SEDAR34-WP18: Estimates for Atlantic Sharpnose and Bonnethead Sharks in the Gulf of Mexico, 1972-2011

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Abstract

WinBUGS shrimp bycatch estimates for Atlantic sharpnose and bonnethead sharks in the Gulf of Mexico were generated using the approaches developed by Scott Nichols in the SEDAR 7 Gulf of Mexico red snapper assessment (Nichols 2004a, 2004b) and SEDAR 13 Gulf of Mexico small coastal sharks assessment (Nichols 2007). In addition to the two WinBUGS shrimp bycatch estimations, we also did two "back-of-the-envelope" estimates of the observed bycatch.

Introduction

A WinBUGS shrimp bycatch estimation model was developed and applied in the SEDAR 7 Gulf of Mexico red snapper assessment (Nichols 2004a, 2004b). The central tendencies for annual bycatch for red snapper were not greatly different from the generalized linear model (GLM) results, but the confidence intervals were more plausible (Nichols 2007). Although this model is robust for data-rich species such as red snapper, this model was unexpectedly sensitive to the prior distribution used for the year effects. To solve for the unexpected sensitivity to the priors used for the year effect for data-poor species such as sharks, an overall mean CPUE term was added to the WinBUGS shrimp bycatch estimation model structure in SEDAR 13 (Nichols 2007). This change makes the model look more like a traditional analysis of variance structure, but there is a cost: running times were roughly tripled. Because the WinBUGS shrimp bycatch estimation model, priors, and datasets used for the SEDAR 13 Gulf of Mexico Atlantic sharpnose and bonnethead sharks assessment were not well documented, we are not able to reproduce the SEDAR 13 results. Therefore, we presented the WinBUGS bycatch estimates for Atlantic sharpnose and bonnethead sharks in the Gulf of Mexico based on two WinBUGS models with a variety of combinations of prior distribution assumptions, depth-zone strata, and datasets in this report.

Methods

WinBUGS shrimp bycatch estimates for Atlantic sharpnose and bonnethead sharks in the Gulf of Mexico were generated using the approaches developed by Scott Nichols in the SEDAR 7 Gulf of Mexico red snapper assessment (Nichols 2004a, 2004b) and SEDAR 13 Gulf of Mexico small coastal sharks assessment (Nichols 2007). Recently, Linton (2012) used the approaches developed by Scott Nichols in the SEDAR 7 Gulf of Mexico red snapper assessment for the SEDAR 31 Gulf of Mexico red snapper assessment. A brief summary of the data sources and models are provided in this report and in Linton (2012), while a more detailed description can be found in Nichols (2004a, 2004b, 2007). The data used in this analysis came from various shrimp observer programs, the SEAMAP groundfish survey, shrimp effort estimates and the Vessel Operating Units file (VOUF). The primary data on CPUE in the shrimp fishery came from a series of shrimp observer programs, which began in 1972 and extend to the current shrimp observer program (Scott-Denton 2004). In the Gulf of Mexico, red snapper *Lutjanus campechanus* and 14 other species of commercial, recreational and ecological importance were recorded. These included: Atlantic croaker, *Micropogonias undulates*; black drum, *Pogonias cromis*; cobia, *Rachycentron canadum*; king mackerel, *Scomberomorus cavalla*; lane snapper, *Lutjanus synagris*; longspine porgy, *Stenotomus caprinus*; red drum, *Sciaenops ocellatus*; seatrout, *Cynoscion spp*.; other snapper, *Lutjanus spp.*; grouped sharks, *Order Selachii*; southern flounder, *Paralichthys lethostigma*; spotted seatrout, *Cynoscion nebulosus*; Spanish mackerel, *Scomberomorus maculatus*; and vermilion snapper, *Rhomboplites aurorubens*. The remaining finfish species were grouped into a finfish other category (Scott-Denton 2004). The following changes have been made in observer program methods since SEDAR 13 (Scott-Denton et al. 2012, Scott-Denton personal communication). From 1992 through 2008 (except for characterization trips coded GC and FC), all shark species were grouped. Beginning January 2009, identification of some shark species (as well as other species) was implemented. Both Atlantic sharpnose and bonnethead sharks are on the list of species to be identified - that began in January 2009.

Additional CPUE data were obtained from the SEAMAP groundfish survey. Only data from 40 ft trawls by the Oregon II were used in this analysis, because these trawls were identified as being most similar to trawls conducted by the shrimp fishery (Linton 2012).

Point estimates and associated standard errors of shrimp effort were generated by the NMFS Galveston Lab using their SN-pooled model (Nance 2004). In order to assign fishing activity to a geographical location, the continental shelf of the Gulf of Mexico has been divided into 21 statistical grids (Figure 1) (Nance 2004). Effort was estimated by year, season, area, and depth. There are 960 or 1440 year/season/area/depth combinations with 2 or 3 depth-zone strata, respectively (Table 1). Shrimp effort declined sharply from 2002 to 2008, and has remained at relatively low levels from 2008 to 2011 (Figure 2). Most shrimp effort takes place at depths less than 30 fathoms. In the 3 depth-zone strata, seven out of 1440 combinations did not have estimates of shrimp effort due to a lack of reported effort for those combinations. All seven empty combinations represented depths greater than 30 fathoms. Since the Galveston lab effort estimates were used to specify year/season/area/depth-specific priors on the predicted effort in the WinBUGS shrimp bycatch estimation model, the empty combinations needed to be filled to ensure that each combination had a prior. Therefore, the empty combinations were filled using the procedure developed in SEADAR 31 (i.e. using the average effort and standard error calculated from the year/season/area/depth combinations in the two years preceding and following the empty combination) (Linton 2012).

Most observer program CPUE data were expressed in fish per net-hour, while the shrimp effort data were expressed in vessel-days. Therefore, data from the VOUF were needed to estimate the average number of nets per vessel (NPV) for the shrimp fishery. The VOUF average nets per vessel were used to specify priors on the predicted nets per vessel in the WinBUGS shrimp bycatch estimation model. The average number of nets per vessel increased gradually from 1972 to 1996, and remained relatively constant from 1996 to 2011 at approximately three nets per vessel (Figure 2).

WinBUGS shrimp bycatch estimation model 1 (Eq1) was used to estimate shrimp bycatch CPUE in the SEDAR 7 (i.e. model 02 from Nichols 2004a) and SEDAR 31 Gulf of Mexico red snapper assessments (Linton 2012).

$$\ln(CPUE)_{[i,j,k,l,m]} = \quad year_{[i]} + season_{[j]} + area_{[k]} + depth_{[l]} + dataset_{[m]} + local_{[i,j,k,l,m]} \quad \text{(Eq1)}$$

WinBUGS shrimp bycatch estimation model 2 (Eq2) was used to estimate shrimp bycatch CPUE in the SEDAR 13 Gulf of Mexico small coastal sharks assessment (Nichols 2007).

$$\ln(CPUE)_{[i,j,k,l,m]} = mean + year_{[i]} + season_{[j]} + area_{[k]} + depth_{[l]} + dataset_{[m]} + local_{[i,j,k,l,m]} \quad \text{(Eq2)}$$

Where $CPUE_{[i,j,k,l,m]}$ is year/season/area/depth/dataset-specific CPUE, $year_{[i]}$, $season_{[j]}$, $area_{[k]}$, $depth_{[l]}$ and $dataset_{[m]}$ are main the effects, and $local_{[i,j,k,l,m]}$ is the local effect. The factor levels for the main effects are presented in Table 1.

Two dataset scenarios were evaluated based on alternative combinations of observer program data (Table 1). The first dataset scenario combined non-BRD and BRD data and resulted in two CPUE time series (Observer program non-BRD/BRD, Research vessel). The second dataset scenario separated non-BRD and BRD data and resulted in three CPUE time series (Observer program non-BRD, Observer program BRD, Research vessel). When combined observer program non-BRD/BRD datasets are used, there will be only one combined observer program CPUE for each year/season/area/depth combination. When separated observer program non-BRD/BRD datasets are used, there will be two observer program CPUEs (i.e. CUPE with BRD and CPUE without BRD) for each year/season/area/depth combination.

Two depth strata scenarios were evaluated based on alternative combinations of depth data (Table 1). The first included 2 depth-zone strata (<= 10fm, > 10fm). The second included 3 depth-zone strata (<= 10fm, >10fm & <=30fm, >30fm).

The only difference between the SEDAR 7 and SEDAR 13 WinBUGS shrimp bycatch estimation models is an overall mean CPUE term in the model structure. Adding an overall mean CPUE term to the WinBUGS shrimp bycatch estimation model was supposed to solve the unexpected sensitivity to the priors used for the year effect, especially for data-poor species such as sharks (SEDAR 13-DW32, Nichols 2007). We used the observed overall mean CPUE to specify priors on the predicted mean CPUE in Eq2.

The main effects and local term in Eq1 and Eq2 were assigned normal prior distributions on the log-scale. The local term was used to model perturbations from main predictions. A lognormal hyper prior was assigned to the precision ($1/\sigma^2$) parameter of the local term. Therefore, the data determined the distribution of the local term in year/season/area/depth/dataset combinations with data, while the distribution of the local term defaulted to the prior with fitted precision for year/season/area/depth/dataset combinations without data. In effect, the local term became a fixed effect for year/season/area/depth/dataset combinations with data and a random effect for year/season/area/depth/dataset combinations without data (Linton 2012).

Catch were estimated with the following equation:

$$catch_{[i,j,k,l]} = CPUE_{[i,j,k,l,m]} * npv_{[i,j,k,l]} * effort_{[i,j,k,l]} \qquad \text{(Eq3)}$$

where $catch_{[i,j,k,l]}$ is year/season/area/depth-specific catch, $CPUE_{[i,j,k,l,m]}$ is year/season/area/depth/dataset-specific CPUE, $npv_{[i,j,k,l]}$ is year/season/area/depth-specific nets per vessel, $effort_{[i,j,k,l]}$ is year/season/area/depth-specific effort. $catch_{[i,j,k,l]}$ was assumed to follow a negative binomial distribution, which was modeled as a conjugate gamma-Poisson distribution due to computational issues.

The shrimp bycatch estimation models were fit using WinBUGS version 1.4.3. Markov Chain Monte Carlo (MCMC) methods were used to estimate the marginal posterior distributions of key parameters and derived quantities. Convergence of the chains was determined by visual inspection of trace plots, marginal posterior density plots, and Gelman-Rubin statistic (Brooks and Gelman 1998) plots. Convergence of the chains takes more iterations for the SEDAR 7 model than the SEDAR 13 model. We did a couple of test runs with the SEDAR 13 model with 20000 and 54000 iteration and found the results are almost identical between 20000 and 54000 iterations. To save time, we ran two parallel chains of 54000 iterations for the SEDAR 7 model and ran two parallel chains of 20000 iterations for the SEDAR 13 model. The first 4000 iterations of each chain were dropped as a burn-in period, to remove the effects of the initial parameter values. A thinning interval of five iterations (i.e. only every fifth iteration was saved) was applied to each chain, to reduce autocorrelation in parameter estimates and derived quantities. For each WinBUGS shrimp bycatch estimation model, 2 or 3 depth-zone strata and combined or separated observer program non-BRD/BRD datasets scenarios were used in bycatch estimations (see Table 1 for details).

In addition to the two WinBUGS shrimp bycatch estimations, we also did two "back-of-the-envelope" estimates of the observed bycatch. WinBUGS shrimp bycatch estimation models have been accepted and applied in a series of SEDARs for shrimp bycatch estimates since 2004. However comparisons of the observed and WinBUGS shrimp bycatch estimations might further demonstrate the justifications of using the WinBUGS shrimp bycatch estimation models and the limitations of the "back-of-the-envelope" estimates of the observed bycatch.

Approach 1:

$$Annual\_All\_Tow\_CPUE\_A1_{[yr]} = Average(All\_Tow\_CPUE_{[yr]}) \quad \text{Eq4)}$$

$$Obs\_Bycatch\_A1_{[yr]} = Annual\_All\_Tow\_CPUE\_A1_{[yr]} * effort_{[yr]} * npv_{[yr]} \quad \text{(Eq5)}$$

Where yr is year (1972-2011), $Annual\_All\_Tow\_CPUE\_A1_{[yr]}$ is the observed annual all-tow CPUE estimated with approach 1, $All\_Tow\_CPUE_{[yr]}$ is the observed all-tow CPUE, $effort_{[yr]}$ is annual effort, $npv_{[yr]}$ is year-specific nets per vessel, $Obs\_Bycatch\_A1_{[yr]}$ is the observed annual bycatch estimated with approach 1.

Approach 2:

$$Annual\_NZCT\_CPUE\_A2_{[yr]} = \exp\{average[\ln(NZCT\_CPUE_{[yr]})] + 0.5*var[\ln(NZCT\_CPUE_{[yr]})]\} \quad \text{(Eq6)}$$

$$Annual\_All\_Tow\_CPUE\_A2_{[yr]} = Annual\_NZCT\_CPUE\_A2_{[yr]} * Percent\_of\_NZCT_{[yr]} \quad \text{(Eq7)}$$

$$Obs\_Bycatch\_A2_{[yr]} = Annual\_NZCT\_CPUE\_A2_{[yr]} * effort_{[yr]} * npv_{[yr]} \quad \text{(Eq8)}$$

Where $Annual\_NZCT\_CPUE\_A2_{[yr]}$ is the observed annual non-zero-catch-tow CPUE estimated with approach 2, $NZCT\_CPUE_{[yr]}$ is the observed non-zero-catch-tow CPUE, $Annual\_All\_Tow\_CPUE\_A2_{[yr]}$ is the observed annual all-tow CPUE estimated with approach 2, $Percent\_of\_NZCT_{[yr]}$ is the observed annual percent of non-zero-catch tows, $Obs\_Bycatch\_A2_{[yr]}$ is the observed annual bycatch estimated with approach 2.

Results and discussion

Atlantic sharpnose shark

The WinBUGS shrimp bycatch estimation model, priors, and data used in the SEDAR 13 Atlantic sharpnose shark in the Gulf of Mexico were not well documented. With the prior for the year effect set equal to 0 (i.e. yx= 0), WinBUGS estimates of bycatch with the SEDAR 7 model (i.e. Eq1 of this report) are similar to the SEDAR 13 estimates during 1972-1992 (Figure 3).

WinBUGS estimates of bycatch in the present analysis are extremely high in 1981, 2009, 2010 and 2011. The changes in observer program methods (see Methods for details) might be the reasons why the estimates are very different between the present analysis and the SEDAR 13 after 1992, and why the estimates of bycatch in the present analysis are extremely high in 2009, 2010 and 2011.

WinBUGS estimates of bycatch are sensitive to the priors used for the year effect with the SEDAR 7 model (Figure 4). After adding an overall mean CPUE term to the SEDAR 7 model (i.e. Eq2 of this report), the estimates of bycatch are not sensitive to the priors used for the overall mean CPUE term (Figure 5). WinBUGS estimates of bycatch for data-poor Atlantic sharpnose shark are much lower with the overall mean CPUE term than without the overall mean CPUE term for most of years (Figure 6). However, estimates of bycatch for data-rich Gulf of Mexico red snapper are almost identical with or without the overall mean CPUE term added to the SEDAR 7 model (Figure 7).

Deleting data from the most recent five years (2007-2011) led to a slight decrease in our WinBUGS estimates of historical bycatch (1972-2006) with or without an overall mean CPUE term added to the SEDAR 7 model (Figures 8 and 9).

Without an overall mean CPUE term added to the SEDAR 7 model (i.e. Eq1 of this report), estimates of bycatch are slightly lower with combined observer program non-BRD/BRD datasets (2DS) than with separated observer program non-BRD/BRD datasets (3DS) regardless of whether 2 or 3 depth-zone strata are considered (2DP or 3DP) (Figures 10 and 11). With an overall mean CPUE term added to the SEDAR 7 model (i.e. Eq2 of this report), estimates of bycatch are almost identical with combined or separated observer program non-BRD/BRD datasets (2DS or 3DS) regardless of whether 2 or 3 depth-zone strata are considered (2DP or 3DP) (Figures 12 and 13). Given there are Non-Zero-Catch (NZC) tows from the observer program with and without BRDs in only 2 years (2002 and 2011) since BRDs were implemented in 1998, the effects of BRDs on bycatch estimates should be treated with great caution.

Without an overall mean CPUE term added to the SEDAR 7 model, estimates of bycatch seem to be slightly higher with 2 depth-zone strata (2DP) than with 3 depth-zone strata (3DP) regardless of whether combined or separated observer program non-BRD/BRD datasets are used (2DS or 3DS) (Figures 14 and 15). With an overall mean CPUE term added to the SEDAR 7 model, estimates of bycatch are almost identical with 2 or 3 depth-zone strata (2DP or 3DP) regardless of whether combined or separated observer program non-BRD/BRD datasets are used (2DS or 3DS) (Figures 16 and 17).

Estimates of bycatch are high in 1981, 2009, 2011 and 2011. A number of high NZC-tow catch tows are found in 2009, 2010 and 2011, but not in 1981 (Figure 18). However the observed NZC-tow CPUEs seem not to be very different from the observed overall mean NZC-tow CPUE in these three years (Figure 19). Only 5% of tows caught Atlantic sharpnose shark (Figure 20), but 40% of tows caught red snapper. Average number of NZC tows for Atlantic sharpnose shark is only 69 a year (Figure 21), but average number of NZC tows for red snapper is about 617 a year. Total number of NZC tows for Atlantic sharpnose shark is only 2751 during 1972-2011. Given there are 960 or 1440 year/season/area/depth combinations with 2 or 3 depth-zone strata, Atlantic sharpnose are a data-poor species and zero inflated. Estimates of bycatch are high in 1981, 2009, 2010 and 2011, but the observed annual mean all-tow CPUEs and annual mean NZC-tow CPUEs seem not to be very different from their overall mean CPUEs in these 4 years (Figures 22 and 23). Observed overall all-tow CPUE for Atlantic sharpnose shark is 0.37 sharks per net-hour.

"Back-of-the-envelope" estimates of the observed bycatch are almost identical with approach 1 and approach 2 (Figure 24, see Methods for details). "Back-of-the-envelope" estimates of the observed bycatch are much higher than WinBUGS estimates of bycatch in SEDAR 13 (Figure 24).

Without an overall mean CPUE term added to the SEDAR 7 model and with combined observer program non-BRD/BRD datasets (2DS), the variability of bycatch estimates with 3 depth-zone strata (3DP) seems to be smaller than with 2 depth-zone strata (2DP) (Figure 25). With an overall mean CPUE term added to the SEDAR 7 model and with combined observer program non-BRD/BRD datasets (2DS), the variability of bycatch estimates with 2 or 3 depth-zone strata (2 DP or 3DP) is almost identical (Figure 25). The variability of bycatch estimates is much lower with the overall mean CPUE term than without the overall mean CPUE term for most of years (Figure 25).

Without an overall mean CPUE term added to the SEDAR 7 model and with separated observer program non-BRD/BRD datasets (3DS), the variability of bycatch estimates with 3 depth-zone strata (3DP) seems to be smaller than with 2 depth-zone strata (2DP) (Figure 26). With an overall mean CPUE term added to the SEDAR 7 model and with separated observer program non-BRD/BRD datasets (3DS), the variability of bycatch estimates with 2 or 3 depth-zone strata (2DP or 3DP) is almost identical (Figure 26). The variability of bycatch estimates is much lower with the overall mean CPUE term than without the overall mean CPUE term for most of years (Figure 26).

Recommended WinBUGS Estimates of Bycatch for Atlantic Sharpnose Shark in the Gulf of Mexico

With or without an overall mean CPUE term added to the SEDAR 7 WinBUGS shrimp bycatch estimation model and with combined observer program non-BRD/BRD datasets (2DS), estimates of bycatch with 2 or 3 depth-zone strata (2DP or 3DP) are very similar. To be consistent with SEDAR 13 and given there are NZC tows from the observer program with and without BRDs in only 2 years (2002 and 2011) since BRDs were implemented in 1998, 2 depth-zone strata (2DP) and combined observer program non-BRD/BRD datasets (2DS) are recommended for SEDAR 34 (Figures 27 and 28, Tables 2 and 3).

With an overall mean CPUE term added to the SEDAR 7 model (used in the SEDAR 13 for Atlantic sharpnose and bonnethead sharks in the Gulf of Mexico, but not used in the SEDAR 31 for red snapper in the Gulf of Mexico), estimates of bycatch are not sensitive to the priors and the variability of bycatch estimates is much lower. However, estimates of bycatch are more-SEDAR-13-like with the prior for the year effect set equal to 0 without an overall mean CPUE term added to the SEDAR 7 model during 1972-1992 (Figures 27 and 28, Tables 2 and 3).

Estimates of bycatch are high in1981, 2009, 2010 and 2011 (Figures 27 and 28, Tables 2 and 3). An extremely high estimate of bycatch in 1981 was replaced with the geometric mean of 1978-1982 in SEDAR 13.

The changes in observer program methods (see Methods for details) might be the reasons why the estimates are very different between the present analysis and SEDAR 13 after 1992, and why the estimates of bycatch in the present analysis are extremely high in 2009, 2010 and 2011. The panel needs to decide which model should be used for SEDAR 34 and what should be done for the high estimates of bycatch in1981, 2009, 2010 and 2011 for SEDAR 34.

Bonnethead Shark

The WinBUGS shrimp bycatch estimation model, priors, and data used for the SEDAR 13 bonnethead were not well documented. With the prior for the year effect set equal to -2 (i.e. yx= -2), WinBUGS estimates of bycatch with the model used in SEADAR 7 (Nichols 2004, Eq1 of this report) are similar to the SEDAR 13 estimates during 1972-1992 (Figure 29). As in SEDAR 13, WinBUGS estimate of bycatch is extremely high in 1980 in this analysis. WinBUGS estimates of bycatch in the present analysis are high in 2009, 2010 and 2011, but these estimates are not very different from the overall mean of the SEDAR 13 estimates. The changes in observer program methods (Scott-Denton et al. 2012, Scott-Denton personal communication, see Methods for details) might be the reasons why the estimates are very different between the present analysis and SEDAR 13 after 1992, and why the estimates of bycatch in the present analysis are high in 2009, 2010 and 2011.

WinBUGS estimates of bycatch are sensitive to the priors used for the year effect with the SEDAR 7 model (Figure 29). After adding an overall mean CPUE term to the SEDAR 7 WinBUGS shrimp bycatch estimation model (i.e. Eq2 of this report), the estimates of bycatch are not sensitive to the priors used for the overall mean CPUE. WinBUGS estimates of bycatch for data-poor Gulf of Mexico bonnethead shark are lower with the overall mean CPUE term than without the overall mean CPUE term for most years (Figure 30). However, estimates of bycatch for data-rich Gulf of Mexico red snapper are almost identical with or without the overall mean CPUE term added to the SEDAR 7 model (Figure 7).

Without an overall mean CPUE term added to the SEDAR 7 model (i.e. Eq1 of this report), estimates of bycatch are slightly lower with combined observer program non-BRD/BRD datasets (2DS) than with separated observer program non-BRD/BRD datasets (3DS) regardless of whether 2 or 3 depth-zone strata are considered (2DP or 3DP) (Figures 31 and 32). With an overall mean CPUE term added to the SEDAR 7 model (i.e. Eq2 of this report), estimates of bycatch are almost identical with combined or separated observer program non-BRD/BRD datasets (2DS or 3DS) regardless of whether 2 or 3 depth-zone strata are considered (2DP or 3DP) (Figures 33 and 34). Given there are NZC tows from the observer program with and without BRDs in only 3 years (2002, 2005 and 2011) since BRDs were implemented in 1998, the effects of BRDs on bycatch estimates should be treated with great caution.

Without an overall mean CPUE term added to the SEDAR 7 model (i.e. Eq1 of this report), estimates of bycatch seem to be slightly higher with 2 depth-zone strata (2DP) than with 3 depth-zone strata (3DP) regardless of whether combined or separated observer program non-BRD/BRD datasets (2DS or 3DS) are used (Figures 35 and 36). With an overall mean CPUE term added to the SEDAR 7 model (i.e. Eq2 of this report), estimates of bycatch are almost identical with 2 or 3 depth-zone strata (2DP or 3DP) regardless of whether combined or separated observer program non-BRD/BRD datasets (2DS or 3DS) are used (Figures 37 and 38).

Estimate of bycatch is extremely high in 1980, but the observed NZC-tow catch and NZC-tow CPUEs seem not to be very different from their overall mean NZC-tow catch/CPUE in 1980 (Figures 39 and 40). Only 1.6% of tows caught bonnethead shark (Figure 41), but 40% of tows caught red snapper. Average number of NZC tows for bonnethead shark is only 23 a year (Figure 42), but average number of NZC tows for red snapper is about 617 a year. Total number of NZC tows for bonnethead shark is only 905 during 1972-2011. Given there are 960 or 1440 year/season/area/depth combinations with 2 or 3 depth-zone strata, bonnethead are a data-poor species and zero inflated. Estimate of bycatch is extremely high in 1980, but the observed annual mean all-tow CPUEs and annual mean NZC-tow CPUEs seem not to be very different from their overall mean CPUEs in 1980 (Figures 43 and 44). Observed overall all-tow CPUE for bonnethead shark is 0.07 sharks per net-hour.

"Back-of-the-envelope" estimates of the observed bycatch are almost identical with approach 1 and approach 2 (Figure 45, see Methods for details). "Back-of-the-envelope" estimates of the observed bycatch are much higher than WinBUGS estimates of bycatch in SEDAR 13 before 2000 (Figure 45).

Without an overall mean CPUE term added to the SEDAR 7 model (i.e. Eq1 of this report) and with combined observer program non-BRD/BRD datasets (2DS), the variability of bycatch estimates with 3 depth-zone strata (3DP) seems to be smaller than with 2 depth-zone strata (2DP) (Figure 46). With an overall mean CPUE term added to the SEDAR 7 model (i.e. Eq2 of this report) and with combined observer program non-BRD/BRD datasets (2DS), the variability of bycatch estimates with 2 or 3 depth-zone strata (3DP) is almost identical (Figure 46). The variability of bycatch estimates is much lower with the overall mean CPUE term than without the overall mean CPUE term for most of years (Figure 46).

Without an overall mean CPUE term added to the SEDAR 7 model (i.e. Eq1 of this report) and with combined observer program non-BRD/BRD datasets (2DS), the variability of bycatch estimates with 3 depth-zone strata (3DP) seems to be smaller than with 2 depth-zone strata (2DP) (Figure 47). With an overall mean CPUE term added to the SEDAR 7 model (i.e. Eq2 of this report) and with combined observer program non-BRD/BRD datasets (2DS), the variability of bycatch estimates with 2 or 3 depth-zone strata (2DP or 3DP) is almost identical (Figure 47). The variability of bycatch estimates is much lower with the overall mean CPUE term than without the overall mean CPUE term for most of years (Figure 47).

Recommended WinBUGS Estimates of Bycatch for Bonnethead Shark in the Gulf of Mexico

With or without an overall mean CPUE term added to the SEDAR 7 WinBUGS shrimp bycatch estimation model and with combined observer program non-BRD/BRD datasets (2DS), estimates of bycatch with 2 or 3 depth-zone strata (2DP or 3DP) are very similar. To be consistent with SEDAR 13 and given there are NZC tows from the observer program with and without BRDs in only 3 years (2002, 2005 and 2011) since BRDs were implemented in 1998, 2 depth-zone strata (2DP) and combined observer program non-BRD/BRD datasets (2DS) are recommended for SEDAR 34 (Figures 48 and 49, Tables 4 and 5).

With an overall mean CPUE term added to the SEDAR 7 model (used in SEDAR 13 for Atlantic sharpnose and bonnethead sharks in the Gulf of Mexico, but not in SEDAR 31 for red snapper in the Gulf of Mexico), estimates of bycatch are not sensitive to the priors and the variability of bycatch estimates is much lower. However, estimates of bycatch are more-SEDAR-13-like with the prior for the year effect set equal to -2 without an overall mean CPUE term added to the SEDAR 7 model during 1972-1992 (Figures 48 and 49, Tables 4 and 5). An extremely high estimate of bycatch in 1980 was replaced with the geometric mean of 1977-1983 in SEDAR 13.

The changes in observer program methods (see Methods for details) might be the reasons that estimates are very different between the present analysis and SEDAR 13 after 1992, and estimates of bycatch in the present analysis are high in 1980, 2009, 2010 and 2011. The panel needs to decide which model should be used for SEDAR 34 and what should be done for the high estimates of bycatch in 1980, 2009, 2010 and 2011 for SEDAR 34

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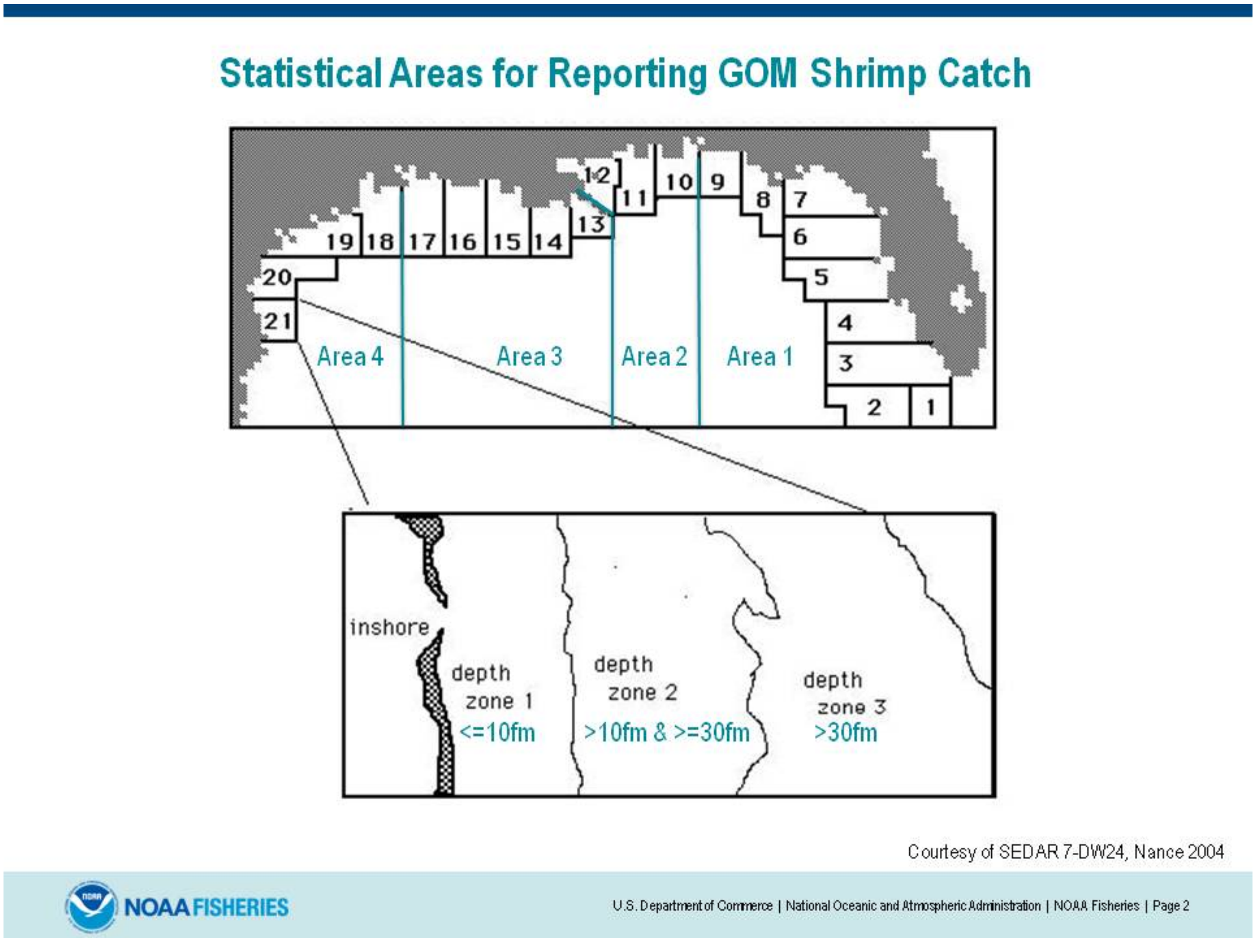

Figure 1 . Diagram of statistical grids and depth zones

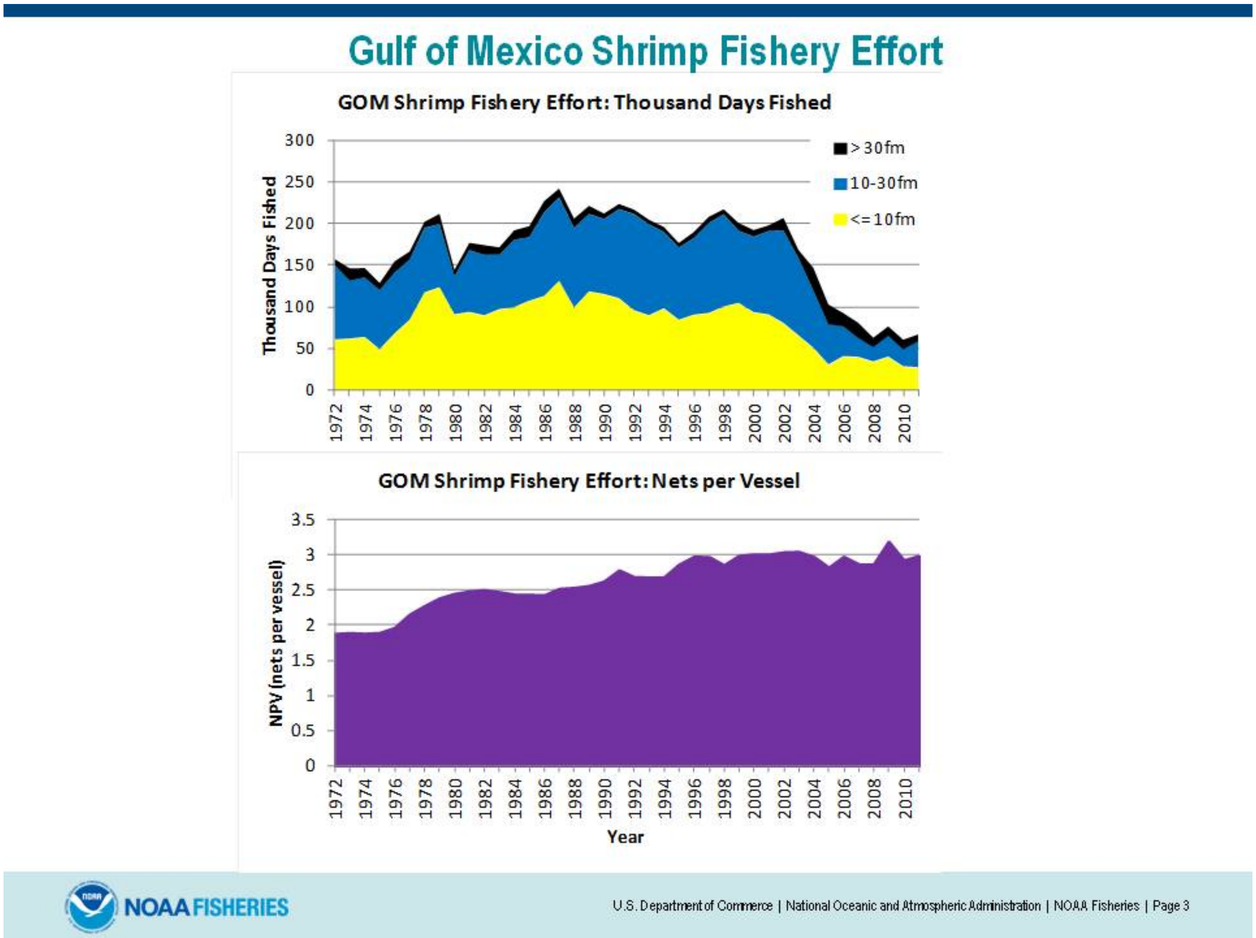

Figure 2. Gulf of Mexico shrimp fishery effort (thousand vessel-days) and nets per vessel.

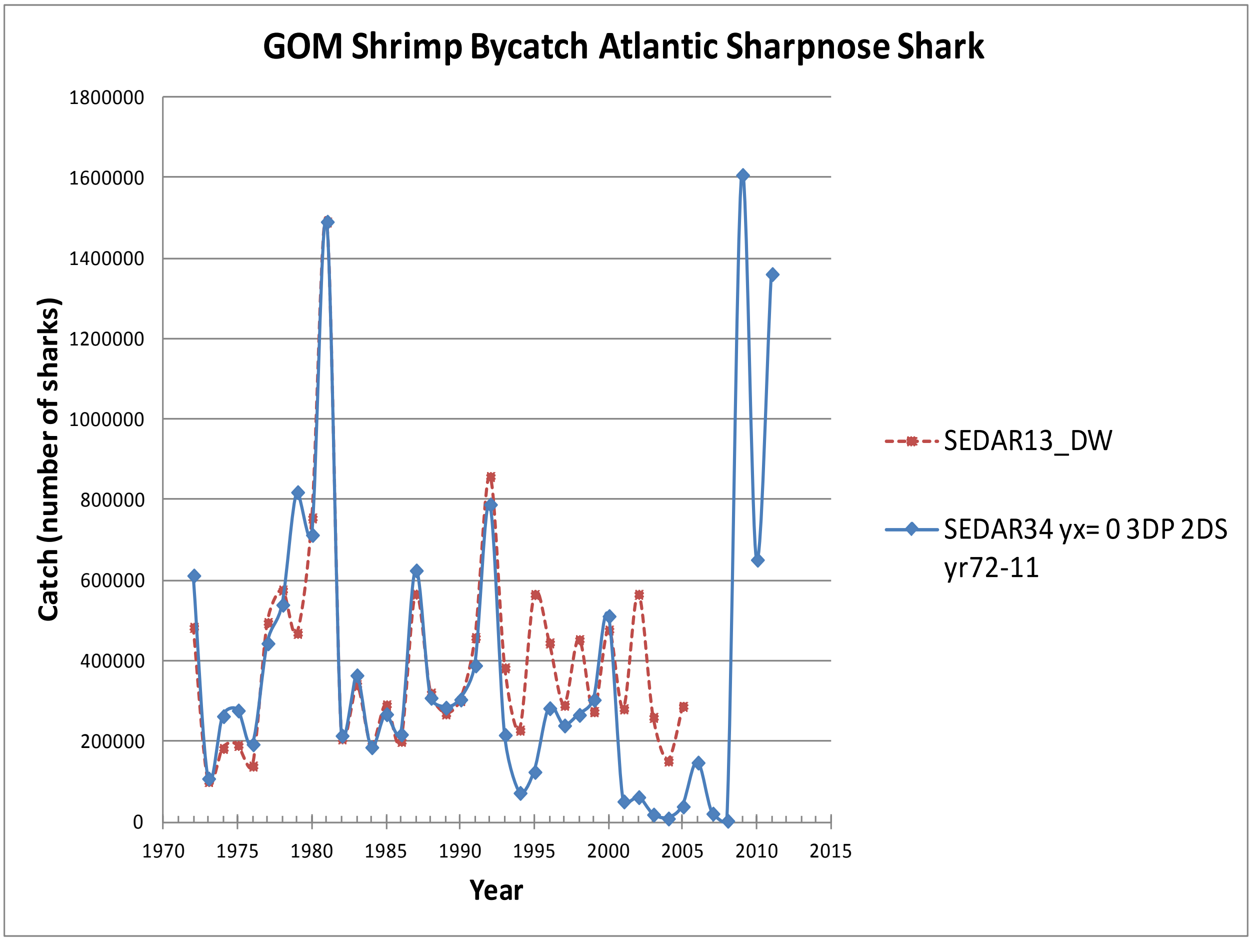

Figure 3. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model and priors used in the SEDAR 7 (Nichols 2004, Eq1 of this report) and SEDAR 31 for red snapper assessment (Linton 2012) with 3 depth-zone strata (3DP) and combined observer program non-BRD/BRD datasets (2DS).

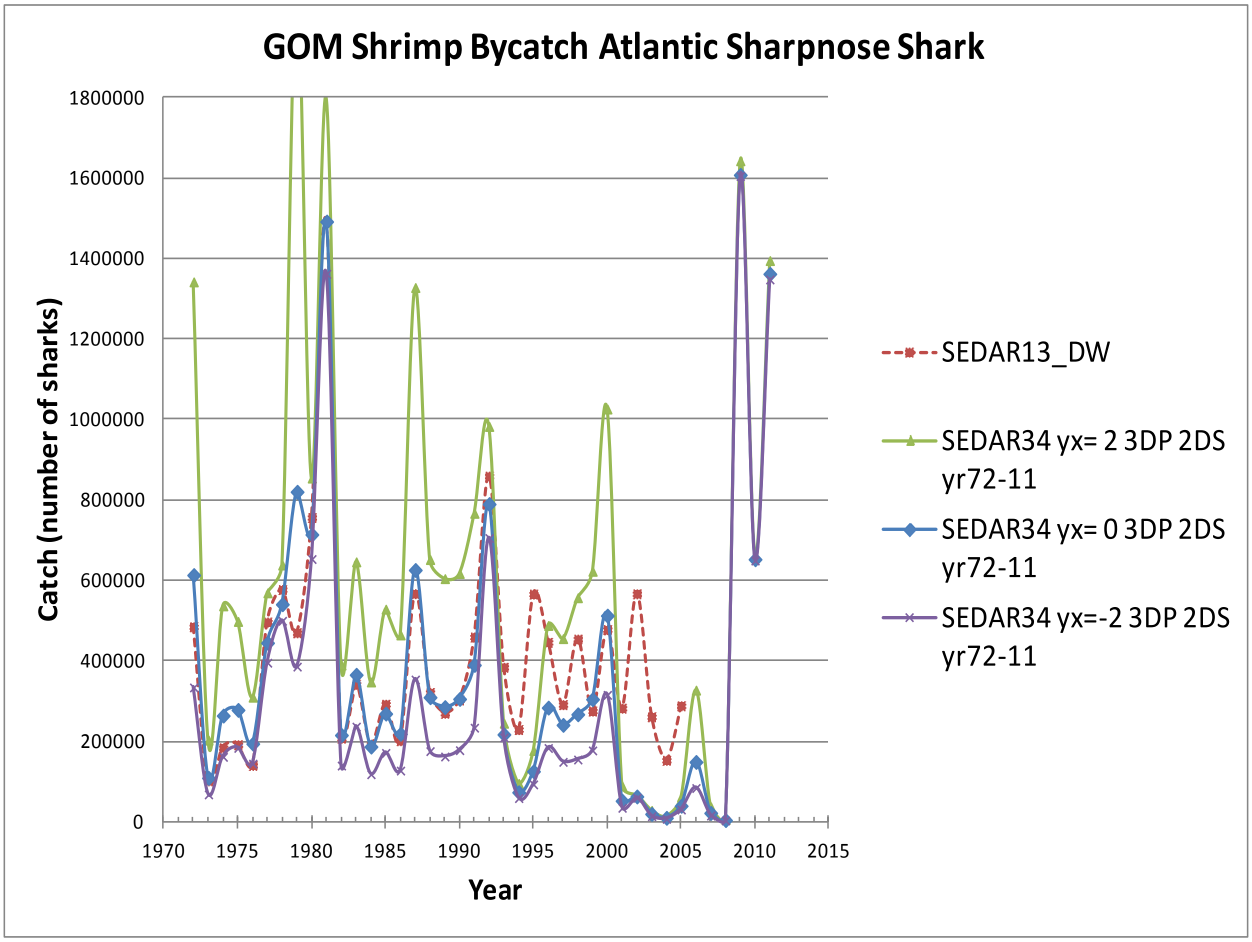

Figure 4. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model used in SEDAR 7 (Nichols 2004, Eq1 of this report) with 3 depth-zone strata (3DP) and combined observer program non-BRD/BRD datasets (2DS) with a variety of priors for year effect.

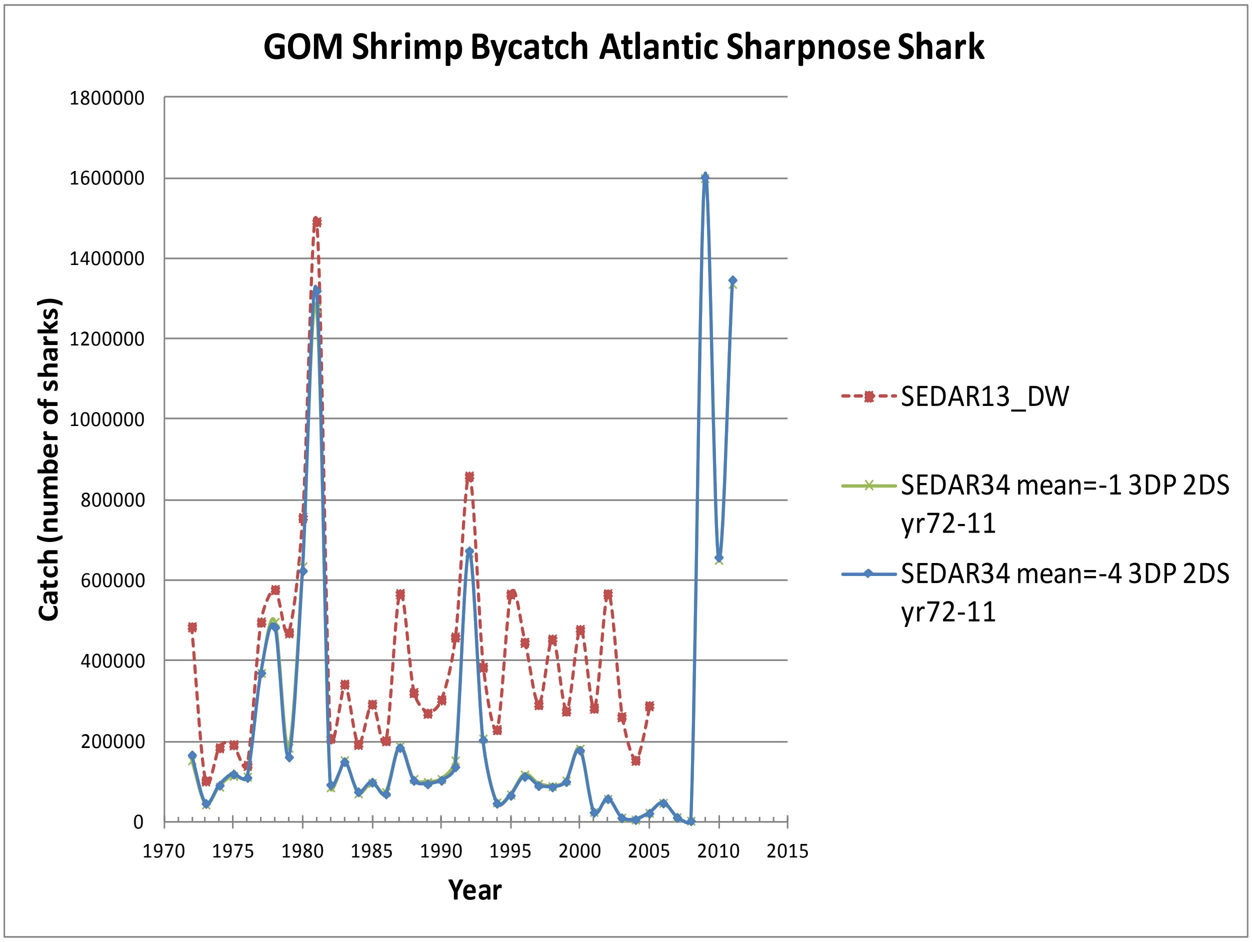

Figure 5. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model used in SEDAR 13 (Nichols 2007, Eq2 of this report) with 3 depth-zone strata (3DP) and combined observer program non-BRD/BRD datasets (2DS) with a variety of priors for the overall mean CPUE term.

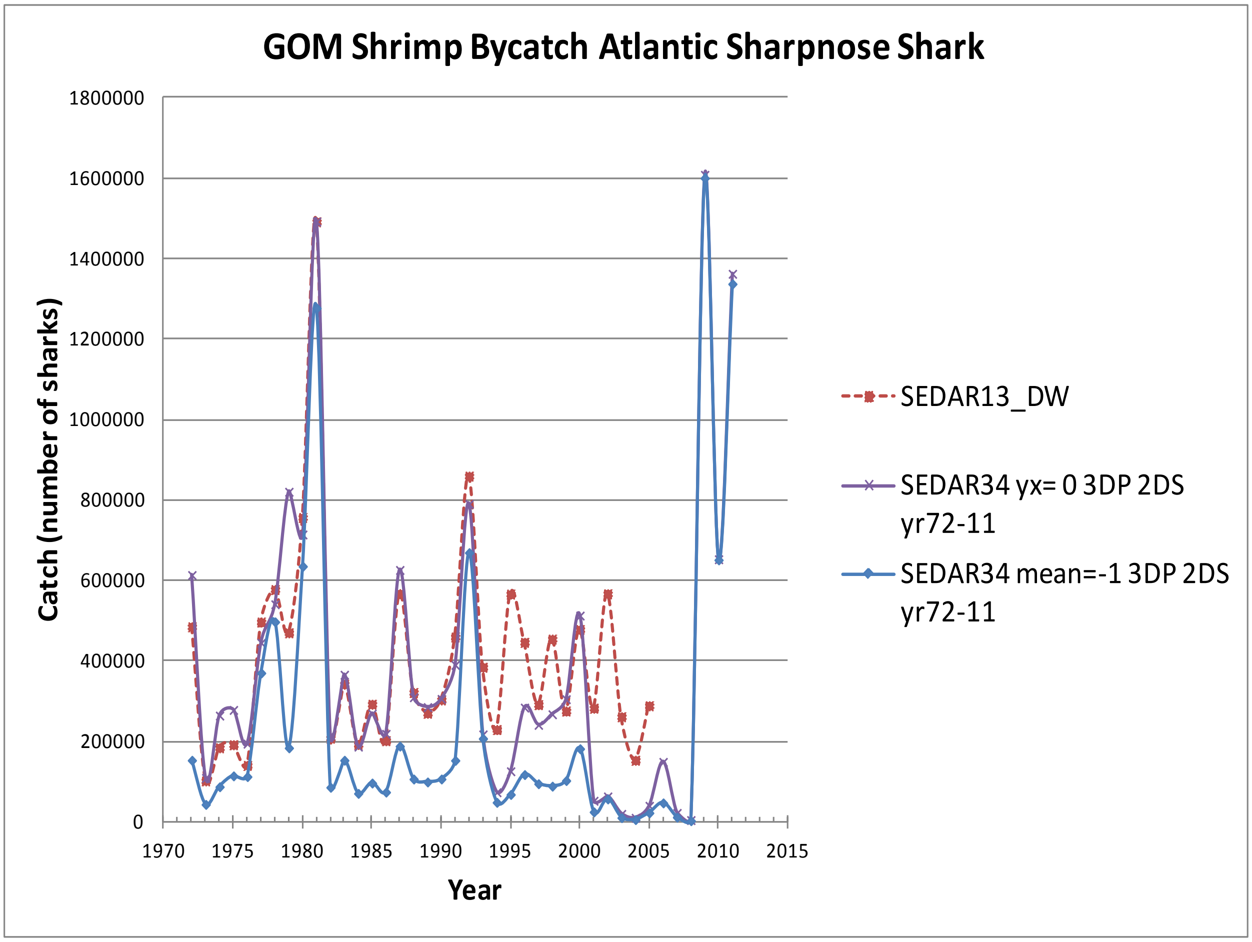

Figure 6. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the models used in SEDAR 7 (Nichols 2004, Eq1 of this report) and SEDAR 13 (Nichols 2007, Eq2 of this report) with 3 depth-zone strata (3DP) and combined observer program non-BRD/BRD datasets (2DS).

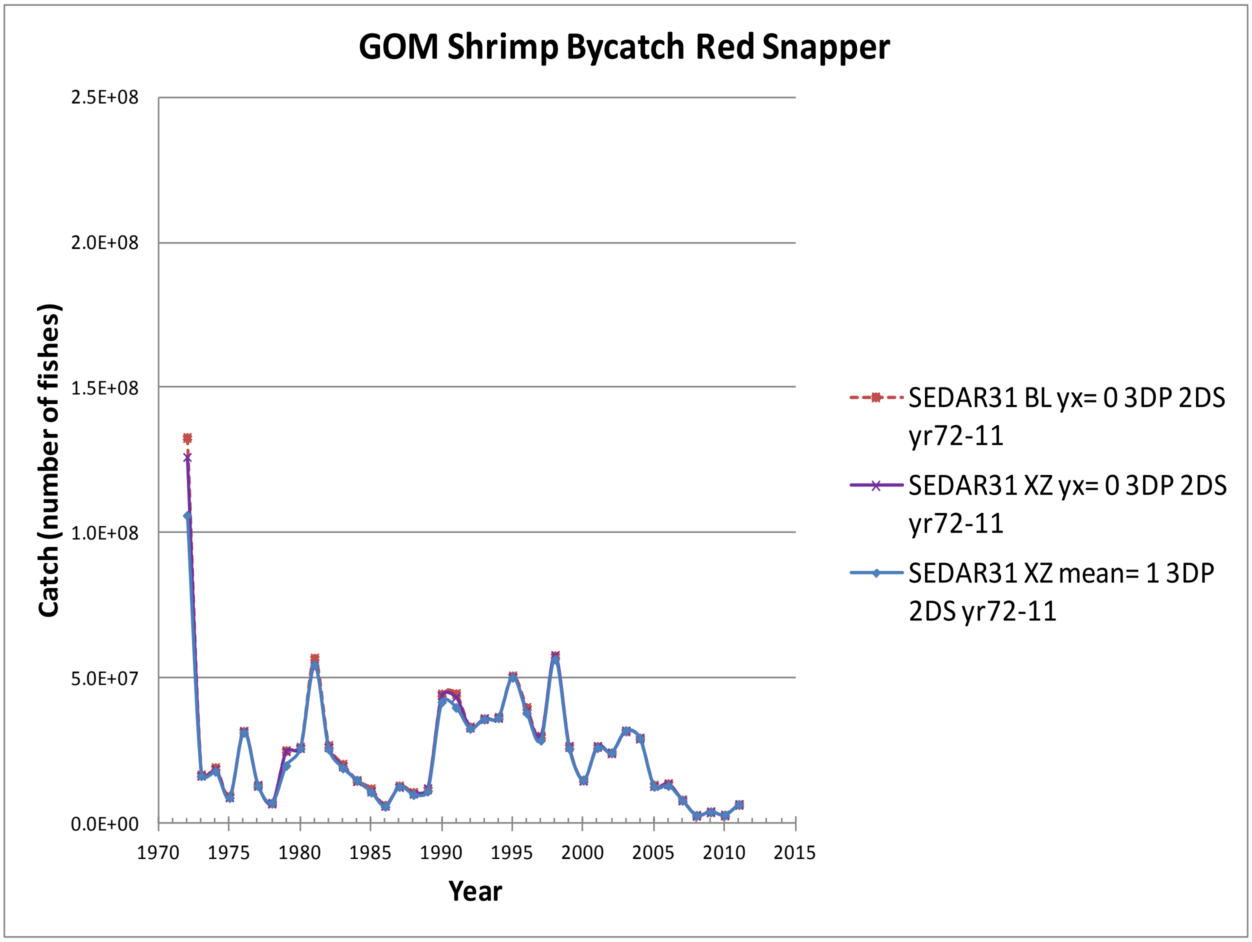

Figure 7. WinBUGS shrimp bycatch estimates for Gulf of Mexico red snapper with the models used in SEDAR 7 (Nichols 2004, Eq1 of this report) and SEDAR 13 (Nichols 2007, Eq2 of this report) with 3 depth-zone strata (3DP) and combined observer program non-BRD/BRD datasets (2DS).

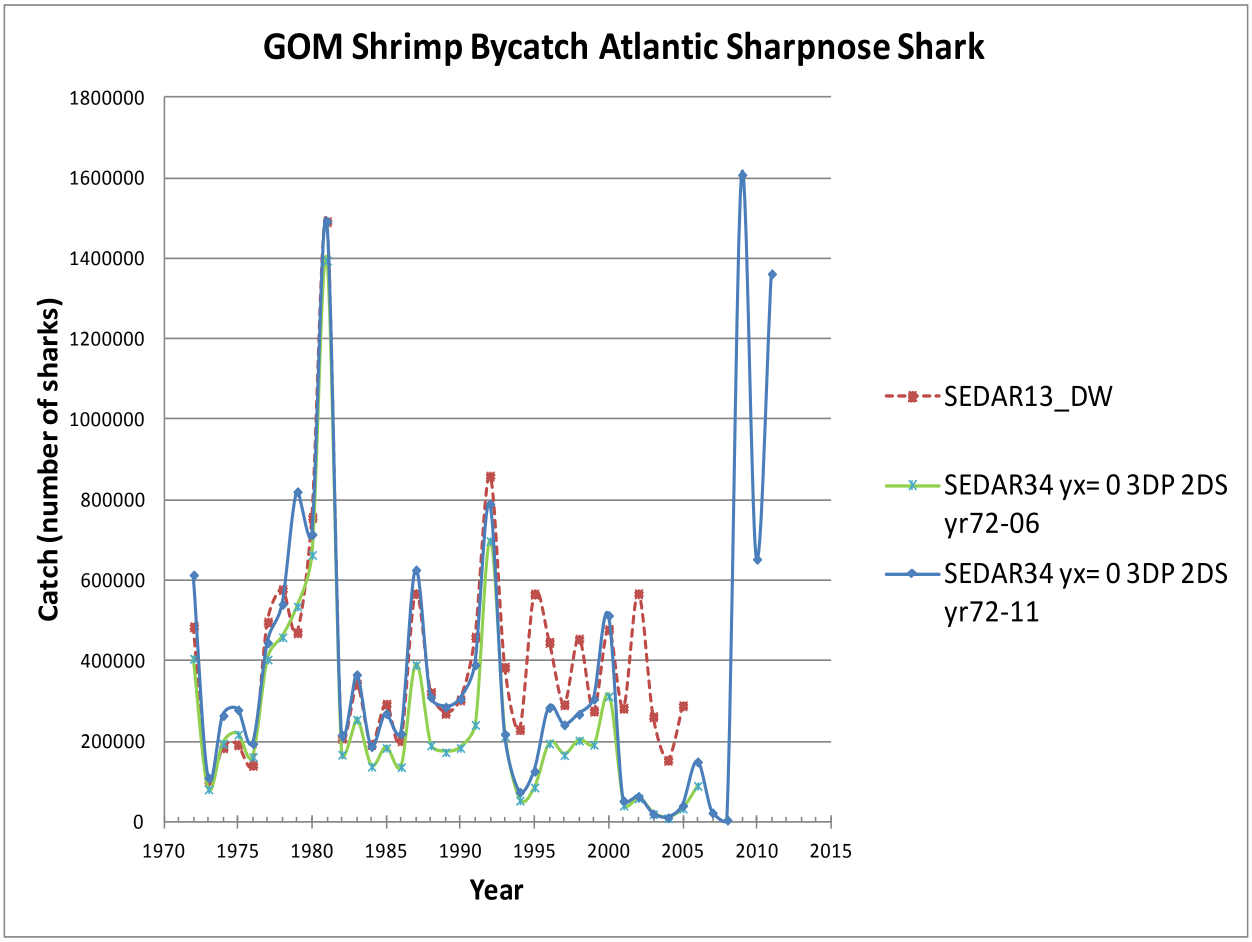

Figure 8. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the models used in SEDAR 7 (Nichols 2004, Eq1 of this report) with 3 depth-zone strata (3DP) and combined observer program non-BRD/BRD datasets (2DS).

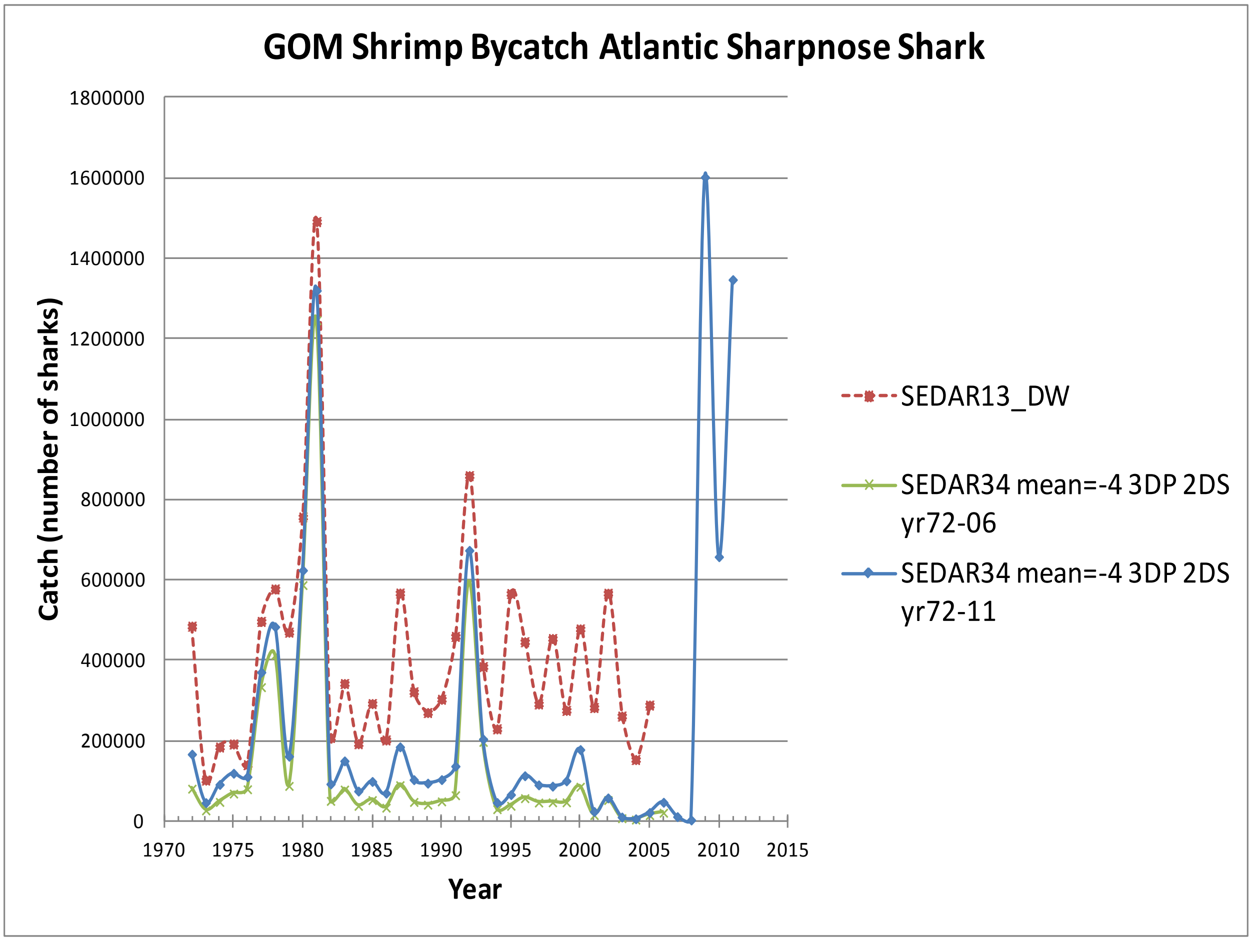

Figure 9. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model used in SEDAR 13 (Nichols 2007, Eq2 of this report) with 3 depth-zone strata (3DP) and combined observer program non-BRD/BRD datasets (2DS).

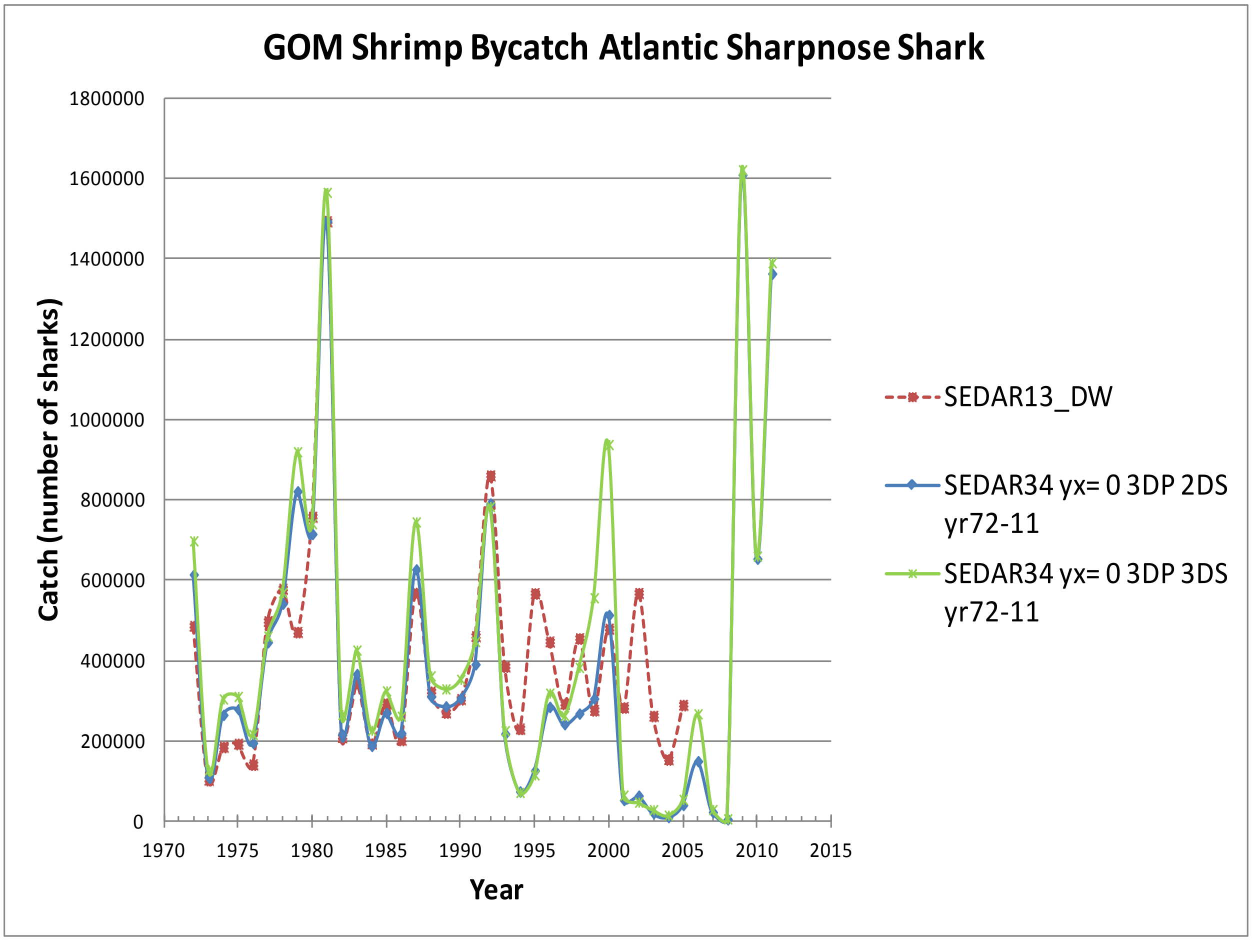

Figure 10. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model used in SEDAR 7 (Nichols 2004, Eq1 of this report) with 3 depth-zone strata (3DP) and combined or separated observer program non-BRD/BRD datasets (2DS or 3DS).

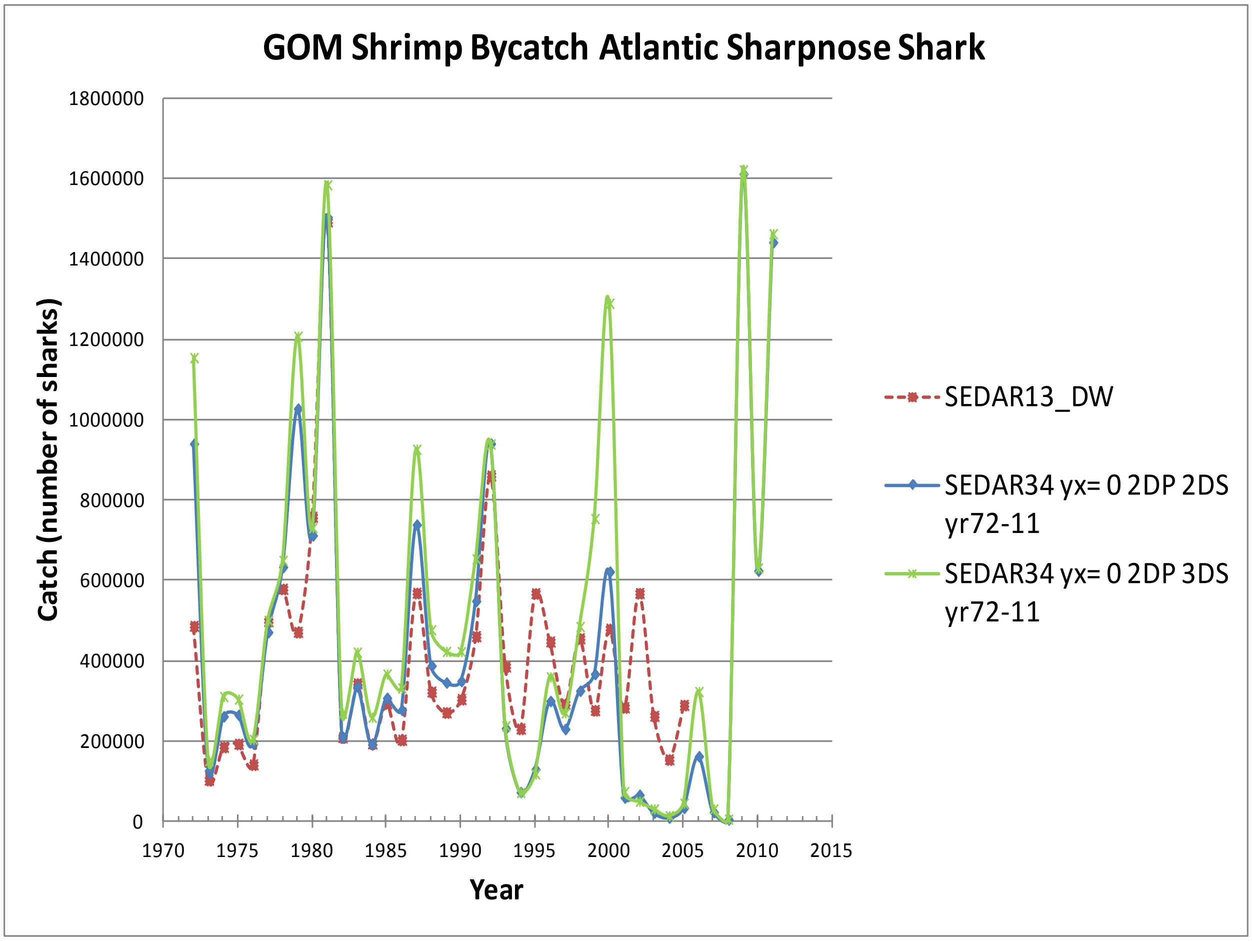

Figure 11. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model used in SEDAR 7 (Nichols 2004, Eq1 of this report) with 2 depth-zone strata (2DP) and combined or separated observer program non-BRD/BRD datasets (2DS or 3DS).

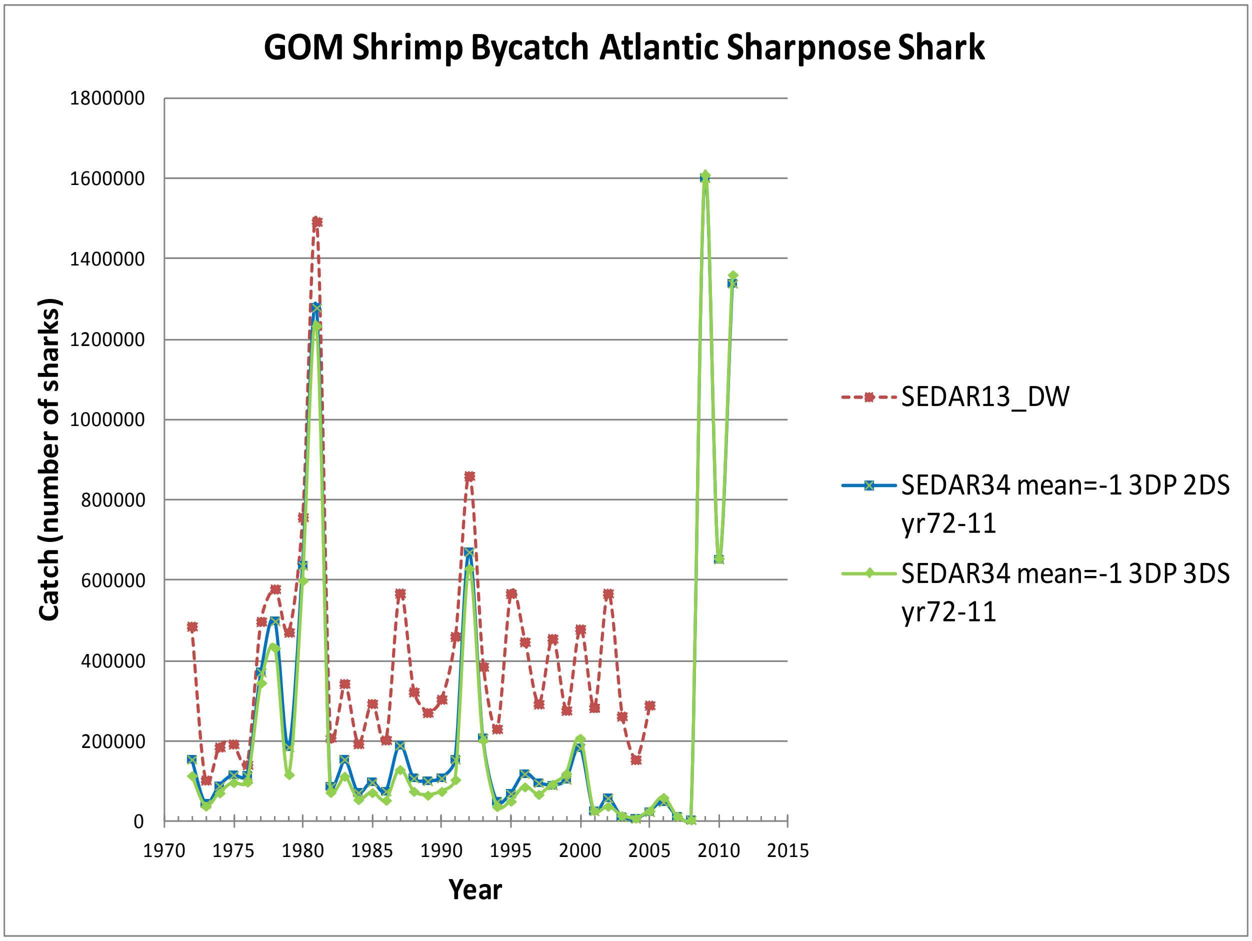

Figure 12. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model used in SEDAR 13 (Nichols 2007, Eq2 of this report) with 2 depth-zone strata (3DP) and combined or separated observer program non-BRD/BRD datasets (2DS or 3DS).

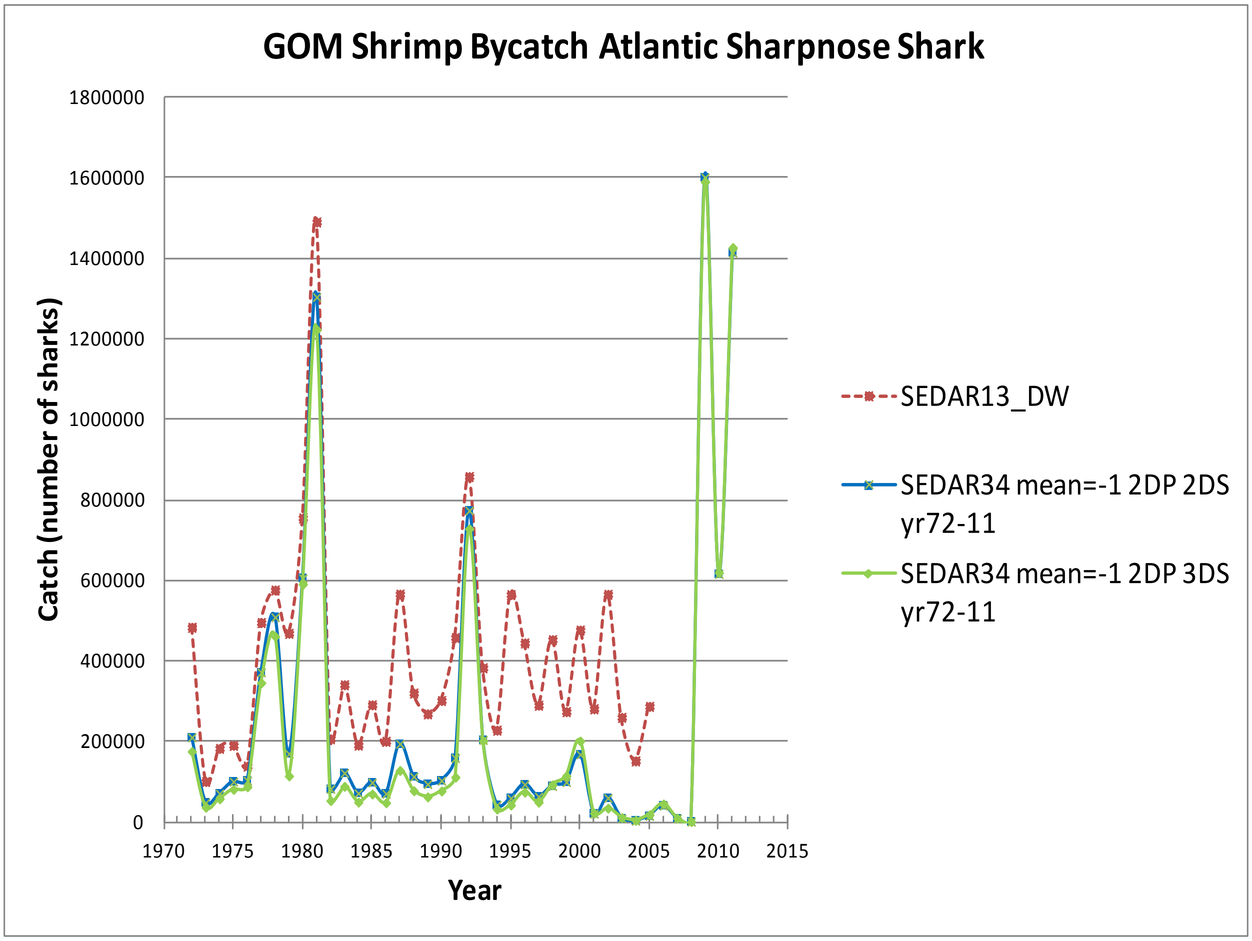

Figure 13. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model used in SEDAR 13 (Nichols 2007, Eq2 of this report) with 2 depth-zone strata (2DP) and combined or separated observer program non-BRD/BRD datasets (2DS or 3DS).

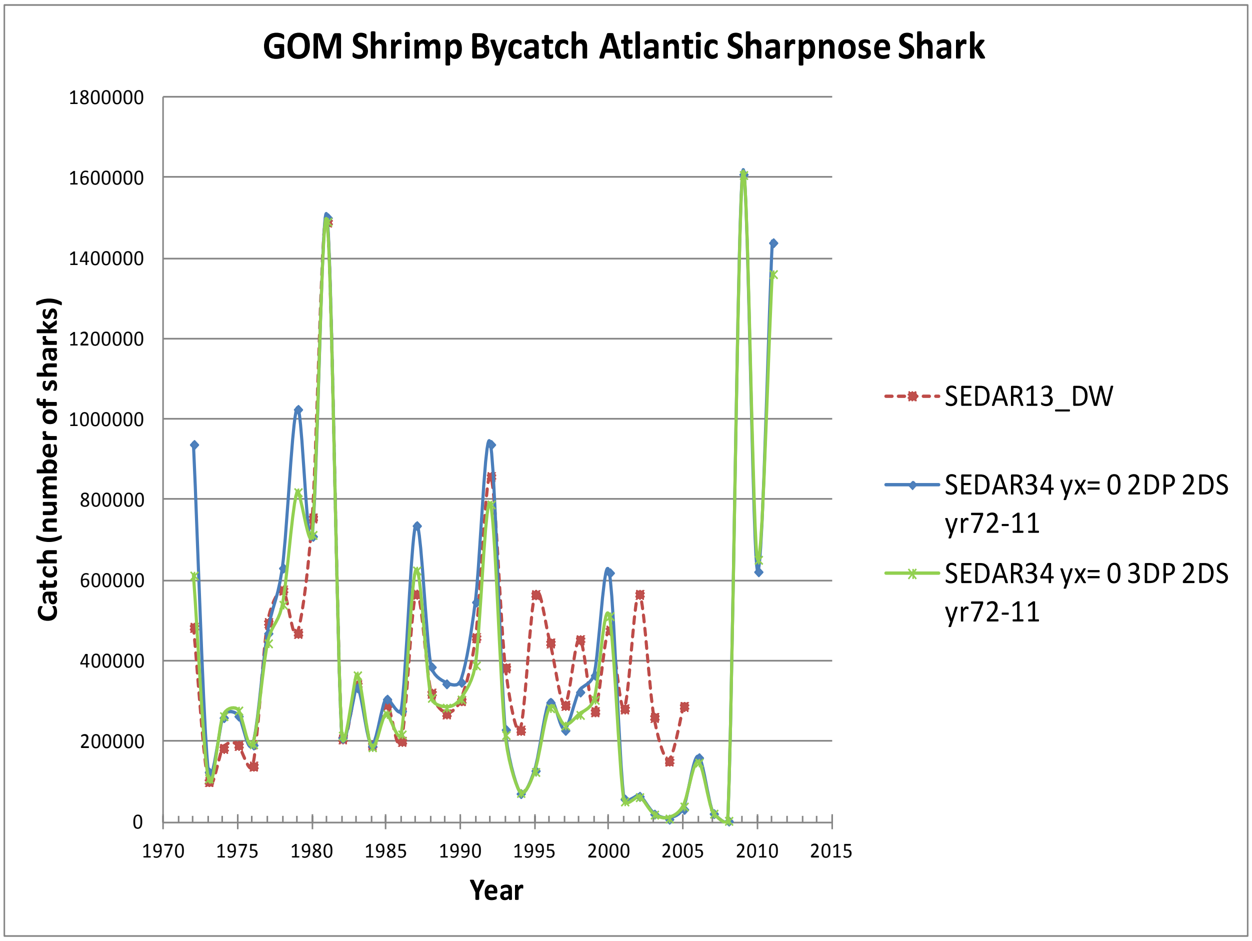

Figure 14. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model used in SEDAR 7 (Nichols 2004, Eq1 of this report) with 2 or 3 depth-zone strata (2DP or 3DP) and combined observer program non-BRD/BRD datasets (2DS).

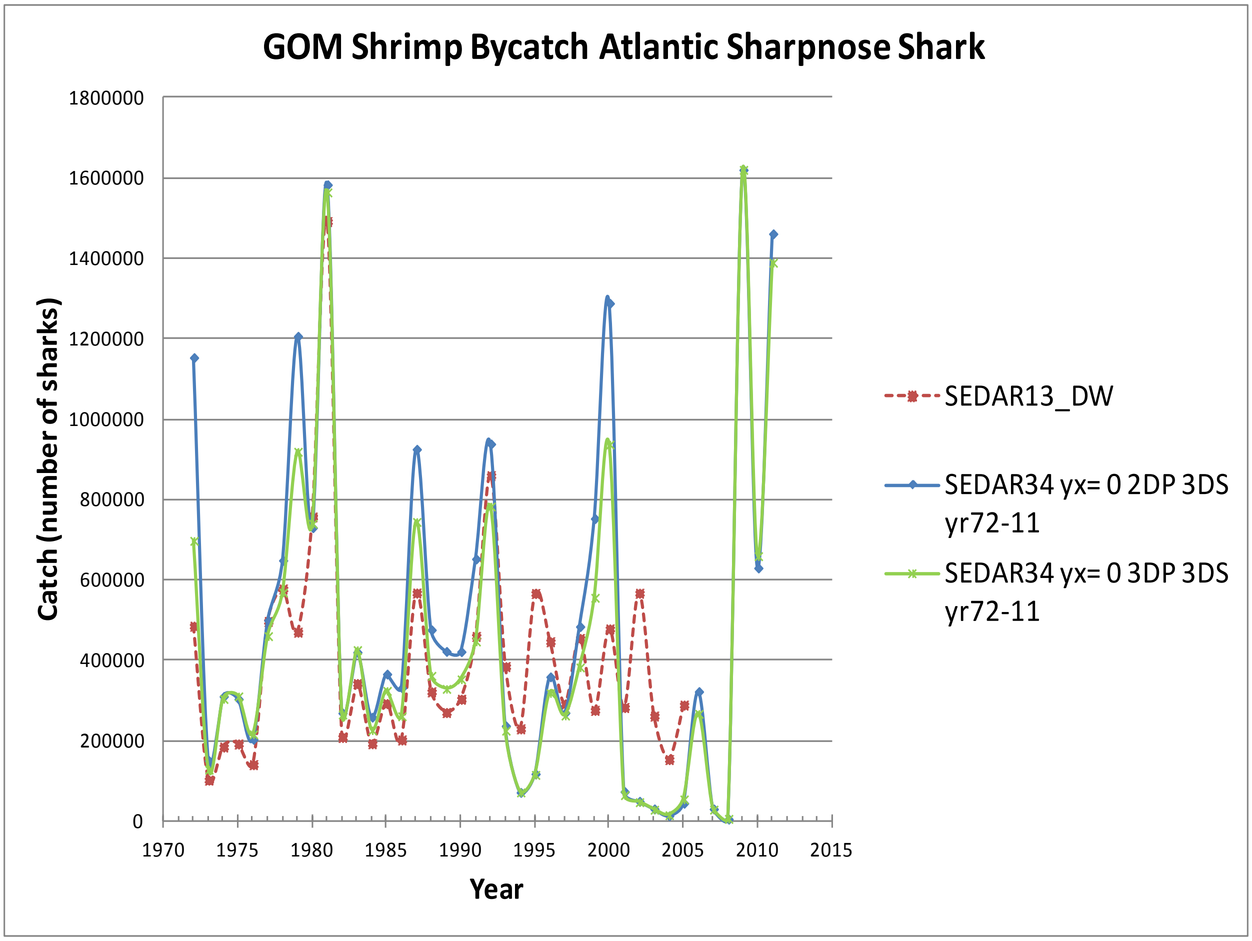

Figure 15. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model used in SEDAR 7 (Nichols 2004, Eq1 of this report) with 2 or 3 depth-zone strata (2DP or 3DP) and separated observer program non-BRD/BRD datasets (3DS).

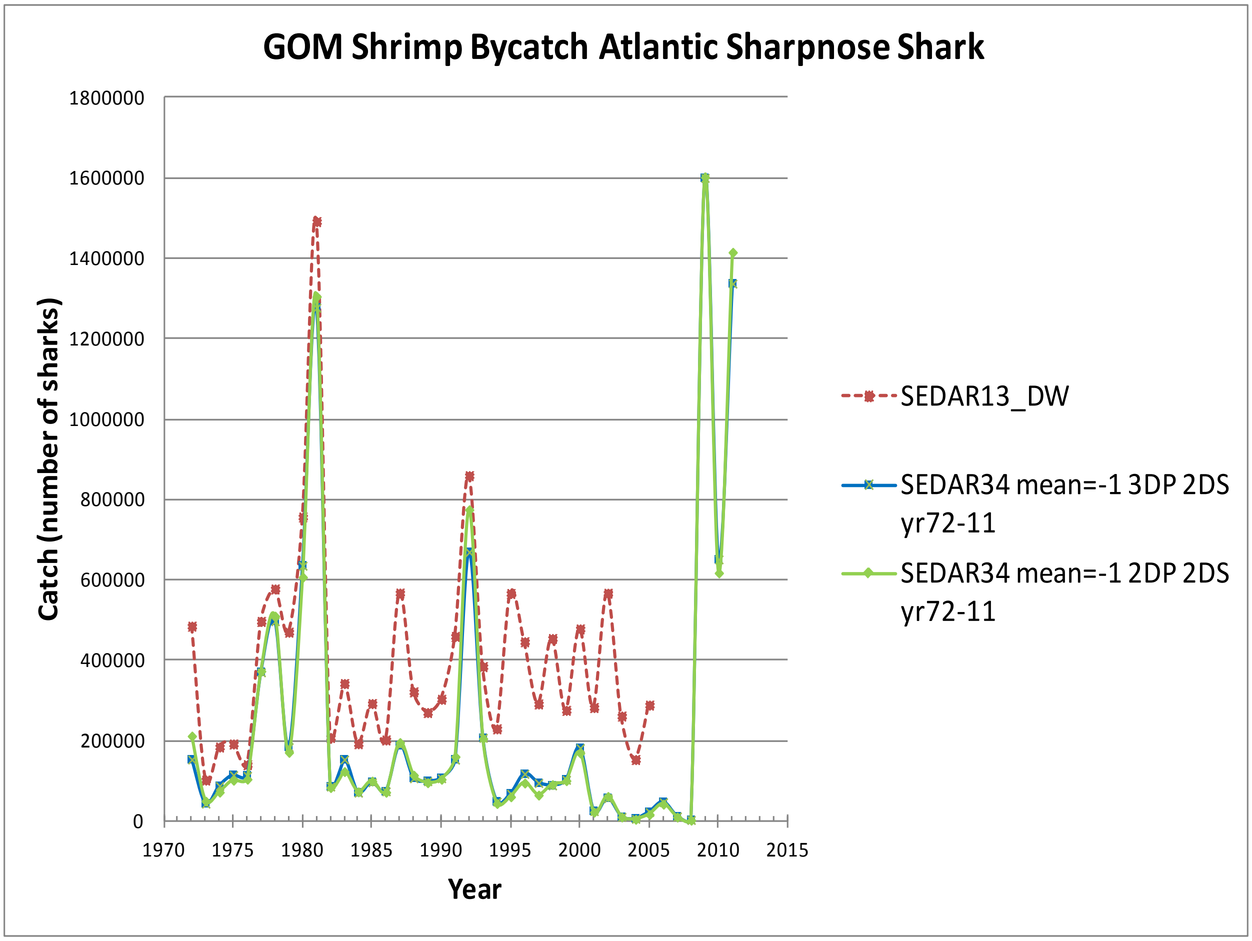

Figure 16. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model used in SEDAR 13 (Nichols 2007, Eq2 of this report) with 2 or 3 depth-zone strata (2DP or 3DP) and combined observer program non-BRD/BRD datasets (2DS).

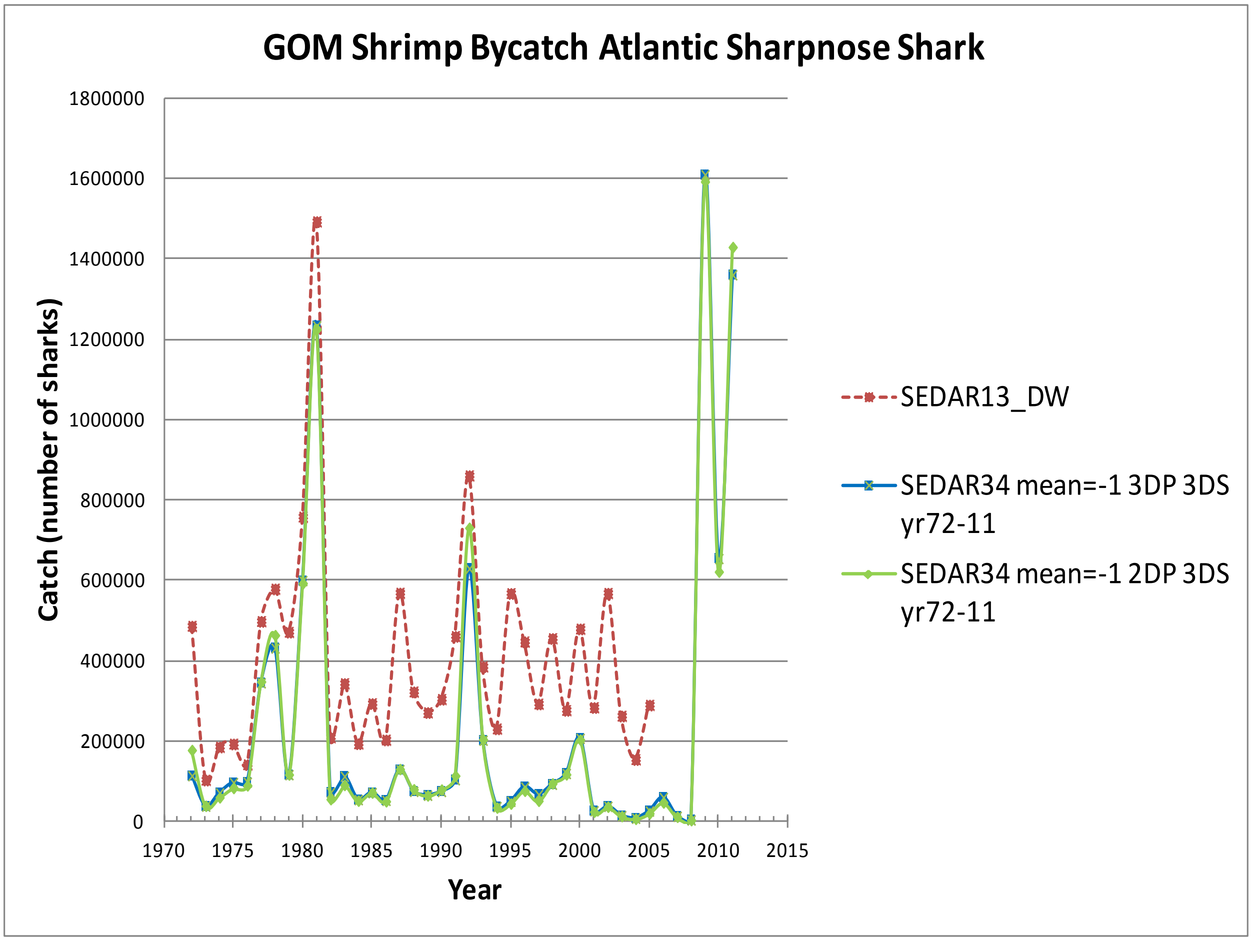

Figure 17. WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model used in SEDAR 13 (Nichols 2007, Eq2 of this report) with 2 or 3 depth-zone strata (2DP or 3DP) and separated observer program non-BRD/BRD datasets (3DS).

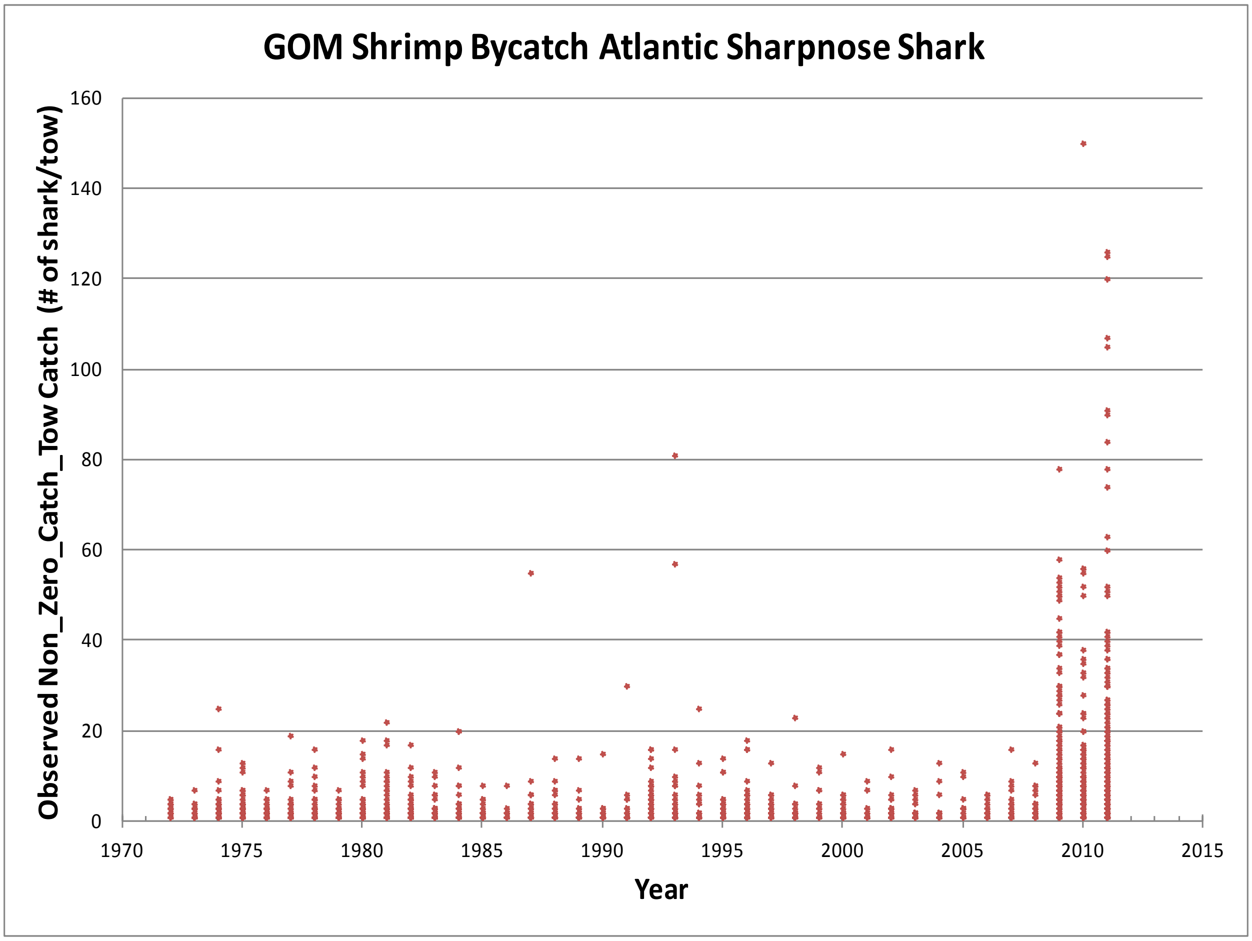

Figure 18. Observed non-zero-catch-tow catch (# of sharks per tow) for Atlantic sharpnose shark in the Gulf of Mexico.

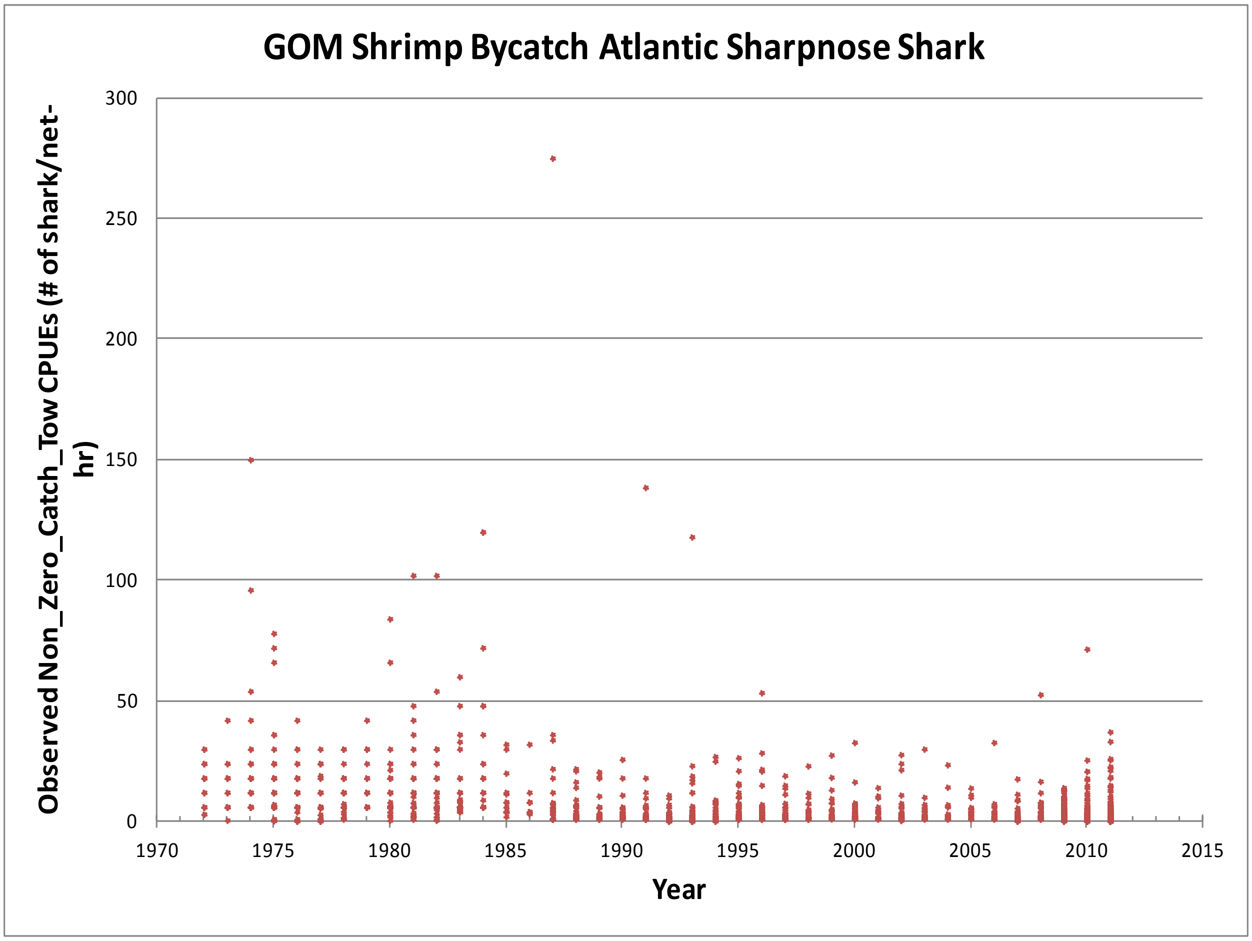

Figure 19. Observed non-zero-catch-tow CPUEs (# of sharks per net-hour) for Atlantic sharpnose shark in the Gulf of Mexico.

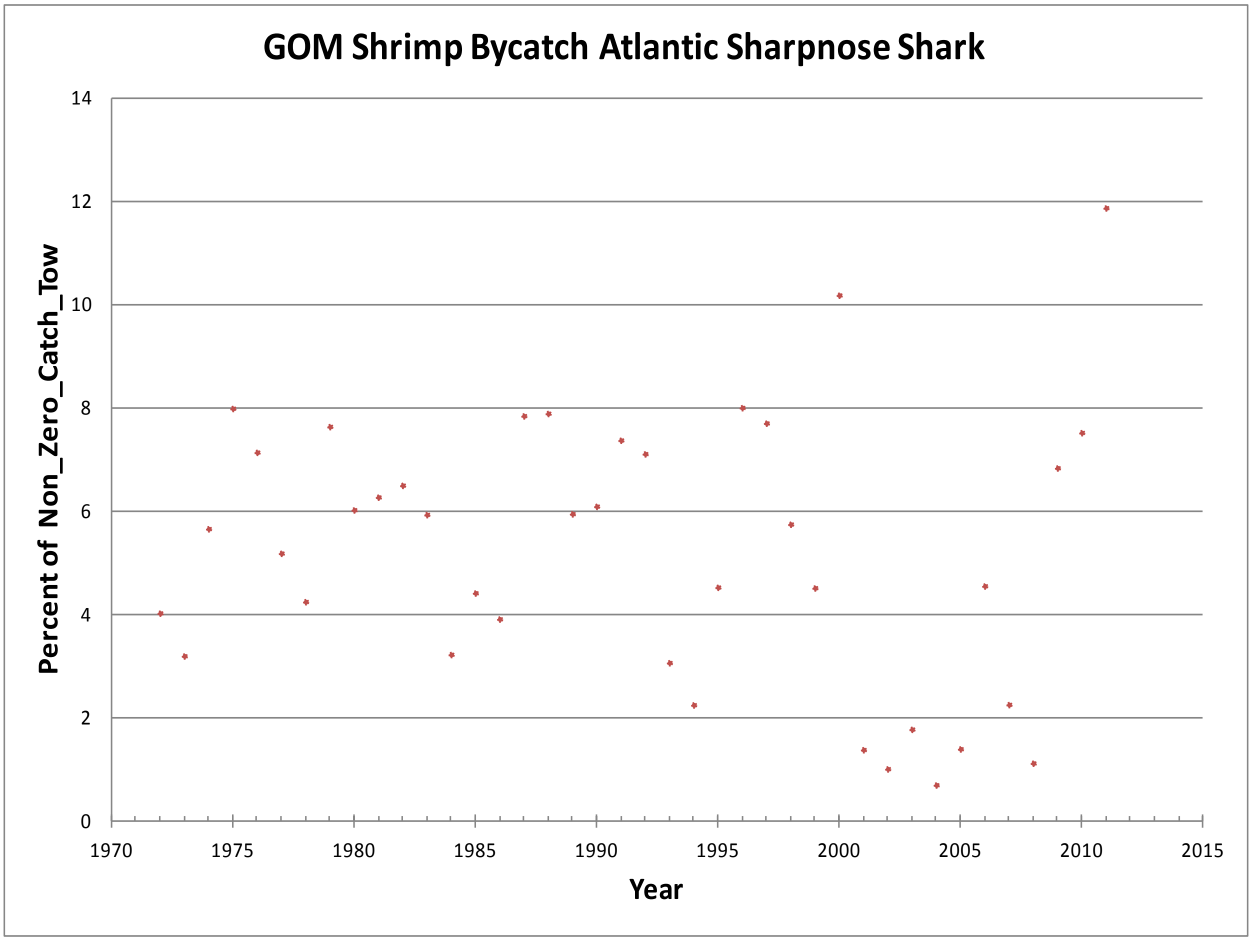

Figure 20. Observed percent of non-zero-catch tows for Atlantic sharpnose shark in the Gulf of Mexico.

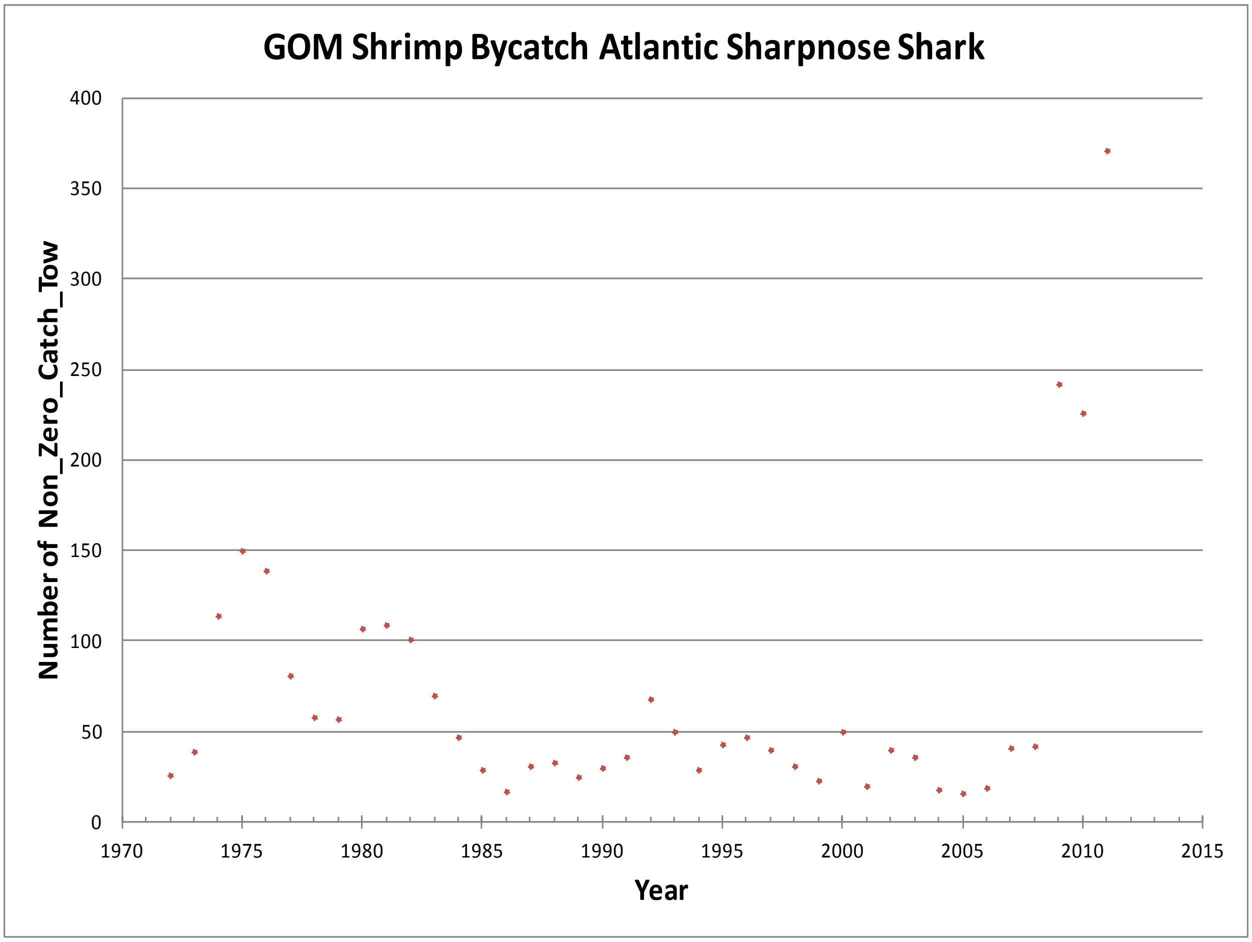

Figure 21. Observed number of non-zero-catch tows per year for Atlantic sharpnose shark in the Gulf of Mexico.

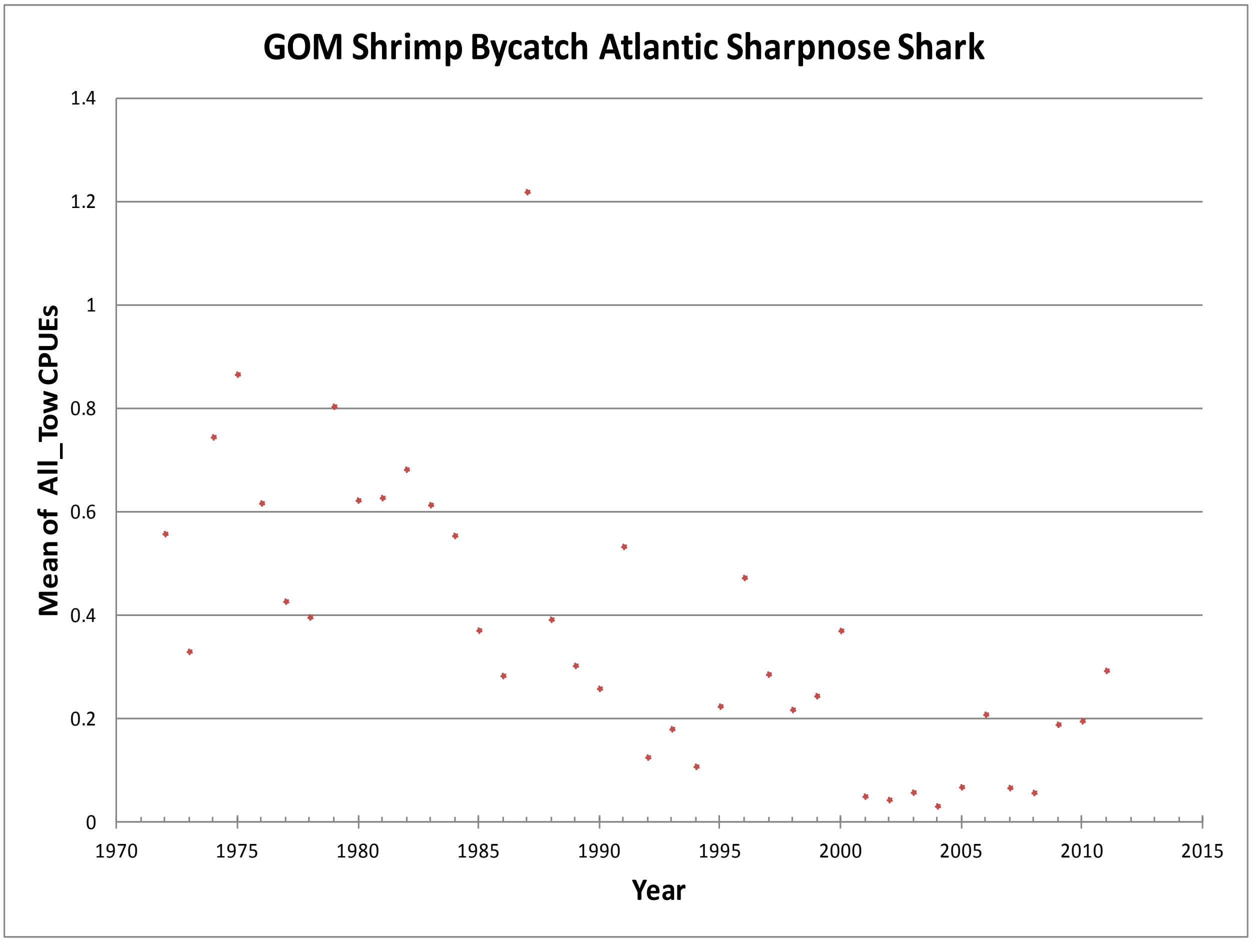

Figure 22. Observed annual mean all-tow CPUEs for Atlantic sharpnose in the Gulf of Mexico.

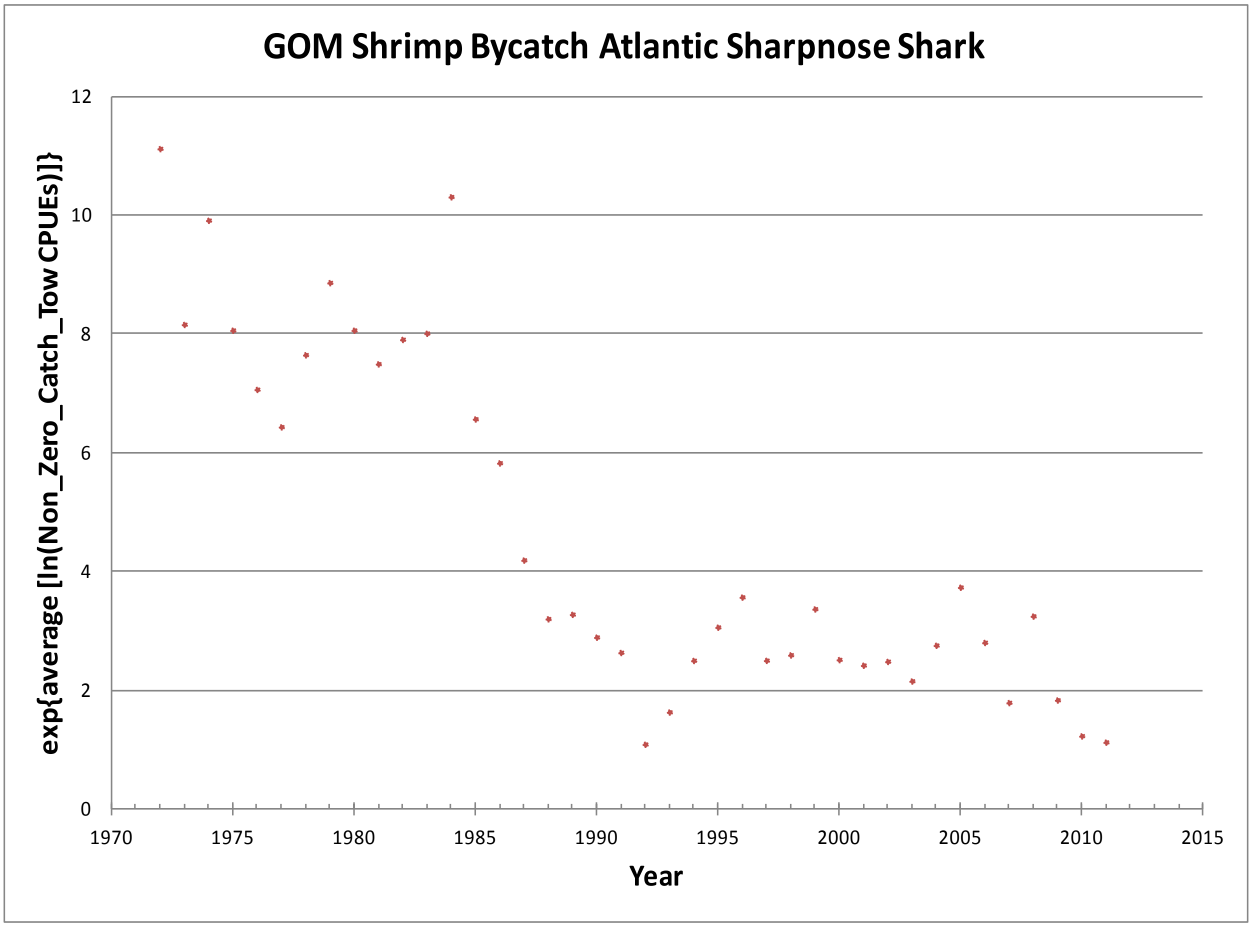

Figure 23. Observed annual mean non-zero-catch-tow CPUEs for Atlantic sharpnose shark in the Gulf of Mexico.

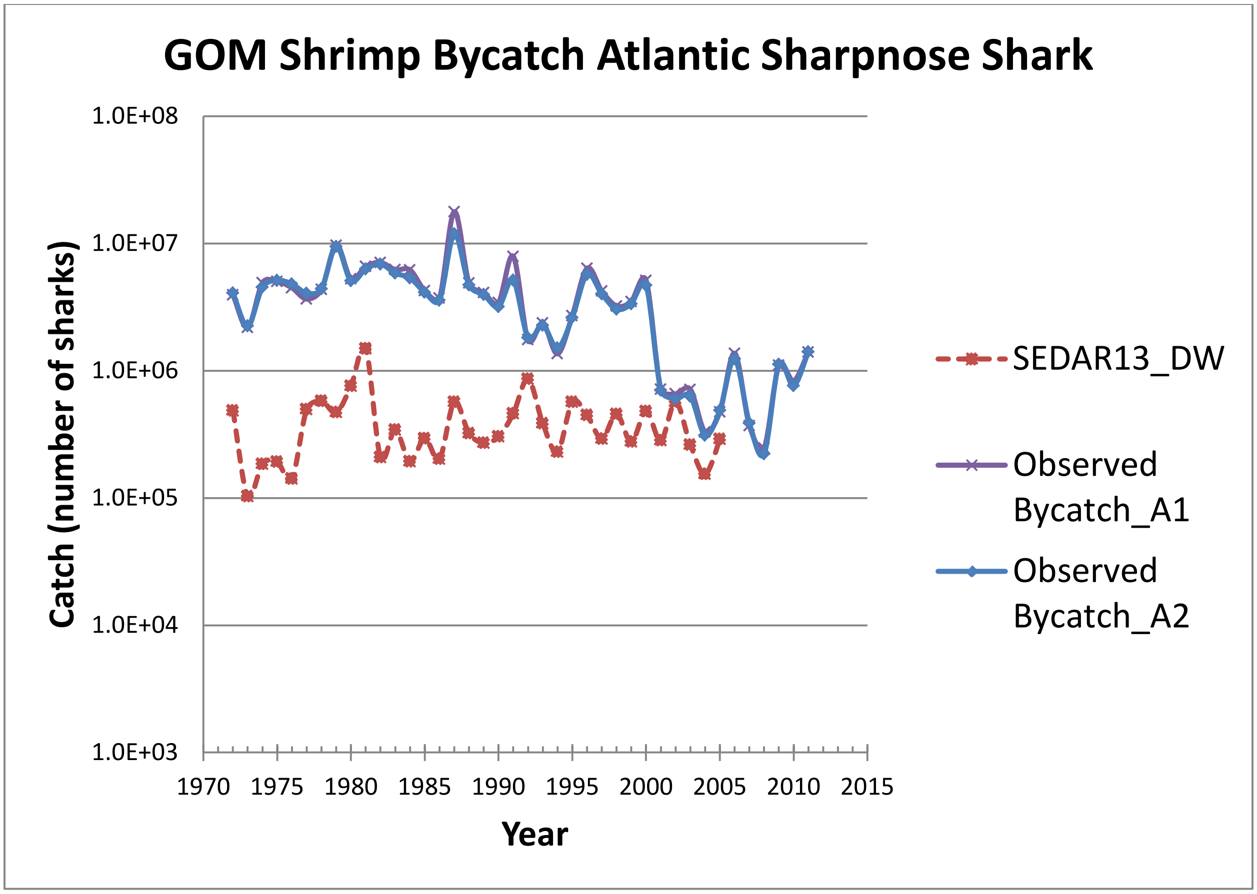

Figure 24. “Back-of-the-envelope” estimates of the observed bycatch for Atlantic sharpnose shark in the Gulf of Mexico with approach 1 (Observed Bycatch_A1) and approach 2 (Observed Bycatch_A2) (see Methods for details).

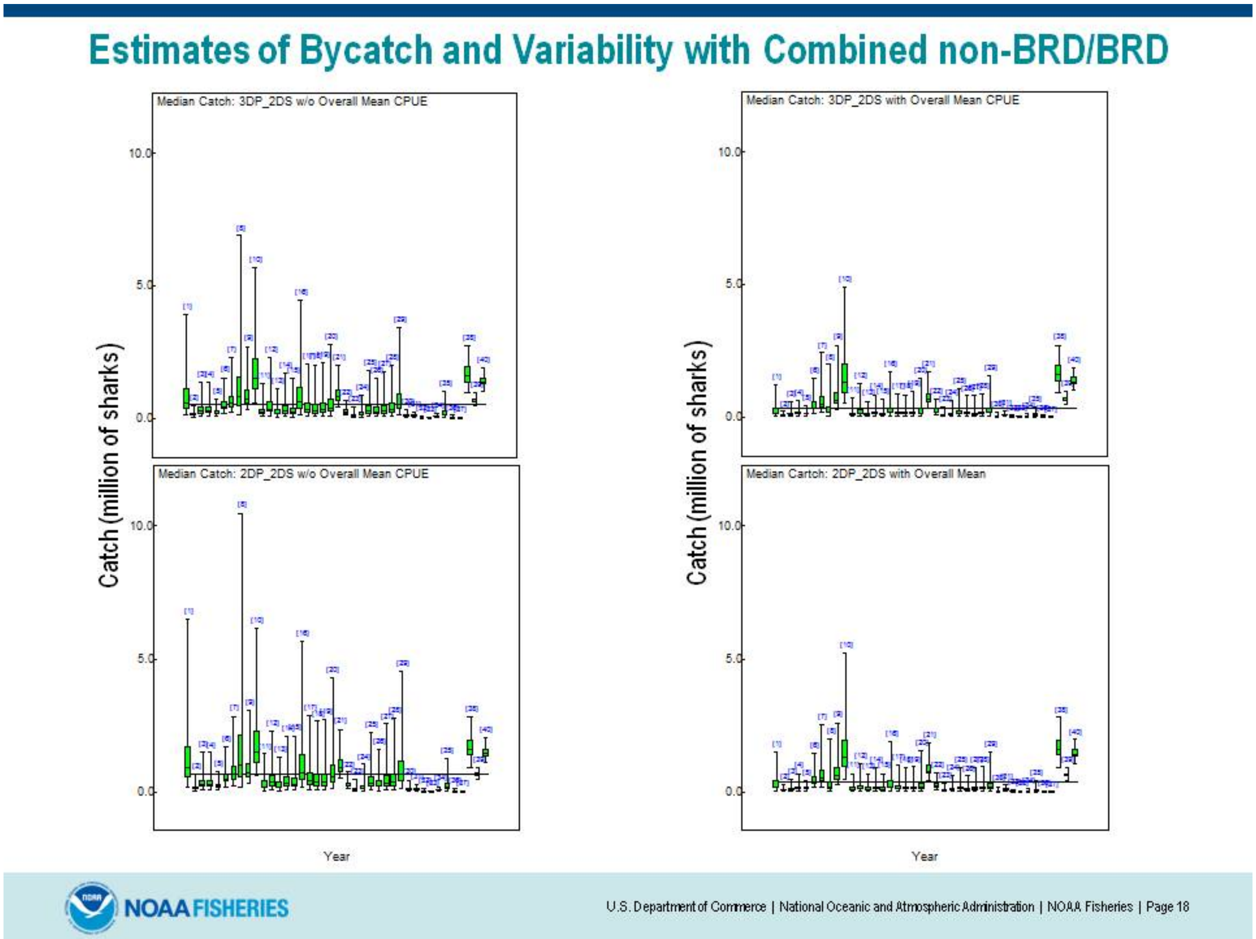

Figure 25. With combined observer program non-BRD/BRD datasets (2DS), WinBUGS estimates of bycatch and variability for Atlantic sharpnose shark in the Gulf of Mexico without or with an overall mean CPUE term added to the SEDAR 7 WinBUGS shrimp bycatch estimation model (left panels or right panels) and with 3 or 2 depth-zone strata (3DP or 2DP; upper panels or lower panels).

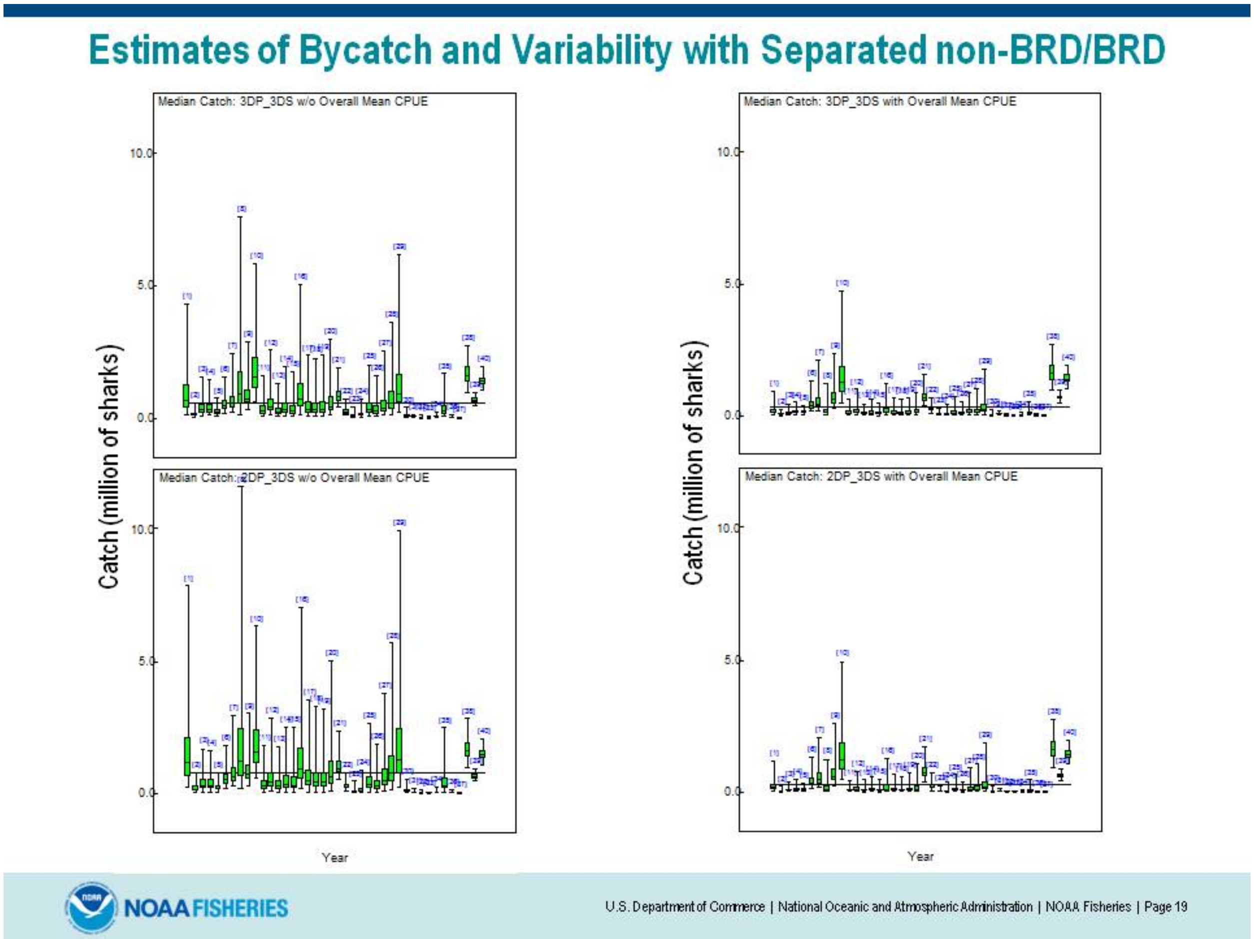

Figure 26. With separated observer program non-BRD/BRD datasets (3DS), WinBUGS estimates of bycatch and variability for Atlantic sharpnose shark in the Gulf of Mexico without or with an overall mean CPUE term added to the SEDAR 7 WinBUGS shrimp bycatch estimation model (left panels or right panels) and with 3 or 2 depth-zone strata (3DP or 2DP; upper panels or lower panels).

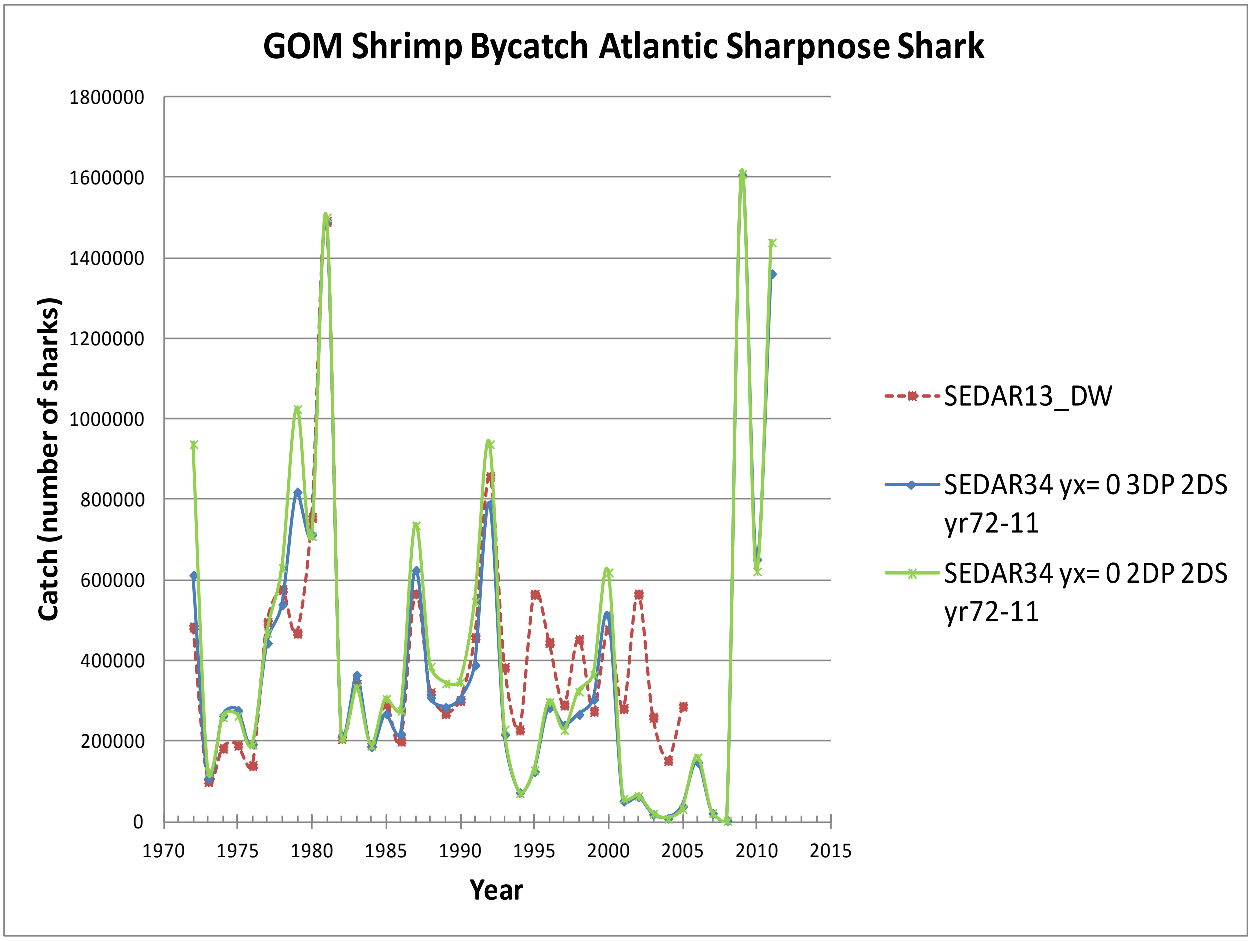

Figure 27. Recommended WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model used in SEDAR 7 (Nichols 2004, Eq1 of this report) with 2 or 3 depth-zone strata (2DP or 3DP) and combined observer program non-BRD/BRD datasets (2DS).

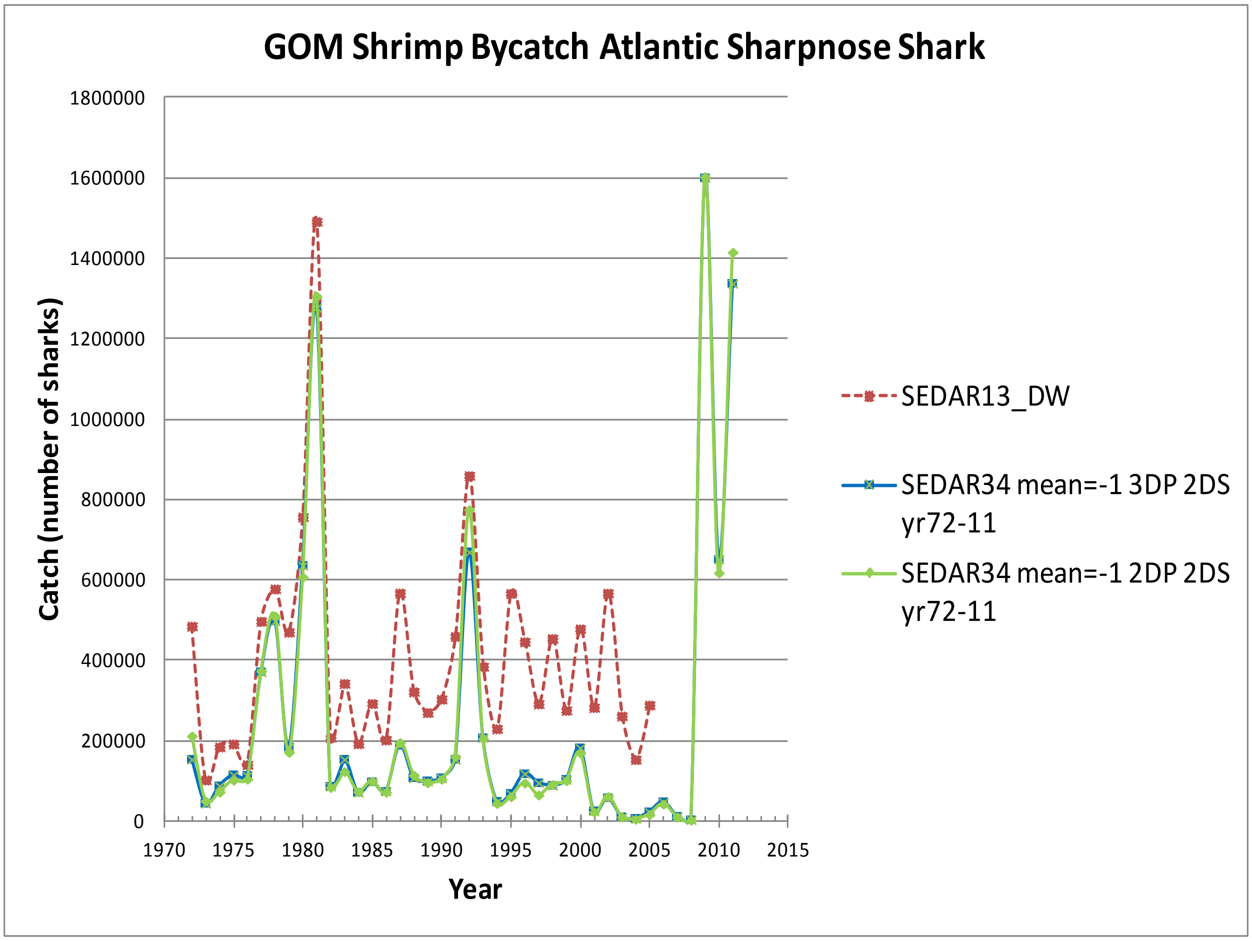

Figure 28. Recommended WinBUGS shrimp bycatch estimates for Atlantic sharpnose shark in the Gulf of Mexico with the model used in SEDAR 13 (Nichols 2007, Eq2 of this report) with 2 or 3 depth-zone strata (2DP or 3DP) and combined observer program non-BRD/BRD datasets (2DS).

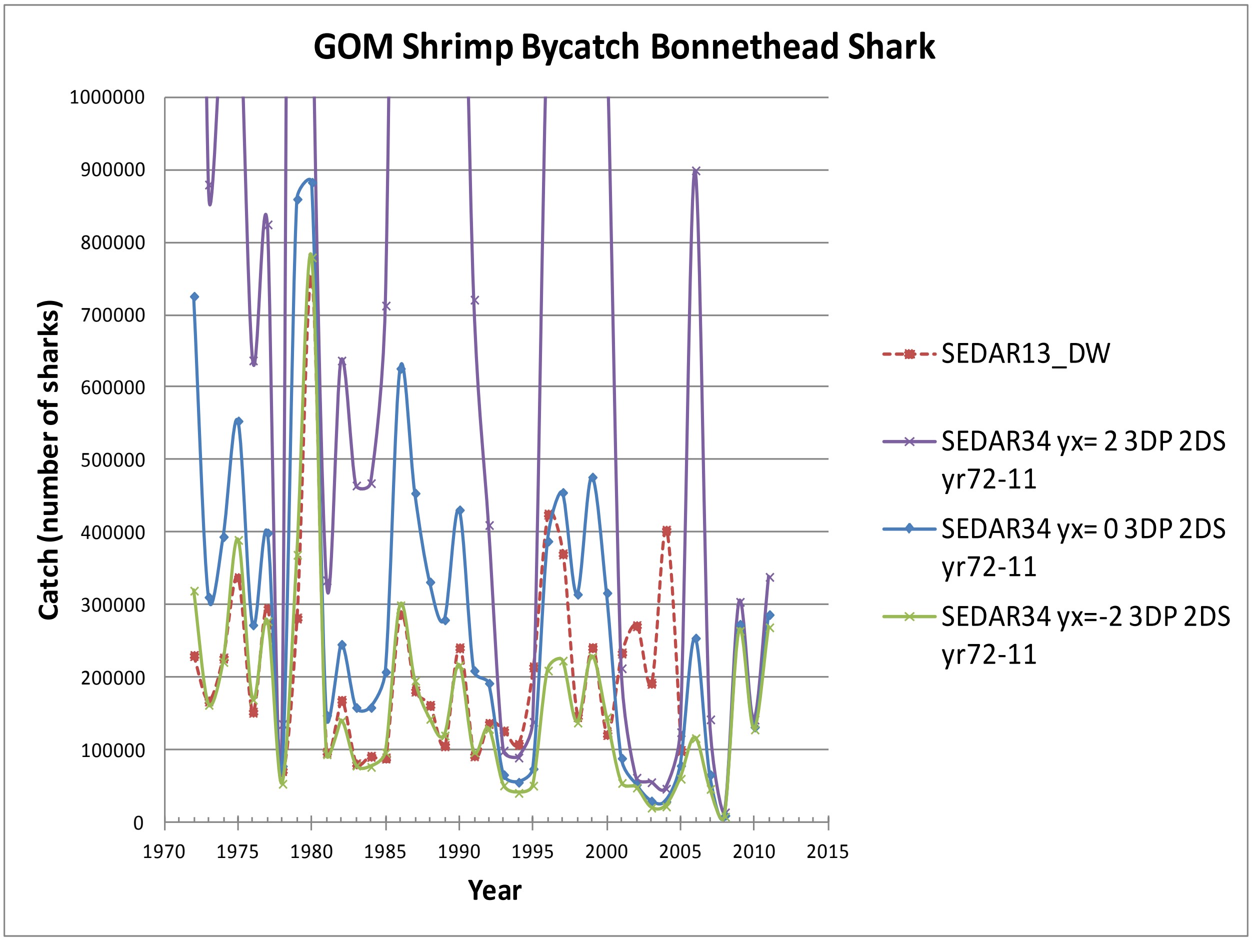

Figure 29. WinBUGS shrimp bycatch estimates for bonnethead shark in the Gulf of Mexico with the model used in SEDAR 7 (Nichols 2004, Eq1 of this report) with 3 depth-zone strata (3DP) and combined observer program non-BRD/BRD datasets (2DS) with a variety of priors for year effect.

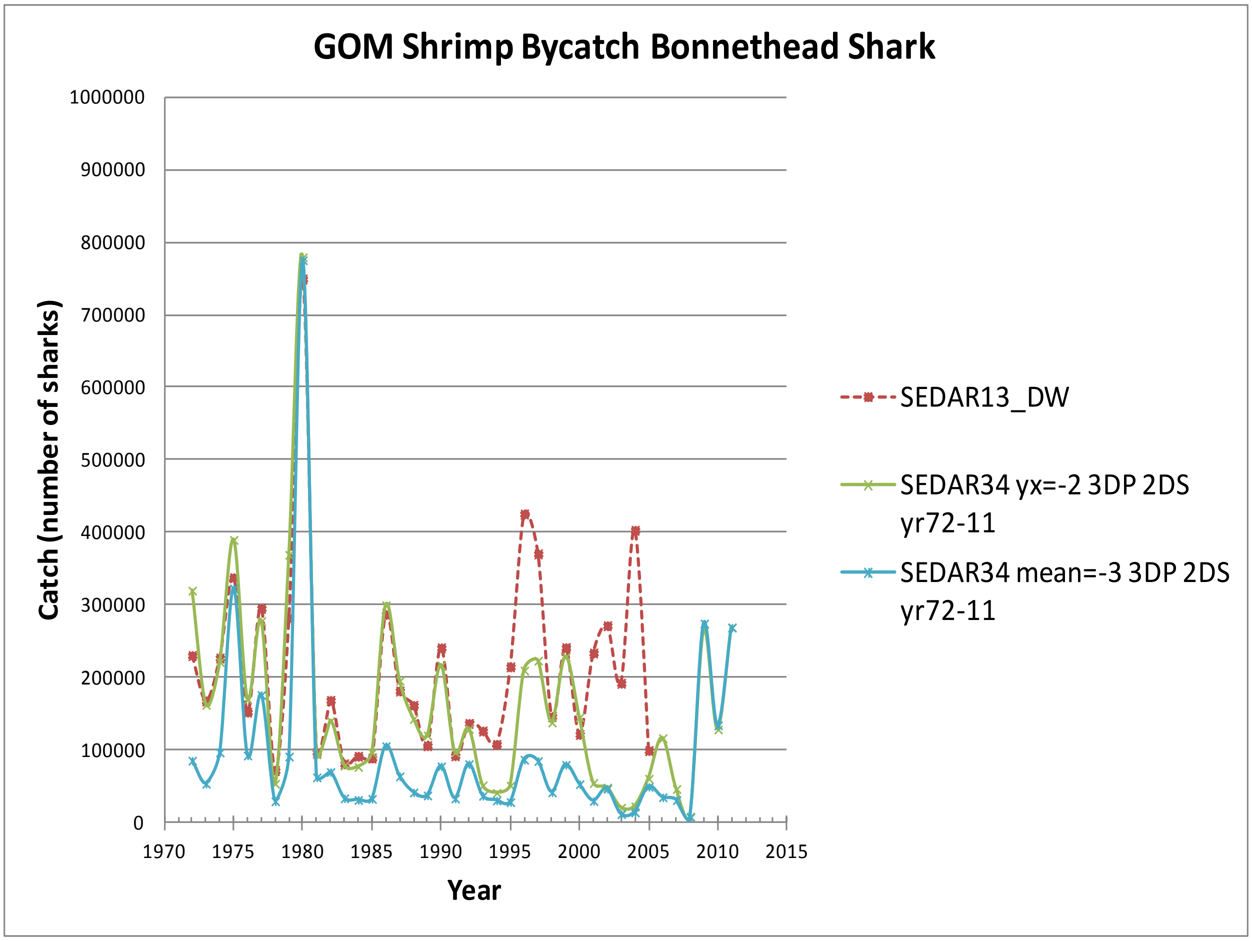

Figure 30. WinBUGS shrimp bycatch estimates for bonnethead shark in the Gulf of Mexico with the models used in SEDAR 7 (Nichols 2004, Eq1 of this report) and SEDAR 13 (Nichols 2007, Eq2 of this report) with 3 depth-zone strata (3DP) and combined observer program non-BRD/BRD datasets (2DS).

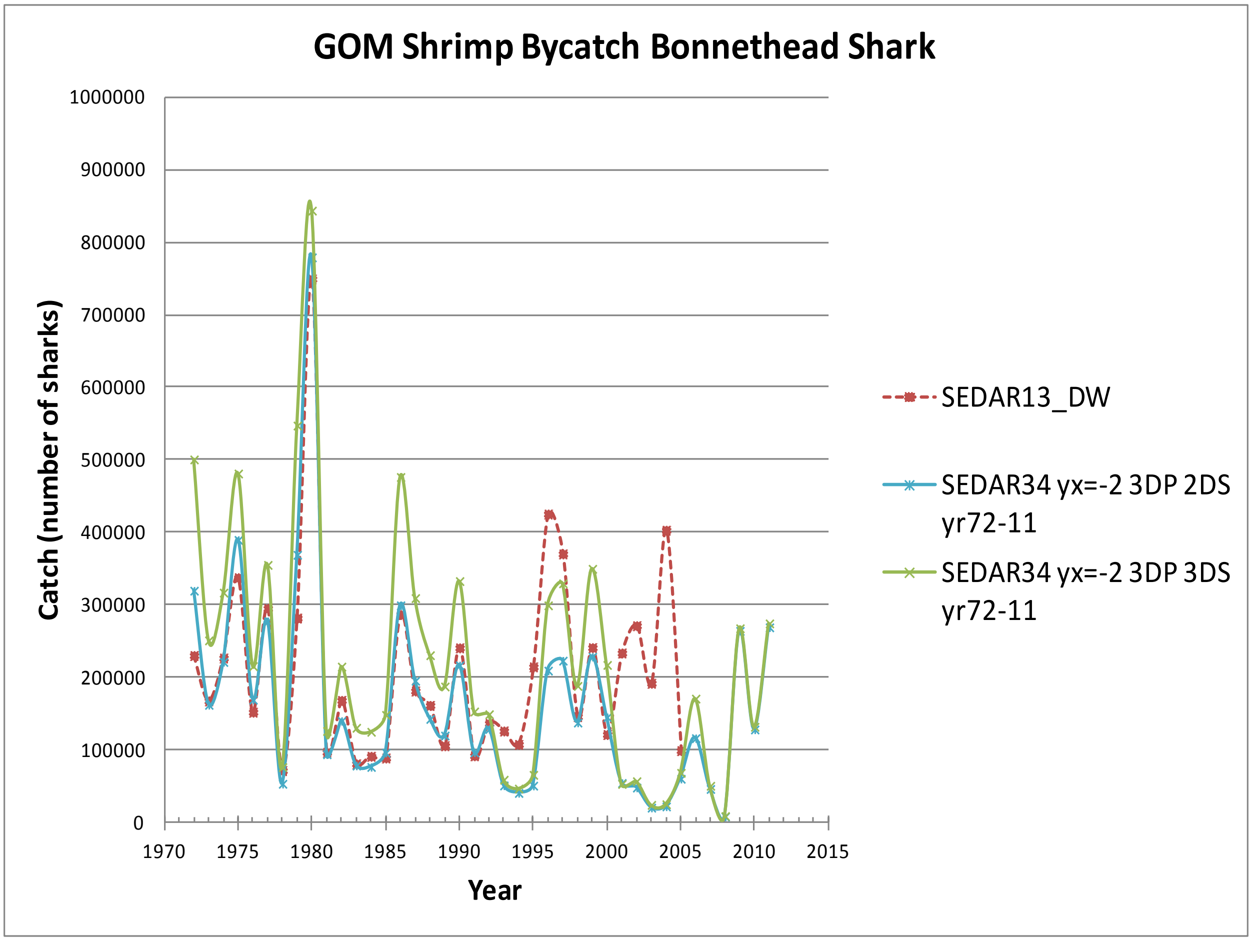

Figure 31. WinBUGS shrimp bycatch estimates for bonnethead shark in the Gulf of Mexico with the model used in SEDAR 7 (Nichols 2004, Eq1 of this report) with 3 depth-zone strata (3DP) and combined or separated observer program non-BRD/BRD datasets (2DS or 3DS).

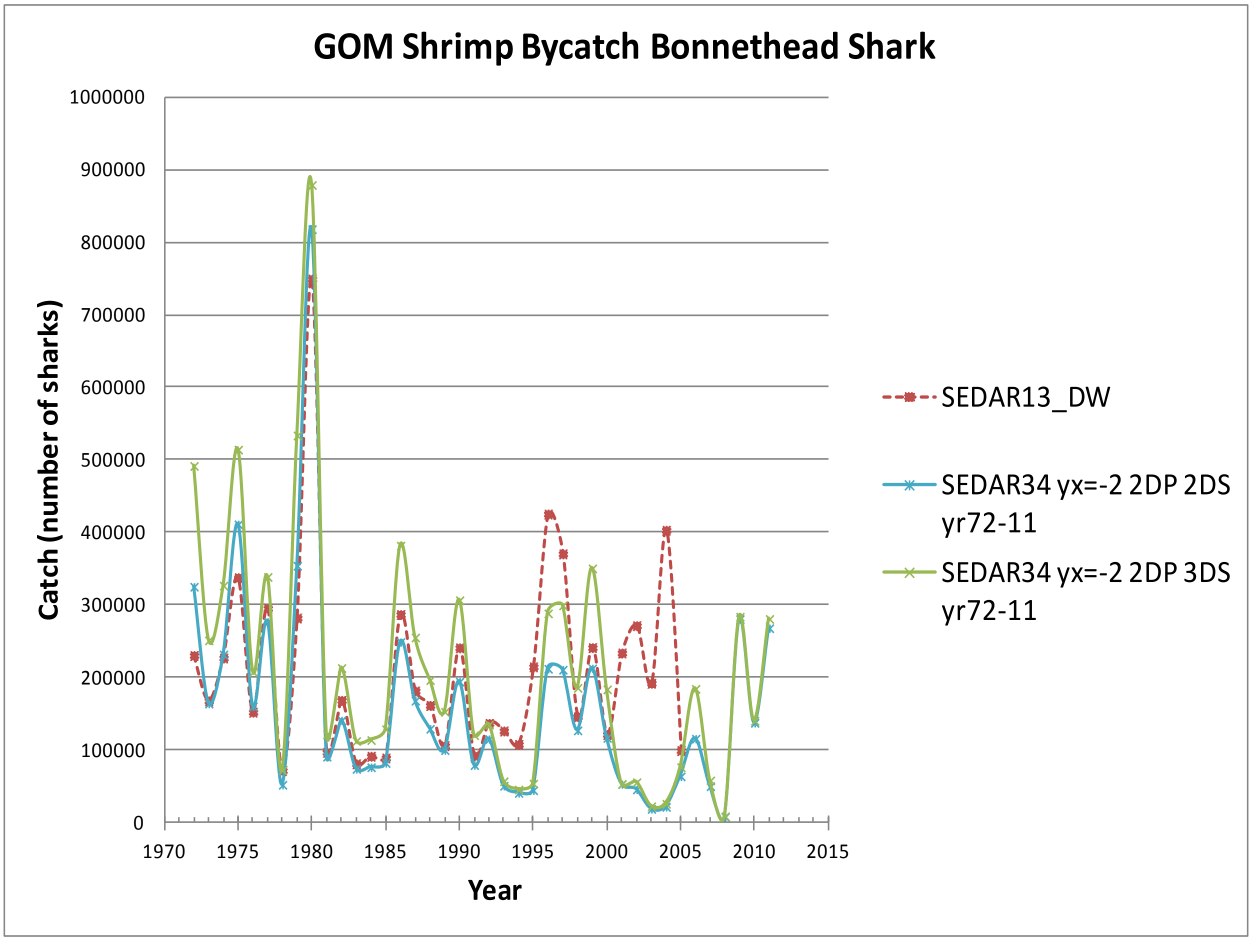

Figure 32. WinBUGS shrimp bycatch estimates for bonnethead shark in the Gulf of Mexico with the model used in SEDAR 7 (Nichols 2004, Eq1 of this report) with 2 depth-zone strata (2DP) and combined or separated observer program non-BRD/BRD datasets (2DS or 3DS).

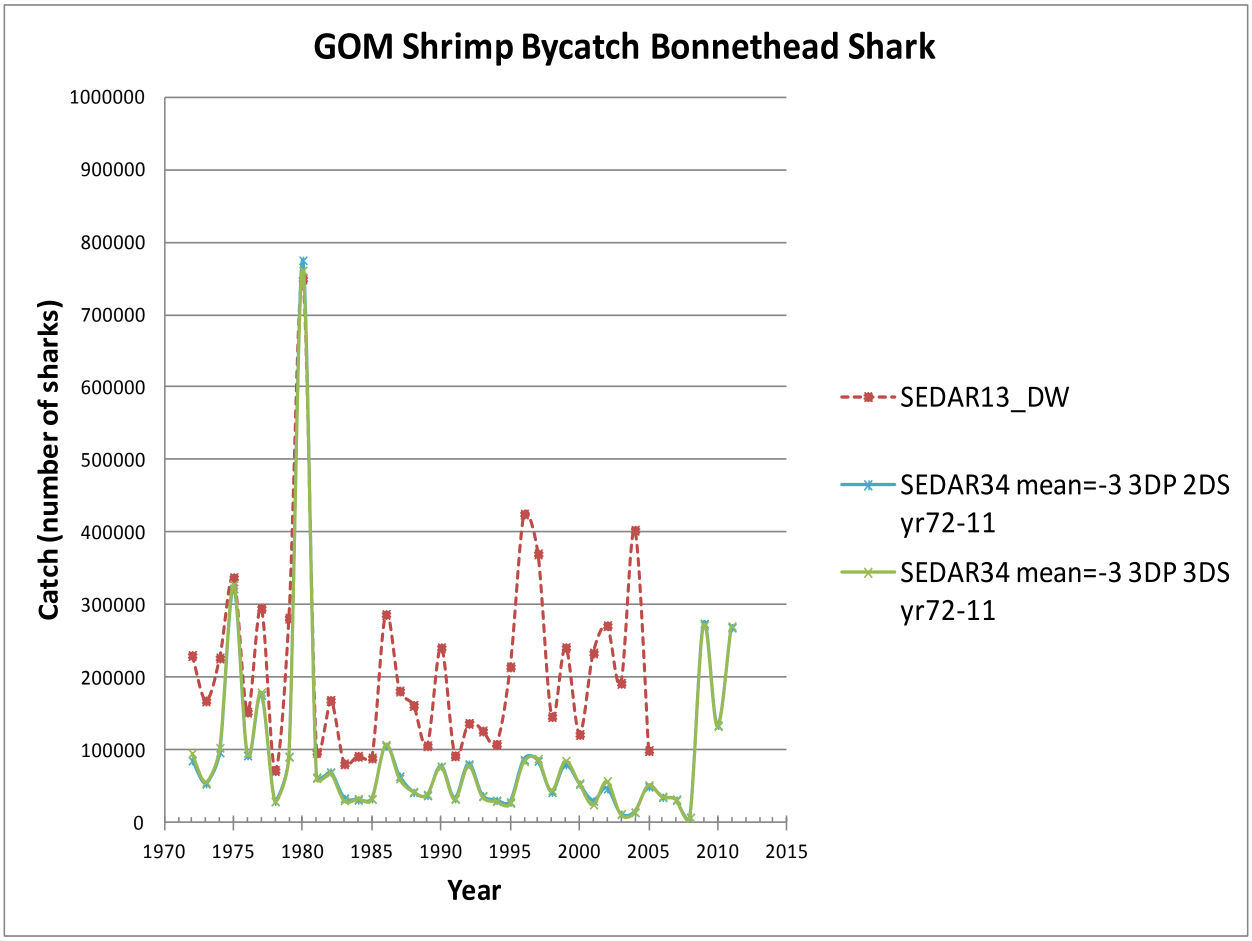

Figure 33. WinBUGS shrimp bycatch estimates for bonnethead shark in the Gulf of Mexico with the model used in SEDAR 13 (Nichols 2007, Eq2 of this report) with 2 depth-zone strata (3DP) and combined or separated observer program non-BRD/BRD datasets (2DS or 3DS).

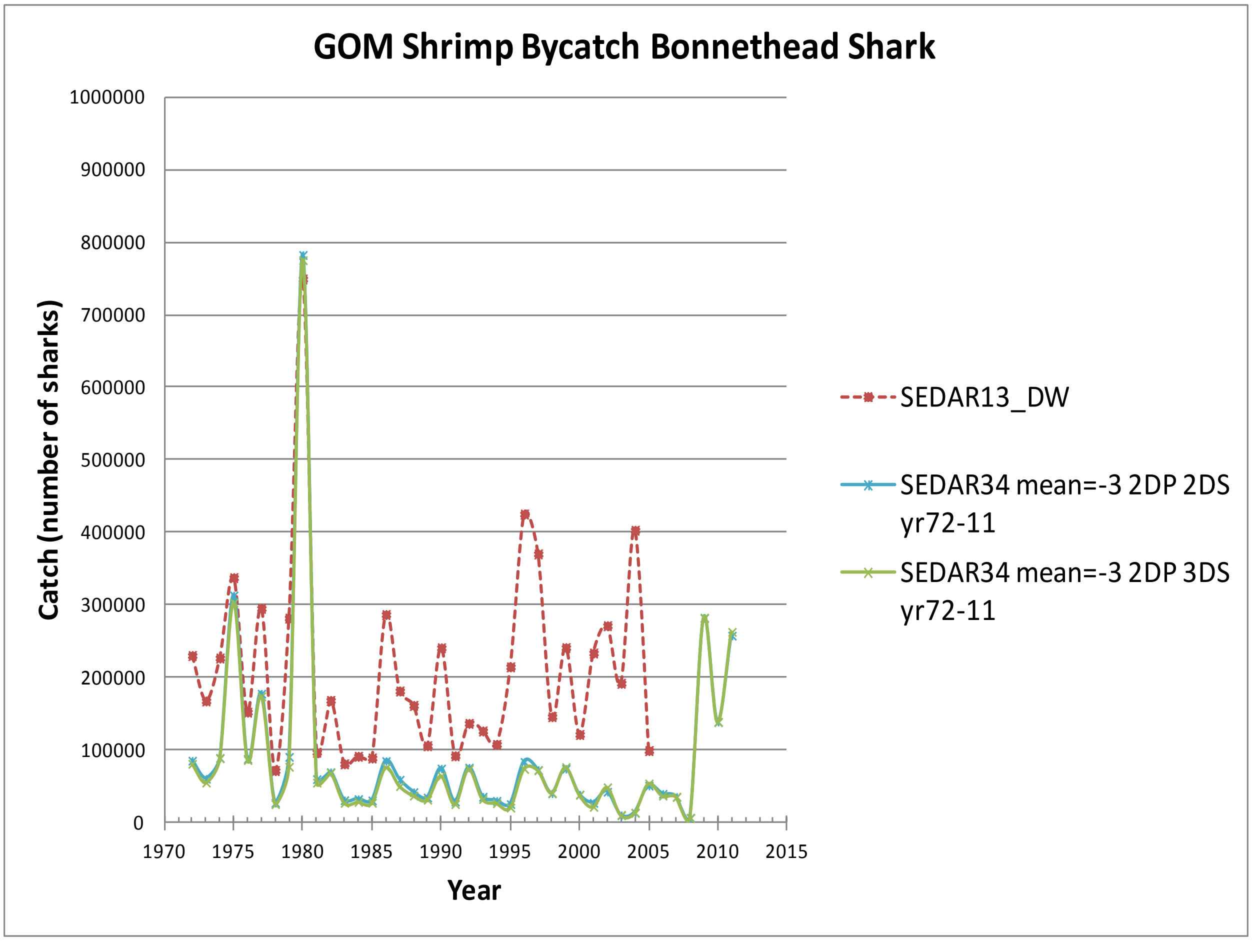

Figure 34. WinBUGS shrimp bycatch estimates for bonnethead shark in the Gulf of Mexico with the model used in SEDAR 13 (Nichols 2007, Eq2 of this report) with 2 depth zone strata (2DP) and combined or separated observer program non-BRD/BRD datasets (2DS or 3DS).

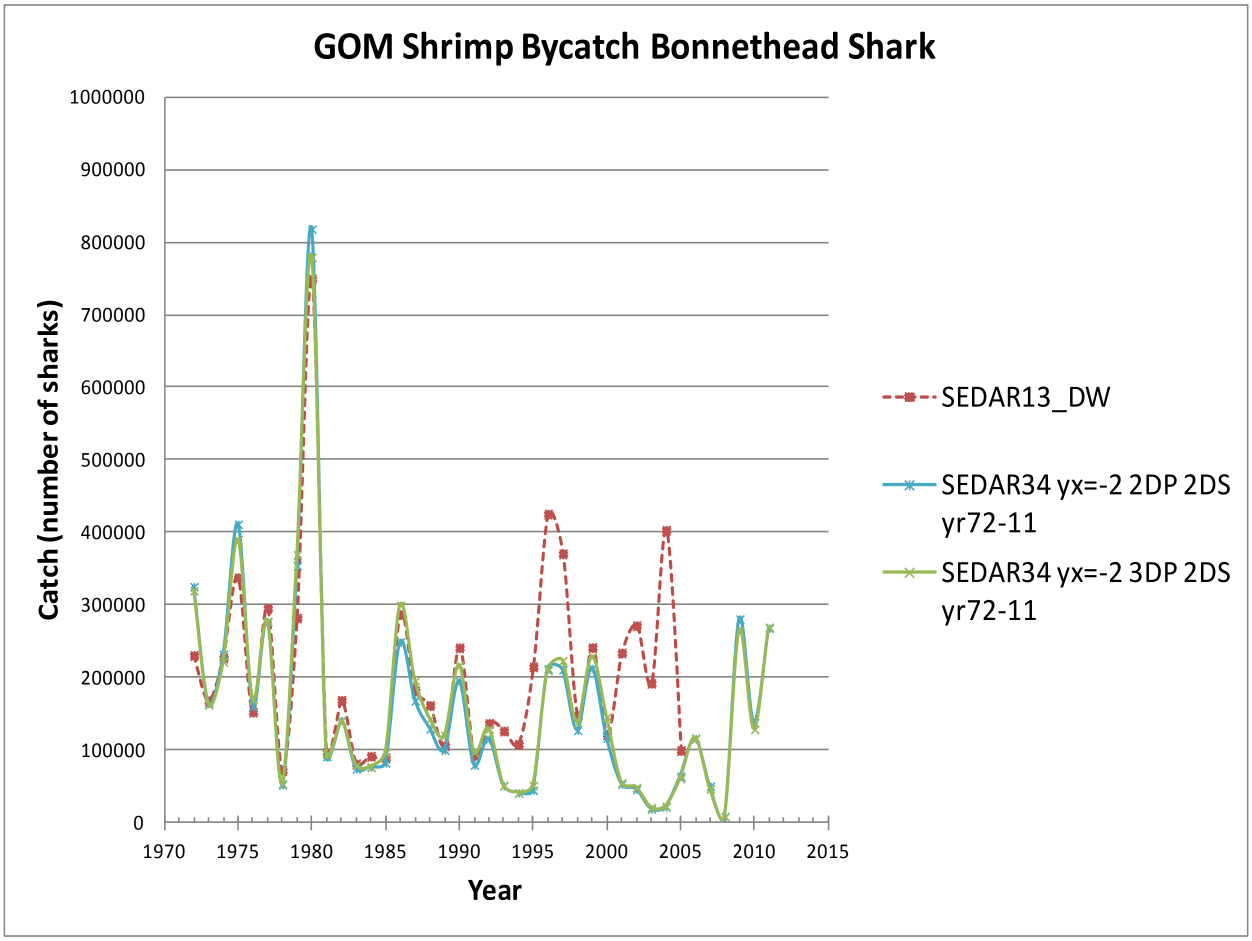

Figure 35. WinBUGS shrimp bycatch estimates for bonnethead shark in the Gulf of Mexico with the model used in SEDAR 7 (Nichols 2004, Eq1 of this report) with 2 or 3 depth-zone strata (2DP or 3DP) and combined observer program non-BRD/BRD datasets (2DS).

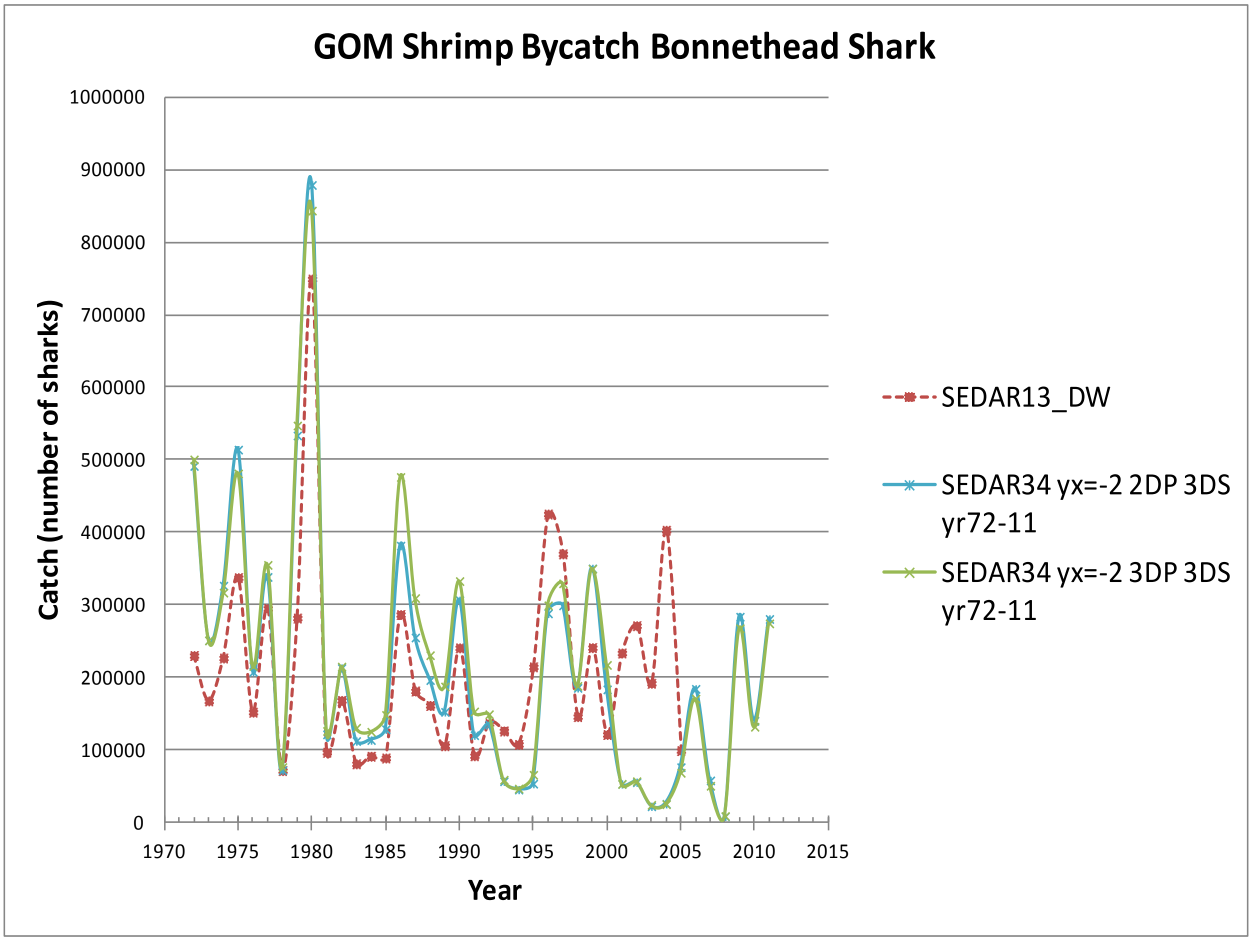

Figure 36. WinBUGS shrimp bycatch estimates for bonnethead shark in the Gulf of Mexico with the model used in SEDAR 7 (Nichols 2004, Eq1 of this report) with 2 or 3 depth zone strata (2DP or 3DP) and separated observer program non-BRD/BRD datasets (3DS).

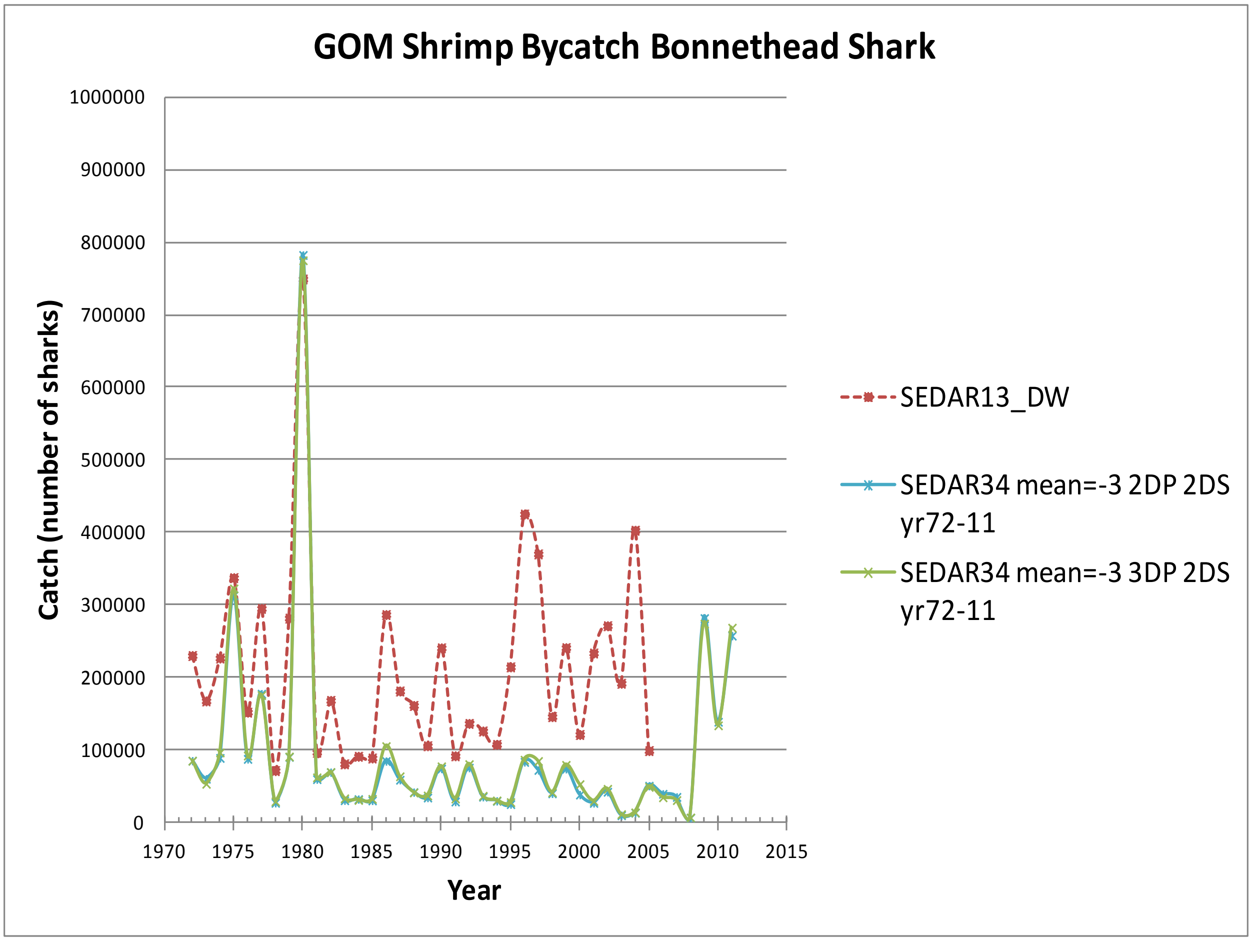

Figure 37. WinBUGS shrimp bycatch estimates for bonnethead shark in the Gulf of Mexico with the model used in SEDAR 13 (Nichols 2007, Eq2 of this report) with 2 or 3 depth-zone strata (2DP or 3DP) and combined observer program non-BRD/BRD datasets (2DS).

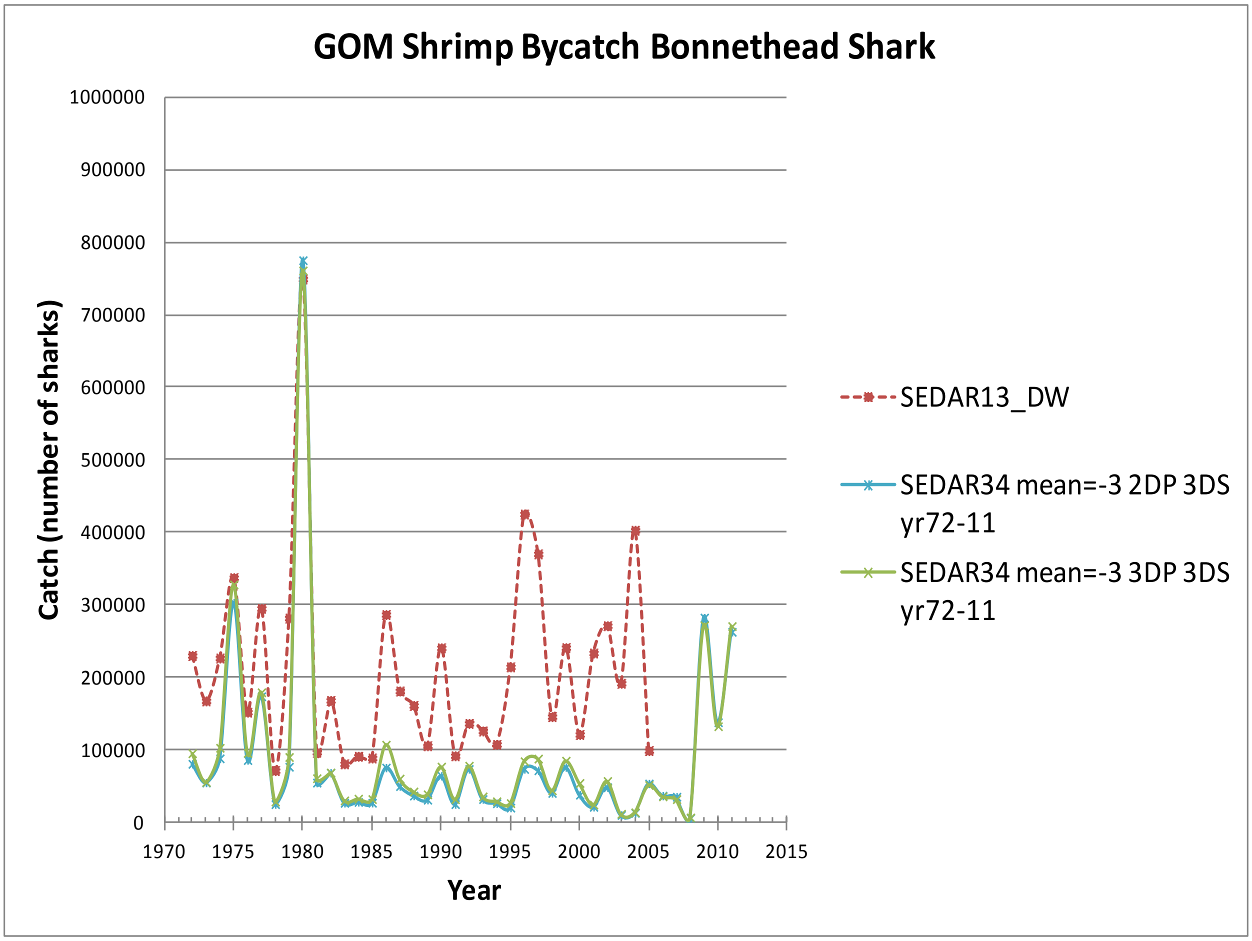

Figure 38. WinBUGS shrimp bycatch estimates for bonnethead shark in the Gulf of Mexico with the model used in SEDAR 13 (Nichols 2007, Eq2 of this report) with 2 or 3 depth-zone strata (2DP or 3DP) and separated observer program non-BRD/BRD datasets (3DS).

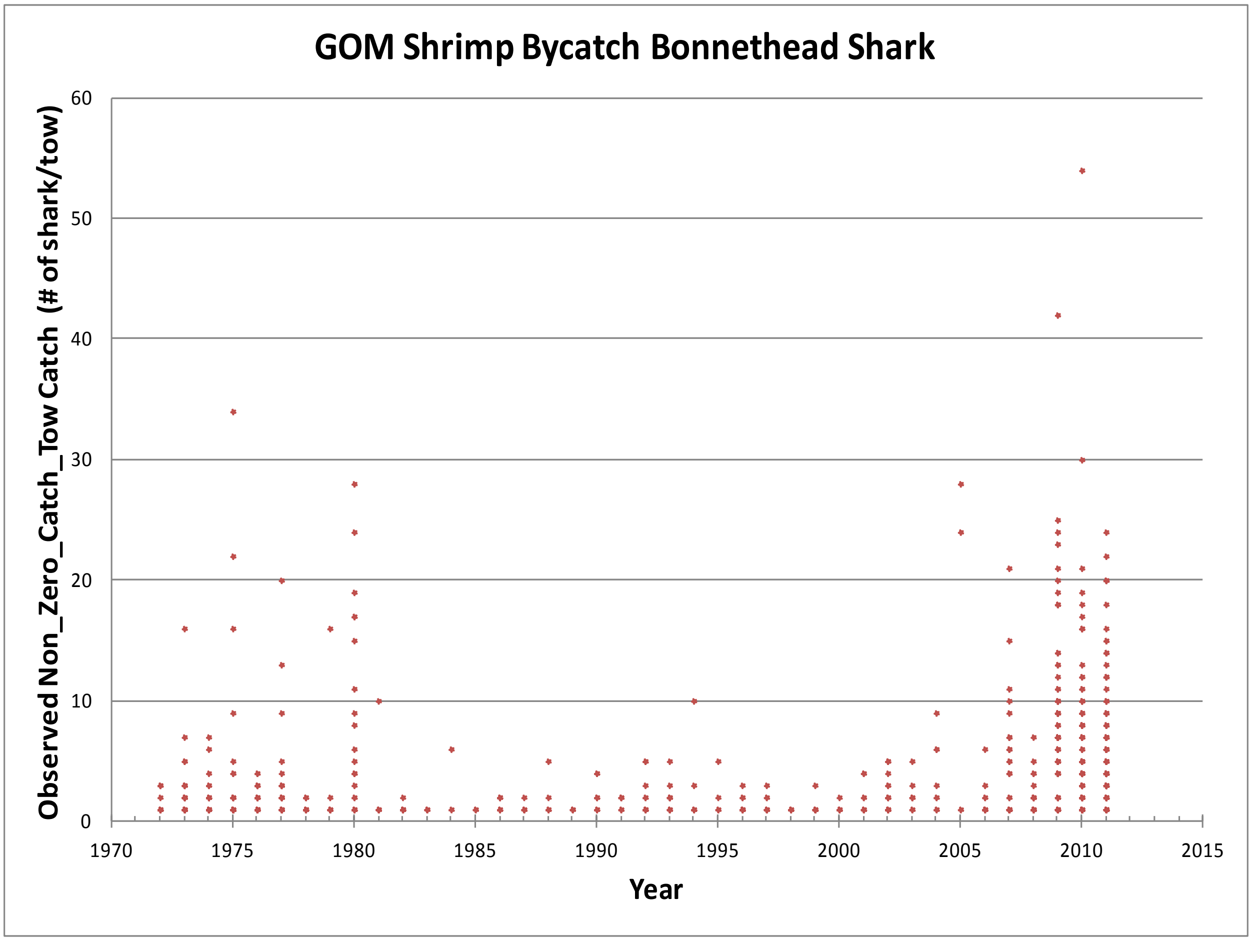

Figure 39. Observed non-zero-catch-tow catch (# of sharks per tow) for bonnethead shark in the Gulf of Mexico.

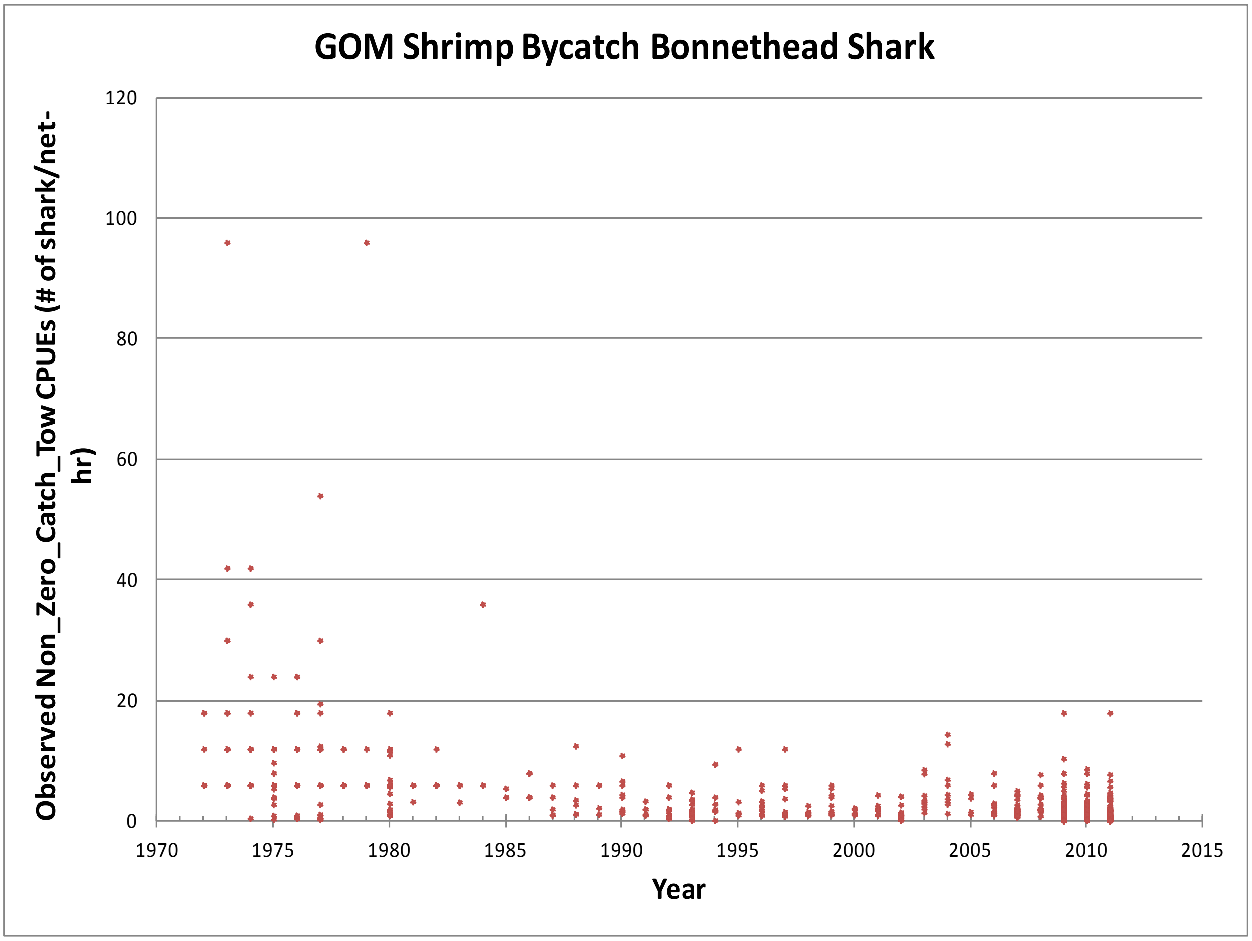

Figure 40. Observed non-zero-catch-tow CPUEs (# of sharks per net-hour) for bonnethead shark in the Gulf of Mexico.

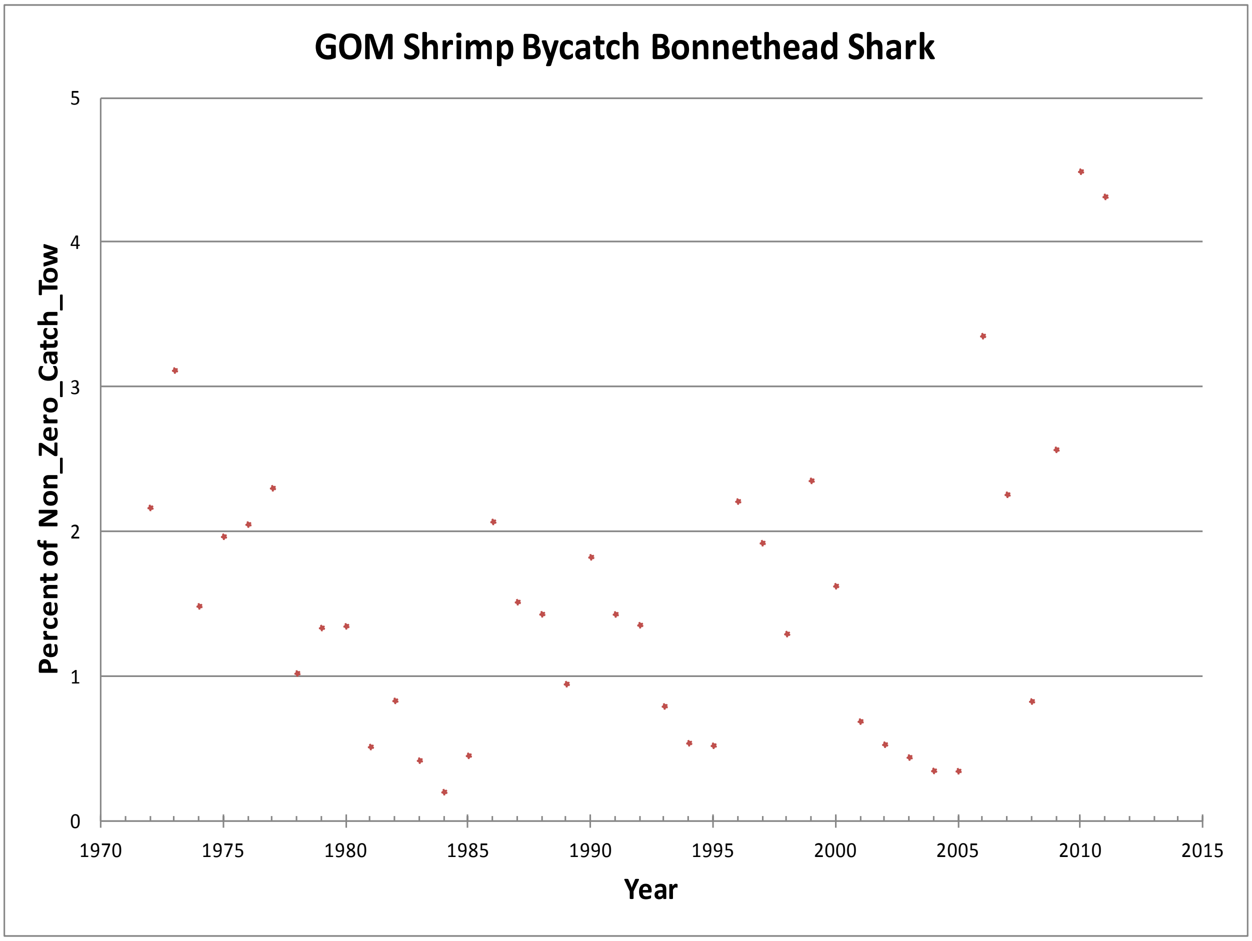

Figure 41. Observed percent of non-zero-catch tows for bonnethead shark in the Gulf of Mexico.

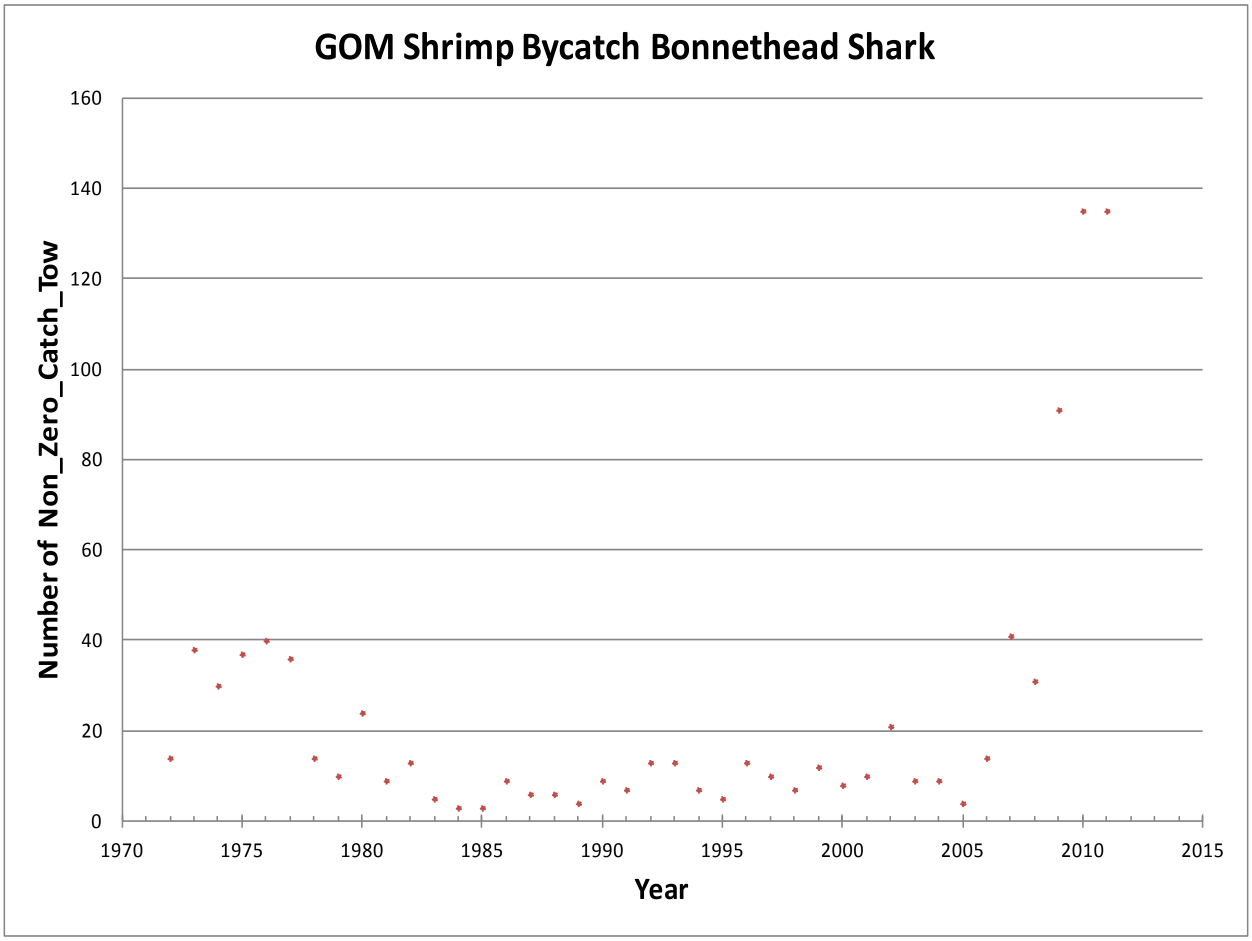

Figure 42. Observed number of non-zero-catch tows per year for bonnethead shark in the Gulf of Mexico.

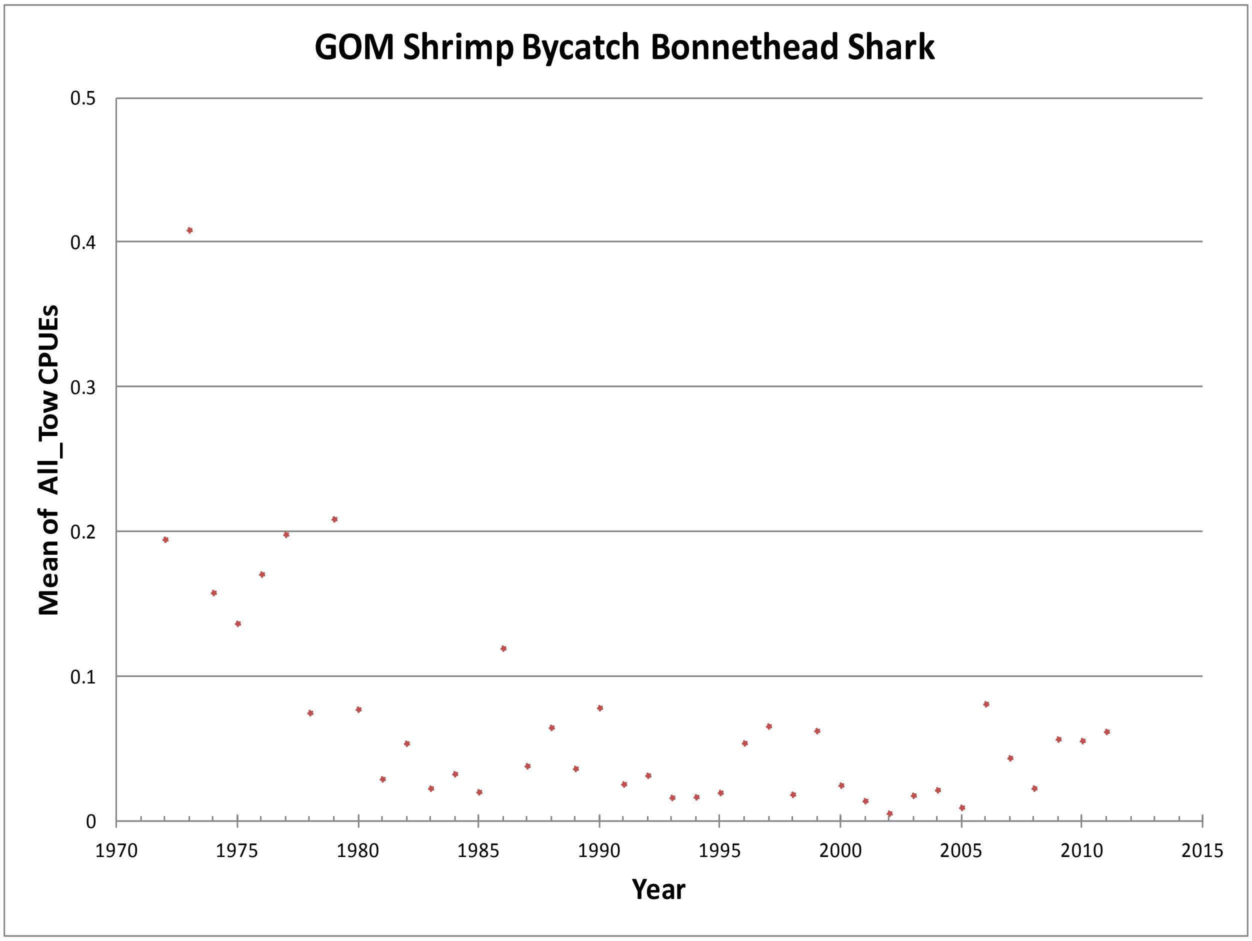

Figure 43. Observed annual mean all-tow CPUEs for bonnethead shark in the Gulf of Mexico.

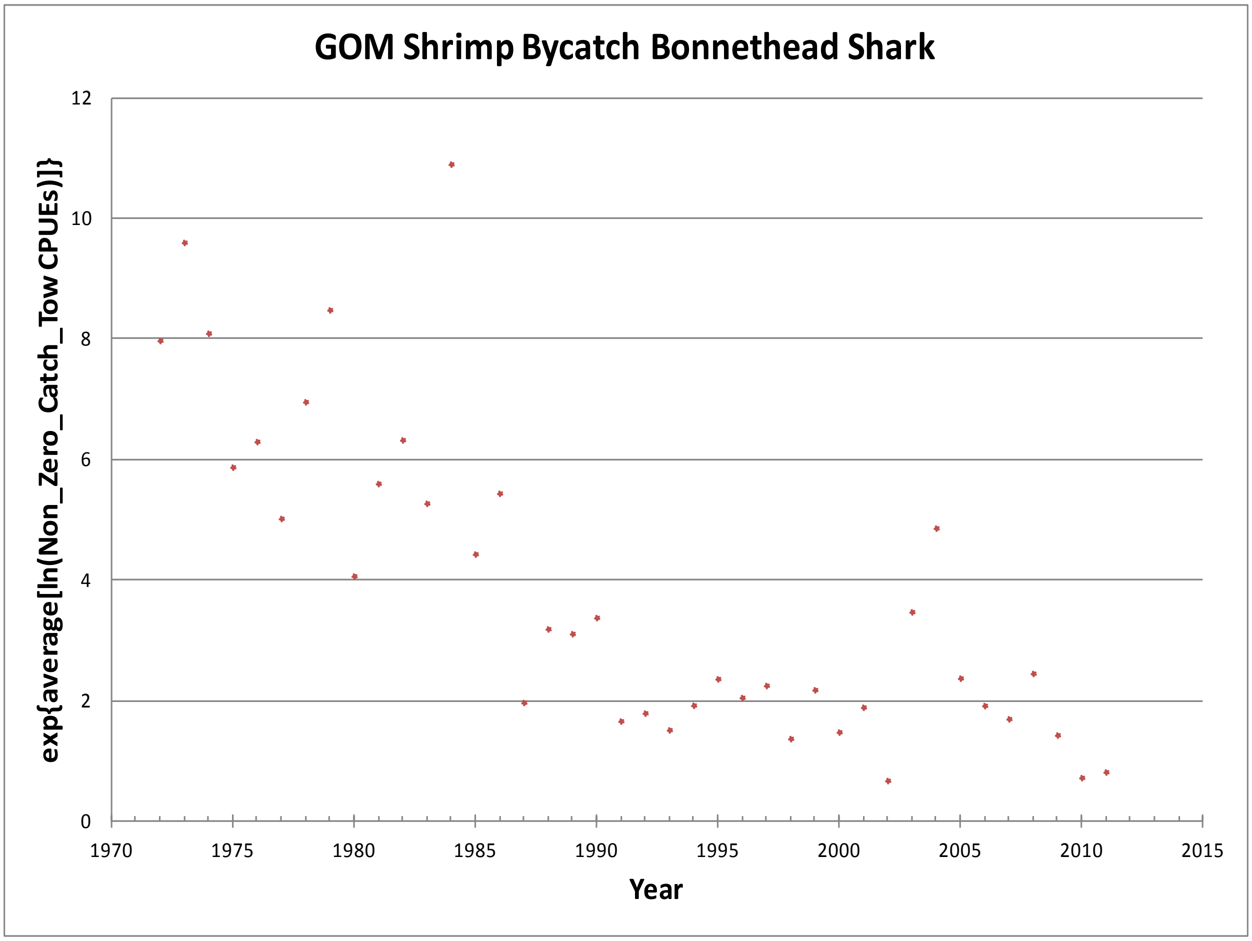

Figure 44. Observed annual mean non-zero-catch-tow CPUEs for bonnethead shark in the Gulf of Mexico.

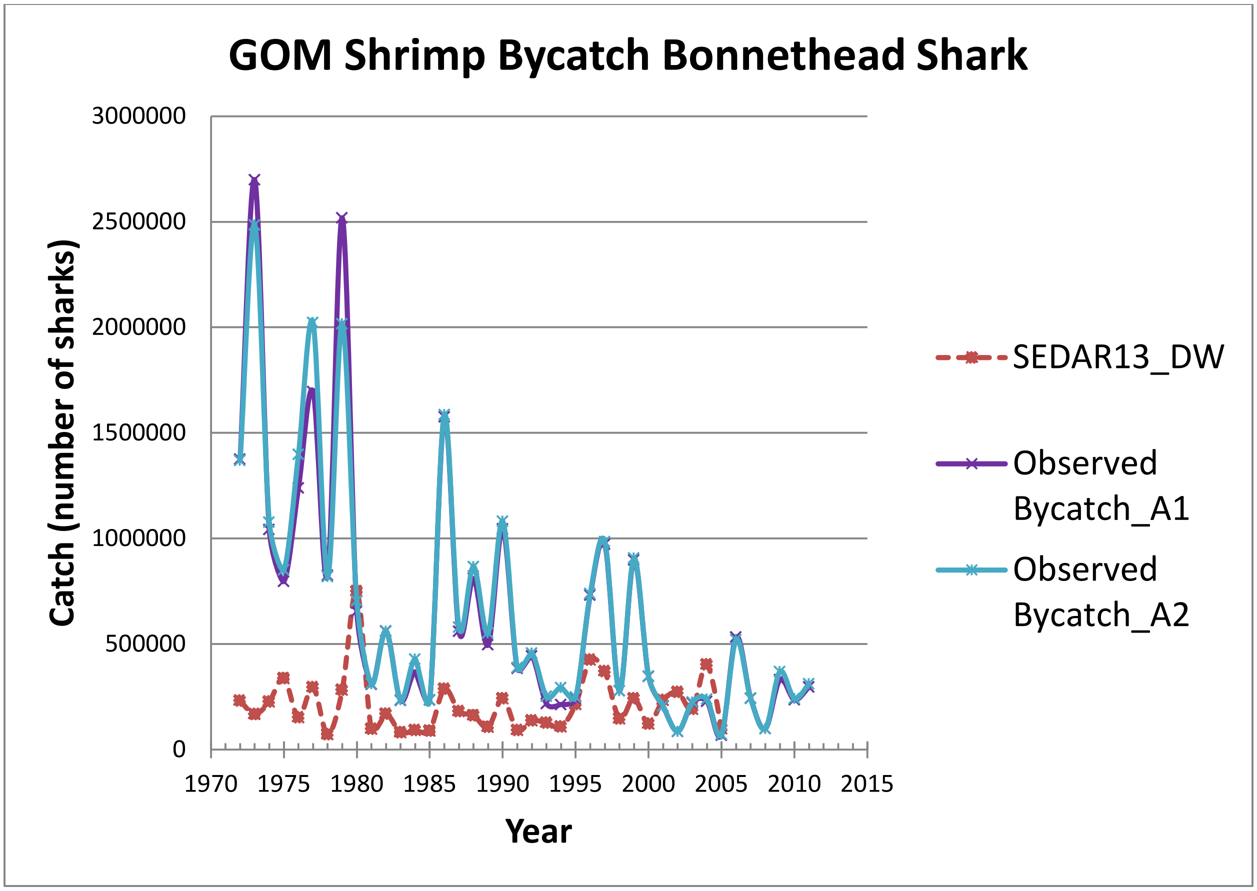

Figure 45. “Back-of-the-envelope” estimates of the observed bycatch for bonnethead shark in the Gulf of Mexico with approach 1 (Observed Bycatch_A1) and approach 2 (Observed Bycatch_A2) (see Methods for details).

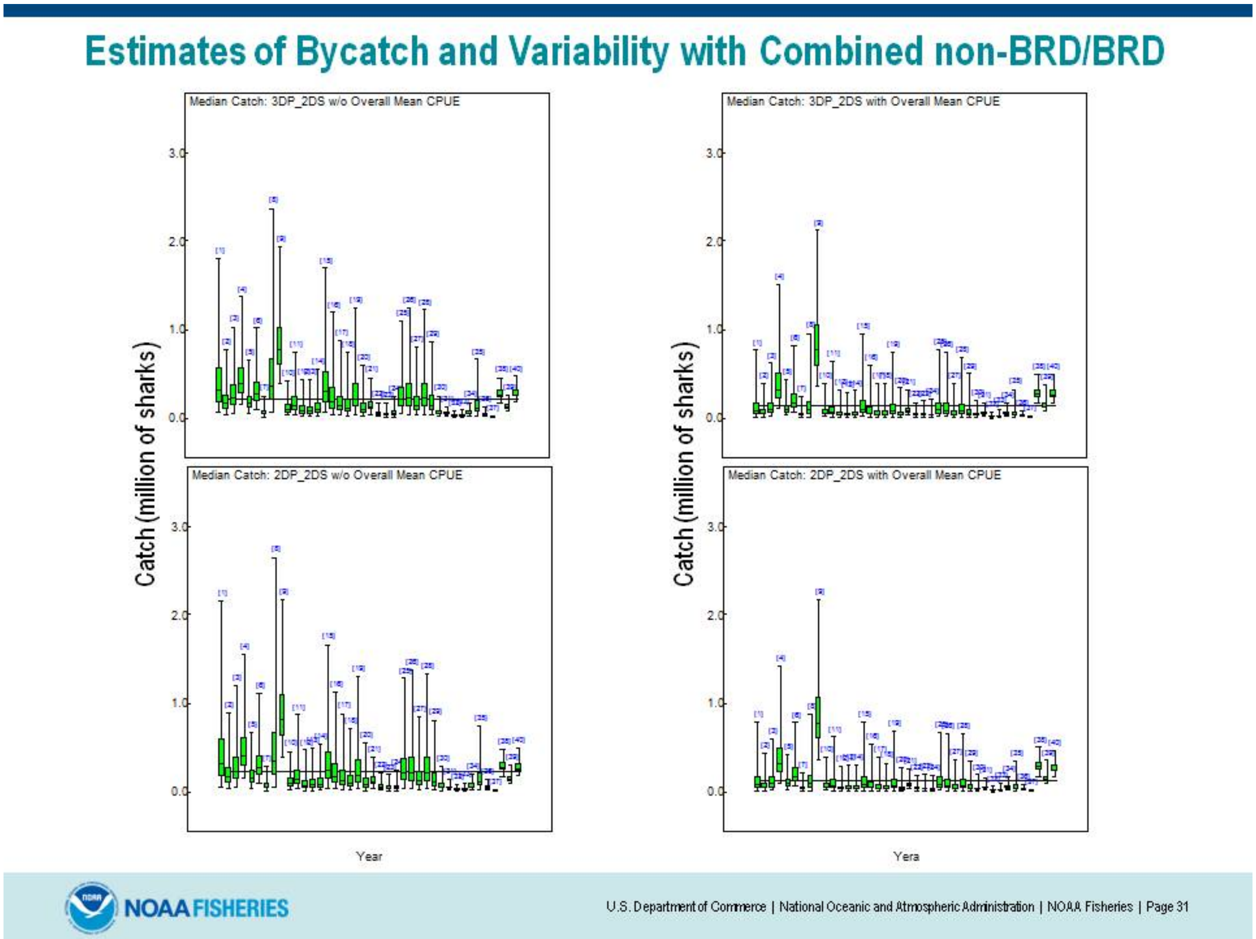

Figure 46. With combined observer program non-BRD/BRD datasets (2DS), WinBUGS estimates of bycatch and variability for bonnethead shark in the Gulf of Mexico without or with an overall mean CPUE term added to the SEDAR 7 WinBUGS shrimp bycatch estimation model (left panels or right panels) and with 3 or 2 depth-zone strata (3DP or 2DP; upper panels or lower panels).

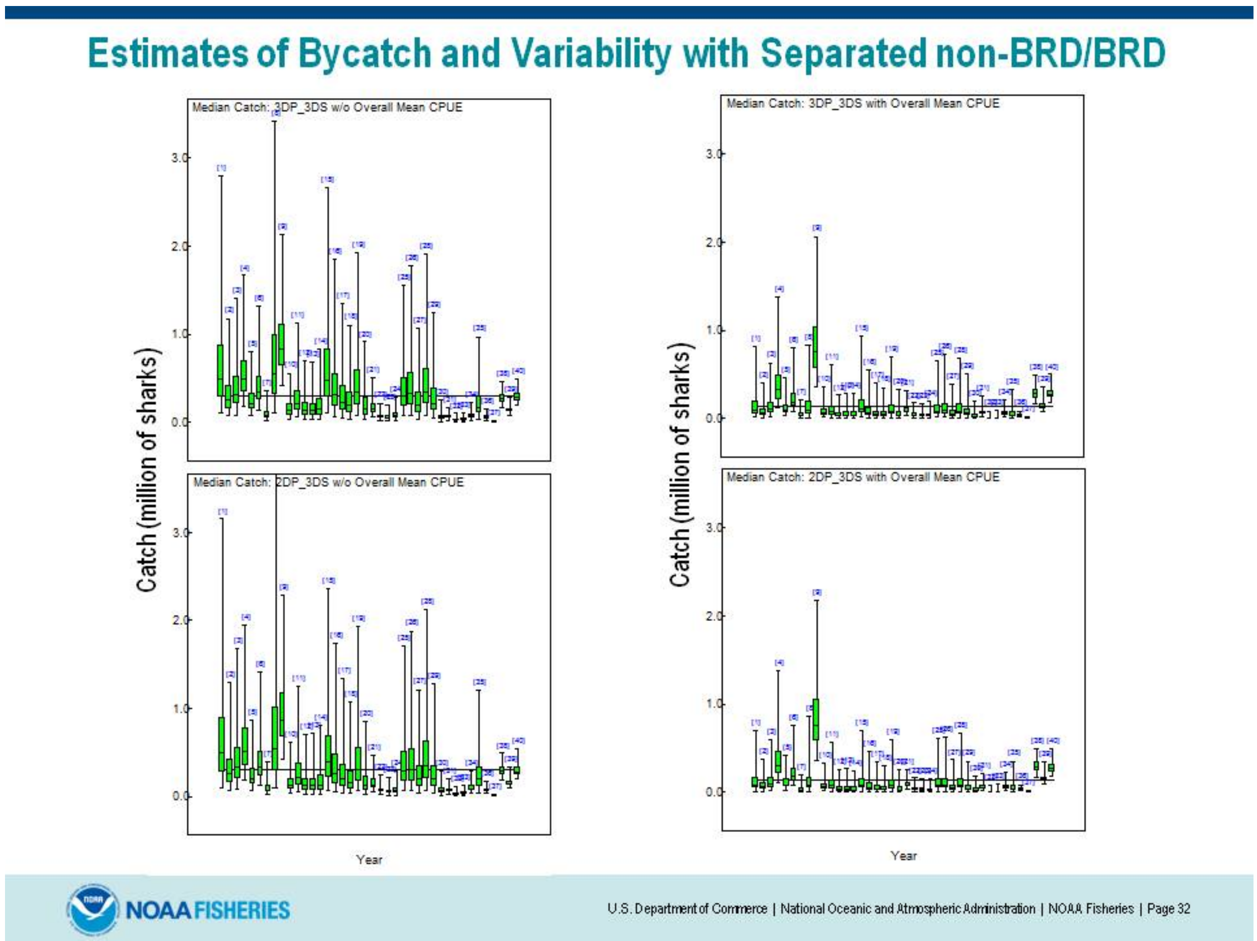

Figure 47. With separated observer program non-BRD/BRD datasets (3DS), WinBUGS estimates of bycatch and variability for bonnethead shark in the Gulf of Mexico without or with an overall mean CPUE term added to the SEDAR 7 WinBUGS shrimp bycatch estimation model (left panels or right panels) and with 3 or 2 depth-zone strata (3DP or 2DP; upper panels or lower panels).

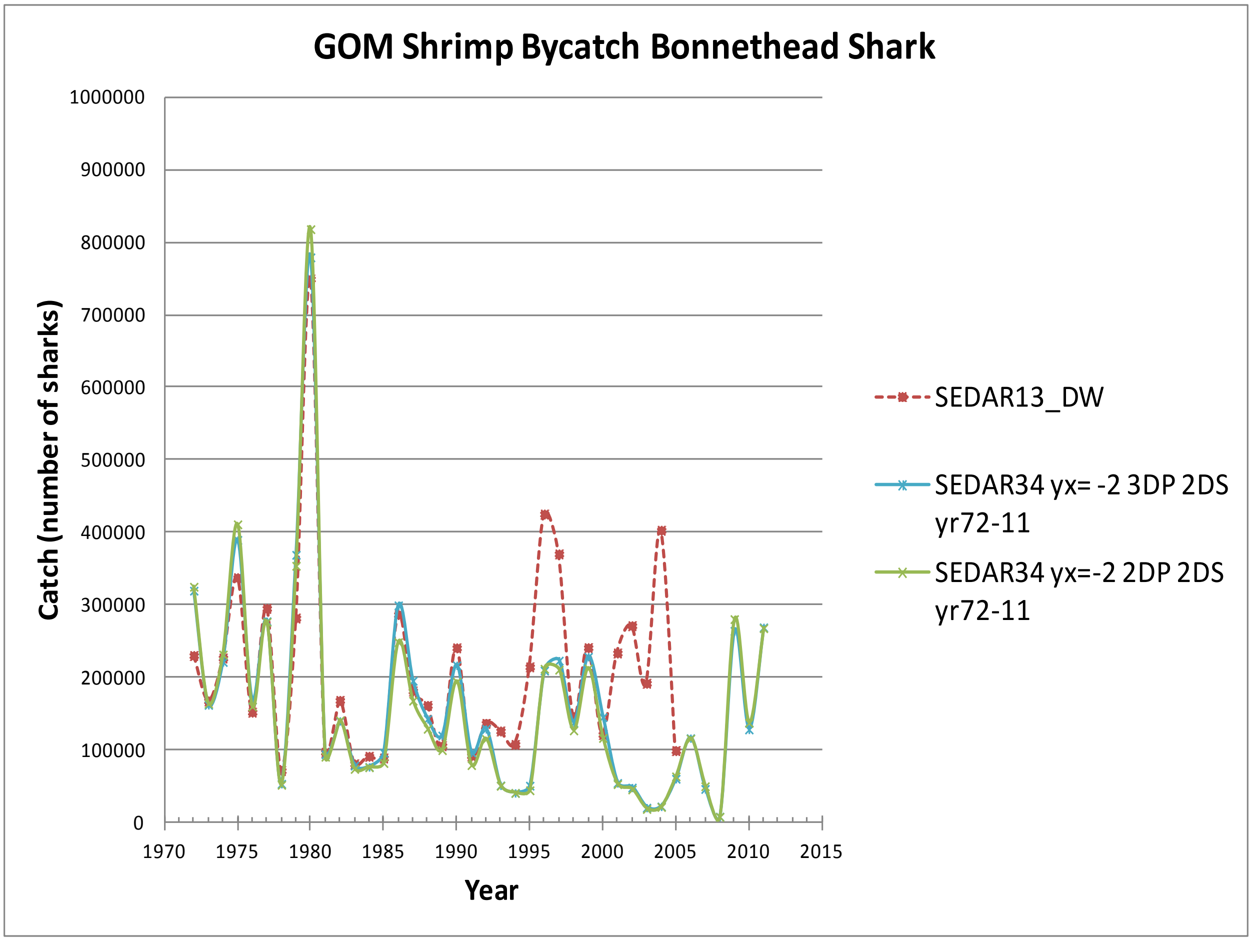

Figure 48. Recommended WinBUGS shrimp bycatch estimates for bonnethead shark in the Gulf of Mexico with the model used in SEDAR 7 (Nichols 2004, Eq1 of this report) with 2 or 3 depth-zone strata (2DP or 3DP) and combined observer program non-BRD/BRD datasets (2DS).

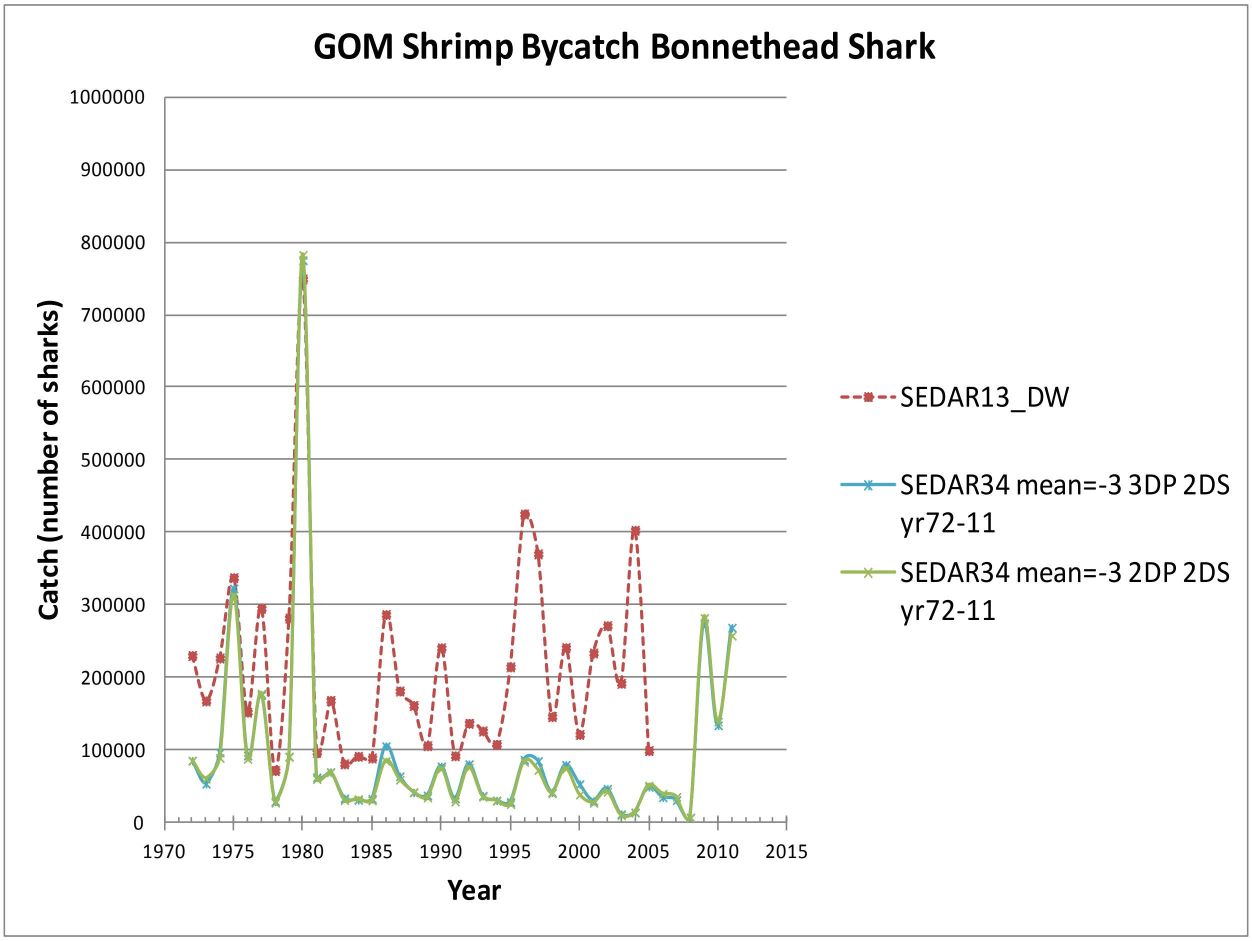

Figure 49. Recommended WinBUGS shrimp bycatch estimates for bonnethead shark in the Gulf of Mexico with the model used in SEDAR 13 (Nichols 2007, Eq2 of this report) with 2 or 3 depth-zone strata (2DP or 3DP) and combined observer program non-BRD/BRD datasets (2DS).

Table 1. List of factor levels for the main effects of the WinBUGS shrimp bycatch estimation models.

Main Effect	Levels	Description
Year	40	1972-2011
Season	3	Jan-Apr, May-Aug, Sep-Dec
Area	4	Statistical grids 1-9, 10-12, 13-17, 18-21
Depth	2	<= 10fm, > 10fm
	3	<= 10fm, >10fm & <=30fm, >30fm
Dataset	2	Observer program non-BRD/BRD
		Research vessel
	3	Observer program non-BRD
		Observer program BRD
		Research vessel

Table 2. Recommended WinBUGS estimates of bycatch (million sharks) and variability without an overall mean CPUE term added to the SEDAR 7 WinBUGS shrimp bycatch estimation model with 2 depth-zone strata (2DP) and combined observer program non-BRD/BRD datasets (2DS) for Atlantic sharpnose shark in the Gulf of Mexico. Annual 1-40 are year 1972-2011.

node	**mean**	**sd**	**MC error**	**2.5%**	**median**	**97.5%**	**start**	**sample**
annual[1]	1.553	3.323	0.0453	0.1805	0.9398	6.652	4001	20000
annual[2]	0.1788	0.2021	0.003774	0.03189	0.1266	0.6377	4001	20000
annual[3]	0.3872	0.4916	0.00924	0.06468	0.2615	1.488	4001	20000
annual[4]	0.396	0.4823	0.008356	0.0734	0.2652	1.481	4001	20000
annual[5]	0.25	0.2308	0.003247	0.06859	0.1935	0.779	4001	20000
annual[6]	0.5915	0.4711	0.004669	0.1919	0.471	1.693	4001	20000
annual[7]	0.8569	0.8921	0.0098	0.2444	0.633	2.904	4001	20000
annual[8]	2.196	5.799	0.08306	0.1514	1.027	10.75	4001	20000
annual[9]	0.9488	1.015	0.01045	0.3021	0.7117	3.062	4001	20000
annual[10]	1.969	1.933	0.0217	0.5854	1.503	5.977	4001	20000
annual[11]	0.3434	0.5202	0.007313	0.04751	0.2111	1.436	4001	20000
annual[12]	0.5579	0.9889	0.01191	0.07502	0.3356	2.379	4001	20000
annual[13]	0.316	0.5472	0.007558	0.04053	0.1913	1.297	4001	20000
annual[14]	0.5052	0.9076	0.01028	0.06542	0.3074	2.135	4001	20000
annual[15]	0.5071	3.202	0.02497	0.052	0.2777	2.11	4001	20000
annual[16]	1.269	2.104	0.02888	0.1384	0.7383	5.522	4001	20000
annual[17]	0.6565	1.142	0.01226	0.07621	0.3874	2.806	4001	20000
annual[18]	0.6113	1.373	0.01338	0.0638	0.3456	2.639	4001	20000
annual[19]	0.6463	2.735	0.02099	0.06611	0.3493	2.726	4001	20000
annual[20]	0.9665	2.438	0.02245	0.1078	0.5486	4.235	4001	20000
annual[21]	1.067	0.6714	0.006791	0.5017	0.9399	2.391	4001	20000
annual[22]	0.2808	0.1906	0.00185	0.1041	0.2318	0.7488	4001	20000
annual[23]	0.1169	0.1825	0.001915	0.02232	0.07296	0.4832	4001	20000
annual[24]	0.2318	0.5394	0.005269	0.0312	0.1299	0.9964	4001	20000
annual[25]	0.5381	1.927	0.01709	0.06477	0.2996	2.23	4001	20000
annual[26]	0.3754	0.591	0.007316	0.05045	0.23	1.544	4001	20000
annual[27]	0.5807	1.174	0.01239	0.06683	0.3252	2.549	4001	20000
annual[28]	0.635	1.094	0.01381	0.06986	0.3669	2.781	4001	20000
annual[29]	1.054	2.067	0.02122	0.1219	0.6214	4.47	4001	20000
annual[30]	0.1023	0.1849	0.00259	0.0135	0.05944	0.4389	4001	20000
annual[31]	0.08788	0.09452	0.001035	0.02844	0.06631	0.2785	4001	20000
annual[32]	0.03077	0.03898	5.539E-4	0.006721	0.02202	0.108	4001	20000
annual[33]	0.01338	0.01556	2.314E-4	0.003028	0.009573	0.04665	4001	20000
annual[34]	0.05035	0.06794	9.1E-4	0.01018	0.03382	0.1867	4001	20000
annual[35]	0.2826	0.5238	0.006088	0.03012	0.1622	1.26	4001	20000
annual[36]	0.03253	0.04242	6.694E-4	0.008443	0.0232	0.1101	4001	20000
annual[37]	0.006836	0.03351	2.7E-4	0.002137	0.004781	0.02178	4001	20000
annual[38]	1.668	0.4675	0.003524	0.939	1.611	2.743	4001	20000
annual[39]	0.6374	0.1149	9.237E-4	0.4574	0.624	0.9012	4001	20000
annual[40]	1.468	0.2473	0.002068	1.075	1.441	2.011	4001	20000

Table 3. Recommended WinBUGS estimates of bycatch (million sharks) and variability with an overall mean CPUE term added to the SEDAR 7 WinBUGS shrimp bycatch estimation model with 2 depth-zone strata (2DP) and combined observer program non-BRD/BRD datasets (2DS) for Atlantic sharpnose shark in the Gulf of Mexico. Annual 1-40 are year 1972-2011.

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
annual[1]	0.3571	0.612	0.0161	0.04679	0.2125	1.539	4001	6400
annual[2]	0.07378	0.1278	0.002631	0.0116	0.05033	0.264	4001	6400
annual[3]	0.1158	0.1627	0.004409	0.01512	0.07283	0.4792	4001	6400
annual[4]	0.1646	0.3139	0.006219	0.02878	0.1025	0.6473	4001	6400
annual[5]	0.1336	0.1126	0.002465	0.03748	0.1051	0.4111	4001	6400
annual[6]	0.4782	0.3857	0.00593	0.1454	0.3739	1.444	4001	6400
annual[7]	0.7366	1.211	0.02026	0.201	0.5108	2.475	4001	6400
annual[8]	0.3922	1.275	0.03048	0.02339	0.1718	1.956	4001	6400
annual[9]	0.8115	0.8628	0.01546	0.2575	0.6077	2.574	4001	6400
annual[10]	1.733	2.482	0.03817	0.4817	1.306	5.315	4001	6400
annual[11]	0.1531	0.3047	0.006226	0.01511	0.08431	0.6749	4001	6400
annual[12]	0.23	0.4161	0.009276	0.0217	0.124	1.111	4001	6400
annual[13]	0.1344	0.2431	0.005843	0.01281	0.07364	0.6159	4001	6400
annual[14]	0.1816	0.3128	0.006597	0.0184	0.1004	0.8441	4001	6400
annual[15]	0.1386	0.2813	0.005534	0.01182	0.07258	0.6695	4001	6400
annual[16]	0.3863	0.7552	0.01507	0.03319	0.1963	1.922	4001	6400
annual[17]	0.22	0.5887	0.009457	0.01955	0.1149	1.04	4001	6400
annual[18]	0.1893	0.4168	0.007624	0.01603	0.09636	0.88	4001	6400
annual[19]	0.2107	0.7115	0.0101	0.01857	0.1049	0.9704	4001	6400
annual[20]	0.3235	0.8985	0.01452	0.02778	0.161	1.464	4001	6400
annual[21]	0.8699	0.4899	0.008245	0.4282	0.7756	1.863	4001	6400
annual[22]	0.2541	0.1912	0.003186	0.08956	0.2061	0.6923	4001	6400
annual[23]	0.08094	0.2155	0.003316	0.01272	0.04461	0.3506	4001	6400
annual[24]	0.1218	0.3083	0.005124	0.01313	0.06136	0.5747	4001	6400
annual[25]	0.1853	0.4151	0.007187	0.01791	0.09554	0.9081	4001	6400
annual[26]	0.1266	0.3812	0.007033	0.01309	0.06552	0.5999	4001	6400
annual[27]	0.1868	0.4136	0.006806	0.01801	0.09162	0.9267	4001	6400
annual[28]	0.1891	0.3357	0.007162	0.01838	0.1014	0.9111	4001	6400
annual[29]	0.3218	0.6832	0.01192	0.02981	0.1702	1.454	4001	6400
annual[30]	0.04283	0.09208	0.001468	0.004794	0.0231	0.1907	4001	6400
annual[31]	0.08389	0.07834	0.001404	0.02515	0.06211	0.2808	4001	6400
annual[32]	0.01617	0.02143	4.863E-4	0.003013	0.01107	0.06089	4001	6400
annual[33]	0.0081	0.01025	2.53E-4	0.001553	0.005356	0.03315	4001	6400
annual[34]	0.02608	0.03887	7.892E-4	0.00518	0.01734	0.1034	4001	6400
annual[35]	0.07842	0.141	0.002481	0.007044	0.04292	0.3615	4001	6400
annual[36]	0.01408	0.01556	3.042E-4	0.004589	0.01084	0.04165	4001	6400
annual[37]	0.004133	0.005369	1.034E-4	0.001412	0.0031	0.01282	4001	6400
annual[38]	1.664	0.4666	0.006035	0.935	1.603	2.762	4001	6400
annual[39]	0.6316	0.1131	0.001504	0.4551	0.6183	0.8963	4001	6400
annual[40]	1.439	0.2324	0.003112	1.061	1.416	1.971	4001	6400

Table 4. Recommended WinBUGS estimates of bycatch (million sharks) and variability without an overall mean CPUE term added to the SEDAR 7 WinBUGS shrimp bycatch estimation model with 2 depth-zone strata (2DP) and combined observer program non-BRD/BRD datasets (2DS) for bonnethead shark in the Gulf of Mexico. Annual 1-40 are year 1972-2011.

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
annual[1]	0.5223	0.8261	0.01254	0.05766	0.3254	2.108	4001	20000
annual[2]	0.2393	0.2829	0.004323	0.0401	0.1644	0.8926	4001	20000
annual[3]	0.3326	0.3671	0.006707	0.05504	0.232	1.213	4001	20000
annual[4]	0.5272	0.4579	0.006011	0.1553	0.4114	1.585	4001	20000
annual[5]	0.21	0.1926	0.002861	0.05163	0.1606	0.6644	4001	20000
annual[6]	0.3575	0.3187	0.00408	0.102	0.2769	1.112	4001	20000
annual[7]	0.07846	0.1324	0.001644	0.01257	0.05254	0.2914	4001	20000
annual[8]	0.6071	0.9498	0.0146	0.06047	0.3543	2.721	4001	20000
annual[9]	0.932	0.4807	0.005183	0.3911	0.818	2.156	4001	20000
annual[10]	0.1289	0.1453	0.002089	0.02675	0.09128	0.4643	4001	20000
annual[11]	0.2222	0.3902	0.004497	0.03141	0.1412	0.8585	4001	20000
annual[12]	0.1184	0.1882	0.00272	0.01465	0.07443	0.4855	4001	20000
annual[13]	0.1239	0.179	0.003107	0.01445	0.07673	0.5082	4001	20000
annual[14]	0.1331	0.1919	0.002512	0.01574	0.08258	0.5537	4001	20000
annual[15]	0.4008	0.5458	0.006684	0.04961	0.2491	1.66	4001	20000
annual[16]	0.2736	0.4187	0.004671	0.03103	0.1684	1.147	4001	20000
annual[17]	0.2085	0.298	0.003861	0.02369	0.1297	0.8812	4001	20000
annual[18]	0.1693	0.5088	0.004444	0.01806	0.1003	0.7147	4001	20000
annual[19]	0.3185	0.4762	0.005671	0.03759	0.1947	1.319	4001	20000
annual[20]	0.1338	0.2181	0.002901	0.01401	0.07971	0.5602	4001	20000
annual[21]	0.1416	0.1068	0.001265	0.04489	0.1155	0.3961	4001	20000
annual[22]	0.06866	0.07807	8.126E-4	0.01939	0.05116	0.2223	4001	20000
annual[23]	0.05886	0.1246	0.001087	0.013	0.04134	0.2022	4001	20000
annual[24]	0.06581	0.08079	9.338E-4	0.01173	0.04501	0.2533	4001	20000
annual[25]	0.3247	0.4058	0.004878	0.04815	0.2124	1.3	4001	20000
annual[26]	0.3358	0.4598	0.005455	0.04288	0.2111	1.392	4001	20000
annual[27]	0.202	0.2672	0.003722	0.02343	0.1275	0.8507	4001	20000
annual[28]	0.3321	0.496	0.006565	0.0425	0.2129	1.34	4001	20000
annual[29]	0.1909	0.2976	0.003426	0.02084	0.1171	0.8021	4001	20000
annual[30]	0.07803	0.09588	0.001332	0.01452	0.05346	0.2934	4001	20000
annual[31]	0.05521	0.03841	5.836E-4	0.02219	0.04616	0.1445	4001	20000
annual[32]	0.02612	0.02828	4.038E-4	0.005245	0.01928	0.08652	4001	20000
annual[33]	0.0311	0.03367	4.476E-4	0.00643	0.02204	0.111	4001	20000
annual[34]	0.07769	0.05996	7.964E-4	0.02627	0.06413	0.2086	4001	20000
annual[35]	0.1858	0.2608	0.003047	0.02253	0.116	0.778	4001	20000
annual[36]	0.05866	0.03704	5.734E-4	0.02661	0.05056	0.1409	4001	20000
annual[37]	0.009708	0.006359	7.557E-5	0.004192	0.008362	0.02276	4001	20000
annual[38]	0.2939	0.08234	6.72E-4	0.1746	0.2808	0.4905	4001	20000
annual[39]	0.152	0.06598	6.154E-4	0.08993	0.1379	0.299	4001	20000
annual[40]	0.2871	0.09444	0.00105	0.1865	0.2683	0.4951	4001	20000

Table 5. Recommended WinBUGS estimates of bycatch (million sharks) and variability with an overall mean CPUE term added to the SEDAR 7 WinBUGS shrimp bycatch estimation model with 2 depth-zone strata (2DP) and combined observer program non-BRD/BRD datasets (2DS) for bonnethead shark in the Gulf of Mexico. Annual 1-40 are year 1972-2011.

node	mean	sd	MC error	2.5%	median	97.5%	start	sample
annual[1]	0.1678	0.439	0.008765	0.01353	0.08576	0.7917	4001	6400
annual[2]	0.1015	0.1832	0.003891	0.01189	0.0609	0.4263	4001	6400
annual[3]	0.1467	0.2293	0.00498	0.01853	0.08958	0.6097	4001	6400
annual[4]	0.4257	0.5281	0.01029	0.1116	0.3135	1.404	4001	6400
annual[5]	0.1252	0.2422	0.004228	0.02749	0.08823	0.4252	4001	6400
annual[6]	0.2453	0.4189	0.006217	0.06745	0.1781	0.791	4001	6400
annual[7]	0.04911	0.09028	0.001933	0.005594	0.02777	0.214	4001	6400
annual[8]	0.1849	0.4275	0.00843	0.01312	0.09102	0.952	4001	6400
annual[9]	0.9053	0.5296	0.008699	0.3642	0.7825	2.164	4001	6400
annual[10]	0.09998	0.4069	0.005931	0.01722	0.06036	0.3885	4001	6400
annual[11]	0.1329	0.3048	0.005797	0.01216	0.06994	0.6587	4001	6400
annual[12]	0.0619	0.1495	0.003147	0.004942	0.03132	0.2985	4001	6400
annual[13]	0.06444	0.1629	0.003366	0.004786	0.03286	0.2995	4001	6400
annual[14]	0.06014	0.1125	0.002335	0.004569	0.03103	0.2911	4001	6400
annual[15]	0.1614	0.2792	0.005051	0.01373	0.08527	0.8426	4001	6400
annual[16]	0.114	0.2515	0.004371	0.008692	0.05952	0.5155	4001	6400
annual[17]	0.08286	0.1481	0.002716	0.006442	0.04245	0.4332	4001	6400
annual[18]	0.06924	0.167	0.003078	0.005532	0.03499	0.3276	4001	6400
annual[19]	0.1464	0.2977	0.006606	0.0117	0.07493	0.6886	4001	6400
annual[20]	0.05687	0.1178	0.002181	0.004327	0.0295	0.2619	4001	6400
annual[21]	0.09427	0.0778	0.001476	0.02928	0.07621	0.2733	4001	6400
annual[22]	0.05457	0.08822	0.001534	0.01343	0.03611	0.194	4001	6400
annual[23]	0.04739	0.06839	0.001221	0.009029	0.03043	0.2043	4001	6400
annual[24]	0.04754	0.1299	0.001983	0.005731	0.02597	0.2005	4001	6400
annual[25]	0.153	0.2977	0.005693	0.01514	0.0841	0.6644	4001	6400
annual[26]	0.1411	0.2808	0.00503	0.01181	0.07302	0.6854	4001	6400
annual[27]	0.09808	1.561	0.01951	0.006062	0.04077	0.3558	4001	6400
annual[28]	0.1371	0.2568	0.005402	0.01174	0.07463	0.6217	4001	6400
annual[29]	0.07512	0.1667	0.003185	0.005782	0.03908	0.3551	4001	6400
annual[30]	0.04734	0.09018	0.001775	0.006764	0.02764	0.2057	4001	6400
annual[31]	0.05517	0.05154	9.97E-4	0.02019	0.04295	0.1634	4001	6400
annual[32]	0.01625	0.02387	5.3E-4	0.002311	0.01063	0.06532	4001	6400
annual[33]	0.02369	0.04076	8.153E-4	0.003405	0.01405	0.1028	4001	6400
annual[34]	0.06491	0.05799	0.001042	0.02144	0.05129	0.1831	4001	6400
annual[35]	0.07879	0.2348	0.00351	0.006426	0.04014	0.3654	4001	6400
annual[36]	0.03986	0.01883	5.001E-4	0.02059	0.03589	0.08327	4001	6400
annual[37]	0.008585	0.007163	1.363E-4	0.003278	0.007104	0.02212	4001	6400
annual[38]	0.2968	0.08415	0.001208	0.1726	0.2822	0.4987	4001	6400
annual[39]	0.1604	0.09496	0.001571	0.08929	0.1394	0.3603	4001	6400
annual[40]	0.2764	0.1003	0.00174	0.18	0.258	0.479	4001	6400

ADDENDUM TO:

Shrimp Fishery Bycatch Estimates for Atlantic Sharpnose and Bonnethead Sharks in the Gulf of Mexico, 1972-2011

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The panel recommended methods

The panel noted that WinBUGS annual shrimp bycatch estimates for Atlantic sharpnose and bonnethead sharks in the Gulf of Mexico were poorly estimated, having very large variances in most of years. From 1992 through 2008 (except for characterization trips coded GC and FC), all shark species were grouped. Beginning January 2009, Atlantic sharpnose and bonnethead sharks were identified to species (Scott-Denton et al. 2012, Scott-Denton personal communication). The available data have become much larger and commercial fleet representation through stratified selection has become much better since mandatory observer coverage of the shrimp fleet began in 2007 (Scott-Denton personal communication). Accordingly, the panel decided to use two approaches to calculate the 2009-2011 mean of observed season/area/depth specific CPUE. Annual shrimp bycatch estimates for Atlantic sharpnose and bonnethead sharks in the Gulf of Mexico were calculated based on the 2009-2011 mean of observed season/area/depth-specific CPUE, year/season/area/depth-specific shrimp effort and year-specific net per vessel (NPV).

Approach 1:

$$\text{Annual\_All\_Tow\_CPUE\_A1}_{[yr,\ sea,\ ar,\ dp]} = \text{Average}(\text{All\_Tow\_CPUE}_{[yr,\ sea,\ ar,\ dp]}) \qquad \text{(Step1)}$$

$$\text{2009\_2011\_Mean\_Annual\_All\_Tow\_CPUE\_A1}_{[sea,\ ar,\ dp]} = \text{Mean}(\text{Annual\_All\_Tow\_CPUE\_A1}_{[yr,\ sea,\ ar,\ dp]}) \qquad \text{(Step2)}$$

where yr = 2009, 2010 and 2011

$$\text{Obs\_Bycatch\_A1}_{[yr,\ sea,\ ar,\ dp]} = \text{2009\_2011\_Mean\_All\_Tow\_CPUE\_A1}_{[sea,\ ar,\ dp]} * \text{effort}_{[yr,\ sea,\ ar,\ dp]} * \text{npv}_{[yr]} \qquad \text{(Step3)}$$

where yr = 1972 - 2011

$$\text{Obs\_Bycatch\_A1}_{[yr]} = \text{sum}(\text{Observed\_Bycatch\_A1}_{[yr,\ sea,\ ar,\ dp]}) \qquad \text{(Step4)}$$

where yr is year (1972-2011), sea is season (3 seasons), ar is area (4 areas), dp is depth (2 depth-zones), $Annual\_All\_Tow\_CPUE\_A1_{[yr, sea, ar, dp]}$ is the observed annual all-tow year/season/area/depth-specific CPUE estimated with approach 1, $All\_Tow\_CPUE_{[yr, sea, ar, dp]}$ is the observed all-tow year/season/area/depth-specific CPUE, $2009\_2011\_Mean\_Annual\_All\_Tow\_CPUE\_A1_{[sea, ar, dp]}$ is the 2009-2011 mean of season/area/depth-specific CPUE estimated with approach 1, $effort_{[yr, sea, ar, dp]}$ is year/season/area/depth-specific effort, $npv_{[yr]\ i}$ is year-specific nets per vessel, $Obs\_Bycatch\_A1_{[yr, sea, ar, dp]}$ is the observed year/season/area/depth-specific bycatch estimated with approach 1, $Obs\_Bycatch\_A1_{[yr]}$ is the observed annual bycatch estimated with approach 1.

Approach 2:

$$Annual\_NZCT\_CPUE\_A2_{[yr,sea, ar, dp]} = \exp\{average[\ln(NZCT\_CPUE_{[yr, sea, ar, dp]})] + 0.5*var(\ln(NZCT\_CPUE_{[yr, sea, ar, dp]}))\} \quad \text{(Step1a)}$$

$$Annual\_All\_Tow\_CPUE\_A2_{[yr,sea, ar, dp]} = Annual\_NZCT\_CPUE\_A2_{[yr,sea, ar, dp]}*Percent\_of\_NZCT_{[yr, sea, ar, dp]} \quad \text{(Step1b)}$$

$$2009\_2011\_Mean\_Annual\_All\_Tow\_CPUE\_A2_{[sea, ar, dp]} = Mean(Annual\_All\_Tow\_CPUE\_A2_{[yr, sea, ar, dp]}) \quad \text{(Step2)}$$

where yr = 2009, 2010 and 2011

$$Obs\_Bycatch\_A2_{[yr, sea, ar, dp]} = 2009\_2011\_Mean\_All\_Tow\_CPUE\_A2_{[sea, ar, dp]}*effort_{[yr, sea, ar, dp]}*npv_{[yr]} \quad \text{(Step3)}$$

where yr = 1972 - 2011

$$Obs\_Bycatch\_A2_{[yr]} = sum(Observed\_Bycatch\_A2_{[yr, sea, ar, dp]}) \quad \text{(Step4)}$$

$Annual\_NZCT\_CPUE\_A2_{[yr,sea, ar, dp]}$ is the observed annual non-zero-catch-tow year/season/area/depth-specific CPUE estimated with approach 2, $NZCT\_CPUE_{[yr, sea, ar, dp]}$ is the observed non-zero-catch-tow year/season/area/depth-specific CPUE, $Annual\_All\_Tow\_CPUE\_A2_{[yr, sea, ar, dp]}$ is the observed annual all-tow year/season/area/depth-specific CPUE estimated with approach 2, $Percent\_of\_NZCT_{[yr, sea, ar, dp]}$ is the observed year/season/area/depth-specific percent of non-zero-catch tows, $2009\_2011\_Mean\_Annual\_All\_Tow\_CPUE\_A2_{[sea, ar, dp]}$ is the 2009-2011 mean of season/area/depth-specific CPUE estimated with approach 2, $Obs\_Bycatch\_A2_{[yr, sea, ar, dp]}$ is the observed year/season/area/depth-specific bycatch estimated with approach 2, $Obs\_Bycatch\_A2_{[yr]}$ is the observed annual bycatch estimated with approach 2. Basically, estimates of the observed annual all-tow year/season/area/depth- specific CPUE with approach 2 were calculated based on a simplified delta-lognormal model (Sprugel 1983, Lo et al. 1992).

Results and discussion

Shrimp fishery effort and nets per vessel

Point estimates and associated standard errors of shrimp effort were generated by the NMFS Galveston Lab using their SN-pooled model (Nance 2004). Shrimp effort declined sharply from 2002 to 2008, and has remained at relatively low levels from 2008 to 2011 (Figure 1). The average number of nets per vessel increased gradually from 1972 to 1996, and remained relatively constant from 1996 to 2011 at approximately three nets per vessel (Figure 1).

Atlantic sharpnose shark

Estimates of the observed CPUE (number of sharks per net-hour) for Atlantic sharpnose shark in the Gulf of Mexico during 2009-2011 are almost identical with approach 1 and approach 2 of the panel recommended methods (see the panel recommended methods for details) (Tables 1-4). With only observer program data, estimates of the observed CPUE (number of sharks per net-hour) for Atlantic sharpnose shark in the Gulf of Mexico during 2009-2011 in the present analysis (average CPUEs in Table 4) are similar to those calculated here from published observer data in the Gulf of Mexico penaeid shrimp fishery during the years 2009 and 2010 (Scott-Denton et al. 2012; see Appendix A for details). Estimates of the observed bycatch for Atlantic sharpnose shark in the Gulf of Mexico are almost identical with approach 1 and approach 2 of the panel recommended methods (Figures 2 and 3, Tables 5 and 6). Estimates of the observed bycatch are slightly higher with both observer program and research vessel data than with only observer program data used to calculate the 2009-2011 mean season/area/depth-specific CPUE (Figures 2 and 3, Tables 5 and 6).
The majority of data during 2009-2011 are from the observer program (Tables 1 and 3). With only observer program data, the observed shrimp bycatch for Atlantic sharpnose shark are about 1 million sharks during 2009-2011, but can be as high as 4 million sharks in the earlier years when shrimp fishery effort were high (Figures 2 and 3, Tables 5 and 6).

Bonnethead Shark

Estimates of the observed CPUE (number of sharks per net-hour) for bonnethead shark in the Gulf of Mexico during 2009-2011 are almost identical with approach 1 and approach 2 of the panel recommended methods (see the panel recommended methods for details) (Tables 7-10). With only observer program data, estimates of the observed CPUE (number of sharks per net-hour) for bonnethead shark in the Gulf of Mexico during 2009-2011 in the present analysis (average CPUEs in Table 10) are similar to the published predicted observer CPUE (Raborn et al. 2012, Figure 3, lower panel), and to those calculated here from published observer data in the Gulf of Mexico penaeid shrimp fishery during the years 2009 and 2010 (Scott-Denton et al. 2012; see Appendix A for details). Estimates of the observed bycatch for bonnethead shark in the Gulf of Mexico are almost identical with approach 1 and approach 2 of the panel recommended methods (Figures 4 and 5, Tables 11 and 12). Estimates of the observed bycatch are slightly higher with both observer program and research vessel data than with only observer program data used to calculate the 2009-2011 mean season/area/depth-specific CPUE (Figures 4 and 5, Tables 11 and 12). The majority of data during 2009-2011 are from the observer program

(Tables 7 and 9). With only observer program data, the observed shrimp bycatch for bonnethead shark are about 200,000 sharks for 2009-2011, but can be as high as 700,000 sharks in the earlier years when shrimp fishery effort were high (Figures 4 and 5, Tables 11 and 12).

Acknowledgments

The authors thank the SEDAR 34 panel for helping us to develop these methods for shrimp fishery bycatch estimates for Atlantic sharpnose and bonnethead sharks. We particularly thank Drs. Babcock, Latour, Hueter and Porch for constructive comments and suggestions.

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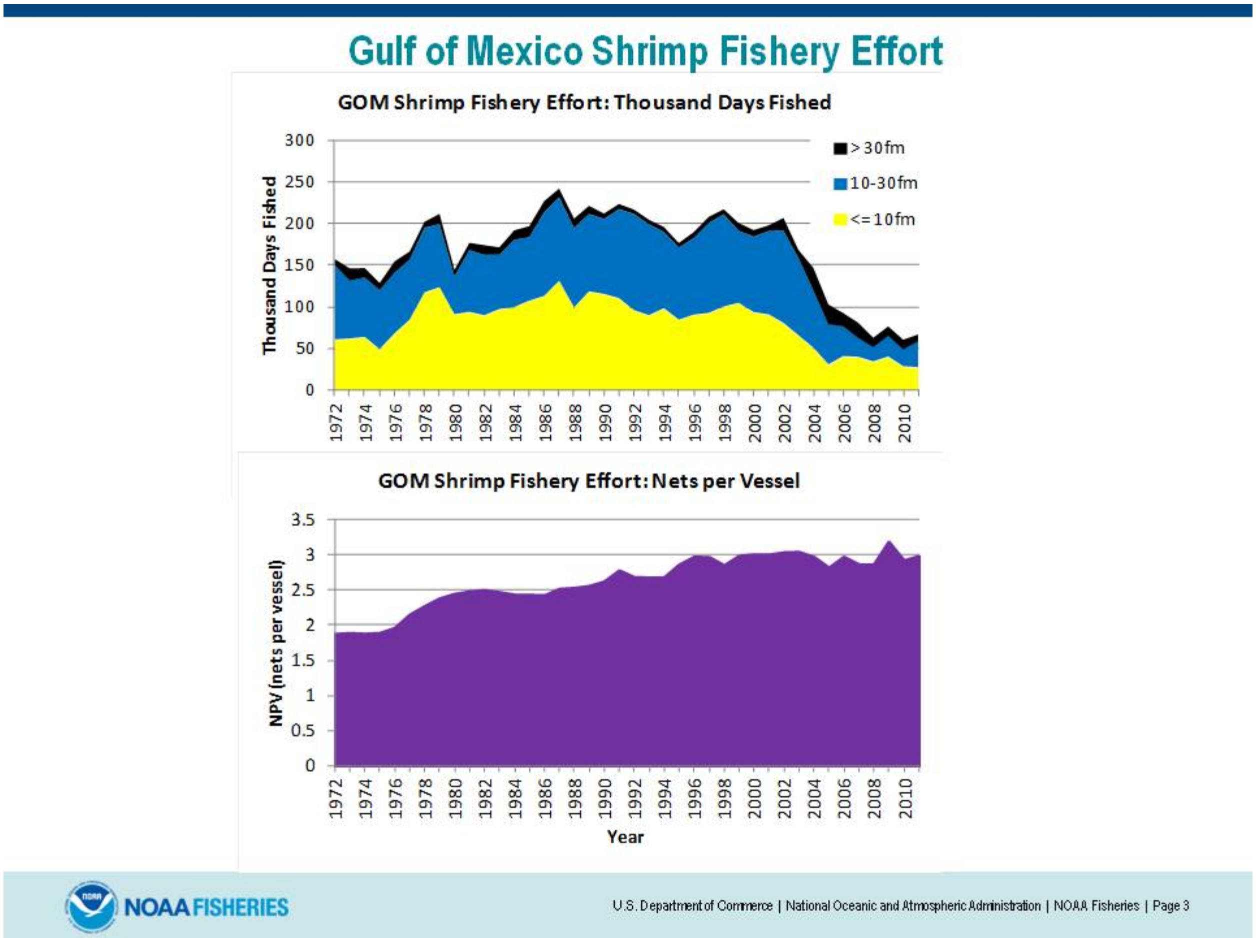

Figure 1. Gulf of Mexico shrimp fishery effort (thousand vessel-days) and nets per vessel.

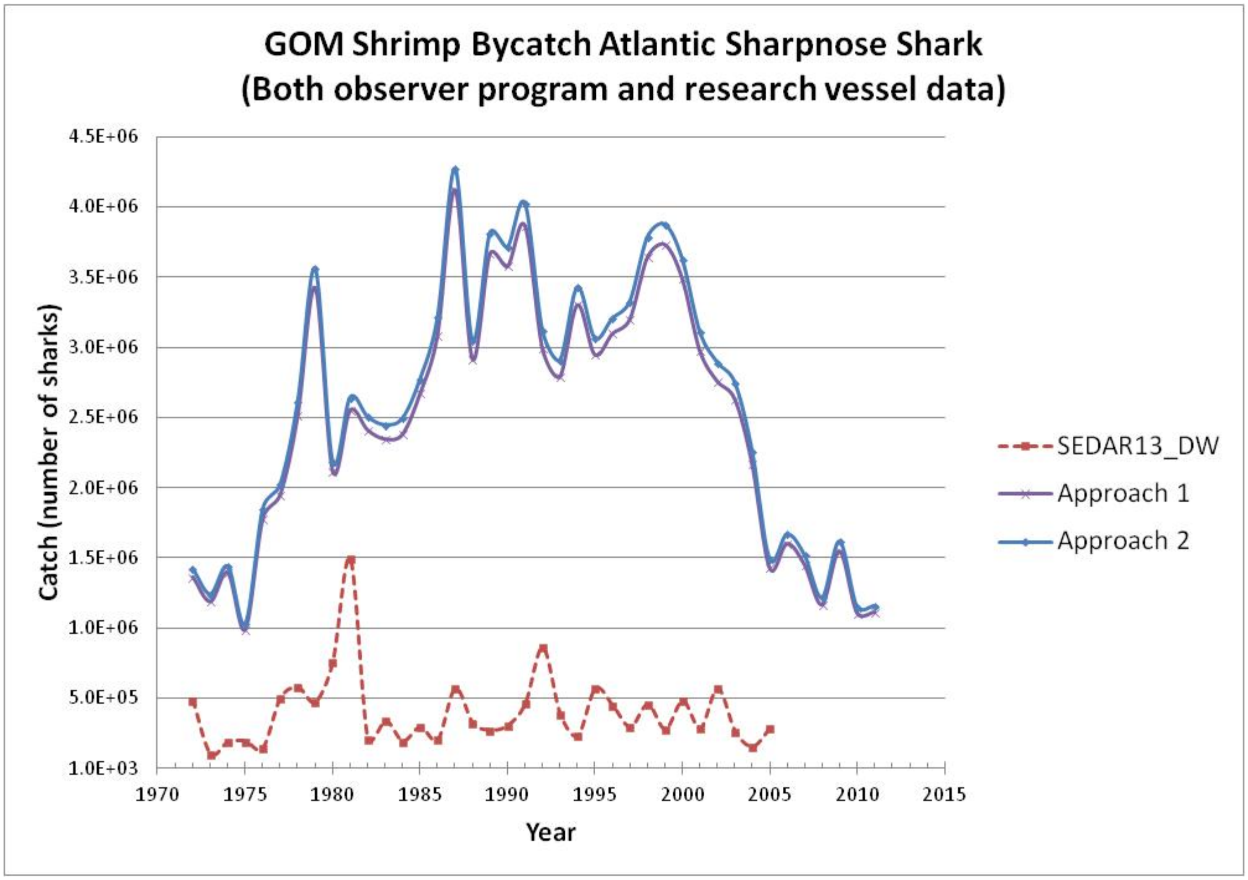

Figure 2. Estimates of the observed bycatch for Atlantic sharpnose shark in the Gulf of Mexico with approach 1 and approach 2 of the panel recommended methods (see the panel recommended methods for details). Both observer program and research vessel data were used to calculate the 2009-2011 mean season/area/depth-specific CPUE. SEDAR 13_DW is the SEDAR 13 WinBUGS estimates of shrimp bycatch.

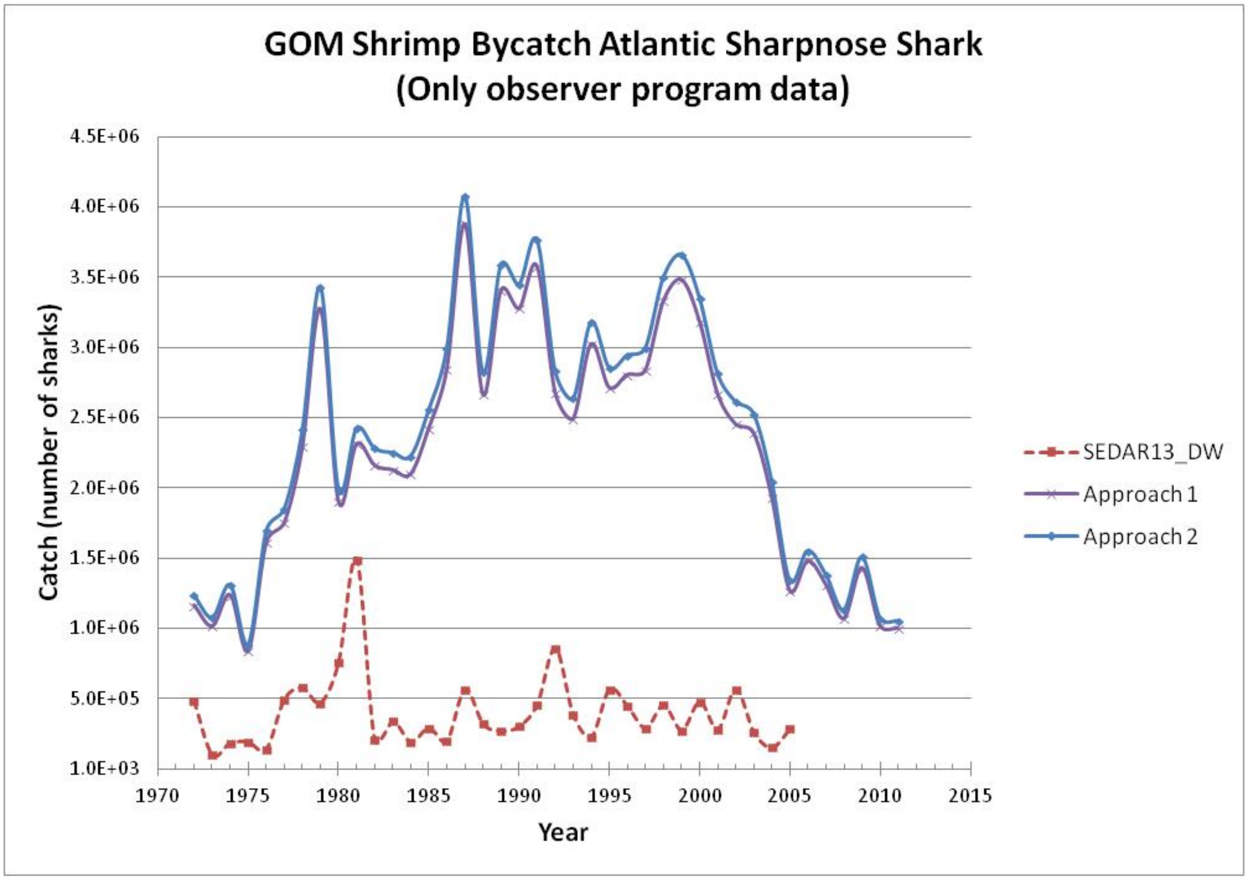

Figure 3. Estimates of the observed bycatch for Atlantic sharpnose shark in the Gulf of Mexico with approach 1 and approach 2 of the panel recommended methods (see the panel recommended methods for details). Only observer program data were used to calculate the 2009-2011 mean season/area/depth-specific CPUE. SEDAR 13_DW is the SEDAR 13 WinBUGS estimates of shrimp bycatch.

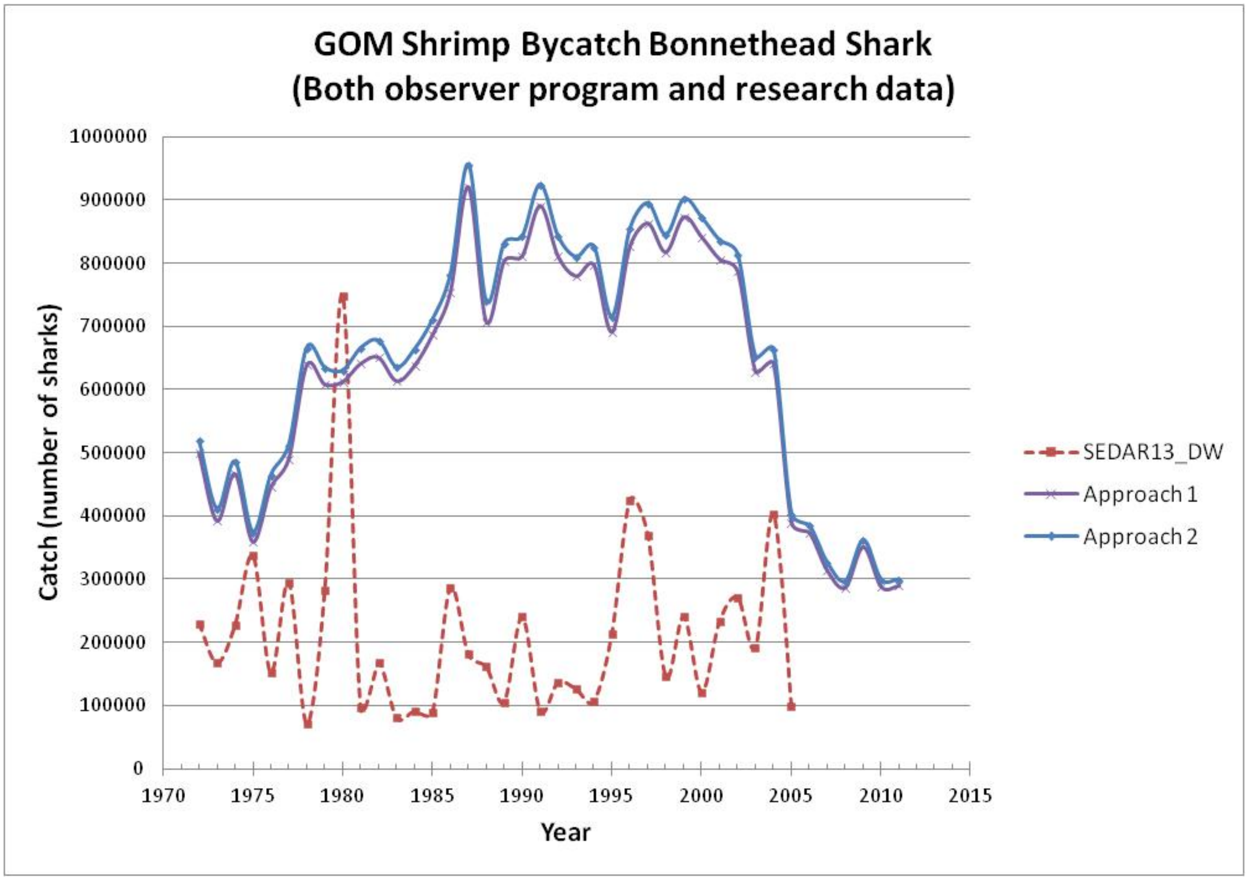

Figure 4. Estimates of the observed bycatch for bonnethead shark in the Gulf of Mexico with approach 1 and approach 2 of the panel recommended methods (see the panel recommended methods for details). Both observer program and research vessel data were used to calculate the 2009-2011 mean season/area/depth-specific CPUE. SEDAR 13_DW is the SEDAR 13 WinBUGS estimates of shrimp bycatch.

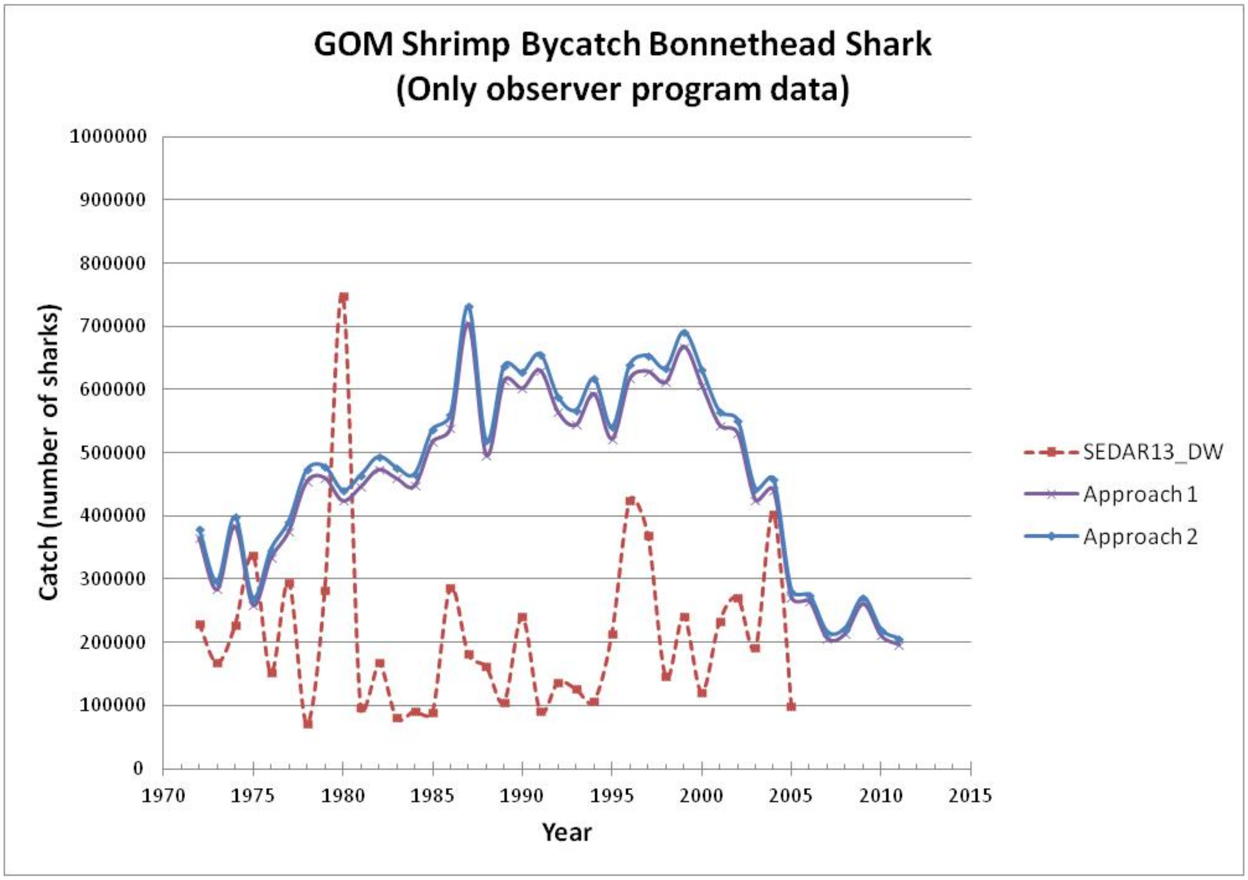

Figure 5. Estimates of the observed bycatch for bonnethead shark in the Gulf of Mexico with approach 1 and approach 2 of the panel recommended methods (see the panel recommended methods for details). Only observer program data were used to calculate the 2009-2011 mean season/area/depth-specific CPUE. SEDAR 13_DW is the SEDAR 13 WinBUGS estimates of shrimp bycatch.

Table 1a. Estimates of the observed CPUE (number of sharks per net-hour) for Atlantic sharpnose shark in the Gulf of Mexico in 2009 with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Num_of_NZCT is number of non-zero-catch-tow and Num_of_All_Tow is number of all-tow. Both observer program and research vessel data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2	Num_of_NZCT	Num_of_All_Tow
2009	1	1	1	0	0	0	137
2009	1	1	2	0.1092938	0.109957	25	364
2009	1	2	1	0	0	0	35
2009	1	2	2	0	0	0	26
2009	1	3	1	0.0060439	0.0061839	2	71
2009	1	3	2	0.0999133	0.1001375	17	181
2009	1	4	1	0	0	0	107
2009	1	4	2	0.024566	0.0251227	13	317
2009	2	1	1			0	0
2009	2	1	2	0	0	0	68
2009	2	2	1	0.3084687	0.3236422	15	113
2009	2	2	2	0.3933651	0.4344828	8	63
2009	2	3	1	1.0628124	1.0938279	89	290
2009	2	3	2	0.1319706	0.1324712	14	308
2009	2	4	1	0.6519716	0.6753417	11	87
2009	2	4	2	0.085813	0.0956497	20	527
2009	3	1	1			0	0
2009	3	1	2	0	0	0	33
2009	3	2	1	0.2296806	0.4423629	2	65
2009	3	2	2	0.5299463	0.5925248	3	30
2009	3	3	1	0.0402989	0.0402989	2	99
2009	3	3	2	0.1481032	0.1550382	5	148
2009	3	4	1	0.0098179	0.0202537	2	182
2009	3	4	2	0.1228093	0.1110658	14	287

Table 1b. Estimates of the observed CPUE (number of sharks per net-hour) for Atlantic sharpnose shark in the Gulf of Mexico in 2010 with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Num_of_NZCT is number of non-zero-catch-tow and Num_of_All_Tow is number of all-tow. Both observer program and research vessel data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2	Num_of_NZCT	Num_of_All_Tow
2010	1	1	1	0.0114695	0.0115073	6	115
2010	1	1	2	0.3175955	0.3148734	48	217
2010	1	2	1	0.0156128	0.0156128	1	63
2010	1	2	2	0.0901512	0.0895116	9	56
2010	1	3	1	0.1165121	0.1184839	5	56
2010	1	3	2	0.1674475	0.19576	21	140
2010	1	4	1	0.0126724	0.0128512	3	220
2010	1	4	2	0.1103447	0.1126697	22	143
2010	2	1	1	0.0029146	0.0029146	1	73
2010	2	1	2	0.005949	0.0059585	4	138
2010	2	2	1			0	0
2010	2	2	2			0	0
2010	2	3	1	0.1569067	0.1603798	13	164
2010	2	3	2	0.0081496	0.0081496	1	245
2010	2	4	1	1.4951694	1.3929409	48	222
2010	2	4	2	0.0650645	0.0910408	8	331
2010	3	1	1	0	0	0	40
2010	3	1	2	0.0880009	0.0459894	8	172
2010	3	2	1	0	0	0	79
2010	3	2	2	0.0742784	0.134831	2	38
2010	3	3	1	0.0517909	0.0540853	3	230
2010	3	3	2	0.1862465	0.2056987	14	155
2010	3	4	1	0.4397718	0.4487798	4	27
2010	3	4	2	0.149461	0.1501128	5	80

Table 1c. Estimates of the observed CPUE (number of sharks per net-hour) for Atlantic sharpnose shark in the Gulf of Mexico in 2011 with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Num_of_NZCT is number of non-zero-catch-tow and Num_of_All_Tow is number of all-tow. Both observer program and research vessel data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2	Num_of_NZCT	Num_of_All_Tow
2011	1	1	1	0.0286225	0.0286225	1	65
2011	1	1	2	0.3293877	0.3267277	34	229
2011	1	2	1	0.0227906	0.0227906	1	27
2011	1	2	2	0	0	0	8
2011	1	3	1	0.0797517	0.079574	16	82
2011	1	3	2	0.2538568	0.292273	28	123
2011	1	4	1	0	0	0	34
2011	1	4	2	0.141047	0.1522544	9	28
2011	2	1	1	0	0	0	10
2011	2	1	2	0.0073859	0.0074863	2	190
2011	2	2	1	0.0838191	0.0838191	1	30
2011	2	2	2	0.0860023	0.0860023	1	27
2011	2	3	1	1.1130045	1.1615024	110	438
2011	2	3	2	0.1790874	0.2125167	23	296
2011	2	4	1	1.0422725	1.1325553	14	83
2011	2	4	2	0.0386912	0.049173	6	290
2011	3	1	1			0	0
2011	3	1	2	0	0	0	20
2011	3	2	1	0.0650904	0.0715383	4	88
2011	3	2	2	0.1298701	0.1298701	1	7
2011	3	3	1	0.0400728	0.0425086	6	217
2011	3	3	2	0.1848273	0.198051	46	360
2011	3	4	1	0.2809356	0.2851198	6	72
2011	3	4	2	0.1283785	0.1208752	62	401

Table 2. Estimates of the observed 2009-2011 mean CPUE (number of sharks per net-hour) for Atlantic sharpnose shark in the Gulf of Mexico with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Both observer program and research vessel data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2
2009-2011	1	1	1	0.013364	0.0133766
2009-2011	1	1	2	0.2520923	0.2505194
2009-2011	1	2	1	0.0128011	0.0128011
2009-2011	1	2	2	0.0300504	0.0298372
2009-2011	1	3	1	0.0674359	0.0680806
2009-2011	1	3	2	0.1737392	0.1960568
2009-2011	1	4	1	0.0042241	0.0042837
2009-2011	1	4	2	0.0919859	0.0966823
2009-2011	2	1	1	0.0014573	0.0014573
2009-2011	2	1	2	0.004445	0.0044816
2009-2011	2	2	1	0.1961439	0.2037307
2009-2011	2	2	2	0.2396837	0.2602426
2009-2011	2	3	1	0.7775745	0.8052367
2009-2011	2	3	2	0.1064025	0.1177125
2009-2011	2	4	1	1.0631378	1.066946
2009-2011	2	4	2	0.0631895	0.0786212
2009-2011	3	1	1	0	0
2009-2011	3	1	2	0.0293336	0.0153298
2009-2011	3	2	1	0.098257	0.1713004
2009-2011	3	2	2	0.2446983	0.285742
2009-2011	3	3	1	0.0440542	0.0456309
2009-2011	3	3	2	0.173059	0.1862626
2009-2011	3	4	1	0.2435084	0.2513844
2009-2011	3	4	2	0.1335496	0.1273513

Table 3a. Estimates of the observed CPUE (number of sharks per net-hour) for Atlantic sharpnose shark in the Gulf of Mexico in 2009 with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Num_of_NZCT is number of non-zero-catch-tow and Num_of_All_Tow is number of all-tow. Only observer program data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2	Num_of_NZCT	Num_of_All_Tow
2009	1	1	1	0	0	0	137
2009	1	1	2	0.1092938	0.109957	25	364
2009	1	2	1	0	0	0	35
2009	1	2	2	0	0	0	26
2009	1	3	1	0.0060439	0.006184	2	71
2009	1	3	2	0.0999133	0.100137	17	181
2009	1	4	1	0	0	0	107
2009	1	4	2	0.024566	0.025123	13	317
2009	2	1	1			0	0
2009	2	1	2	0	0	0	62
2009	2	2	1	0.2287682	0.254962	14	100
2009	2	2	2	0.2784044	0.309683	5	33
2009	2	3	1	1.0994353	1.127666	86	264
2009	2	3	2	0.1302488	0.131438	9	190
2009	2	4	1	0.7124849	0.72768	9	60
2009	2	4	2	0.0658548	0.075142	15	416
2009	3	1	1			0	0
2009	3	1	2	0	0	0	33
2009	3	2	1	0.2332693	0.449275	2	64
2009	3	2	2	0	0	0	9
2009	3	3	1	0.0266018	0.026602	1	75
2009	3	3	2	0	0	0	59
2009	3	4	1	0.0113093	0.02333	2	158
2009	3	4	2	0.0304407	0.030444	5	175

Table 3b. Estimates of the observed CPUE (number of sharks per net-hour) for Atlantic sharpnose shark in the Gulf of Mexico in 2010 with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Num_of_NZCT is number of non-zero-catch-tow and Num_of_All_Tow is number of all-tow. Only observer program data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_	CPUE_A2	Num_of_NZCT	Num_of_All_Tow
2010	1	1	1	0.011	0.011507	6	115
2010	1	1	2	0.318	0.314873	48	217
2010	1	2	1	0.016	0.015613	1	63
2010	1	2	2	0.09	0.089512	9	56
2010	1	3	1	0.117	0.118484	5	56
2010	1	3	2	0.167	0.19576	21	140
2010	1	4	1	0.013	0.012851	3	220
2010	1	4	2	0.11	0.11267	22	143
2010	2	1	1	0.003	0.002915	1	73
2010	2	1	2	0.006	0.005959	4	138
2010	2	2	1			0	0
2010	2	2	2			0	0
2010	2	3	1	0.148	0.152086	11	147
2010	2	3	2	0	0	0	175
2010	2	4	1	1.396	1.248154	44	208
2010	2	4	2	0.015	0.03063	3	238
2010	3	1	1	0	0	0	28
2010	3	1	2	0.009	0.008585	7	136
2010	3	2	1	0	0	0	78
2010	3	2	2	0.088	0.160112	2	32
2010	3	3	1	0.055	0.057062	3	218
2010	3	3	2	0.162	0.19089	8	92
2010	3	4	1	0	0	0	11
2010	3	4	2	0	0	0	16

Table 3c. Estimates of the observed CPUE (number of sharks per net-hour) for Atlantic sharpnose shark in the Gulf of Mexico in 2011 with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Num_of_NZCT is number of non-zero-catch-tow and Num_of_All_Tow is number of all-tow. Only observer program data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2	Num_of_NZCT	Num_of_All_Tow
2011	1	1	1	0.0286225	0.028623	1	65
2011	1	1	2	0.3293877	0.326728	34	229
2011	1	2	1	0.0227906	0.022791	1	27
2011	1	2	2	0	0	0	8
2011	1	3	1	0.0797517	0.079574	16	82
2011	1	3	2	0.2538568	0.292273	28	123
2011	1	4	1	0	0	0	34
2011	1	4	2	0.141047	0.152254	9	28
2011	2	1	1	0	0	0	10
2011	2	1	2	0.0073859	0.007486	2	190
2011	2	2	1	0.0838191	0.083819	1	30
2011	2	2	2	0.0860023	0.086002	1	27
2011	2	3	1	1.1416767	1.191424	110	427
2011	2	3	2	0.204336	0.24691	21	240
2011	2	4	1	1.0241812	1.347987	9	67
2011	2	4	2	0.0413946	0.052048	5	224
2011	3	1	1			0	0
2011	3	1	2			0	0
2011	3	2	1	0.0650904	0.071538	4	88
2011	3	2	2	0.1298701	0.12987	1	7
2011	3	3	1	0.0416067	0.044136	6	209
2011	3	3	2	0.1912804	0.200717	42	296
2011	3	4	1	0.298882	0.304002	5	61
2011	3	4	2	0.0899861	0.092209	56	329

Table 4. Estimates of the observed 2009-2011 mean CPUE (number of sharks per net-hour) for Atlantic sharpnose shark in the Gulf of Mexico with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Only observer program data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2
2009-2011	1	1	1	0.013364	0.013377
2009-2011	1	1	2	0.2520923	0.250519
2009-2011	1	2	1	0.0128011	0.012801
2009-2011	1	2	2	0.0300504	0.029837
2009-2011	1	3	1	0.0674359	0.068081
2009-2011	1	3	2	0.1737392	0.196057
2009-2011	1	4	1	0.0042241	0.004284
2009-2011	1	4	2	0.0919859	0.096682
2009-2011	2	1	1	0.0014573	0.001457
2009-2011	2	1	2	0.004445	0.004482
2009-2011	2	2	1	0.1562937	0.16939
2009-2011	2	2	2	0.1822034	0.197843
2009-2011	2	3	1	0.7964102	0.823725
2009-2011	2	3	2	0.1115283	0.126116
2009-2011	2	4	1	1.0441712	1.10794
2009-2011	2	4	2	0.0408618	0.052607
2009-2011	3	1	1	0	0
2009-2011	3	1	2	0.0042912	0.004292
2009-2011	3	2	1	0.0994532	0.173604
2009-2011	3	2	2	0.0726919	0.096661
2009-2011	3	3	1	0.0409501	0.0426
2009-2011	3	3	2	0.1176128	0.130536
2009-2011	3	4	1	0.1033971	0.109111
2009-2011	3	4	2	0.0401423	0.040884

Table 5. Estimates of the observed bycatch (number of sharks) for Atlantic sharpnose shark in the Gulf of Mexico with approach 1 and approach 2 of the panel recommended methods (see the panel recommended methods for details). Both observer program and research vessel data were used to calculate the 2009-2011 mean season/area/depth-specific CPUE. SEDAR 13_DW is the SEDAR 13 WinBUGS estimates of shrimp bycatch.

Year	Approach 1	Approach 2	SEDAR13_DW
1972	1365522	1422459	485780
1973	1189617	1241543	102900
1974	1394789	1440367	185074
1975	990645	1029583	192627
1976	1780807	1850610	141282
1977	1952194	2025140	497629
1978	2514724	2614700	578336
1979	3427417	3561873	470857
1980	2121636	2187498	757373
1981	2553588	2644922	1492272
1982	2413181	2505621	208879
1983	2349153	2448163	343009
1984	2383432	2496825	193399
1985	2673584	2775932	293171
1986	3089617	3215083	202706
1987	4127271	4273709	568133
1988	2918367	3048250	322388
1989	3670661	3815194	270901
1990	3580019	3715753	303917
1991	3870599	4024674	460335
1992	2995321	3121647	860192
1993	2793500	2910446	385082
1994	3306494	3429462	230386
1995	2951009	3065855	567054
1996	3099648	3206330	446999
1997	3202290	3327074	292293
1998	3642543	3785008	455072
1999	3736649	3877861	276374
2000	3493913	3630363	478883
2001	2980603	3111770	283371
2002	2760828	2893424	567679
2003	2636467	2752540	262108
2004	2168997	2260969	153970
2005	1428652	1491249	289384
2006	1603260	1669057	
2007	1450598	1518844	
2008	1168092	1217179	
2009	1548571	1618142	
2010	1107616	1150473	
2011	1113726	1159506	

Table 6. Estimates of the observed bycatch (number of sharks) for Atlantic sharpnose shark in the Gulf of Mexico with approach 1 and approach 2 of the panel recommended methods (see the panel recommended methods for details). Only observer program data were used to calculate the 2009-2011 mean season/area/depth-specific CPUE. SEDAR 13_DW is the SEDAR 13 WinBUGS estimates of shrimp bycatch.

Year	Approach 1	Approach 2	SEDAR13_DW
1972	1163149	1236950	485780
1973	1013814	1078956	102900
1974	1235082	1311877	185074
1975	836478	887606	192627
1976	1611488	1699434	141282
1977	1752682	1854595	497629
1978	2293856	2419793	578336
1979	3274229	3433420	470857
1980	1901637	1992198	757373
1981	2311962	2426643	1492272
1982	2160239	2283663	208879
1983	2128193	2253326	343009
1984	2098598	2229429	193399
1985	2424682	2560196	293171
1986	2847092	2997862	202706
1987	3881729	4081231	568133
1988	2665342	2825408	322388
1989	3407877	3591398	270901
1990	3278538	3453795	303917
1991	3579660	3766927	460335
1992	2679226	2834675	860192
1993	2494099	2639156	385082
1994	3024176	3183885	230386
1995	2714607	2859289	567054
1996	2806698	2947817	446999
1997	2839919	2999804	292293
1998	3332483	3503358	455072
1999	3484582	3664070	276374
2000	3187967	3356108	478883
2001	2670884	2817594	283371
2002	2453672	2616622	567679
2003	2390733	2531348	262108
2004	1935499	2052087	153970
2005	1268526	1344095	289384
2006	1478053	1554828	
2007	1309910	1383821	
2008	1068332	1133960	
2009	1428879	1511599	
2010	1017488	1075332	
2011	998346	1054936	

Table 7a. Estimates of the observed CPUE (number of sharks per net-hour) for bonnethead shark in the Gulf of Mexico in 2009 with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Num_of_NZCT is number of non-zero-catch-tow and Num_of_All_Tow is number of all-tow. Both observer program and research vessel data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2	Num_of_NZCT	Num_of_All_Tow
2009	1	1	1	0.016586	0.0166297	2	137
2009	1	1	2	0.007134	0.0071567	2	364
2009	1	2	1	0	0	0	35
2009	1	2	2	0	0	0	26
2009	1	3	1	0	0	0	71
2009	1	3	2	0	0	0	181
2009	1	4	1	0.378081	0.3797414	17	107
2009	1	4	2	0.013178	0.0149534	11	317
2009	2	1	1			0	0
2009	2	1	2	0	0	0	68
2009	2	2	1	0	0	0	113
2009	2	2	2	0	0	0	63
2009	2	3	1	0.073061	0.0736903	12	290
2009	2	3	2	0.006454	0.0064541	1	308
2009	2	4	1	0.040719	0.0535449	2	87
2009	2	4	2	0.027974	0.0465958	5	527
2009	3	1	1			0	0
2009	3	1	2	0	0	0	33
2009	3	2	1	0.030729	0.0307286	1	65
2009	3	2	2	0	0	0	30
2009	3	3	1	0.060349	0.0641147	2	99
2009	3	3	2	0.120784	0.1233138	5	148
2009	3	4	1	0.068256	0.0933148	6	182
2009	3	4	2	0.252467	0.2355355	25	287

Table 7b. Estimates of the observed CPUE (number of sharks per net-hour) for bonnethead shark in the Gulf of Mexico in 2010 with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Num_of_NZCT is number of non-zero-catch-tow and Num_of_All_Tow is number of all-tow. Both observer program and research vessel data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2	Num_of_NZCT	Num_of_All_Tow
2010	1	1	1	0.076407	0.0707707	24	115
2010	1	1	2	0.143819	0.14478	19	218
2010	1	2	1	0.006479	0.0066291	2	63
2010	1	2	2	0	0	0	56
2010	1	3	1	0	0	0	56
2010	1	3	2	0.040952	0.0486538	2	140
2010	1	4	1	0.14811	0.1538714	26	220
2010	1	4	2	0.047458	0.0494418	13	143
2010	2	1	1	0	0	0	73
2010	2	1	2	0	0	0	138
2010	2	2	1			0	0
2010	2	2	2			0	0
2010	2	3	1	0.005081	0.0050813	1	164
2010	2	3	2	0	0	0	245
2010	2	4	1	0.13995	0.1407812	14	222
2010	2	4	2	0.005953	0.0059531	1	331
2010	3	1	1	0.044792	0.0447917	1	40
2010	3	1	2	0.035933	0.0330878	17	172
2010	3	2	1	0.059722	0.0604811	2	79
2010	3	2	2	0	0	0	38
2010	3	3	1	0	0	0	230
2010	3	3	2	0.090725	0.0990778	3	155
2010	3	4	1	0.072622	0.0726216	1	27
2010	3	4	2	0.246612	0.2774884	9	80

Table 7c. Estimates of the observed CPUE (number of sharks per net-hour) for bonnethead shark in the Gulf of Mexico in 2011 with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Num_of_NZCT is number of non-zero-catch-tow and Num_of_All_Tow is number of all-tow. Both observer program and research vessel data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2	Num_of_NZCT	Num_of_All_Tow
2011	1	1	1	0	0	0	65
2011	1	1	2	0.099436	0.094082	18	229
2011	1	2	1	0	0	0	27
2011	1	2	2	0	0	0	8
2011	1	3	1	0.111549	0.1125971	9	82
2011	1	3	2	0.008311	0.008466	7	123
2011	1	4	1	0.228385	0.2283851	1	34
2011	1	4	2	0.05819	0.0603207	7	28
2011	2	1	1	0	0	0	10
2011	2	1	2	0	0	0	190
2011	2	2	1	0	0	0	30
2011	2	2	2	0	0	0	27
2011	2	3	1	0.03287	0.0356454	10	438
2011	2	3	2	0.001095	0.0011063	2	296
2011	2	4	1	0.423666	0.4338736	11	83
2011	2	4	2	0.028584	0.037453	6	290
2011	3	1	1			0	0
2011	3	1	2	0	0	0	20
2011	3	2	1	0.009881	0.0098814	1	88
2011	3	2	2	0	0	0	7
2011	3	3	1	0.028025	0.0283888	8	217
2011	3	3	2	0.080526	0.0865685	15	360
2011	3	4	1	0.133194	0.1385172	4	72
2011	3	4	2	0.120541	0.1076658	36	402

Table 8. Estimates of the observed 2009-2011 mean CPUE (number of sharks per net-hour) for bonnethead shark in the Gulf of Mexico with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Both observer program and research vessel data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2
2009-2011	1	1	1	0.030997	0.0291335
2009-2011	1	1	2	0.083463	0.0820062
2009-2011	2	1	1	0.00216	0.0022097
2009-2011	2	1	2	0	0
2009-2011	3	1	1	0.037183	0.0375324
2009-2011	3	1	2	0.016421	0.0190399
2009-2011	4	1	1	0.251525	0.2539993
2009-2011	4	1	2	0.039609	0.041572
2009-2011	1	2	1	0	0
2009-2011	1	2	2	0	0
2009-2011	2	2	1	0	0
2009-2011	2	2	2	0	0
2009-2011	3	2	1	0.037004	0.038139
2009-2011	3	2	2	0.002516	0.0025201
2009-2011	4	2	1	0.201445	0.2093999
2009-2011	4	2	2	0.020837	0.0300006
2009-2011	1	3	1	0.044792	0.0447917
2009-2011	1	3	2	0.011978	0.0110293
2009-2011	2	3	1	0.033444	0.0336971
2009-2011	2	3	2	0	0
2009-2011	3	3	1	0.029458	0.0308345
2009-2011	3	3	2	0.097345	0.1029867
2009-2011	4	3	1	0.091357	0.1014846
2009-2011	4	3	2	0.20654	0.2068966

Table 9a. Estimates of the observed CPUE (number of sharks per net-hour) for bonnethead shark in the Gulf of Mexico in 2009 with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Num_of_NZCT is number of non-zero-catch-tow and Num_of_All_Tow is number of all-tow. Only observer program data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2	Num_of_NZCT	Num_of_All_Tow
2009	1	1	1	0.0165856	0.0166297	2	137
2009	1	1	2	0.0071338	0.0071567	2	364
2009	1	2	1	0	0	0	35
2009	1	2	2	0	0	0	26
2009	1	3	1	0	0	0	71
2009	1	3	2	0	0	0	181
2009	1	4	1	0.3780812	0.3797414	17	107
2009	1	4	2	0.0131779	0.0149534	11	317
2009	2	1	1			0	0
2009	2	1	2	0	0	0	62
2009	2	2	1	0	0	0	100
2009	2	2	2	0	0	0	33
2009	2	3	1	0.0802565	0.0809476	12	264
2009	2	3	2	0	0	0	190
2009	2	4	1	0.0590424	0.0776401	2	60
2009	2	4	2	0.0008744	0.0008746	2	416
2009	3	1	1			0	0
2009	3	1	2	0	0	0	33
2009	3	2	1	0.0312087	0.0312087	1	64
2009	3	2	2	0	0	0	9
2009	3	3	1	0	0	0	75
2009	3	3	2	0	0	0	59
2009	3	4	1	0.0282707	0.037337	5	158
2009	3	4	2	0.1874246	0.1869778	15	175

Table 9b. Estimates of the observed CPUE (number of sharks per net-hour) for bonnethead shark in the Gulf of Mexico in 2010 with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Num_of_NZCT is number of non-zero-catch-tow and Num_of_All_Tow is number of all-tow. Only observer program data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2	Num_of_NZCT	Num_of_All_Tow
2010	1	1	1	0.0764068	0.0707707	24	115
2010	1	1	2	0.1438194	0.14478	19	218
2010	1	2	1	0.0064794	0.0066291	2	63
2010	1	2	2	0	0	0	56
2010	1	3	1	0	0	0	56
2010	1	3	2	0.0409521	0.0486538	2	140
2010	1	4	1	0.1481098	0.1538714	26	220
2010	1	4	2	0.0474578	0.0494418	13	143
2010	2	1	1	0	0	0	73
2010	2	1	2	0	0	0	138
2010	2	2	1			0	0
2010	2	2	2			0	0
2010	2	3	1	0.0056689	0.0056689	1	147
2010	2	3	2	0	0	0	175
2010	2	4	1	0.1398967	0.1409898	13	208
2010	2	4	2	0	0	0	238
2010	3	1	1	0.0639881	0.0639881	1	28
2010	3	1	2	0.0307719	0.0303255	16	136
2010	3	2	1	0.0350021	0.0350021	1	78
2010	3	2	2	0	0	0	32
2010	3	3	1	0	0	0	218
2010	3	3	2	0	0	0	92
2010	3	4	1	0	0	0	11
2010	3	4	2	0.1127629	0.1245388	3	16

Table 9c. Estimates of the observed CPUE (number of sharks per net-hour) for bonnethead shark in the Gulf of Mexico in 2011 with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Num_of_NZCT is number of non-zero-catch-tow and Num_of_All_Tow is number of all-tow. Only observer program data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2	Num_of_NZCT	Num_of_All_Tow
2011	1	1	1	0	0	0	65
2011	1	1	2	0.099436	0.094082	18	229
2011	1	2	1	0	0	0	27
2011	1	2	2	0	0	0	8
2011	1	3	1	0.1115491	0.1125971	9	82
2011	1	3	2	0.008311	0.008466	7	123
2011	1	4	1	0.2283851	0.2283851	1	34
2011	1	4	2	0.0581904	0.0603207	7	28
2011	2	1	1	0	0	0	10
2011	2	1	2	0	0	0	190
2011	2	2	1	0	0	0	30
2011	2	2	2	0	0	0	27
2011	2	3	1	0.0337166	0.0365637	10	427
2011	2	3	2	0.0013503	0.0013644	2	240
2011	2	4	1	0.5248406	0.5374852	11	67
2011	2	4	2	0.0281372	0.0376669	5	224
2011	3	1	1			0	0
2011	3	1	2			0	0
2011	3	2	1	0.0098814	0.0098814	1	88
2011	3	2	2	0	0	0	7
2011	3	3	1	0.029098	0.0294754	8	209
2011	3	3	2	0.0512056	0.0548591	10	296
2011	3	4	1	0.1246608	0.1365175	3	61
2011	3	4	2	0.0622466	0.0654304	30	330

Table 10. Estimates of the observed 2009-2011 mean CPUE (number of sharks per net-hour) for bonnethead shark in the Gulf of Mexico with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (see the panel recommended methods for details). Only observer program data were used to calculate the year/season/area/depth-specific CPUE.

Year	Season	Area	Depth	CPUE_A1	CPUE_A2
2009-2011	1	1	1	0.0309975	0.0291335
2009-2011	1	1	2	0.0834631	0.0820062
2009-2011	2	1	1	0.0021598	0.0022097
2009-2011	2	1	2	0	0
2009-2011	3	1	1	0.037183	0.0375324
2009-2011	3	1	2	0.016421	0.0190399
2009-2011	4	1	1	0.2515254	0.2539993
2009-2011	4	1	2	0.0396087	0.041572
2009-2011	1	2	1	0	0
2009-2011	1	2	2	0	0
2009-2011	2	2	1	0	0
2009-2011	2	2	2	0	0
2009-2011	3	2	1	0.0398807	0.0410601
2009-2011	3	2	2	0.0004501	0.0004548
2009-2011	4	2	1	0.2412599	0.2520384
2009-2011	4	2	2	0.0096705	0.0128471
2009-2011	1	3	1	0.0639881	0.0639881
2009-2011	1	3	2	0.015386	0.0151628
2009-2011	2	3	1	0.0253641	0.0253641
2009-2011	2	3	2	0	0
2009-2011	3	3	1	0.0096993	0.0098251
2009-2011	3	3	2	0.0170685	0.0182864
2009-2011	4	3	1	0.0509772	0.0579515
2009-2011	4	3	2	0.1208114	0.125649

Table 11. Estimates of the observed bycatch (number of sharks) for bonnethead shark in the Gulf of Mexico with approach 1 and approach 2 of the panel recommended methods (see the panel recommended methods for details). Both observer program and research vessel data were used to calculate the 2009-2011 mean season/area/depth-specific CPUE. SEDAR 13_DW is the SEDAR 13 WinBUGS estimates of shrimp bycatch.

Year	Approach 1	Approach 2	SEDAR13_DW
1972	500664	519326	230616
1973	393026	411143	168133
1974	467561	486197	227183
1975	359882	374545	337902
1976	446398	465160	152590
1977	491196	512919	295526
1978	639387	666623	72078
1979	609246	635002	282239
1980	613130	630490	749312
1981	641777	665696	97393
1982	651490	677741	168807
1983	614338	635747	81431
1984	638620	663855	91813
1985	687294	711196	89457
1986	755180	783074	287078
1987	921556	956753	181772
1988	708409	740048	161864
1989	804285	832433	106352
1990	812158	842865	241231
1991	891639	925034	92551
1992	811766	842868	137106
1993	780600	810129	126692
1994	797742	826339	108176
1995	692240	715459	215025
1996	827447	855227	425538
1997	864228	895596	370649
1998	818442	845187	146460
1999	874091	902049	241472
2000	842270	872480	121864
2001	806928	836235	234102
2002	788247	814864	271715
2003	629392	651997	192434
2004	641538	663818	403209
2005	390182	403683	99658
2006	374602	384879	
2007	314101	325743	
2008	287635	296719	
2009	351646	361770	
2010	288418	298728	
2011	290148	299852	

Table 12. Estimates of the observed bycatch (number of sharks) for bonnethead shark in the Gulf of Mexico with approach 1 and approach 2 of the panel recommended methods (see the panel recommended methods for details). Only observer program data were used to calculate the 2009-2011 mean season/area/depth-specific CPUE. SEDAR 13_DW is the SEDAR 13 WinBUGS estimates of shrimp bycatch.

Year	Approach 1	Approach 2	SEDAR13_DW
1972	366007	380611	230616
1973	284212	296969	168133
1974	384162	398815	227183
1975	259886	270341	337902
1976	333620	347250	152590
1977	376396	392289	295526
1978	455314	473648	72078
1979	461102	478923	282239
1980	424565	441095	749312
1981	446661	464932	97393
1982	473850	494076	168807
1983	459989	477111	81431
1984	448333	466717	91813
1985	518090	537800	89457
1986	539144	560602	287078
1987	704664	732879	181772
1988	497227	519674	161864
1989	615209	639275	106352
1990	602547	628154	241231
1991	631019	657016	92551
1992	564848	589138	137106
1993	544845	568336	126692
1994	593922	617885	108176
1995	522754	541393	215025
1996	618281	640860	425538
1997	629491	654673	370649
1998	612424	635173	146460
1999	668693	692372	241472
2000	607648	632060	121864
2001	544106	565435	234102
2002	531970	552071	271715
2003	425890	443194	192434
2004	441748	458552	403209
2005	271592	282080	99658
2006	265738	275100	
2007	207199	216325	
2008	214549	222920	
2009	261648	270946	
2010	211176	219822	
2011	197110	205641	

Appendix A.

Observed Atlantic sharpnose shark and bonnethead shark catch (kg) per unit of effort (sampled-net-hrs) (CPUE) in the Gulf of Mexico penaeid shrimp fishery during the years 2009 and 2010 was calculated here from published information available in Scott-Denton et al. (2012) as 0.091 kg/sampled-net-hrs and 0.035 kg/sampled-net-hrs, respectively.

Assumptions and Calculations

Shark species level characterization catch (kg) per unit of effort (sampled-net-hrs) in the Gulf of Mexico penaeid shrimp fishery was calculated here from observed hours towed (h) for species level characterization in the Gulf of Mexico penaeid shrimp fishery (n = 11,322 nets; 63,023.5 h; Scott-Denton et al. 2012; their Figure 5) during July 2007 to December 2010 (42 months).

Assumption 1.—Observed hours (h) for species level characterization in the Gulf of Mexico penaeid shrimp fishery (n = 11,322 nets; 63,023.5 h; Scott-Denton et al. 2012; their Figure 5) is already multiplied by the number of nets sampled per tow (=> h = sampled-net-hrs)

Assumption 2.—Sharks are only identified to species during January 2009 – December 2010 (24 months) (Scott-Denton et al. 2012; their P. 3-4): "From 2007 through 2008, all shark species were grouped. Beginning January 2009, identification of some shark species (as well as other species) was implemented; however, for the purpose of CPUE and variance analyses (2007–10), all sharks were grouped for consistency throughout the time series."

Then, sampled-net-hrs for shark species level characterization in the Gulf of Mexico penaeid shrimp fishery between January 2009 and December 2010 can be calculated as:

(Equation A.1) Shark species level characterization effort (sampled-net-hrs) = (24 months/42 months)* 63,023.5 h = 36,013 sampled-net-hrs.

Assumption 3.—Observed extrapolated Atlantic sharpnose catch from all sampled nets for species level characterization in the Gulf of Mexico penaeid shrimp fishery during January 2009 – December 2010 is equal to 3,276.2 kg (Scott-Denton et al. 2012; their Table 9 Gulf Mandatory Penaeid) .

Then, Atlantic sharpnose shark species level characterization catch (kg) per unit of effort (sampled-net-hrs) in the Gulf of Mexico penaeid shrimp fishery during January 2009 – December 2010 can be calculated as:

(Equation A.2) Observed Atlantic sharpnose shark CPUE (2009, 2010) = 3,276.2 kg/36,013 sampled-net-hrs = 0.091 kg/sampled-net-hrs

Assumption 4.—Observed extrapolated bonnethead shark catch from all sampled nets for species level characterization in the Gulf of Mexico penaeid shrimp fishery during January 2009 – December 2010 is equal to 1,252 kg (Scott-Denton et al. 2012; their Table 9 Gulf Mandatory Penaeid) .

(Equation A.3) Observed bonnethead shark CPUE (2009, 2010) = 1,252.0 kg/36,013 sampled-net-hrs = 0.035 kg/sampled-net-hrs

Discussion

The CPUE (in weight) of Atlantic shark and bonnethead shark calculate here based on published information available in Scott-Denton et al. (2012) appeared to be within the range of the estimated CPUE (in numbers) for Atlantic sharpnose and bonnethead shark, respectively, in the Gulf of Mexico estimated with approach 1 (CPUE_A1) and approach 2 (CPUE_A2) of the panel recommended methods (e.g., see Tables 4 and 10, respectively, in the main document). However, exact comparisons will depend upon the average weight assigned to Atlantic sharpnose and bonnethead sharks captured in the Gulf of Mexico penaeid shrimp fishery during the years 2009 and 2010, which is not available in Scott-Denton et al. (2012).

The method used here to calculate CPUE based on published information available in Scott-Denton et al. (2012) included several assumptions, identified above, which may introduce bias. In addition, the calculations used here assumed that extrapolated catch of Atlantic shark and bonnethead shark Scott-Denton et al. (2012; their Table 9) only represented observed catch for species level characterization in the Gulf of Mexico penaeid shrimp fishery during January 2009 – December 2010 (24 months). As a result, this assumption ignores the fact that Atlantic shark and bonnethead shark may have been identified to species during voluntary BRD certification trips (389) during 2009 (347 BRD certification trips) and 2010 (41 BRD certification trips) (Scott-Denton et al. 2012; their Table 1), which may also introduce some bias.

References

Scott-Denton, E., Cryer, P.F., Duffy, M.R., Gocke, J.P., Harrelson, M.R., Kinsella, D.L., Nance, J.M., Pulver, J.R., Smith, R.C., and Williams, J.A. 2012. Characterization of the U.S. Gulf of Mexico and South Atlantic penaeid and rock shrimp fisheries based on observer data. Marine Fisheries Review 74:1-27.