estimated steepness in the Beverton-Holt spawner-recruit function (Table 3.1.1).

3.2. Data Sources

The model was parameterized with data from 1984 through 2011. The model structure included 1 fleet:

1) Commercial in- and off- shore shrimp catch statistics (statistical zones 7-21)

and 3 indices of abundance:

1. SEAMAP Summer Groundfish Trawls (Fisheries-independent; 1987-2011)
2. SEAMAP Fall Groundfish Trawls (Fisheries-independent; 1987-2011)
3. Louisiana Monthly Shrimp Trawl Surveys (Fisheries-independent; Western Subset of surveys, 1984-2011)

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 *L. setiferus* fishing grounds are located primarily within sub-areas 7-21. 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 white shrimp commercial catch data from statistical zones 7-21 from January 1984 through December 2011 including: directed fishing effort by year and month, i.e., effort for those trips where >90 percent of the catch were white shrimp, used to calculate monthly CPUE; total catch by size, i.e., size composition data consisting of count of numbers of shrimp per pound. To calculate CPUE statistics the methods outlined in Nance et al. (2008) were used. Beginning with pilot studies in 1999, an electronic logbook program (ELB) was initiated to augment shrimp fishing effort measurements. Gallaway et al. (2003a, 2003b) provides an in-depth description of this ELB data collection program and data collection procedures. These ELB data have been used to supplement the effort and location data collected by NMFS port agents and state trip tickets since 2006.

Total catch in pounds of shrimp tails by month from January 1984 through December 2011 was a primary input in each model. 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, was recorded at a finer scale, thus allowing us to partition this size category into four additional count categories, therefore having finer resolution for the smaller sized shrimp in the catch. This resulted in a total of 11 count categories for the data collected from 1984 to present; <15, 15-20, 21-25, 26-30, 31-40, 41-50, 51-67, 68-80, 81-100,101-115, and >115 (Hart and Nance 2010). These data are entered into the model as monthly catch in pounds in each of the eleven size bins for the years 1984-2011

3.2.2. Growth Curve and other Population Level Rates - Growth parameters k and linf derived and reported by Klima (1964, 1974) were used as initial parameter values. Data inputs included a summer and fall growth curve; natural mortality rate (0.27) per month as previously used in the historical VPA) (Nichols 1984). Conversion factors to go from total length to the poundage breaks between the catch count categories presented by Brunenmeister (1980) were entered as parameters. After several initial model runs it was decided to use the fall growth curve for the entire year as it had the largest population spread of the two seasonal curves.

3.2.3. Size Selectivity - A dome shaped (double normal) selectivity pattern with 4 estimated parameters was used in the model. This resulting pattern provided a good fit to the data as will be shown in the results. In addition, months were modeled as years (336 “years”).

3.2.4. Catchability Q – Catchability was fixed during the early years of the time series and then set as a random walk from 2004-2011.

3.2.5. Louisiana Monthly Shrimp Survey Data – Shrimp data collected by the State of Louisiana from 1984–2011 were included in the models. These data were collected and provided by staff of the Louisiana Department of Wildlife and Fisheries (LDWF) and included size composition and indexes of abundance. The methodology of the data collection used by the LDWF is included in Appendix 1.

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. These SEAMAP sampling data inputs were collected from statistical zones 7-21. Sampling index data using the delta log normal index from 1987-2011 were survey model inputs. Size compositions for white shrimp collected and measured in 1987-2011 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 the commercial fishing fleet selectivity I used a double normal setup and developed two seasonal selectivity curves; one curve for August-April, and one for the months of May–July. An overview of the model setup is presented in table 3.1.1. Natural mortality was fixed at 0.27 per month (Nichols 1984) for all shrimp ages in the model. I used the hybrid method of F approximation (Methot 2009). For a more detailed technical description of fishery selectivity, natural mortality M, and fishing mortality F settings used in Stock Synthesis, consult Methot and Wetzel (2012).

3.3.2. Time-Varying Parameters

I developed two selectivity curves, using an environmental link setup for selectivity. This allowed for potentially higher selectivity for the large shrimp which are present during the spring fishing season. In addition, R_0 (unfished recruitment) was set as an estimated parameter. Recruitment was also modeled with monthly deviations superimposed on a 12 month cycle.

3.3.3. Parameter Estimation

Stock Synthesis requires the model to be initialized with approximations for certain parameters which are then estimated by the model in preset phases. These initial approximations scale the parameters to biologically reasonable values, and facilitate the evaluation of parameters, e.g., mortality, recruitment deviations, and selectivity deviations, estimated in subsequent phases.

4. RESULTS

4.1. Parameter Estimates, Model Setups, and Model Fits

The model setup and overview is presented in table 3.1.1

4.2. CPUE

Catch rate fluctuations both within and between years were revealed, with a close fit of expected to observed catch rates. Figures 4.2.1 illustrates the fit to the catch rates for this model with the random walk Q setup beginning in 2004.

The increase in the commercial fishery CPUE observed during this time period is also supported by the increasing trend in CPUE measured in the fishery independent SEAMAP and Louisiana survey data. Model fit to the Louisiana survey data is shown in Figure 4.2.2.

4.3. Generalized Size Comps

The model fit to the size composition of the catch for the commercial fishing fleet is shown in figure 4.3.1. A seasonal pattern in the sizes of shrimp catch is evident in the residual plots of the commercial fleet (Figure 4.3.2). Fits to the size composition for the Louisiana data are shown in figure 4.3.3 and 4.3.4.

4.4. Fishery Selectivity for the Commercial Fleet and Louisiana Surveys

Two selectivity curves were developed for the commercial fishery. These curves were fit to the seasonal harvest of large shrimp which are present in the spring fishery. The Stock Synthesis model results illustrate the fishery selectivity for the months of August-April and May-July (Figure 4.4.1). Size selectivity fits for the Louisiana survey are shown in figure 4.4.2.

4.5. SEAMAP CPUE, Size Composition, and Selectivity

The use of these fishery independent data has provided added information on some of the trends we see in the shrimp fishery, thus allowing me to better tune the models recruitment parameters. The summer and fall SEAMAP cruises reveal a recent increase in CPUE, similar to the commercial fishery (Figures 4.5.1). Figures 4.5.2, 4.5.3, and 4.5.4 show the good model fit to the size composition data for 1987-2011 for summer and fall surveys. Selectivity fits are shown for summer and fall SEAMAP data in figure 4.4.2.

4.6. Fishing Mortality

Stock Synthesis outputs F values by age and month, e.g., for 2011 the number of F values is 12 months x 24 ages = 288 F values. These rates were discussed at length during the workshop. To manage this large number of Fs per year, the consensus of the working group was to calculate the F rates in the following manner:

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

Equation 1 resulted in the calculation of weighted average monthly F values. To manage for overfishing, the fishery needs an index. Therefore, I propose using the annual monthly weighted apical F-value by year across all ages in the fishery depicted in figure 4.6.1. Fishing mortality has shown a decrease in recent years of the time period and are currently at an all-time low over the time series modeled.

4.7. Steepness, Natural Mortality, Spawning Biomass, and Recruitment

The model was set to estimate steepness for the spawner-recruit curve, with a steepness value of 0.84 estimated for the 2011 fishing season. Spawning biomass shows an increase in recent years (Figure 4.7.1). Spawning biomass for the 2011 season was equal to 664.7 metric tons. Recruitment also showed an increasing trend in recent years (Figure 4.7.2). The number of recruits for 2011 equaled 14.2 billion individuals. While it appears that the number of recruits has declined from 2010 to 2011 this may not be an actual reduction in recruits. This lower number which is seen between the last two years is partially a function of the method used to sum the monthly recruits into an annual number, in concert with 2011 being the terminal year in the model.

5. CONCLUSIONS

The Stock Synthesis model developed provides outputs for new overfished and overfishing definitions for the Gulf of Mexico white shrimp fishery. The model outputs reveal an increasing spawning biomass and recruitment in recent years, and a decreasing trend in fishing mortality (F) during the later portion of the time series. This assessment also provides evidence that the Gulf of Mexico white shrimp stocks are not overfished or undergoing overfishing.

6. REFERENCES

Brunenmeister, S.L. 1980. 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.

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 pp.

Klima, E. F. 1964. Mark-recapture experiments with brown and white shrimp in the northern Gulf of Mexico. Proceedings of the Gulf Caribbean Fisheries Institute. 17th Annual Session. p. 52-64.

Klima, E. F. 1974. A white shrimp mark-recapture study. Transactions of the American Fisheries Society 103(1):107-113.

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.

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 3.1.1. 2012 White shrimp Stock Synthesis stock assessment model configuration and parameter overview.

Model Number	Selectivity Setup	Q Setup	Steepness	R0	Recruitment Deviations	Mortality Setup	Control File Name
3	Environmental Link with Seasonal Changes (May-July)	Random Walk	Estimated	Estimated	Monthly and 12 Month Cycles	Constant M	White_2011_LA_R1_Steep_Cnst-M_recdev_RndQ-tun-3.ctl

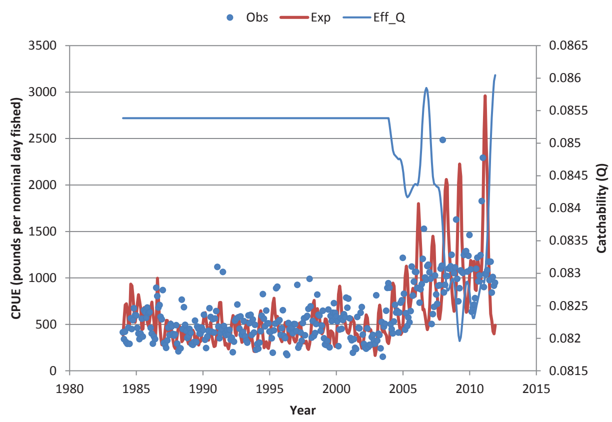

Figure 4.2.1. White shrimp CPUE and Q fits.

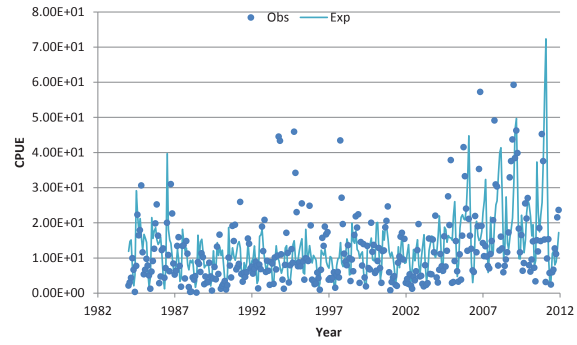

Figure 4.2.2. Louisiana survey CPUE fits.

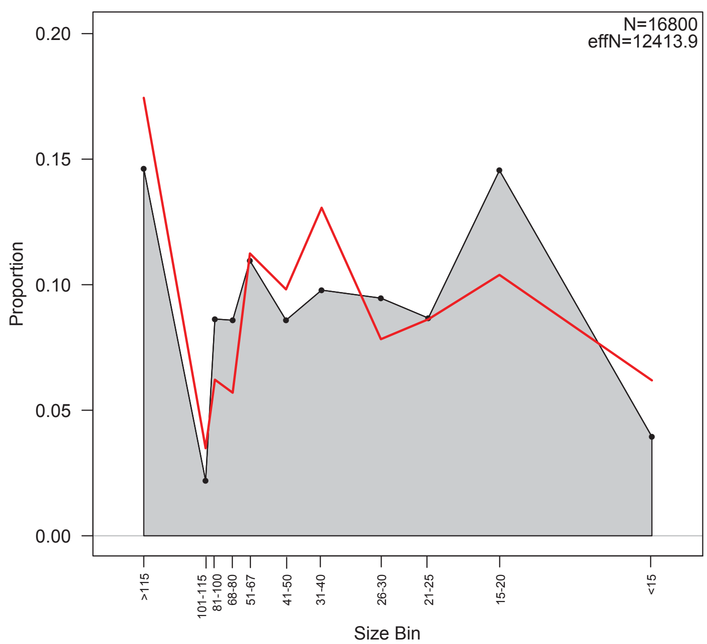

Figure 4.3.1. Size composition fits for the commercial white shrimp fishery, 1984-2011.

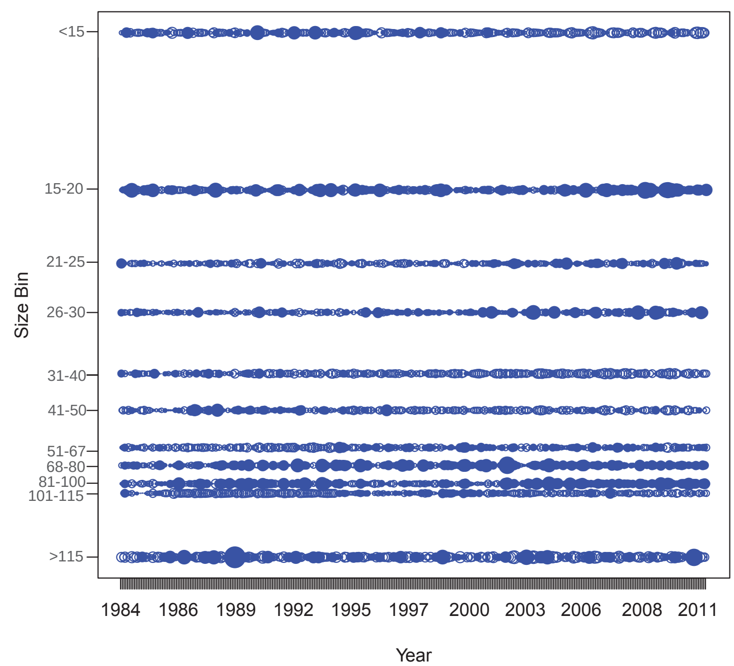

Figure 4.3.2. Residual fits for the commercial white shrimp fishery, 1984-2011.

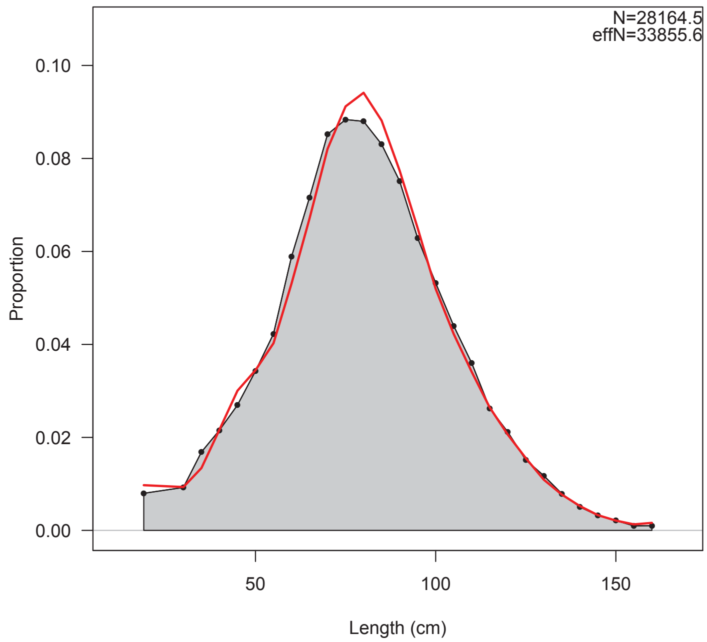

Figure 4.3.3. Size composition fits for the Louisiana West survey, 1984-2011.

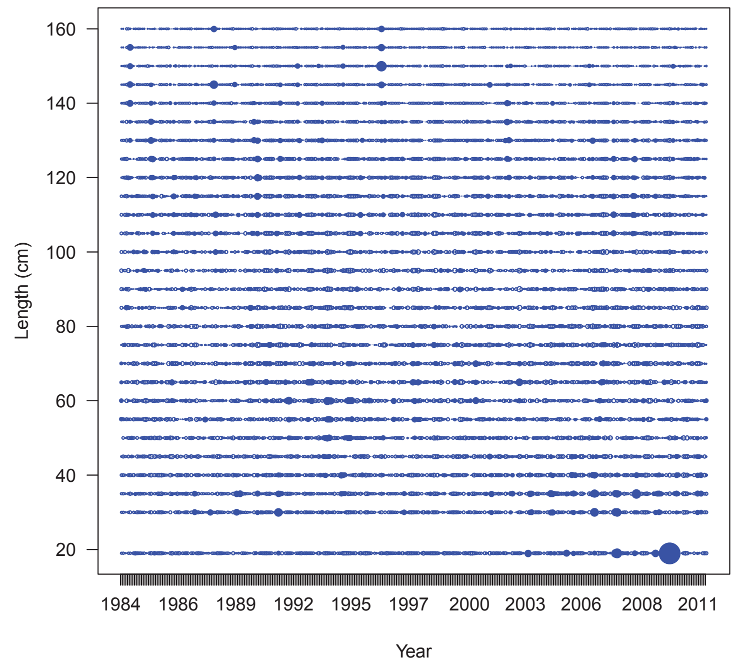

Figure 4.3.4. Residual fits for the Louisiana West survey, 1984-2011.

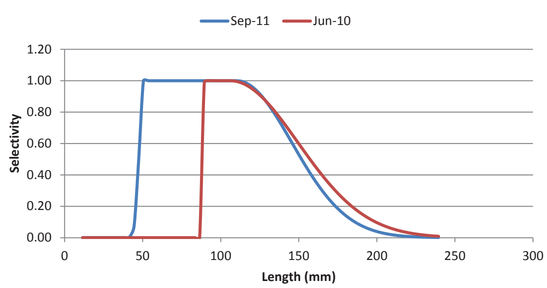

Figure 4.4.1. White shrimp commercial fishery size selectivity.

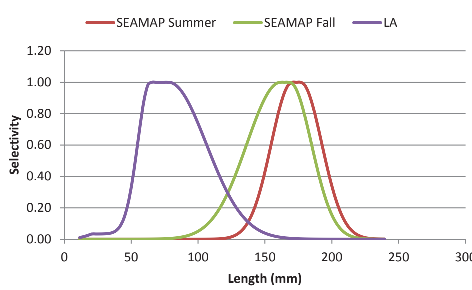

Figure 4.4.2. White shrimp Louisiana and Summer and Fall SEAMAP survey's size selectivity.

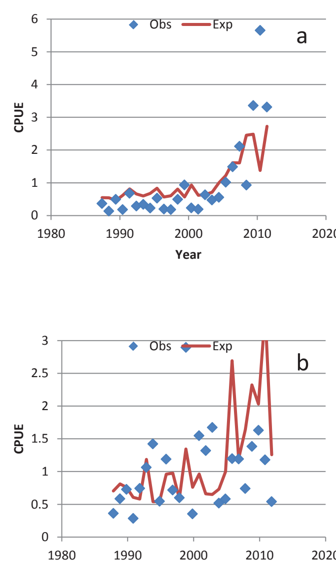

Figure 4.5.1. White shrimp SEAMAP survey CPUE. Panel a is Summer and panel b is Fall CPUE fits.

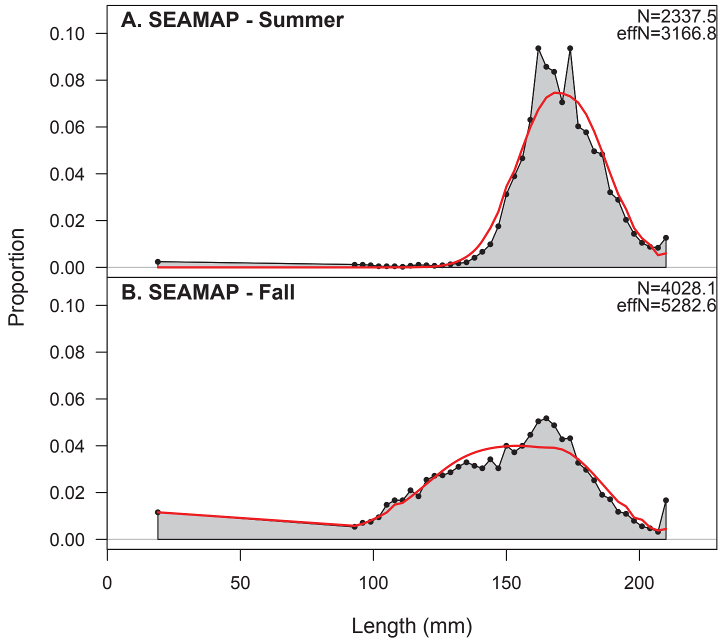

Figure 4.5.2. Size composition fits for the summer and fall SEAMAP surveys, 1987-2011.

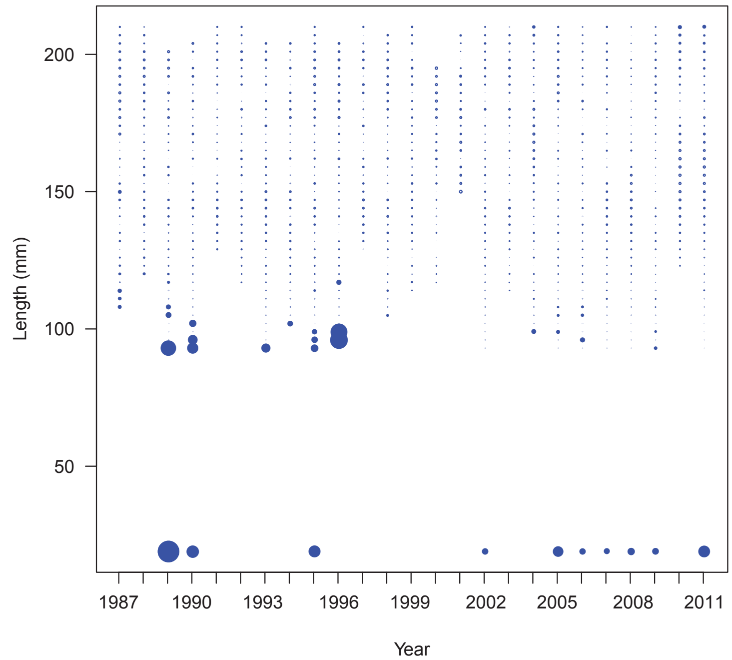

Figure 4.5.3. Residual fits for the summer SEAMAP survey, 1987-2011.

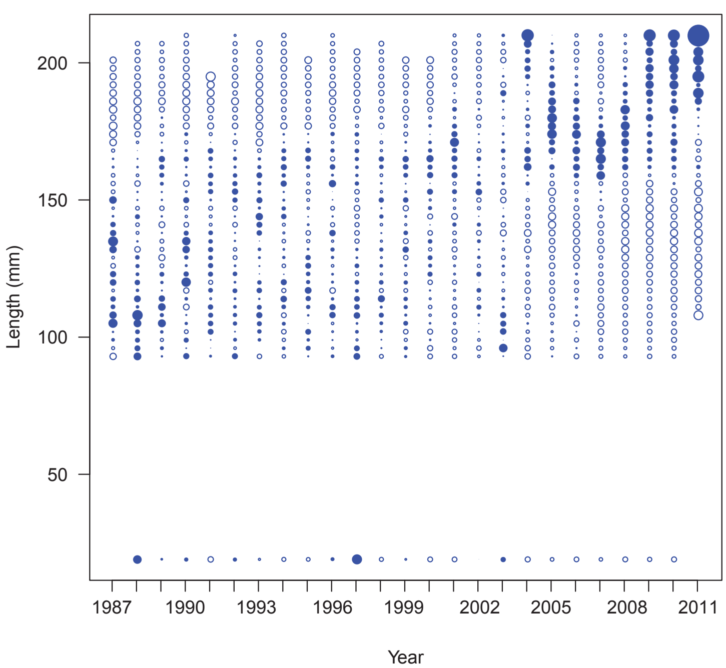

Figure 4.5.4. Residual fits for the fall SEAMAP survey, 1987-2011.

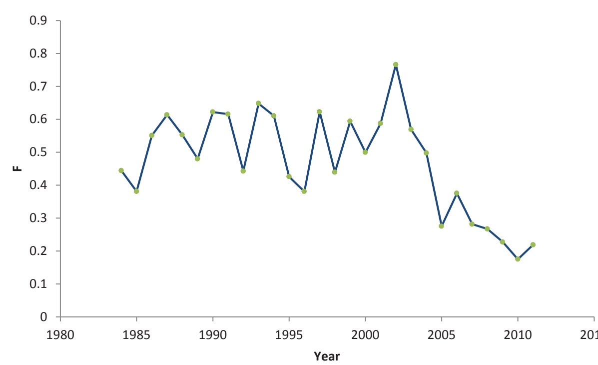

Figure 4.6.1. White shrimp annual apical monthly weighted F-values values across all ages.

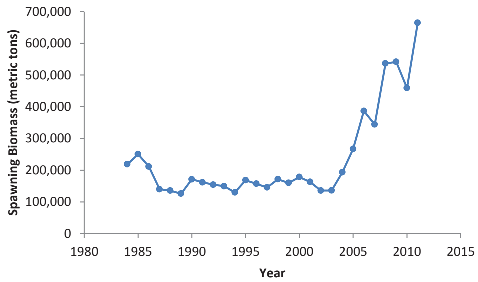

Figure 4.7.1. White shrimp spawning biomass estimates .

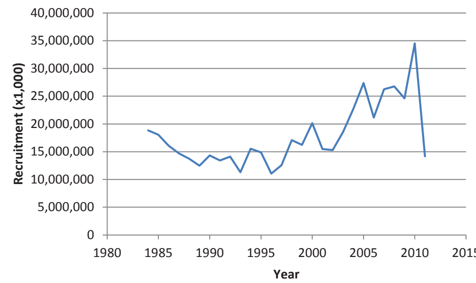

Figure 4.7.2. White shrimp recruitment model estimates.

Appendix 1. Louisiana state shrimp survey methodology.

Fishery-independent catch rates of brown and white shrimp from the Louisiana Department of Wildlife and Fisheries 16' marine trawl survey, 1967-2011

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Introduction

The Louisiana Department of Wildlife and Fisheries (LDWF) Marine Fisheries Section conducts routine standardized sampling as part of long-term comprehensive monitoring programs to collect life-history information and measure relative abundance/size composition of recreationally and commercially important species (LDWF 2002). These programs include the 16' marine trawl survey, 1967-present. This survey uses a standardized design and is conducted throughout the year at fixed sampling locations.

Methods

Brown and white shrimp (*Farfantepenaeus aztecus* and *Litopenaeus setiferus*) abundance indices are developed from the LDWF fishery-independent 16' marine trawl survey. Sampling gear is a 4.9m flat otter trawl with a body and cod-end consisting of 19mm and 6.4mm bar meshes, respectively. Samples are 10 minute tows. All captured shrimp are enumerated and a maximum of 50 randomly selected shrimp per species per sample are measured (i.e., total length in 5mm bins). When more than 50 shrimp per species per sample are captured, catch-at-size is derived as the product of total catch and proportional p_l subsample at size, i.e. $\sum_l p_l = 1$.

Only those fixed stations sampled regularly through time are included in index development. Due to the addition of stations in 1980, separate indices are developed for each survey era: 1967-1979 and 1980-2011 (Figures 1, 2). Catch per unit effort is defined as the number of individuals caught per 10 minute trawl tow.

A delta approach (Pennington 1983; Pennington 1996) is used to estimate catch rates of each shrimp species in each month and year as:

$$I_{my} = c_{my} p_{my} \quad [1]$$

where c_{my} are estimated mean CPUE of positive catches in each month and year (assumed as lognormal distributions) and p_{my} are estimated mean probabilities of capturing the species of interest in each month and year (assumed as binomial distributions). The lognormal and binomial means are estimated, in this case, as sample means (i.e., generalized linear models were not used). The lognormal component considers only those samples in which species of interest were captured (i.e. the geometric mean of successful trawl tows only). The binomial component considers all samples (i.e. the proportion of trawl tows capturing the species of interest). Each index is then computed from equation [1] with variances for each month and year approximated as:

$$V(I_{my}) \approx V(c_{my}) p_{my}^2 + V(p_{my}) c_{my}^2 + 2 c_{my} p_{my} \mathrm{Cov}(c_m, p_m) \quad [2]$$

where Cov(c_m, p_m) $\approx \rho_{c,p}\left[SE\left(c_{my}\right)SE\left(p_{my}\right)\right]$ and $\rho_{c,p}$ represents the correlation between c_{my} and p_{my} among years. Lognormal variances $V(c_{my})$ are converted from arithmetic scale coefficient of variations as $ln(CV^2 + 1)$. Index coefficient of variations CV_{my} are derived as $\sqrt{V(I_{my})}/I_{my}$.

Results/Discussion

White Shrimp p_{my}, I_{my}, and CV_{my} are summarized in Tables 1-3; catch-at-size by year and month is provided in White.xlsx.

Brown shrimp p_{my}, I_{my}, and CV_{my} are summarized in Tables 4-6; catch-at-size by year and month is provided in Brown.xlsx.

Literature Cited

LDWF. 2002. Marine Fisheries Division Field Procedures Manual. Louisiana Department of Wildlife and Fisheries, Version 02-1, Baton Rouge, LA.

Pennington, M. 1983. Efficient estimators of abundance, for fish and plankton surveys. Biometrics 46: 1185-1192.

Pennington, M. 1996. Estimating the mean and variance from highly skewed marine data. National Marine Fisheries Service Fishery Bulletin 94: 498-505.

Tables

Table 1: Proportion of tows capturing white shrimp *Litopenaeus setiferus* derived from the Louisiana Department of Wildlife and Fisheries 16' marine trawl survey (1967-1979 and 1980-2011).

	Proportion positive trawl tows by year/month											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1967	0.67	0.57	0.89	0.81	0.67	0.06	0.75	0.91	0.93	1.00	1.00	1.00
1968	0.18	0.75	0.22	0.78	0.63	0.36	0.57	0.77	0.75	0.83	0.92	0.75
1969	0.30	0.29	0.55	0.77	0.67	0.31	0.60	0.86	0.86	1.00	1.00	0.85
1970	0.18	0.53	0.93	1.00	0.80	0.24	0.55	0.81	0.91	0.90	0.94	1.00
1971	0.63	0.60	0.91	0.94	0.94	0.32	0.24	0.64	0.79	0.83	0.92	0.78
1972	0.54	0.59	0.94	0.88	0.73	0.16	0.24	0.54	0.68	0.83	0.86	0.50
1973	0.17	0.04	0.65	0.62	0.62	0.33	0.57	0.78	0.94	0.85	1.00	0.61
1974	0.41	0.33	0.83	0.91	0.60	0.17	0.37	0.57	0.86	0.93	1.00	0.75
1975	0.68	0.79	0.81	0.90	0.85	0.47	0.51	0.75	0.73	0.92	0.92	0.81
1976	0.31	0.59	0.90	0.97	0.78	0.49	0.67	0.67	0.73	0.83	0.76	0.56
1977	0.20	0.00	0.38	0.69	0.38	0.36	0.69	0.72	0.77	0.84	0.90	0.88
1978	0.27	0.00	0.44	0.85	0.80	0.54	0.79	0.97	0.97	0.94	0.92	0.90
1979	0.17	0.33	0.59	0.86	0.61	0.10	0.58	0.82	0.91	0.97	0.86	0.82
1980	0.41	0.25	0.44	0.59	0.66	0.49	0.60	0.80	0.88	0.92	0.95	0.91
1981	0.50	0.50	0.62	0.65	0.62	0.37	0.58	0.77	0.78	0.89	0.83	0.77
1982	0.44	0.37	0.51	0.66	0.58	0.28	0.52	0.76	0.77	0.85	0.89	0.89
1983	0.60	0.40	0.72	0.74	0.74	0.50	0.55	0.75	0.77	0.83	0.88	0.89
1984	0.25	0.40	0.59	0.73	0.62	0.17	0.57	0.86	0.82	0.89	0.84	0.83
1985	0.37	0.44	0.81	0.78	0.63	0.40	0.62	0.75	0.81	0.94	0.95	0.93
1986	0.54	0.68	0.81	0.70	0.61	0.47	0.81	0.88	0.69	0.95	0.97	0.76
1987	0.72	0.69	0.82	0.81	0.71	0.46	0.82	0.76	0.72	0.78	0.81	0.75
1988	0.21	0.17	0.54	0.66	0.51	0.08	0.40	0.66	0.75	0.86	0.81	0.62
1989	0.58	0.42	0.59	0.64	0.44	0.30	0.67	0.73	0.68	0.88	0.85	0.48
1990	0.30	0.46	0.52	0.51	0.28	0.35	0.72	0.74	0.71	0.81	0.74	0.74
1991	0.56	0.56	0.66	0.85	0.71	0.59	0.61	0.66	0.74	0.82	0.77	0.62
1992	0.43	0.45	0.61	0.67	0.56	0.37	0.62	0.66	0.79	0.83	0.83	0.68
1993	0.55	0.54	0.45	0.74	0.77	0.48	0.73	0.69	0.75	0.89	0.93	0.77
1994	0.36	0.34	0.66	0.76	0.74	0.60	0.75	0.79	0.78	0.87	0.80	0.78
1995	0.66	0.68	0.70	0.75	0.66	0.64	0.68	0.77	0.73	0.86	0.84	0.61
1996	0.36	0.31	0.50	0.58	0.57	0.33	0.58	0.69	0.64	0.83	0.74	0.78
1997	0.41	0.45	0.65	0.63	0.61	0.41	0.54	0.61	0.58	0.92	0.90	0.72
1998	0.64	0.76	0.67	0.79	0.74	0.56	0.62	0.69	0.80	0.89	0.88	0.88
1999	0.50	0.76	0.69	0.67	0.50	0.40	0.58	0.62	0.61	0.81	0.76	0.86
2000	0.58	0.55	0.63	0.62	0.59	0.50	0.64	0.83	0.87	0.87	0.89	0.41
2001	0.21	0.41	0.66	0.64	0.47	0.39	0.63	0.62	0.71	0.87	0.93	0.83
2002	0.40	0.64	0.52	0.71	0.55	0.47	0.66	0.71	0.73	0.92	0.95	0.76
2003	0.41	0.55	0.52	0.70	0.58	0.52	0.83	0.68	0.75	0.82	0.81	0.83
2004	0.64	0.54	0.73	0.79	0.71	0.73	0.85	0.81	0.85	0.89	0.94	0.79
2005	0.44	0.49	0.71	0.78	0.78	0.66	0.84	0.73	0.89	0.92	0.90	0.90
2006	0.89	0.79	0.85	0.81	0.76	0.80	0.84	0.82	0.83	0.90	0.91	0.79
2007	0.74	0.58	0.73	0.74	0.78	0.65	0.83	0.78	0.86	0.92	0.84	0.81
2008	0.58	0.75	0.82	0.85	0.81	0.78	0.81	0.91	0.90	0.95	0.87	0.85
2009	0.87	0.84	0.81	0.91	0.84	0.75	0.76	0.77	0.86	0.97	0.90	0.85
2010	0.43	0.39	0.52	0.77	0.80	0.75	0.74	0.85	0.91	0.86	0.99	0.84
2011	0.56	0.42	0.74	0.83	0.70	0.53	0.67	0.73	0.80	0.89	0.93	0.86

Table 2: Delta lognormal mean catch per tow of white shrimp *Litopenaeus setiferus* derived from the Louisiana Department of Wildlife and Fisheries 16' marine trawl survey (1967-1979 and 1980-2011).

	Delta lognormal mean catch per tow by year/month											
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***
1967	*1.4*	*1.5*	*3.1*	*11.8*	*3.6*	*0.3*	*3.2*	*13.4*	*18.4*	*50.4*	*80.3*	*24.7*
1968	*1.2*	*0.9*	*2.3*	*6.3*	*12.6*	*0.5*	*3.3*	*10.8*	*7.0*	*11.2*	*25.8*	*10.9*
1969	*0.6*	*0.5*	*1.4*	*5.5*	*7.4*	*1.5*	*2.5*	*13.7*	*15.6*	*35.1*	*15.8*	*5.7*
1970	*0.2*	*1.7*	*10.6*	*37.1*	*13.3*	*0.8*	*4.4*	*18.1*	*17.0*	*23.3*	*57.3*	*11.6*
1971	*1.6*	*4.3*	*12.5*	*23.3*	*18.3*	*1.1*	*0.6*	*9.9*	*8.9*	*16.8*	*31.4*	*8.1*
1972	*3.0*	*6.7*	*11.6*	*27.2*	*10.3*	*0.4*	*0.6*	*3.0*	*6.0*	*18.1*	*19.7*	*1.9*
1973	*0.6*	*0.0*	*4.4*	*5.5*	*6.5*	*1.2*	*4.2*	*8.7*	*18.1*	*16.7*	*23.1*	*6.5*
1974	*3.8*	*2.6*	*7.5*	*11.6*	*3.1*	*0.3*	*2.0*	*13.3*	*9.3*	*25.3*	*54.8*	*4.6*
1975	*5.1*	*7.5*	*11.0*	*16.7*	*11.3*	*1.8*	*3.7*	*5.9*	*9.7*	*21.5*	*44.7*	*3.8*
1976	*1.4*	*5.7*	*15.3*	*24.4*	*9.5*	*1.9*	*18.8*	*19.6*	*9.8*	*30.0*	*5.7*	*2.7*
1977	*0.3*	.	*0.7*	*2.2*	*1.4*	*1.2*	*11.2*	*43.6*	*32.6*	*33.9*	*56.6*	*19.6*
1978	*0.8*	.	*2.7*	*11.0*	*4.7*	*2.7*	*18.8*	*27.2*	*11.3*	*16.8*	*27.9*	*12.4*
1979	*2.0*	*0.9*	*12.7*	*4.1*	*3.6*	*0.2*	*6.7*	*8.9*	*6.0*	*33.4*	*16.9*	*2.0*
1980	*1.4*	*0.6*	*1.8*	*4.3*	*6.0*	*1.3*	*4.9*	*13.6*	*13.2*	*23.9*	*37.3*	*15.3*
1981	*1.4*	*3.2*	*3.7*	*7.4*	*3.5*	*1.0*	*5.2*	*13.6*	*8.6*	*19.8*	*16.0*	*12.3*
1982	*2.2*	*1.2*	*3.4*	*6.2*	*5.4*	*0.5*	*3.4*	*8.6*	*8.6*	*16.5*	*14.8*	*15.5*
1983	*2.9*	*3.0*	*4.6*	*9.7*	*10.3*	*1.7*	*2.8*	*8.3*	*7.2*	*9.6*	*19.5*	*19.7*
1984	*1.9*	*2.6*	*3.4*	*7.9*	*4.4*	*0.3*	*5.7*	*16.2*	*11.8*	*15.0*	*22.7*	*9.0*
1985	*4.5*	*5.6*	*7.3*	*6.3*	*3.9*	*1.0*	*5.4*	*7.9*	*11.2*	*16.1*	*22.4*	*15.7*
1986	*2.4*	*4.3*	*10.9*	*11.4*	*3.8*	*6.4*	*17.1*	*10.5*	*5.5*	*27.8*	*22.2*	*8.4*
1987	*5.0*	*5.6*	*12.0*	*13.5*	*6.1*	*1.5*	*11.0*	*12.5*	*3.6*	*11.4*	*10.2*	*2.0*
1988	*0.3*	*0.3*	*3.5*	*3.0*	*3.1*	*0.1*	*7.0*	*6.2*	*5.0*	*9.8*	*8.0*	*2.0*
1989	*3.7*	*2.3*	*2.7*	*6.5*	*3.0*	*0.8*	*3.7*	*5.6*	*3.6*	*9.7*	*4.7*	*14.6*
1990	*1.0*	*1.7*	*2.2*	*2.6*	*0.8*	*1.8*	*8.2*	*6.3*	*3.9*	*15.4*	*13.7*	*13.3*
1991	*5.6*	*5.6*	*6.8*	*19.6*	*4.6*	*2.6*	*5.2*	*3.8*	*4.9*	*11.8*	*12.5*	*5.7*
1992	*6.6*	*4.5*	*6.0*	*6.8*	*5.8*	*1.1*	*6.3*	*5.4*	*14.7*	*10.8*	*17.3*	*5.0*
1993	*6.5*	*4.5*	*2.1*	*7.1*	*8.4*	*2.3*	*7.2*	*7.0*	*8.5*	*29.6*	*32.5*	*7.3*
1994	*3.3*	*1.0*	*6.8*	*10.8*	*8.7*	*2.5*	*6.2*	*9.6*	*8.2*	*27.3*	*29.0*	*17.4*
1995	*5.4*	*7.7*	*6.2*	*17.2*	*7.0*	*3.4*	*11.3*	*9.2*	*7.4*	*18.6*	*15.9*	*3.0*
1996	*2.9*	*2.0*	*2.1*	*4.1*	*3.2*	*0.7*	*5.4*	*11.6*	*8.9*	*13.8*	*12.8*	*11.9*
1997	*2.8*	*3.6*	*3.5*	*4.0*	*4.6*	*1.1*	*5.4*	*6.5*	*4.6*	*34.3*	*18.4*	*15.1*
1998	*9.1*	*8.1*	*6.8*	*10.1*	*6.8*	*2.7*	*6.3*	*5.8*	*14.7*	*17.1*	*15.5*	*18.1*
1999	*2.4*	*11.8*	*5.7*	*9.4*	*3.3*	*1.5*	*9.0*	*6.0*	*7.2*	*22.2*	*10.4*	*11.2*
2000	*4.5*	*5.1*	*7.6*	*8.7*	*4.8*	*2.1*	*9.0*	*9.9*	*16.7*	*15.3*	*19.2*	*3.9*
2001	*0.7*	*2.5*	*3.6*	*3.2*	*2.0*	*1.5*	*6.4*	*8.4*	*12.4*	*15.9*	*10.0*	*15.1*
2002	*2.4*	*3.6*	*2.4*	*4.3*	*2.1*	*1.0*	*5.0*	*4.4*	*6.6*	*13.6*	*21.5*	*5.6*
2003	*3.9*	*2.1*	*2.0*	*6.8*	*2.4*	*3.0*	*12.9*	*5.2*	*6.9*	*17.3*	*9.6*	*16.1*
2004	*3.4*	*2.4*	*5.5*	*8.3*	*6.3*	*5.2*	*13.8*	*8.8*	*11.3*	*22.9*	*19.0*	*29.8*
2005	*2.3*	*2.7*	*7.9*	*11.7*	*5.2*	*3.2*	*10.3*	*5.6*	*16.3*	*48.6*	*33.3*	*18.9*
2006	*11.6*	*16.0*	*13.7*	*11.0*	*6.4*	*5.7*	*20.7*	*13.8*	*17.0*	*29.0*	*47.1*	*13.0*
2007	*10.3*	*7.8*	*9.7*	*7.3*	*6.6*	*5.7*	*10.6*	*16.5*	*17.2*	*32.5*	*21.9*	*27.5*
2008	*5.7*	*8.9*	*10.7*	*8.3*	*5.3*	*6.7*	*9.8*	*10.2*	*16.2*	*29.4*	*32.9*	*30.8*
2009	*37.3*	*25.4*	*23.1*	*26.4*	*12.7*	*9.8*	*15.5*	*6.3*	*8.8*	*25.8*	*18.2*	*20.3*
2010	*6.2*	*5.0*	*6.9*	*10.5*	*5.5*	*3.3*	*12.1*	*12.5*	*19.4*	*16.7*	*39.7*	*31.8*
2011	*10.6*	*2.4*	*8.2*	*10.8*	*4.6*	*2.2*	*5.9*	*6.1*	*11.0*	*11.1*	*21.8*	*16.5*

Table 3: Coefficient of variation of delta lognormal mean catch per tow of white shrimp *Litopenaeus setiferus* derived from the Louisiana Department of Wildlife and Fisheries 16’ marine trawl survey (1967-1979 and 1980-2011).

	CV of delta lognormal mean catch per tow by year/month											
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***
1967	0.24	0.30	0.11	0.13	0.20	.	0.18	0.10	0.08	0.00	0.00	0.00
1968	0.65	0.81	0.65	0.14	0.20	0.62	0.26	0.15	0.18	0.13	0.08	0.21
1969	0.48	0.89	0.36	0.17	0.22	0.44	0.45	0.11	0.09	0.00	0.01	0.11
1970	.	0.26	0.05	0.00	0.09	0.37	0.16	0.09	0.06	0.08	0.06	0.02
1971	0.23	0.18	0.06	0.05	0.04	0.27	0.40	0.13	0.10	0.09	0.06	0.11
1972	0.20	0.15	0.04	0.07	0.11	0.51	0.44	0.15	0.12	0.09	0.09	0.31
1973	0.49	.	0.14	0.14	0.12	0.26	0.14	0.09	0.05	0.07	0.00	0.17
1974	0.22	0.32	0.08	0.05	0.16	0.51	0.24	0.14	0.07	0.04	0.00	0.14
1975	0.14	0.11	0.08	0.05	0.08	0.19	0.17	0.11	0.10	0.06	0.09	0.17
1976	0.38	0.18	0.06	0.03	0.10	0.18	0.12	0.14	0.11	0.09	0.14	0.25
1977	0.89	.	0.42	0.17	0.24	0.27	0.13	0.11	0.12	0.09	0.06	0.10
1978	0.53	.	0.30	0.09	0.12	0.21	0.11	0.03	0.03	0.04	0.06	0.11
1979	0.65	0.51	0.18	0.13	0.16	0.57	0.17	0.09	0.06	0.03	0.11	0.28
1980	0.23	0.37	0.17	0.10	0.08	0.15	0.08	0.06	0.04	0.03	0.04	0.04
1981	0.21	0.28	0.09	0.07	0.09	0.17	0.08	0.06	0.06	0.04	0.07	0.08
1982	0.20	0.24	0.10	0.07	0.08	0.23	0.10	0.05	0.06	0.04	0.05	0.05
1983	0.14	0.20	0.07	0.07	0.05	0.11	0.09	0.06	0.07	0.05	0.05	0.09
1984	0.34	0.18	0.10	0.06	0.09	0.36	0.09	0.04	0.06	0.04	0.06	0.11
1985	0.19	0.16	0.05	0.05	0.08	0.18	0.07	0.07	0.05	0.03	0.03	0.05
1986	0.15	0.09	0.06	0.06	0.09	0.11	0.05	0.05	0.08	0.03	0.03	0.12
1987	0.10	0.12	0.05	0.04	0.06	0.13	0.05	0.06	0.07	0.06	0.08	0.20
1988	0.54	0.51	0.10	0.08	0.10	.	0.13	0.07	0.07	0.04	0.07	0.16
1989	0.12	0.19	0.10	0.07	0.12	0.25	0.08	0.06	0.09	0.04	0.08	0.18
1990	0.21	0.19	0.12	0.09	0.19	0.14	0.06	0.06	0.08	0.05	0.09	0.09
1991	0.12	0.11	0.08	0.04	0.07	0.09	0.08	0.08	0.07	0.05	0.08	0.12
1992	0.15	0.16	0.08	0.06	0.09	0.15	0.08	0.08	0.06	0.05	0.06	0.12
1993	0.13	0.14	0.13	0.06	0.06	0.11	0.07	0.06	0.06	0.04	0.03	0.08
1994	0.17	0.27	0.08	0.06	0.06	0.09	0.06	0.05	0.06	0.04	0.07	0.07
1995	0.09	0.10	0.07	0.05	0.07	0.08	0.07	0.05	0.07	0.04	0.05	0.14
1996	0.18	0.20	0.12	0.08	0.09	0.20	0.08	0.07	0.08	0.05	0.09	0.08
1997	0.18	0.16	0.09	0.08	0.08	0.14	0.09	0.08	0.08	0.03	0.04	0.07
1998	0.09	0.07	0.07	0.05	0.06	0.10	0.08	0.07	0.06	0.03	0.04	0.04
1999	0.14	0.07	0.06	0.07	0.10	0.14	0.09	0.07	0.08	0.05	0.07	0.05
2000	0.11	0.11	0.08	0.08	0.08	0.11	0.07	0.04	0.04	0.04	0.04	0.16
2001	0.27	0.16	0.08	0.08	0.11	0.16	0.07	0.08	0.06	0.04	0.03	0.05
2002	0.16	0.10	0.10	0.06	0.10	0.16	0.06	0.07	0.07	0.03	0.03	0.08
2003	0.15	0.14	0.11	0.06	0.09	0.10	0.04	0.07	0.06	0.04	0.06	0.05
2004	0.11	0.13	0.06	0.05	0.07	0.06	0.04	0.05	0.05	0.03	0.03	0.06
2005	0.15	0.13	0.06	0.05	0.06	0.08	0.04	0.07	0.05	0.03	0.04	0.04
2006	0.04	0.06	0.04	0.05	0.06	0.06	0.04	0.05	0.05	0.03	0.04	0.06
2007	0.07	0.10	0.06	0.06	0.06	0.08	0.04	0.06	0.04	0.03	0.05	0.06
2008	0.10	0.07	0.05	0.04	0.05	0.05	0.05	0.03	0.03	0.02	0.04	0.05
2009	0.05	0.05	0.05	0.03	0.04	0.05	0.06	0.06	0.04	0.02	0.04	0.05
2010	0.14	0.16	0.09	0.06	0.05	0.08	0.07	0.04	0.03	0.05	0.01	0.05
2011	0.11	0.18	0.08	0.04	0.06	0.10	0.07	0.08	0.07	0.05	0.03	0.05

Table 4: Proportion of tows capturing brown shrimp *Farfantepenaeus aztecus* derived from the Louisiana Department of Wildlife and Fisheries 16' marine trawl survey (1967-1979 and 1980-2011).

	Proportion positive trawl tows by year/month											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1967	0.17	0.29	0.37	0.81	1.00	1.00	1.00	0.82	0.86	0.92	0.80	1.00
1968	0.09	0.00	0.00	0.61	0.88	1.00	0.93	0.85	0.75	0.58	0.69	0.63
1969	0.30	0.14	0.33	0.31	0.92	1.00	1.00	1.00	0.68	0.74	0.50	0.60
1970	0.36	0.16	0.07	0.48	0.97	1.00	0.92	0.77	0.50	0.60	0.56	0.29
1971	0.38	0.20	0.48	0.72	1.00	1.00	0.88	0.89	0.46	0.62	0.42	0.48
1972	0.54	0.53	0.28	0.91	0.97	0.88	0.94	0.61	0.50	0.45	0.48	0.13
1973	0.04	0.00	0.10	0.32	0.76	0.83	0.82	0.81	0.66	0.60	0.62	0.30
1974	0.24	0.43	0.40	0.86	0.97	1.00	0.63	0.35	0.42	0.44	0.75	0.40
1975	0.36	0.21	0.46	0.60	0.91	0.86	0.82	0.59	0.47	0.50	0.75	0.25
1976	0.06	0.14	0.68	0.97	1.00	1.00	0.92	0.63	0.48	0.63	0.24	0.31
1977	0.10	0.00	0.00	0.85	1.00	0.94	0.79	0.69	0.59	0.72	0.60	0.44
1978	0.00	0.00	0.00	0.56	1.00	1.00	0.92	0.68	0.50	0.92	0.84	0.60
1979	0.17	0.08	0.00	0.50	0.94	0.90	0.92	0.71	0.72	0.91	0.79	0.45
1980	0.26	0.18	0.09	0.35	0.76	0.96	0.89	0.76	0.54	0.52	0.56	0.56
1981	0.22	0.13	0.10	0.57	0.98	0.98	0.91	0.76	0.54	0.62	0.56	0.43
1982	0.33	0.16	0.15	0.61	0.90	0.94	0.91	0.75	0.64	0.57	0.49	0.54
1983	0.33	0.28	0.25	0.45	0.76	0.89	0.87	0.88	0.69	0.49	0.57	0.61
1984	0.07	0.02	0.08	0.43	0.91	0.88	0.89	0.84	0.50	0.62	0.36	0.06
1985	0.06	0.06	0.08	0.65	0.97	0.97	0.92	0.49	0.50	0.66	0.54	0.43
1986	0.18	0.04	0.27	0.76	0.96	0.98	0.96	0.67	0.72	0.84	0.69	0.48
1987	0.39	0.03	0.11	0.43	0.96	0.95	0.90	0.71	0.56	0.73	0.41	0.13
1988	0.12	0.00	0.14	0.46	0.91	0.88	0.78	0.48	0.43	0.43	0.34	0.12
1989	0.34	0.26	0.26	0.60	0.93	0.91	0.80	0.66	0.54	0.68	0.55	0.21
1990	0.01	0.04	0.27	0.65	0.97	0.90	0.85	0.58	0.55	0.67	0.53	0.20
1991	0.39	0.31	0.37	0.63	0.81	0.75	0.77	0.45	0.54	0.57	0.31	0.28
1992	0.33	0.15	0.30	0.58	0.91	0.90	0.87	0.56	0.78	0.59	0.47	0.33
1993	0.32	0.26	0.15	0.36	0.84	0.91	0.77	0.70	0.51	0.74	0.66	0.38
1994	0.30	0.24	0.40	0.52	0.85	0.76	0.84	0.56	0.46	0.64	0.51	0.30
1995	0.29	0.21	0.22	0.61	0.96	0.96	0.81	0.59	0.57	0.57	0.34	0.17
1996	0.05	0.03	0.01	0.30	0.92	0.92	0.82	0.65	0.65	0.67	0.57	0.31
1997	0.17	0.09	0.13	0.69	0.80	0.84	0.85	0.62	0.66	0.70	0.32	0.30
1998	0.07	0.11	0.07	0.52	0.93	0.96	0.80	0.58	0.49	0.52	0.54	0.40
1999	0.20	0.23	0.45	0.82	0.98	0.96	0.77	0.43	0.44	0.72	0.46	0.40
2000	0.35	0.34	0.66	0.96	0.98	0.95	0.81	0.69	0.70	0.64	0.51	0.21
2001	0.04	0.00	0.18	0.70	0.97	0.93	0.72	0.58	0.64	0.59	0.55	0.63
2002	0.06	0.04	0.09	0.57	0.94	0.86	0.75	0.54	0.59	0.66	0.49	0.21
2003	0.07	0.10	0.13	0.75	0.97	0.95	0.77	0.43	0.61	0.41	0.34	0.23
2004	0.12	0.18	0.25	0.77	0.95	0.91	0.75	0.52	0.59	0.80	0.67	0.48
2005	0.15	0.17	0.14	0.78	0.98	0.96	0.88	0.62	0.81	0.70	0.58	0.21
2006	0.23	0.33	0.49	0.92	0.97	0.93	0.76	0.55	0.62	0.66	0.50	0.31
2007	0.25	0.11	0.28	0.82	0.99	0.95	0.87	0.67	0.61	0.62	0.51	0.28
2008	0.20	0.30	0.38	0.77	0.88	0.84	0.79	0.60	0.68	0.70	0.65	0.41
2009	0.34	0.25	0.52	0.95	1.00	0.95	0.81	0.59	0.71	0.66	0.26	0.23
2010	0.04	0.06	0.03	0.36	0.96	0.97	0.88	0.63	0.44	0.38	0.38	0.11
2011	0.06	0.00	0.18	0.93	0.98	0.92	0.71	0.51	0.49	0.53	0.46	0.33

Table 5: Delta lognormal mean catch per tow of brown shrimp *Farfantepenaeus aztecus* derived from the Louisiana Department of Wildlife and Fisheries 16' marine trawl survey (1967-1979 and 1980-2011).

	Delta lognormal mean catch per tow by year/month											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1967	0.2	0.3	0.6	12.4	127.2	101.9	62.4	7.5	4.3	4.0	4.7	5.2
1968	0.1	.	.	6.9	60.4	86.7	21.2	7.6	2.9	1.2	2.0	1.9
1969	0.5	0.1	0.4	2.8	66.1	80.6	10.5	7.7	2.3	6.0	2.2	1.3
1970	0.4	0.2	0.1	2.8	61.2	56.8	40.6	6.6	1.9	1.7	1.9	0.4
1971	0.5	0.4	1.2	17.0	105.0	49.8	16.5	7.2	1.3	1.5	1.0	1.1
1972	1.8	1.2	1.5	18.6	32.5	12.6	6.9	1.3	1.0	1.7	1.2	0.3
1973	0.0	.	0.1	1.5	25.1	24.8	12.3	4.5	2.3	2.0	2.6	1.2
1974	0.4	0.7	1.3	21.4	48.0	34.6	3.9	1.1	0.9	1.0	2.5	0.9
1975	0.7	0.7	1.3	4.2	23.4	26.0	11.1	2.9	0.9	1.1	3.7	0.3
1976	0.1	0.1	3.6	47.0	124.8	69.3	11.5	2.6	1.1	1.6	0.3	0.4
1977	0.1	.	.	12.9	101.2	56.1	7.5	3.5	2.8	3.6	2.0	1.2
1978	.	.	.	13.9	450.3	157.6	11.6	3.6	1.7	3.6	3.2	1.1
1979	0.2	0.1	.	2.4	49.8	54.4	24.4	3.7	4.2	5.1	1.7	0.6
1980	0.4	0.2	0.2	1.5	15.3	46.7	18.5	4.0	2.3	2.4	1.4	2.1
1981	0.5	0.1	0.3	6.5	66.8	43.8	9.4	3.3	1.9	3.5	1.5	1.1
1982	1.0	0.5	1.6	18.7	37.3	49.3	16.1	5.7	2.4	2.4	1.5	2.4
1983	0.7	1.1	0.8	2.0	18.3	38.2	21.8	7.3	2.2	1.8	2.6	5.0
1984	0.1	0.0	0.1	5.8	54.2	46.9	23.0	4.5	1.6	2.7	1.3	0.1
1985	0.1	0.1	0.3	13.9	68.2	45.9	13.7	1.4	2.1	2.1	1.6	1.1
1986	0.3	0.1	1.2	29.9	84.4	59.1	11.3	2.7	4.4	7.9	3.5	2.1
1987	0.9	0.0	0.2	2.9	70.3	46.4	10.2	2.7	3.3	5.6	1.9	0.6
1988	0.1	.	0.5	4.3	30.3	18.5	8.5	1.7	1.7	1.5	1.0	0.2
1989	0.8	0.4	0.8	5.7	52.9	39.9	13.1	3.9	3.4	2.6	1.8	0.4
1990	0.0	0.0	1.1	20.2	55.7	26.3	9.9	3.1	2.9	4.0	1.8	1.2
1991	2.8	1.5	1.3	12.0	31.7	14.5	5.3	1.2	3.2	2.2	0.8	0.9
1992	0.6	0.5	2.6	8.9	28.8	28.9	14.6	4.0	6.6	3.4	1.6	1.0
1993	0.8	0.8	0.3	1.7	27.5	56.1	21.9	4.4	3.4	4.1	2.4	1.3
1994	0.6	0.5	1.0	5.4	28.3	19.1	13.0	3.3	2.1	2.7	2.0	0.5
1995	0.5	0.3	0.8	9.5	47.7	27.2	8.7	2.7	2.6	2.0	0.9	0.3
1996	0.1	0.0	0.0	2.2	77.7	53.8	15.3	4.0	2.8	2.8	3.3	1.0
1997	0.7	0.1	0.3	12.9	43.9	55.6	16.8	4.8	3.4	5.4	0.7	0.6
1998	0.2	0.2	0.3	6.3	77.0	58.9	7.5	2.1	2.0	1.5	1.6	1.4
1999	0.3	0.5	2.9	34.2	64.6	27.2	10.0	2.0	2.4	3.4	1.9	1.2
2000	0.6	1.2	3.1	21.9	54.1	23.5	9.3	4.8	4.1	3.5	1.6	0.6
2001	0.1	.	0.5	12.0	41.1	22.3	6.0	3.9	4.3	2.3	2.0	2.1
2002	0.1	0.0	0.1	10.7	39.2	10.5	4.6	2.4	2.6	3.1	1.8	0.4
2003	0.2	0.2	0.4	10.7	65.3	23.0	5.8	1.7	3.0	1.1	0.6	0.4
2004	0.3	0.3	0.9	21.5	79.1	25.0	4.6	2.4	3.8	6.5	4.0	1.9
2005	0.4	0.3	0.3	7.9	69.5	37.6	11.3	2.4	3.7	3.7	2.6	0.5
2006	0.4	0.8	2.5	40.3	100.0	33.0	5.8	2.0	2.6	3.6	2.0	0.8
2007	0.5	0.2	2.2	17.1	77.2	41.5	11.3	4.7	3.2	3.5	1.4	1.1
2008	0.4	0.4	1.7	26.2	72.5	31.4	7.9	3.7	2.9	4.4	2.9	1.1
2009	0.7	0.6	3.7	33.5	59.4	41.3	7.1	2.6	3.3	2.6	0.7	0.5
2010	0.1	0.2	0.1	6.5	61.2	62.0	9.0	3.2	1.7	0.9	0.9	0.2
2011	0.1	.	3.1	45.5	110.2	60.5	10.1	2.6	1.7	2.3	1.6	0.8

Table 6: Coefficient of variation of delta lognormal mean catch per tow of brown shrimp *Farfantepenaeus aztecus* derived from the Louisiana Department of Wildlife and Fisheries 16' marine trawl survey (1967-1979 and 1980-2011).

	CV of delta lognormal mean catch per tow by year/month											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1967	.	.	0.46	0.13	0.00	0.00	0.00	0.15	0.13	0.11	0.17	0.03
1968	.	.	.	0.20	0.10	0.00	0.08	0.13	0.22	0.42	0.24	0.39
1969	0.86	.	0.91	0.44	0.09	0.00	0.02	0.02	0.19	0.13	0.32	0.28
1970	1.01	.	.	0.22	0.03	0.00	0.05	0.11	0.22	0.23	0.26	0.68
1971	0.94	0.56	0.25	0.11	0.00	0.00	0.07	0.07	0.25	0.23	0.29	0.28
1972	0.24	0.26	0.29	0.06	0.03	0.07	0.05	0.20	0.26	0.24	0.31	0.66
1973	.	.	1.05	0.28	0.09	0.08	0.07	0.09	0.17	0.16	0.18	0.34
1974	0.58	0.45	0.25	0.06	0.03	0.00	0.13	0.28	0.32	0.24	0.14	0.33
1975	0.40	0.42	0.22	0.14	0.06	0.07	0.08	0.18	0.29	0.30	0.19	0.96
1976	.	.	0.14	0.03	0.00	0.00	0.05	0.19	0.29	0.22	0.95	0.67
1977	.	.	.	0.09	0.00	0.04	0.10	0.15	0.21	0.14	0.18	0.35
1978	.	.	.	0.18	0.00	0.00	0.06	0.13	0.22	0.07	0.11	0.39
1979	.	.	.	0.25	0.05	0.06	0.06	0.15	0.13	0.07	0.27	0.86
1980	0.48	0.70	0.52	0.17	0.06	0.02	0.03	0.08	0.11	0.12	0.19	0.14
1981	0.41	.	0.38	0.08	0.01	0.01	0.03	0.07	0.11	0.09	0.15	0.21
1982	0.25	0.43	0.23	0.08	0.03	0.03	0.03	0.05	0.08	0.10	0.16	0.14
1983	0.29	0.28	0.18	0.14	0.05	0.03	0.04	0.04	0.09	0.14	0.13	0.20
1984	.	.	0.70	0.12	0.03	0.04	0.04	0.05	0.14	0.10	0.24	.
1985	.	0.96	0.38	0.06	0.02	0.02	0.03	0.14	0.11	0.10	0.15	0.24
1986	0.46	1.03	0.20	0.06	0.02	0.02	0.02	0.10	0.08	0.05	0.13	0.24
1987	0.24	.	0.44	0.11	0.02	0.02	0.04	0.08	0.09	0.07	0.22	0.75
1988	0.93	.	0.28	0.11	0.03	0.04	0.06	0.12	0.13	0.14	0.21	0.68
1989	0.23	0.35	0.21	0.08	0.03	0.04	0.05	0.08	0.11	0.09	0.17	0.46
1990	.	.	0.19	0.06	0.02	0.03	0.04	0.09	0.10	0.08	0.16	0.30
1991	0.17	0.19	0.15	0.07	0.05	0.05	0.06	0.14	0.10	0.11	0.28	0.27
1992	0.27	0.35	0.15	0.08	0.03	0.03	0.04	0.10	0.06	0.10	0.17	0.28
1993	0.23	0.27	0.38	0.14	0.04	0.03	0.06	0.06	0.11	0.07	0.11	0.21
1994	0.24	0.37	0.17	0.10	0.04	0.05	0.05	0.09	0.12	0.10	0.16	0.31
1995	0.29	0.47	0.22	0.07	0.02	0.02	0.05	0.09	0.10	0.11	0.20	0.49
1996	0.68	1.08	.	0.15	0.03	0.03	0.04	0.08	0.08	0.09	0.14	0.23
1997	0.35	.	0.34	0.07	0.05	0.04	0.04	0.08	0.07	0.07	0.22	0.25
1998	0.48	0.50	0.38	0.09	0.03	0.02	0.05	0.10	0.12	0.12	0.13	0.15
1999	0.44	0.31	0.10	0.05	0.01	0.02	0.06	0.12	0.11	0.08	0.14	0.16
2000	0.24	0.18	0.08	0.02	0.01	0.02	0.05	0.07	0.07	0.08	0.14	0.29
2001	0.69	.	0.26	0.06	0.02	0.03	0.06	0.09	0.07	0.09	0.12	0.11
2002	0.79	.	0.95	0.08	0.02	0.04	0.05	0.10	0.09	0.08	0.15	0.40
2003	0.50	0.48	0.27	0.05	0.02	0.02	0.05	0.13	0.08	0.14	0.28	0.31
2004	0.41	0.46	0.18	0.05	0.02	0.03	0.06	0.10	0.09	0.06	0.09	0.13
2005	0.33	0.47	0.28	0.05	0.01	0.02	0.04	0.09	0.07	0.08	0.11	0.32
2006	0.33	0.21	0.10	0.03	0.02	0.03	0.06	0.10	0.09	0.08	0.13	0.23
2007	0.23	0.44	0.16	0.04	0.01	0.02	0.04	0.08	0.09	0.08	0.14	0.21
2008	0.30	0.37	0.14	0.05	0.04	0.04	0.05	0.08	0.08	0.07	0.09	0.17
2009	0.24	0.26	0.09	0.02	0.00	0.02	0.05	0.09	0.07	0.09	0.23	0.31
2010	0.69	0.61	0.58	0.14	0.02	0.02	0.05	0.08	0.12	0.22	0.19	0.43
2011	.	.	0.28	0.03	0.01	0.02	0.06	0.13	0.14	0.14	0.14	0.20

Figures

Figure 1: Sampling locations of the Louisiana Department of Wildlife and Fisheries 16' marine trawl survey used in shrimp abundance index development, 1967-1979.

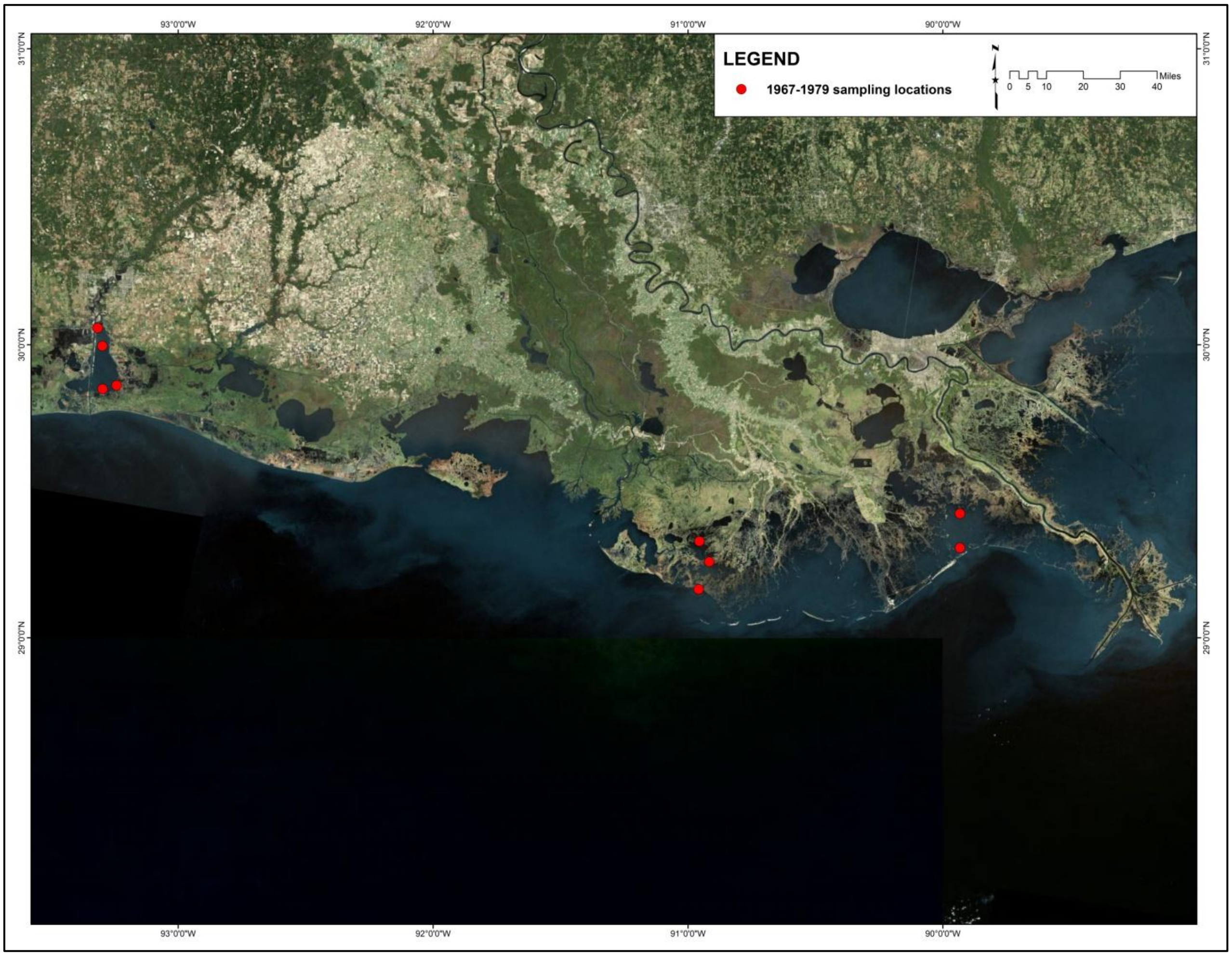
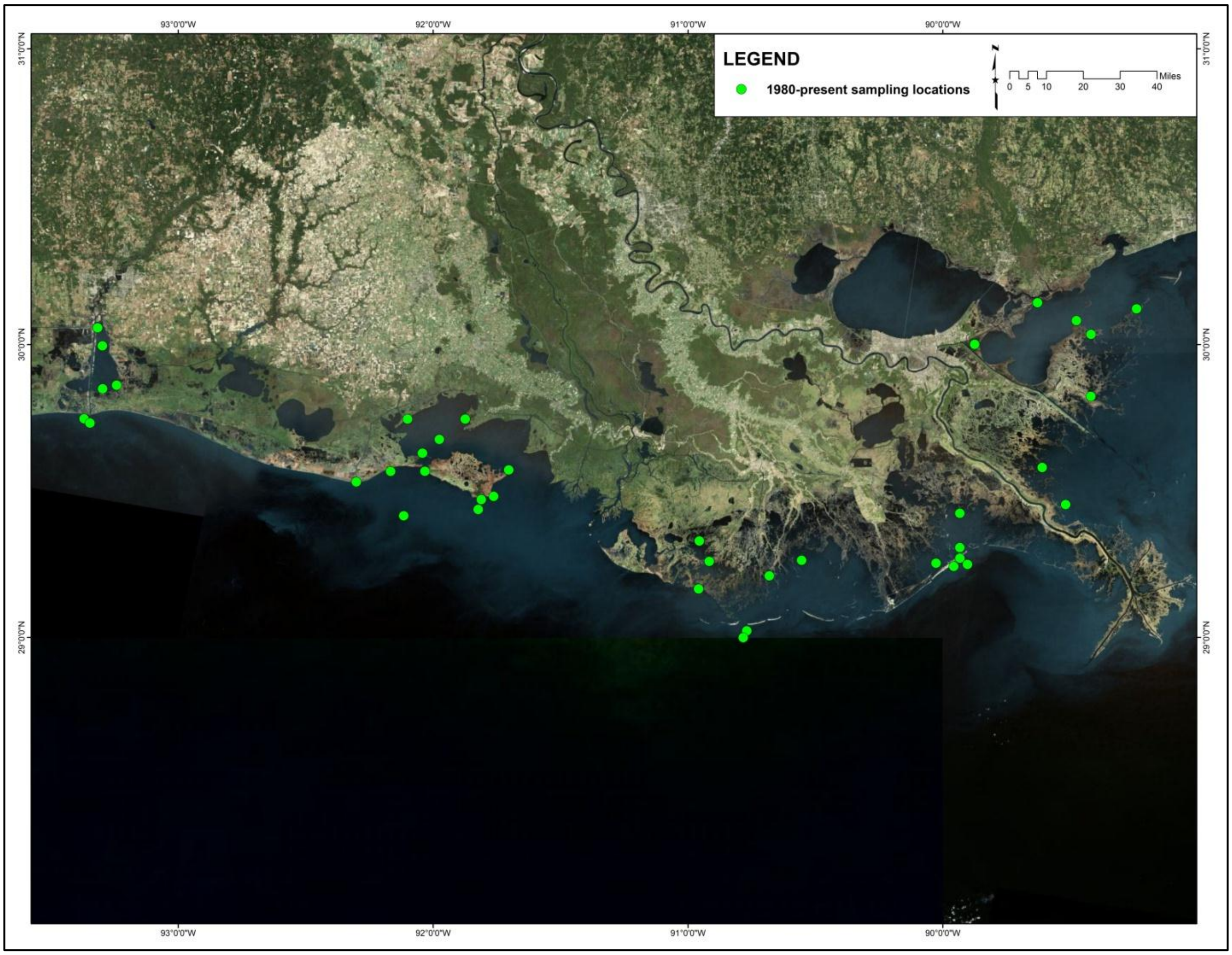


Figure 2: Sampling locations of the Louisiana Department of Wildlife and Fisheries 16' marine trawl survey used in shrimp abundance index development, 1980-2011.



Abundance Indices for Brown and White Shrimp Collected in the Northern Gulf of Mexico During the Summer and Fall SEAMAP Groundfish Surveys

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Survey Design

The basic structure of the SEAMAP groundfish surveys (i.e. 1987- summer of 2008) follows a stratified random station location assignment with strata derived from depth zones (5-6, 6-7, 7-8, 8-9, 9-10, 10-11, 11-12, 12-13, 13-14, 14-15, 15-16, 16-17, 17-18, 18-19, 19-20, 20-22, 22-25, 25-30, 30-35, 35-40, 40-45, 45-50 and 50-60 fathoms), shrimp statistical zones (between 88° and 97° W longitude, statistical zones from west to east: 21-20, 19-18, 17-16, 15-13 and 12-10), and time of day (i.e. day or night). Tows were made perpendicular to the depth zone and tow time was dependent on the length of time needed to cover the depth zone. However, a single tow never exceeded 55 minutes, if additional coverage was needed multiple tows were made to cover the depth zone. In the fall of 2008 there was a change in the groundfish survey design. The major changes included a standardized tow time of 30 minutes which no longer had to cover an entire depth zone. The time of day stratification was also dropped and stations could be sampled whenever the survey vessel arrived. The depth zone strata were dropped in favor of a randomized design within each shrimp statistical zone

Dataset

There were 8,962 stations sampled from 1987-2009, with 4,274 and 4,688 stations sampled in the summer and fall, respectively. An annual breakdown of number of stations sampled by season and shrimp statistical zone is presented in Table 1. One caveat to this dataset is that during the summer survey, the waters off of Texas and closed to commercial shrimping, which leads to a significantly higher catch rate, than is seen in the fall when the waters are open to commercial shrimping.

Indices of Abundance Methods

Delta-lognormal modeling methods were used to estimate relative abundance indices for brown and white shrimp. The index computed by this method is a mathematical combination of yearly abundance estimates from two distinct generalized linear models: a binomial (logistic) model which describes proportion of positive abundance values (i.e. presence/absence) and a lognormal model which describes variability in only the nonzero abundance data.

The delta-lognormal index of relative abundance (I_y) as described by Lo *et al*. (1992) was estimated as:

(1) $I_y = c_y p_y$,

where c_y is the estimate of mean CPUE for positive catches only for year y, and p_y is the estimate of mean probability of occurrence during year y. Both c_y and p_y were estimated using generalized linear models. Data used to estimate abundance for positive catches (c) and probability of occurrence (p) were assumed to have a lognormal distribution and a binomial distribution, respectively, and modeled using the following equations:

(2) $\ln(c) = X\beta + \varepsilon$

and

(3) $p = \frac{e^{X\beta+\varepsilon}}{1+e^{X\beta+\varepsilon}}$,

respectively, where c is a vector of the positive catch data, p is a vector of the presence/absence data, X is the design matrix for main effects, β is the parameter vector for main effects, and ε is a vector of independent normally distributed errors with expectation zero and variance σ^2.

Therefore, c_y and p_y were estimated as least-squares means for each year along with their corresponding standard errors, SE(c_y) and SE(p_y), respectively. From these estimates, I_y was calculated, as in equation (1), and its variance calculated as:

(4) $$V(I_y) \approx V(c_y)p_y^2 + c_y^2 V(p_y) + 2c_y p_y \mathrm{Cov}(c, p),$$

where:

(5) $$\mathrm{Cov}(c, p) \approx \rho_{c,p}\left[\mathrm{SE}(c_y)\mathrm{SE}(p_y)\right],$$

and $\rho_{c,p}$ denotes correlation of *c* and *p* among years.

The submodels of the delta-lognormal model were built using a backward selection procedure based on type 3 analyses with an inclusion level of significance of $\alpha = 0.05$. Binomial submodel performance was evaluated using AIC, while the performance of the lognormal submodel was evaluated based on analyses of residual scatter and QQ plots in addition to AIC. Factors that could be included in the submodels were year, shrimp statistical zone, depth zone, time of day and season (only in annual models). For shrimp statistical zone, only zones 11 and 13-21 were included in the submodels, due to extremely low or nonexistent sampling in the other zones Due to the change in survey design, there was less coverage in all of the original depth zones, therefore the zones were consolidated based upon depths Zimmerman and Nance (2001). The new depth zones were 5-10, 10-15, 15-20, 20-25, 25-30, 35-40, 40-45 and 45-60 fathoms.

Indices of Abundance Results

Brown Shrimp

For the delta-lognormal model built for the summer groundfish survey, all variables were significant in both submodels, therefore no additional model runs were necessary. The annual abundance index is presented in Table 2. The model tables are in Appendix Table 1 and show the significance of each factor in the model.

For the delta-lognormal model built for the fall groundfish survey, all variables were significant in both submodels, therefore no additional model runs were necessary. The annual abundance index is presented in Table 3. The model tables are in Appendix Table 2 and show the significance of each factor in the model.

For the delta-lognormal model built for the annual groundfish survey, all variables were significant in both submodels, therefore no additional model runs were necessary. The annual abundance index is presented in Table 4. The model tables are in Appendix Table 3 and show the significance of each factor in the model.

White Shrimp

For the delta-lognormal model built for the summer groundfish survey, all variables were significant in both submodels, therefore no additional model runs were necessary. The annual abundance index is presented in Table 5. The model tables are in Appendix Table 4 and show the significance of each factor in the model.

For the delta-lognormal model built for the fall groundfish survey, all variables were significant in both submodels, therefore no additional model runs were necessary. The annual abundance index is presented in Table 6. The model tables are in Appendix Table 5 and show the significance of each factor in the model.

For the delta-lognormal model built for the annual groundfish survey, all variables were significant in both submodels, therefore no additional model runs were necessary. The annual abundance index is presented in Table 7. The model tables are in Appendix Table 6 and show the significance of each factor in the model.

Literature Cited

Lo, N.C.H., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. *Canadian Journal of Fisheries and Aquatic Science* 49:2515-2526.

Zimmerman, R.J., J.M. Nance and J. Williams. 2001. Effects of hypoxia on the shrimp fishery off Louisiana and Texas. Pages 293-310 *in* N.N. Rabalais and R.E. Turner, editors. Coastal hypoxia consequences for living resources and ecosystems. Coastal and Estuarine Studies 58. American Geophysical Union, Washington, D.C.

Table 1. Annual breakdown of stations sampled by shrimp statistical zone and season.

Year	Summer											Fall											Annual Total
	11	13	14	15	16	17	18	19	20	21	Seasonal Total	11	13	14	15	16	17	18	19	20	21	Seasonal Total	
1987	14	6	20	19	25	20	16	25	28	19	192	17	15	14	16	17	15	15	15	18	3	145	337
1988	15	5	4	3	19	24	14	25	28	23	160	9	7	22	17	18	26	19	21	31	20	190	350
1989	6	0	3	18	25	7	15	20	29	24	147	22	12	19	17	22	20	17	22	25	26	202	349
1990	26	11	20	15	23	16	20	23	24	20	198	29	14	12	23	22	19	18	22	19	27	205	403
1991	16	12	21	13	23	22	24	18	23	26	198	19	6	24	14	20	25	24	19	25	22	198	396
1992	11	2	20	24	20	25	12	31	26	20	191	15	7	23	14	25	18	17	27	30	18	194	385
1993	14	10	19	17	24	19	14	29	24	22	192	44	10	19	17	26	18	16	25	28	18	221	413
1994	29	6	17	22	25	17	20	22	26	22	206	34	9	16	21	25	20	21	23	24	20	213	419
1995	10	10	16	18	22	23	13	27	26	21	186	19	10	17	18	24	19	14	26	30	19	196	382
1996	12	14	12	19	22	18	17	21	26	25	186	17	9	18	19	17	28	13	25	29	24	199	385
1997	10	0	12	16	22	23	10	28	26	26	173	12	10	17	20	26	19	18	23	22	24	191	364
1998	5	2	14	21	25	18	14	22	36	17	174	14	10	22	14	34	11	15	24	29	22	195	369
1999	14	7	20	19	20	23	13	25	32	20	193	14	9	17	18	29	18	12	28	29	22	196	389
2000	20	2	19	15	19	27	8	29	31	21	191	12	10	14	22	20	26	12	30	25	21	192	383
2001	3	7	18	18	13	3	10	9	17	21	119	12	10	17	19	26	20	14	27	28	23	196	315
2002	11	11	14	21	27	19	15	25	29	22	194	20	10	13	22	22	23	14	26	30	21	201	395
2003	17	9	10	8	2	17	20	22	26	23	154	43	9	16	21	24	22	20	23	25	23	226	380
2004	12	11	18	17	20	25	21	19	25	21	189	8	0	11	18	17	27	14	24	30	21	170	359
2005	10	10	9	11	16	21	5	28	22	27	159	40	11	20	16	33	18	14	23	24	27	226	385
2006	17	11	21	12	20	23	17	23	31	18	193	17	7	22	14	18	28	13	23	32	19	193	386
2007	12	0	6	15	22	23	7	29	32	21	167	0	9	20	17	18	28	17	20	18	26	173	340
2008	15	12	17	17	23	22	17	24	21	29	197	26	8	22	32	42	46	44	19	36	20	295	492
2009	33	11	18	30	39	46	53	33	29	23	315	22	7	12	15	30	49	47	31	36	22	271	586
Total	332	169	348	388	496	481	375	557	617	511	4274	465	209	407	424	555	543	428	546	623	488	4688	8962

Table 2. Indices of brown shrimp developed using the delta-lognormal model for 1987-2009 for the summer groundfish survey. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
1987	0.80208	192	93.968	0.43208	0.12190	0.33890	0.55087
1988	0.71875	160	90.367	0.41552	0.17801	0.29186	0.59157
1989	0.76871	147	149.950	0.68949	0.15338	0.50824	0.93536
1990	0.78788	198	146.991	0.67588	0.12339	0.52857	0.86425
1991	0.76263	198	231.146	1.06283	0.12995	0.82047	1.37680
1992	0.78534	191	45.981	0.21143	0.11658	0.16759	0.26673
1993	0.73958	192	112.783	0.51859	0.13298	0.39794	0.67581
1994	0.78641	206	98.867	0.45460	0.11875	0.35879	0.57600
1995	0.75806	186	181.061	0.83254	0.11503	0.66194	1.04710
1996	0.75806	186	127.468	0.58611	0.15063	0.43439	0.79084
1997	0.79769	173	93.627	0.43051	0.12747	0.33397	0.55495
1998	0.90805	174	158.454	0.72859	0.13063	0.56170	0.94507
1999	0.85492	193	216.321	0.99467	0.12120	0.78125	1.26640
2000	0.86911	191	211.114	0.97073	0.10615	0.78551	1.19962
2001	0.80672	119	109.987	0.50573	0.13746	0.38466	0.66491
2002	0.85567	194	177.824	0.81766	0.12356	0.63923	1.04589
2003	0.90260	154	183.131	0.84206	0.13490	0.64372	1.10150
2004	0.84127	189	264.616	1.21674	0.12336	0.95159	1.55576
2005	0.81132	159	181.711	0.83553	0.13664	0.63655	1.09672
2006	0.89637	193	752.690	3.46095	0.12333	2.70694	4.42499
2007	0.85030	167	300.528	1.38186	0.13288	1.06060	1.80045
2008	0.75127	197	383.772	1.76463	0.15760	1.29004	2.41381
2009	0.93016	315	689.691	3.17128	0.09295	2.63432	3.81769

Table 3. Indices of brown shrimp developed using the delta-lognormal model for 1987-2009 for the fall groundfish survey. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
1987	0.77931	145	54.715	0.57054	0.13407	0.43687	0.74512
1988	0.68947	190	34.371	0.35841	0.12481	0.27950	0.45959
1989	0.79703	202	68.713	0.71651	0.10862	0.57697	0.88981
1990	0.80488	205	96.879	1.01021	0.11519	0.80295	1.27098
1991	0.83333	198	84.743	0.88366	0.10461	0.71725	1.08869
1992	0.87629	194	83.437	0.87004	0.10558	0.70484	1.07397
1993	0.81448	221	76.419	0.79687	0.10697	0.64378	0.98636
1994	0.81221	213	76.709	0.79989	0.09564	0.66092	0.96809
1995	0.89286	196	101.124	1.05448	0.10373	0.85739	1.29688
1996	0.91960	199	72.055	0.75136	0.09785	0.61810	0.91335
1997	0.87435	191	81.662	0.85154	0.11439	0.67790	1.06965
1998	0.88205	195	83.215	0.86773	0.10362	0.70570	1.06695
1999	0.84694	196	77.262	0.80565	0.09338	0.66868	0.97069
2000	0.86979	192	116.432	1.21410	0.10657	0.98163	1.50163
2001	0.84184	196	93.205	0.97190	0.10951	0.78125	1.20908
2002	0.87065	201	88.996	0.92802	0.09378	0.76961	1.11902
2003	0.86283	226	81.847	0.85347	0.09759	0.70247	1.03693
2004	0.85882	170	93.439	0.97434	0.10568	0.78917	1.20296
2005	0.85398	226	109.496	1.14178	0.10655	0.92319	1.41212
2006	0.92228	193	179.113	1.86772	0.10512	1.51445	2.30339
2007	0.86705	173	84.525	0.88139	0.10849	0.70993	1.09427
2008	0.91864	295	178.074	1.85689	0.08644	1.56259	2.20661
2009	0.86716	271	189.257	1.97349	0.08378	1.66952	2.33282

Table 4. Indices of brown shrimp developed using the delta-lognormal model for 1987-2009 for the annual groundfish survey. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
1987	0.79228	337	78.531	0.53132	0.09474	0.43979	0.64189
1988	0.70286	350	56.869	0.38476	0.10656	0.31109	0.47587
1989	0.78510	349	105.196	0.71173	0.09298	0.59119	0.85685
1990	0.79653	403	120.154	0.81293	0.08598	0.68471	0.96517
1991	0.79798	396	139.723	0.94533	0.08470	0.79827	1.11948
1992	0.83117	385	76.070	0.51467	0.08652	0.43303	0.61170
1993	0.77966	413	90.131	0.60980	0.08315	0.51652	0.71993
1994	0.79952	419	87.636	0.59293	0.07796	0.50745	0.69281
1995	0.82723	382	147.177	0.99576	0.08226	0.84494	1.17350
1996	0.84156	385	98.779	0.66832	0.08839	0.56022	0.79727
1997	0.83791	364	88.790	0.60073	0.08592	0.50604	0.71314
1998	0.89431	369	132.271	0.89491	0.08899	0.74927	1.06887
1999	0.85090	389	139.933	0.94675	0.08086	0.80559	1.11265
2000	0.86945	383	158.039	1.06926	0.07706	0.91674	1.24715
2001	0.82857	315	109.112	0.73823	0.08915	0.61789	0.88200
2002	0.86329	395	134.095	0.90725	0.08114	0.77155	1.06682
2003	0.87895	380	131.739	0.89131	0.08420	0.75340	1.05447
2004	0.84958	359	172.900	1.16980	0.08696	0.98339	1.39155
2005	0.83636	385	151.775	1.02687	0.08706	0.86306	1.22177
2006	0.90933	386	365.265	2.47129	0.08245	2.09620	2.91351
2007	0.85882	340	167.770	1.13509	0.08957	0.94926	1.35731
2008	0.85163	492	300.182	2.03096	0.08418	1.71677	2.40265
2009	0.90102	586	347.337	2.35000	0.06236	2.07471	2.66181

Table 5. Indices of white shrimp developed using the delta-lognormal model for 1987-2009 for the summer groundfish survey. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
1987	0.13021	192	0.66187	0.44330	0.45347	0.18667	1.05272
1988	0.09375	160	0.28793	0.19285	0.62182	0.06146	0.60510
1989	0.20408	147	1.13854	0.76256	0.41394	0.34423	1.68926
1990	0.11111	198	0.35910	0.24052	0.51535	0.09112	0.63487
1991	0.23232	198	1.75383	1.17465	0.34449	0.60122	2.29501
1992	0.11518	191	0.83967	0.56238	0.46411	0.23249	1.36039
1993	0.15104	192	1.03593	0.69383	0.41564	0.31226	1.54166
1994	0.11650	206	0.55636	0.37263	0.46769	0.15310	0.90697
1995	0.16667	186	1.37975	0.92411	0.39676	0.43015	1.98530
1996	0.14516	186	0.51229	0.34311	0.45841	0.14325	0.82182
1997	0.15029	173	0.48654	0.32587	0.46810	0.13379	0.79371
1998	0.22414	174	1.29468	0.86713	0.36966	0.42387	1.77395
1999	0.24870	193	2.26853	1.51938	0.33869	0.78602	2.93699
2000	0.14660	191	0.52677	0.35282	0.44881	0.14978	0.83107
2001	0.18487	119	0.52694	0.35293	0.49553	0.13825	0.90094
2002	0.15979	194	1.14146	0.76451	0.40213	0.35246	1.65831
2003	0.16234	154	0.73823	0.49444	0.45188	0.20878	1.17092
2004	0.21164	189	1.47579	0.98843	0.36571	0.48664	2.00763
2005	0.28931	159	2.47101	1.65500	0.34454	0.84701	3.23376
2006	0.30052	193	3.53457	2.36734	0.31272	1.28513	4.36088
2007	0.29940	167	5.12958	3.43562	0.32776	1.81363	6.50823
2008	0.16751	197	1.59702	1.06963	0.38657	0.50709	2.25622
2009	0.29841	315	4.62394	3.09696	0.27324	1.81078	5.29671

Table 6. Indices of white shrimp developed using the delta-lognormal model for 1987-2009 for the fall groundfish survey. The nominal frequency of occurrence, the number of samples (N), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	Frequency	N	DL Index	Scaled Index	CV	LCL	UCL
1987	0.33103	145	1.9058	0.32738	0.33007	0.17208	0.62283
1988	0.37368	190	4.3707	0.75082	0.29201	0.42371	1.33046
1989	0.27228	202	4.1382	0.71087	0.39833	0.32996	1.53151
1990	0.27805	205	1.6746	0.28766	0.58117	0.09780	0.84612
1991	0.25758	198	3.0327	0.52097	0.39778	0.24205	1.12127
1992	0.34021	194	5.0883	0.87408	0.45318	0.36826	2.07466
1993	0.39819	221	7.2817	1.25087	0.29913	0.69652	2.24640
1994	0.34742	213	2.8005	0.48107	0.26566	0.28535	0.81103
1995	0.34184	196	7.2001	1.23685	0.30168	0.68543	2.23188
1996	0.32161	199	5.6405	0.96894	0.31413	0.52462	1.78959
1997	0.29843	191	2.6804	0.46045	0.25582	0.27829	0.76185
1998	0.41026	195	13.3271	2.28936	0.27386	1.33699	3.92011
1999	0.33673	196	2.1736	0.37339	0.32814	0.19697	0.70784
2000	0.40625	192	10.6025	1.82132	0.32532	0.96581	3.43461
2001	0.42857	196	8.4734	1.45558	0.29757	0.81289	2.60639
2002	0.42786	201	9.3967	1.61419	0.32982	0.84886	3.06952
2003	0.28319	226	2.6878	0.46172	0.33269	0.24152	0.88268
2004	0.31765	170	4.3168	0.74155	0.27697	0.43052	1.27727
2005	0.36726	226	5.3686	0.92224	0.30368	0.50918	1.67039
2006	0.36788	193	6.8866	1.18300	0.27473	0.68974	2.02899
2007	0.38150	173	4.9526	0.85076	0.28502	0.48647	1.48784
2008	0.31864	295	9.0771	1.55928	0.23174	0.98688	2.46368
2009	0.39114	271	10.8141	1.85766	0.23149	1.17630	2.93370

Table 7. Indices of white shrimp developed using the delta-lognormal model for 1987-2009 for the annual groundfish survey. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
1987	0.21662	337	1.43406	0.35425	0.23395	0.22325	0.56210
1988	0.24571	350	1.73856	0.42947	0.20782	0.28466	0.64794
1989	0.24355	349	2.97593	0.73513	0.24412	0.45434	1.18944
1990	0.19603	403	1.10804	0.27371	0.27008	0.16100	0.46534
1991	0.24495	396	3.58548	0.88570	0.24588	0.54557	1.43789
1992	0.22857	385	3.25537	0.80415	0.25745	0.48450	1.33470
1993	0.28329	413	4.02487	0.99424	0.22187	0.64134	1.54132
1994	0.23389	419	1.78289	0.44042	0.21114	0.29004	0.66875
1995	0.25654	382	5.13225	1.26779	0.21350	0.83112	1.93387
1996	0.23636	385	2.34643	0.57962	0.20661	0.38509	0.87243
1997	0.22802	364	1.92590	0.47574	0.24543	0.29329	0.77169
1998	0.32249	369	6.77947	1.67469	0.17774	1.17693	2.38298
1999	0.29306	389	3.15180	0.77857	0.25324	0.47287	1.28189
2000	0.27676	383	4.44796	1.09875	0.21498	0.71825	1.68083
2001	0.33651	315	4.13747	1.02205	0.20883	0.67611	1.54501
2002	0.29620	395	5.15714	1.27394	0.20236	0.85338	1.90176
2003	0.23421	380	2.40230	0.59343	0.23208	0.37534	0.93824
2004	0.26184	359	3.55814	0.87895	0.21891	0.57021	1.35484
2005	0.33506	385	4.94382	1.22124	0.20372	0.81592	1.82792
2006	0.33420	386	7.99301	1.97446	0.19756	1.33503	2.92016
2007	0.34118	340	6.78114	1.67510	0.19815	1.13131	2.48027
2008	0.25813	492	4.90864	1.21255	0.19313	0.82695	1.77795
2009	0.34130	586	9.53773	2.35605	0.14873	1.75267	3.16714

APPENDIX

Appendix Table 1. Summary of backward selection procedure for building delta-lognormal submodels for brown shrimp index of relative abundance from 1987 to 2009 for summer groundfish.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 24523.9)*						*Lognormal Submodel Type 3 Tests (AIC 12929.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	22	1479	112.96	5.09	<.0001	<.0001	22	3456	27.72	<.0001
Time of Day	1	3212	139.76	139.76	<.0001	<.0001	1	3456	1203.42	<.0001
Shrimp Statistical Zone	9	3151	293.72	32.63	<.0001	<.0001	9	3456	36.90	<.0001
Depth Zone	8	3021	453.76	56.72	<.0001	<.0001	8	3456	59.39	<.0001

Appendix Table 2. Summary of backward selection procedure for building delta-lognormal submodels for brown shrimp index of relative abundance from 1987 to 2009 for fall groundfish.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 25693.7)*						*Lognormal Submodel Type 3 Tests (AIC 13738.5)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	22	1641	102.03	4.60	<.0001	<.0001	22	3955	13.18	<.0001
Time of Day	1	4171	240.63	240.63	<.0001	<.0001	1	3955	1007.53	<.0001
Shrimp Statistical Zone	9	4126	190.44	21.16	<.0001	<.0001	9	3955	17.52	<.0001
Depth Zone	8	4003	456.80	57.10	<.0001	<.0001	8	3955	41.79	<.0001

Appendix Table 3. Summary of backward selection procedure for building delta-lognormal submodels for brown shrimp index of relative abundance from 1987 to 2009 for annual groundfish.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 47381.7)*						*Lognormal Submodel Type 3 Tests (AIC 27215.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	22	3180	159.08	7.20	<.0001	<.0001	22	7451	34.40	<.0001
Season	1	8391	36.14	36.14	<.0001	<.0001	1	7451	162.89	<.0001
Time of Day	1	8364	363.31	363.31	<.0001	<.0001	1	7451	1988.63	<.0001
Shrimp Statistical Zone	9	8305	352.59	39.18	<.0001	<.0001	9	7451	35.35	<.0001
Depth Zone	8	8111	881.64	110.20	<.0001	<.0001	8	7451	70.44	<.0001

Appendix Table 4. Summary of backward selection procedure for building delta-lognormal submodels for white shrimp index of relative abundance from 1987 to 2009 for summer groundfish.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 23982.1)*						*Lognormal Submodel Type 3 Tests (AIC 2830.0)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	22	4233	144.05	6.55	<.0001	<.0001	22	770	2.64	<.0001
Time of Day	1	4233	27.76	27.76	<.0001	<.0001	1	770	19.97	<.0001
Shrimp Statistical Zone	9	4233	60.74	6.75	<.0001	<.0001	9	770	8.96	<.0001
Depth Zone	8	4233	496.87	62.11	<.0001	<.0001	8	770	13.65	<.0001

Appendix Table 5. Summary of backward selection procedure for building delta-lognormal submodels for white shrimp index of relative abundance from 1987 to 2009 for fall groundfish.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 28462.3)*						*Lognormal Submodel Type 3 Tests (AIC 5568.3)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	22	1646	95.26	4.29	<.0001	<.0001	22	1589	4.41	<.0001
Time of Day	1	3431	4.45	4.45	0.0350	0.0350	1	1589	3.71	0.0543
Shrimp Statistical Zone	9	3292	423.79	47.08	<.0001	<.0001	9	1589	26.32	<.0001
Depth Zone	8	3384	892.65	111.57	<.0001	<.0001	8	1589	40.32	<.0001

Appendix Table 6. Summary of backward selection procedure for building delta-lognormal submodels for white shrimp index of relative abundance from 1987 to 2009 for annual groundfish.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 49627.9)*						*Lognormal Submodel Type 3 Tests (AIC 8518.1)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	22	3179	162.32	7.35	<.0001	<.0001	22	2399	3.98	<.0001
Season	1	8275	429.17	429.17	<.0001	<.0001	1	2399	150.26	<.0001
Time of Day	1	8296	23.54	23.54	<.0001	<.0001	1	2399	16.03	<.0001
Shrimp Statistical Zone	9	8124	487.21	54.13	<.0001	<.0001	9	2399	28.54	<.0001
Depth Zone	8	7469	1653.45	206.68	<.0001	<.0001	8	2399	55.25	<.0001