BYCATCH OF SMALL COASTAL SHARKS IN THE OFFSHORE SHRIMP FISHERY

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Summary

Estimates of offshore shrimp fleet bycatch for Atlantic sharpnose, bonnethead, blacknose, and small coastal sharks combined are provided using procedures used in previous SEDARs. Finetooth was too rare for the standard analysis.

Introduction

Observer programs from 1972-1982 and 1992 to the present provide catch rate information on finfish caught and largely discarded by the shrimp fishery in the offshore Gulf of Mexico. However, the data available are highly unbalanced, usually non-random, and clearly too incomplete for generating a time series on their own. Beginning in 1987, the Pascagoula lab provided estimates of shrimp fleet bycatch based on a simple (main effects only) General Linear Model (GLM), combining catch rates from observer data with research vessel estimates of abundance changes. The GLM procedure was far from ideal, although it was about all that computer hardware and software could handle at the time. Different analytical treatments could result in very different estimates. Formal confidence intervals from the GLM were implausibly narrow. The ad hoc descriptions of uncertainty used instead were not very useful. And of course, several interested groups felt the estimates were just too high.

The controversy subsided in 2004, with the introduction of a Bayesian method using BUGS software. Full structural detail, and many results examining the properties of the new model (really, family of models; one was ultimately selected as the standard) appear in SEDAR7-DW-3 and 54. In summary, the model is structurally similar to the GLM previously used, in that catch rates are modeled as the sum of (log) main effects for year, season (4 month intervals), area (FL, East of river, LA west of river, TX), depth (inside and outside 10 fm), ant data set (shrimping without BRD, shrimping with BRD, research vessel). There is also a ‘local’ effect that models deviations from the main effects pattern for cells with plentiful data, and attaches a common variance estimated in the model for cells with minimal data. Uncertainty in shrimping effort estimates was also taken into account, although the effect of that turned out to be small. The central tendencies for annual bycatch for red snapper were not greatly different than the GLM results, but the confidence intervals were at last plausible, and encompassed most of the variation produced by application of alternative data analyses. Basically, most alternatives proposed over the several preceding years had produced similar estimates for cells with data, but differed greatly in predictions for cells with little or no data. The new Bayesian model identified that variation as true uncertainty, and that uncertainty could be passed to the stock assessment models.

The Bayesian procedure was accepted in SEDAR7, applied again in SEDAR9, and is used here in largely the same form as SEDAR7, with one exception. The SEDAR9 species were much less abundant than red snapper, and a problem arose in that results were unexpectedly sensitive to the prior distribution used for the year effects (SEDAR9-DW-26). Red snapper results did not have this sensitivity. A better, but still decidedly ad hoc solution was found in time for the SEDAR9 Assessment Workshop (SEDAR9-AW-03), and those results were used. Since that time, I have found much simpler solution – include an overall mean term to the model. This change actually makes the model look more like a traditional analysis of variance structure, but there is a cost: running times were roughly tripled. Standard runs range from 30 to 70 hours, depending on the amount of data.

Analysis for small coastal sharks presents one new problem / opportunity. Much of the observer data base records sharks only as ’sharks.’ The numbers of observations potentially available if coastal shark catches could be inferred from total shark catches were not trivial: the number of observer data points would go from about 3000 to about 13000, and the number of cells having data also would increase considerably. I considered a number of approaches to incorporating estimates for the ratio (with variance) of small coastal sharks to total sharks, but most approaches failed. One approach did give results, but the initial results were surprisingly higher than the estimates than the analysis using only records identified to species. The problem was traced to my initial assumption that a common distribution of ratios of small coastals: total sharks would hold for both research vessel and observer data. On checking, ratios in the observer data were consistently lower than in the research vessel data, enough so to explain the discrepancy. Unfortunately, ratio estimates from observer data were so sparse over cells that estimating a reliable distribution from them did not look promising. Even with the faulty distribution (overly narrowed by the large number of research vessel estimates) produced broader confidence intervals than the analysis based on only records identified to species. After spending a considerable amount of time on the problem, I abandoned the approach of modeling total sharks and the ratios that were small coastals. Fortunately, the analyses based only on data identified to species appear reliable, despite the limited amount of observer data, and are recommended for use in the SEDAR13 stock assessments.

Methods

Analyses were developed for Atlantic sharpnose, bonnethead, and blacknose. Finetooth were too rare in the data to even try. Because of the low abundances, I had my doubts that blacknose would run, but it did, and there were no signs of numerical problems. I also made a run for all four species added together at each station.

Description of the collection procedures and the database for the observer programs since 1992 are available in SEDAR7-DW-5. Research vessel data were covered in SEDAR7-DW-1. The basics of shrimp effort data and estimation are covered in SEDAR7-DW-24, and more about their treatment in the bycatch analyses can be found in SEDAR7-DW-54. The analyses reported in this paper are based on updates of observer and effort data obtained in December 2006. In those updates, observer data extend into the spring of 2006. Effort estimate covered 2005. The vessel operating units files (for the nets per vessel statistics) have not been updated since SEDAR7. Research vessel data were available for surveys through November 2006. Although both the summer and fall 2006 survey data should be considered preliminary, no substantial impact on this analysis from future editing is likely.

Although the 2006 data are not complete, I felt enough were available to provide bycatch estimates through 2006. For that, shrimp effort estimates from 2005 were repeated, as the best stand-in for effort expected in 2006. The nets per vessel mean has been held at 3.1 since 2002; there have been no updates since, but the trend leading up to that value was reasonably smooth. Estimates for 2006 will clearly change as the effort data and the rest of the 2006 observer data become available, but with complete survey data for 2006, large changes are not expected.

An example of the BUGS program now used for estimation is included as an appendix. I have reduced the standard run length to 16k iterations to save time. I no longer present many of the internal results or diagnostics from the model runs. Other than problem with a prior noted in SEDAR9, largely corrected by including an overall mean term, there have been no new features or patterns seen in any runs conducted since SEDAR7. SEDAR7-DW-3 discusses modeling strategy, alternatives, and performance properties at length; and should be consulted by anyone having questions about this type of analysis. Most of BUGS plots shown in SEDAR7-DW-3 and 54 are available for the small coastal sharks if anyone wants, but they did not seem to communicate anything new, so I did not include them in this paper.

The results presented in the paper are for annual totals. Estimates are available on a seasonal basis (3 four-month intervals), and given the intensity and annual pattern of shrimping, several of the assessments have used the seasonal resolution. However, the 105 trimester totals make for crowded graphs, so I do not present those.

The quantiles generated by BUGS (which can be thought of as a summary of histograms of the MCMC simulation results) are not directly transferable to the stock assessment models. The BUGS results are put in a parameterized form to capture the central tendencies and uncertainties revealed in the Bayesian analyses. For the bycatch estimates, parameters are reported for a normal distribution on natural log scale. The median of the BUGS analysis is taken as the central tendency. The standard error is estimated as (interquartile range)/1.34898. BUGS reports a mean and standard error as well, but in some analyses results are very skewed even on a log scale. In those situations, a lognormal usually approximates the center of the distribution fairly closely, but may not approximate the extremes very closely. After discussion in previous SEDARs, the extremes were discounted, and the lognormal approximation was accepted as preferred. Hence, the statistics used will be based on median and interquartile range. I decided not to prepare files with these parameter estimates at this time, in favor of waiting for a decision from the assessment modelers as to which temporal resolution is more practical. Once decided, preparing the files (usually transmitted in Excel) does not take long.

The only size composition data for sharks relevant to trawl catches comes from the research vessel surveys. Data are available only since 1987, and are not plentiful. A file containing histograms of these data has been submitted to the workshop, and the DW has been asked (in SEDAR13-DW-31) to examine them for possible use in determining age composition. The distributions are broad and sparse, and may not allow annual breakouts even if something can be determined about overall age composition. If used to suggest age composition for shrimp fleet bycatch, the additional assumption that the research vessel size frequencies apply to commercial shrimping would be required. This may or may not be a sound assumption.

Results

First, here is a qualitative description of the distributions of 3 species based on the medians of the main effects estimated in the models. For sharpnose, the January-April season has the lowest catch rates, and the September-December season the highest, but the difference is less than 40%. Geographically, Florida has the lowest density, less than 1/5 of the other 3 zones, which are all comparable. The shallow (<10 fm) stratum has a higher catch rate (about 1.4x) than the deeper stratum. The research vessel rates run about 18x the rates reported by the observers. For bonnethead, the September-December season catch rates run 2.2x the May-August low season, with January-April between the two. Florida is the area with highest catch rates, about 3x the other zones. Nearshore exceeds offshore by 3x, and research vessel exceeds shrimping by about 6x. For blacknose, September-December is the lowest season, and May-August the highest, but they differ by only about 50%. The LA / MS / AL area east of the river has the highest catch rates, 2.8x that of Texas, which is lowest. Florida comes in just below the east of the river, with LA west of the river between the 2 eastern strata and Texas. The deeper water (>10 fm) show higher catch rates, at 1.4x the shallow zone. Research vessel rates exceed the observer rates by 7x.

The first results for annual estimates of Atlantic sharpnose bycatch are shown in figs 1 & 2 (arithmetic and log scales, respectively). An anomaly in the estimates for the most recent years is very evident. This set of estimates was based on a model with BRDs and non-BRD observer data as separate data sets, and applying results from each set in time and space in accord with the BRD regulations. Unfortunately, the only sizeable amount of data with BRDs <u>and</u> sharks identified to species came from a concentrated area off Florida in 2002. The data may be representative of the larger Florida region, or maybe not, but as that is all there is, it overwhelms the estimation of fishing with BRDs. We found similar anomalies from the same cause with the SEDAR9 species, and elected to set those data aside. Here, I decided to combine BRD and non-BRD data into a single designation, believing that given the sizes of sharks, BRD presence or absence may not be very relevant. The BRD data could then be retained (and there are no reasons to doubt their validity), but they would not overwhelm the analysis. I kept that combination action for the other two species as well.

With the BRD and non-BRD sets combined, Figures 3 and 4 show the annual estimates for sharpnose. Figures 5 and 6 have bonnethead, and figs. 7 and 8 have blacknose. Figures 9 and 10 are for the 4 small coastal species combined. (These are added together at each station, so the resulting estimates need not be directly additive.) The plots are directly output from the BUGs program, with the long, thin vertical lines being 95% (Bayesian) confidence bands, and the thicker bar the interquartile range. There are short horizontal lines for the mean values from the simulations, not always evident, which are not used in the assessment. The long horizontal line is an overall mean, also not formally used for anything. BUGS doesn't label years, so the sequential 1 – 35 represent 1972-2006. Units are millions of fish, or the natural log thereof in the even numbered figures.

Finetooth were simply too rare to be a candidate for the Bayesian analysis. With almost every point a zero, the procedure will crash from numerical problems. We can get an idea of the magnitude, however, from multiplying the average shrimper CPUE (0.00068 finetooth per net hour) by an average effort of about 11.7 million net-hours per year, per SEDAR9-AW-3. This suggests that something on the order of 8000 fish a year may be taken.

Discussion

SEDAR7-DW-3 in particular has an extended discussion of model approach and performance. There is little or nothing new to report here. The only change since SEDAR9, use of an overall mean effect in the model structure, has obviously eliminated the pathologies reported SEDAR9-DW-26, without resorting to the ad hoc techniques of SEDAR9-AW-3. This new structure is thus recommended.

Observer training is sound and thorough, but observer experience varies, so actual taxonomic resolution could be an issue. The majority of the observer data (under the 'Evaluation Protocol') record only to 'sharks,' so there should be no issues there. I always have some concern about records that might not be identified all the way to species when the protocol expects it (in this case, 'Characterization protocol' per SEDAR7-DW-5). Variation in taxonomic resolution is largely undocumented, and thus could be a source of error. However, I noted no fluctuations in results over time that one might expect with serious impact of variable resolution.

Citation Notes

All references are to previous SEDAR documents, posted on the SEFSC website: www.sefsc.noaa.gov/sedar

BUGS software is available (free) at www.mrc-bsu.cam.ac.uk/bugs

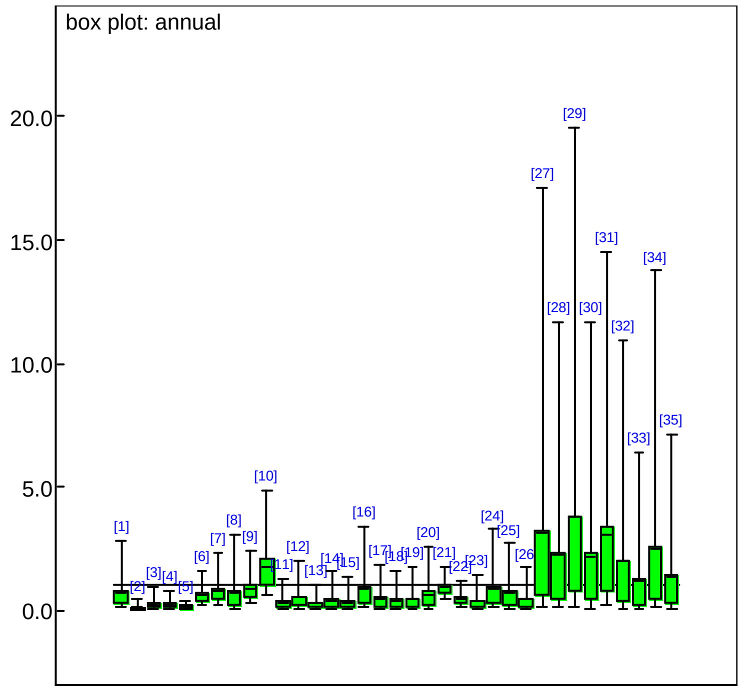

Figure 1. Annual estimates of sharpnose bycatch on an arithmetic scale. This version has separate parameters for BRD and non-BRD fishing. Units are million of fish.

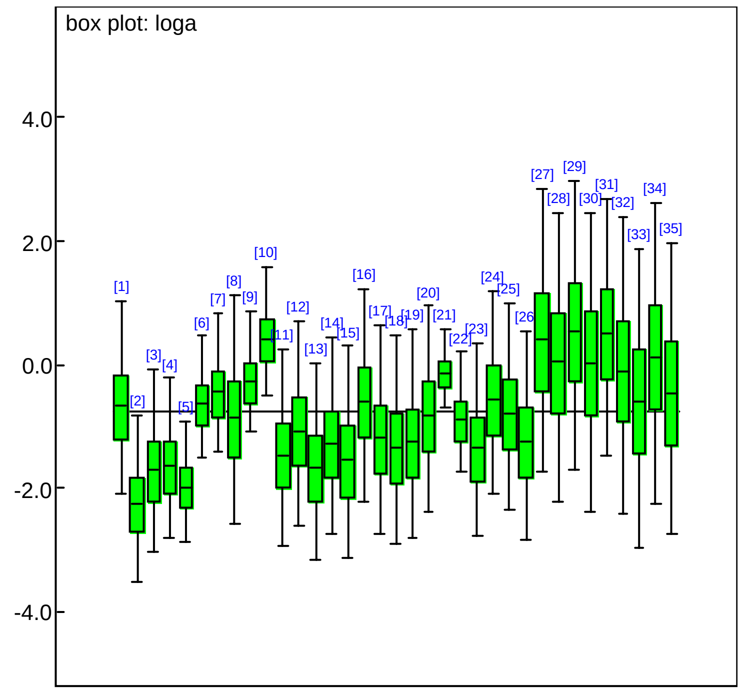

Figure 2.Annual estimates of sharpnose bycatch on an natural log scale. This version has separate parameters for BRD and non-BRD fishing.

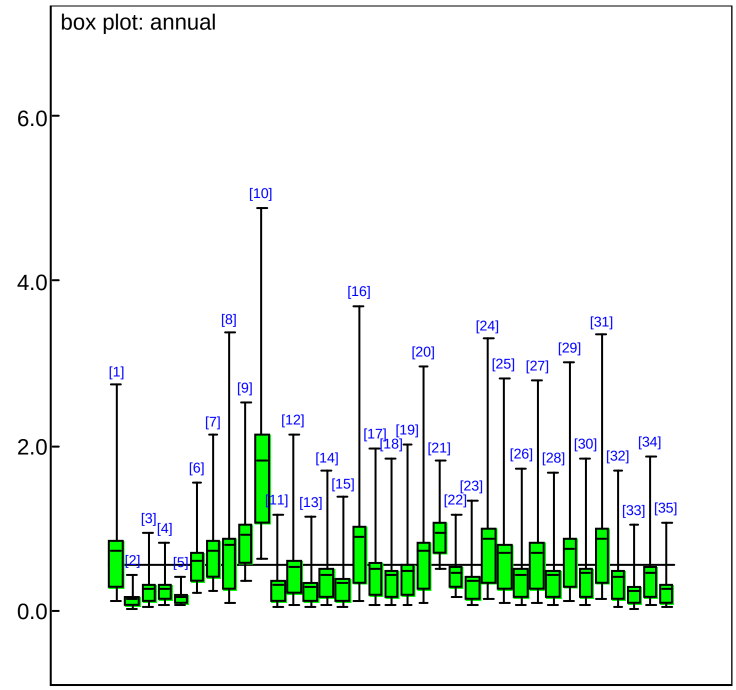

Figure 3. Annual estimates of sharpnose bycatch on an arithmetic scale. This version combines BRD and non-BRD fishing without distinction. Units are millions of fish.

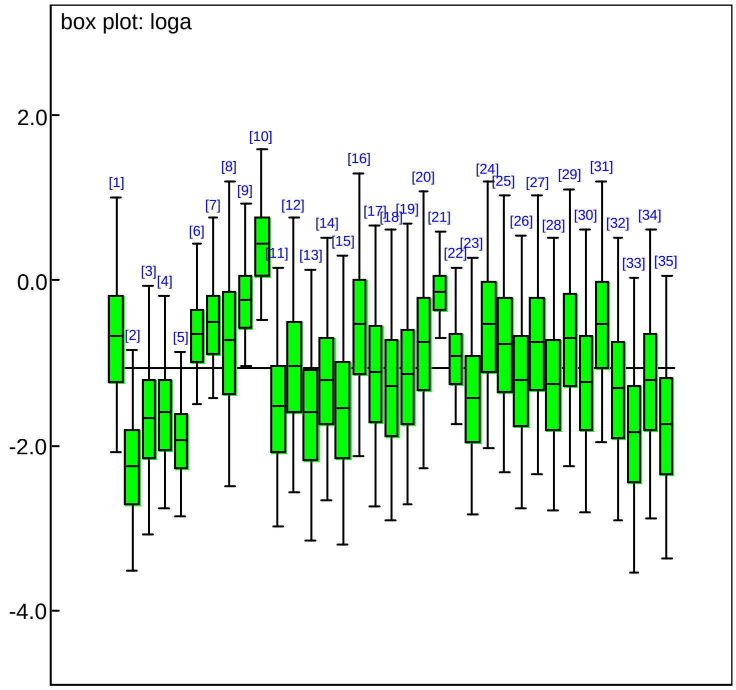

Figure 4. Annual estimates of sharpnose bycatch on a natural log scale. This version combines BRD and non-BRD fishing without distinction.

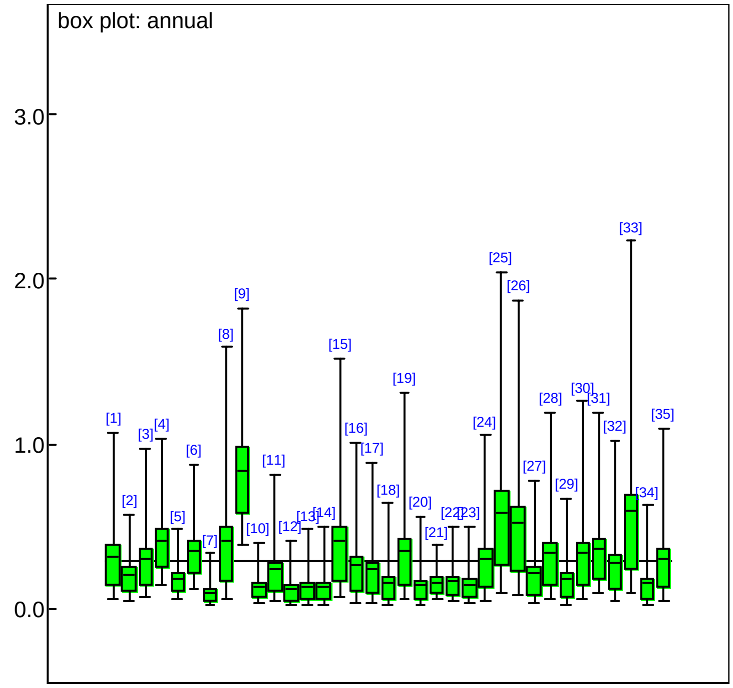

Figure 5. Annual estimates of bonnethead bycatch on an arithmetic scale. Units are millions of fish. (BRD and non-BRD combined as a single data set.)

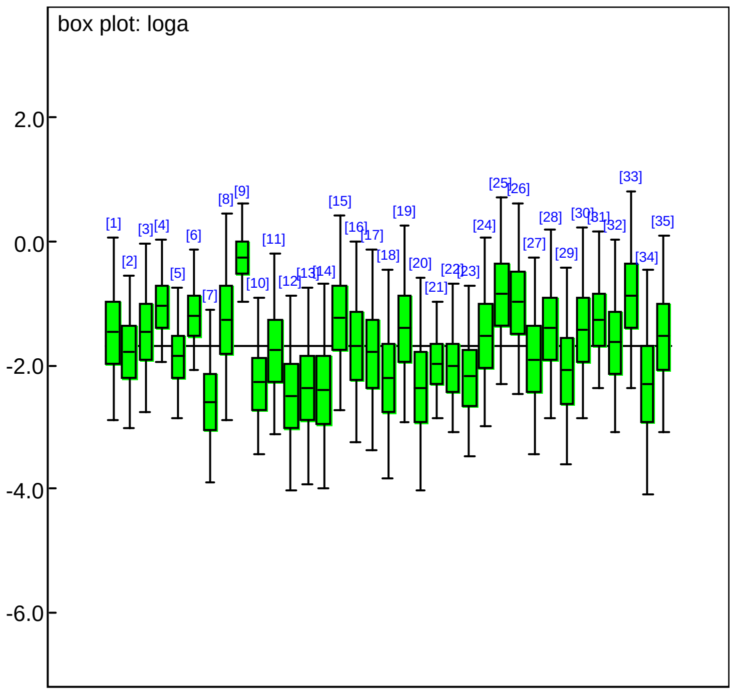

Figure 6. Annual estimates of bonnethead bycatch on a natural log scale (BRD and non-BRD combined as a single data set.)

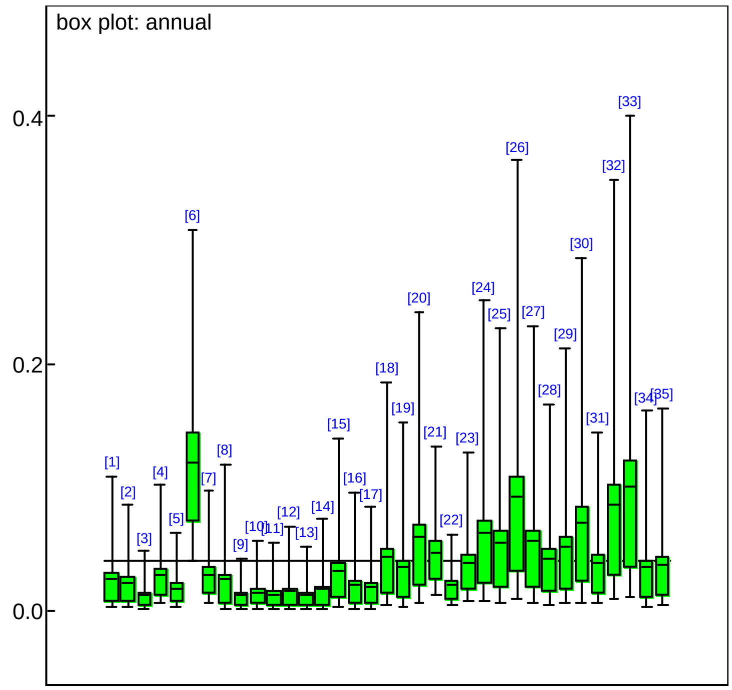

Figure 7. Annual estimates of blacknose on an arithmetic scale. Units are millions of fish. (BRD and non-BRD combined as a single data set.)

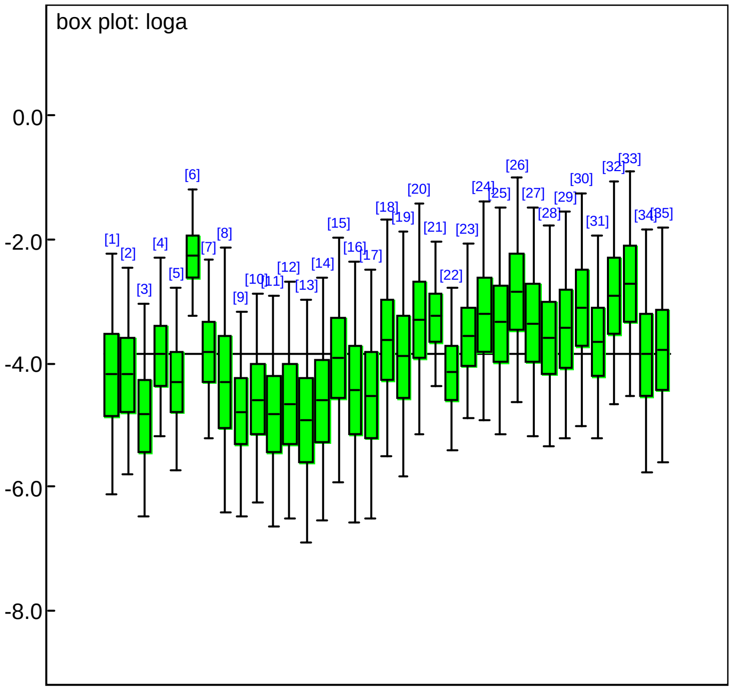

Figure 8. Annual estimates of blacknose on a natural log scale. (BRD and non-BRD combined as a single data set.)

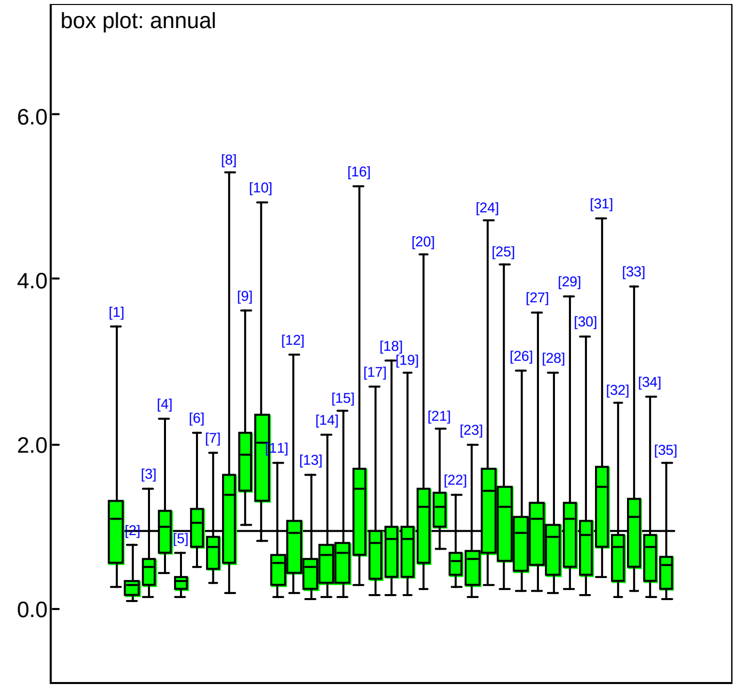

Figure 9. Annual estimates of small coastal shark bycatch on an arithmetic scale. (Data summed at each station.) Units are millions of fish. Brd and non-BRD data combined as a single data set.

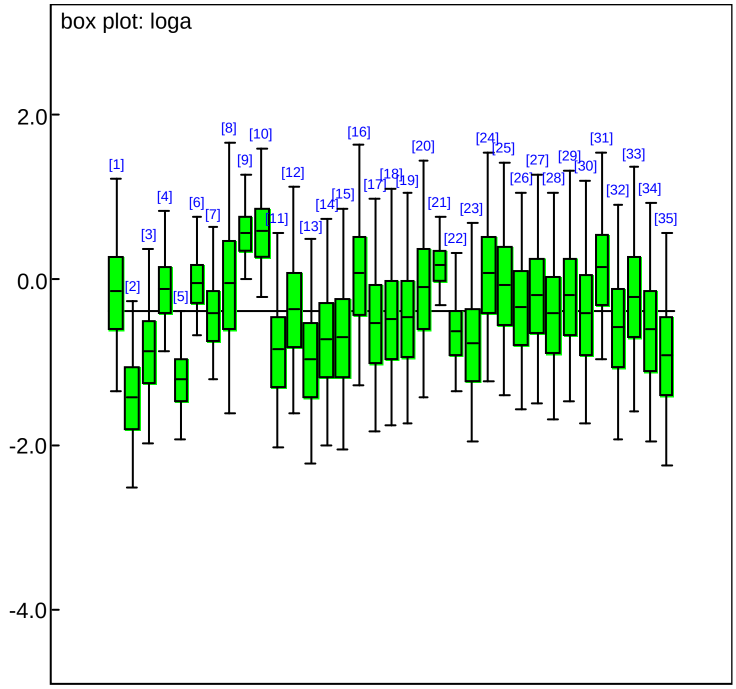

Figure 10. Annual estimates of small coastal sharks.bycatch on a natural log scale. BRD and non-BRD data combined in a single data set.

Appendix. BUGS code for the bycatch analyses. This particular listing was for red snapper. The data count 40000 here, and the mean value of the prior for 'meen' are changed with species. Separate data files input 1) the catch rate data, with stratum identifiers, 2) estimated means for shrimp effort, by stratum, 3) estimated precisions for shrimp effort, by stratum, 4) estimated mean for nets per vessel, by year, and 5) estimated precision for nets per vessel, by year.

```
model U7bycatch06 for RS {

r~dunif(0.03,5)
tau~dlnorm(0,3.5)

meen~dnorm(1,1)
for (i in 1:35)  {
  yraw[i]~dnorm(0,1)
  yx[i]<-yraw[i]-mean(yraw[])
  yef[i]<-meen+yx[i]
  }
for (j in 1:3)  {
  sraw[j]~dnorm(0,1)
  sx[j]<-sraw[j]-mean(sraw[])
  }
for (k in 1:4)  {
  araw[k]~dnorm(0,0.2)
  ax[k]<-araw[k]-mean(araw[])
  }
for (l in 1:2)  {
  zraw[l]~dnorm(0,0.2)
  zx[l]<-zraw[l]-mean(zraw[])
  }
for (m in 1:3)  {
  draw[m]~dnorm(0,1)
  dx[m]<-draw[m]-mean(draw[])
  }
for (i in 1:35)  {
  for (j in 1:3)   {
    for (k in 1:4)  {
      for (l in 1:2)  {
        for (m in 1:3)  {
          local[i,j,k,l,m]~dnorm(0,tau)
          logy[i,j,k,l,m]<-meen+yx[i]+sx[j]+ax[k]+zx[l]+dx[m]+local[i,j,k,l,m]
          y[i,j,k,l,m]<-exp(logy[i,j,k,l,m])
          mu[i,j,k,l,m]<-r/y[i,j,k,l,m]
          }
        }
      }
    }
  }
for (h in 1:45715) {
  lamb[h]~dgamma(r,mu[yr[h],seas[h],ar[h],dp[h],ds[h]])
  lambda[h]<-lamb[h]*hrsfishd[h]
  catch[h]~dpois(lambda[h])
  }
for (i in 1:26)  {
  for (j in 1:3)   {
    for (k in 1:4)  {
      for (l in 1:2)  {
        effort[i,j,k,l]~dnorm(effmean[i,j,k,l],efftau[i,j,k,l])
        npv[i,j,k,l]~dnorm(voufmean[i],vouftau[i])
        take[i,j,k,l]<-y[i,j,k,l,1]*npv[i,j,k,l]*effort[i,j,k,l]
        }
      }
    }
  }
    for (k in 1:4)  {
      for (l in 1:2)  {
        effort[27,1,k,l]~dnorm(effmean[27,1,k,l],efftau[27,1,k,l])
```

```
        npv[27,1,k,l]~dnorm(voufmean[27],vouftau[27])
        take[27,1,k,l]<-y[27,1,k,l,1]*npv[27,1,k,l]*effort[27,1,k,l]
        }
      }
      for (l in 1:2)  {
        effort[27,2,1,l]~dnorm(effmean[27,2,1,l],efftau[27,2,1,l])
        npv[27,2,1,l]~dnorm(voufmean[27],vouftau[27])
        take[27,2,1,l]<-y[27,2,1,l,1]*npv[27,2,1,l]*effort[27,2,1,l]
        }
     for (k in 2:4)  {
      for (l in 1:2)  {
        effort[27,2,k,l]~dnorm(effmean[27,2,k,l],efftau[27,2,k,l])
        npv[27,2,k,l]~dnorm(voufmean[27],vouftau[27])
        take[27,2,k,l]<-y[27,2,k,l,3]*npv[27,2,k,l]*effort[27,2,k,l]
        }
      }
    for (k in 1:4)  {
      for (l in 1:2)  {
        effort[27,3,k,l]~dnorm(effmean[27,3,k,l],efftau[27,3,k,l])
        npv[27,3,k,l]~dnorm(voufmean[27],vouftau[27])
        take[27,3,k,l]<-y[27,3,k,l,3]*npv[27,3,k,l]*effort[27,3,k,l]
        }
      }
for (i in 28:35)  {
  for (j in 1:3)   {
    for (k in 1:4)  {
      for (l in 1:2)  {
        effort[i,j,k,l]~dnorm(effmean[i,j,k,l],efftau[i,j,k,l])
        npv[i,j,k,l]~dnorm(voufmean[i],vouftau[i])
        take[i,j,k,l]<-y[i,j,k,l,3]*npv[i,j,k,l]*effort[i,j,k,l]
        }
      }
    }
  }
for (i in 1:35) {
  annual[i]<-sum(take[i,,,])
  loga[i]<-log(annual[i])
 }
for (i in 1:35)  {
  for (j in 1:3)  {
    trimester[i,j]<-sum(take[i,j,,])
    }
  }
mofam<-ranked(annual[1:35],18)
loquartile<-ranked(annual[1:35],9)
hiquartile<-ranked(annual[1:35],27)
iqram<-hiquartile-loquartile
mofamlog<-ranked(loga[1:35],18)
loqlog<-ranked(loga[1:35],9)
hiqlog<-ranked(loga[1:33],27)
iqramlog<-hiqlog-loqlog
seapprox<-iqramlog/1.34898
taupprox<-1/seapprox
range<-ranked(annual[1:35],35)/ranked(annual[1:35],1)
}

list(tau=0.5, r=0.15, meen=2)
list(tau=0.7, r=0.18, meen=0)
```