Shrimp Fleet Bycatch Estimates for the SEDAR9 Species

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SUMMARY

The Bayesian techniques used to estimate shrimp fleet bycatch for red snapper during SEDAR7 (SEDAR7-DW-3 and -54) were applied to vermilion snapper, gray triggerfish, and greater amberjack. Results for all three species do not appear to be as reliable as the results for red snapper, probably in part due to their lower abundances, but also due to reasons unique for each species. Vermilion snapper are extremely patchy, to the point that the negative binomial error adequate for red snapper may be inappropriate for vermilion. Gray triggerfish have a more "analysis-friendly" distribution, and are probably abundant enough for a reasonable analysis, but the species was not on the list of 22 species to be worked up during "Evaluation Protocol" observer trips. Hence, shrimp observer data relevant to gray triggerfish are very, very sparse. Greater amberjack were likewise not on the list for work-up under the evaluation protocol, but their abundance in trawls is so low that reliable annual estimates may not have been possible even if they had been. It was not possible to obtain an estimate for bycatch with BRDs for triggerfish and amberjack with the Bayesian model. Because of doubts about the reliability of the annual estimates for these species from the SEDAR7 model, I also experimented with a delta distribution-based version of the Bayesian approach, and brought back Model 3 from SEDAR7-DW-3. There is some evidence that the delta implementation may be underestimating bycatch, and the frequencies of occurrence of for vermilion and greater amberjack are so low that one has to be suspicious about results of the CPUE portion of the delta distribution analysis. Model 3 central tendency tended to be intermediate between the SEDAR7 and delta results, but the uncertainty estimates were enormous. In view of the problems with all three models, it may be better for the three SEDAR9 species to ignore estimates of interannual variation, and instead estimate an overall average, and then construct an extremely wide uncertainty interval to incorporate both estimation error (both within and among model choices) and interannual variation. It was not possible to partition the bycatch estimates by age as per SEDAR7-AW-20, as only a handful of fish for these 3 species have been measured across all the observer studies.

INTRODUCTION

A new, Bayesian method for estimation of shrimp fleet bycatch was developed for SEDAR7. Its acceptance brought a welcome respite from many years of controversy over bycatch estimates for red snapper. The primary paper developing the method (SEDAR7-DW-3) considered both red snapper and king mackerel, and provided plausible estimates for both annual means and uncertainties for both species. An update for red snapper (SEDAR7-DW-54) was prepared just prior to the SEDAR7 data workshop, bringing in the latest available data. That update paper also incorporated contributions from uncertainty in shrimping effort estimation to the confidence bands around the bycatch estimates.

In preparation for SEDAR9, the recommended model from SEDAR7 was applied to data for vermilion snapper, gray triggerfish, and greater amberjack. Problems were expected in applying the method to these much less frequently occurring species, but the nature and extent of some of the problems came as a bit of a surprise. This paper first reports the findings of the SEDAR7 model. Because the results did not appear completely satisfactory, I added development of a Bayesian model based on the 'delta distribution,' which splits the analysis into two parts: presence / absence and CPUEs of positive occurrences. The delta approach seemed to address some of the problems, particularly for vermilion snapper, but the approach may introduce some systematic bias for reasons not clear. I also went back to one of the models presented but not recommended in SEDAR7 ('Model 3'), to see if it was less vulnerable to the problems presented by the data for the 3 SEDAR9 species.

SEDAR7-DW-3 covered the development of the primary model and some alternatives in detail, and included an overabundance of commentary on philosophical underpinnings for the Bayesian approach. (It also summarized the history of the GLM method previously used.) These details are not repeated here, but in quick summary, the SEDAR7 model is based on CPUEs generated from a log-linear main effects structure (year + season + area + depth + data set) with an additional 'local effect' term to model deviations from the main effects predictions. This local term is uniquely Bayesian, in a sense serving as a fixed effect for cells in which data are plentiful, a random effect for cells without data, and as something between fixed and random in cells having some but not a lot of data. Variation within cells is modeled with a negative binomial structure, which although not entirely adequate for king mackerel, appeared quite effective for red snapper. The ability to allow finite probability to observations of zero was the real virtue of the negative binomial, eliminating the need for the log(x+c) approximation techniques that were found to be more problematic than commonly believed during the investigations of the properties of the old GLM method. Model 3 has the same structure as the SEDAR7 model for most feature, but substitutes a truly (lognormal) random effect with mean zero and precision estimated by the data for the local effect.) The delta-based model introduced in this paper has two sets of log-linear main effects plus local term structures: one for presence / absence, and one for CPUEs>0. CPUE replaces catch in numbers as the modeled observable, and the within cell variation in CPUE>0 is modeled by a lognormal distribution. Each data point is matched to a (modeled product) of the lognormal CPUE and a Bernoulli variable for presence / absence.

METHODS

The available data are described in SEDAR7-DW-3 and 54. An update of the observer data base was obtained from Galveston Lab on April 25, 2005. At that time, there were no un-archived observer data waiting to be processed. The update added all data used here from 2004, and any data from 2003 not processed in time for SEDAR7, to the observer data sets. Trawl survey data from the Oregon II were updated through the Fall 2004 SEAMAP trawl survey. An update of shrimping effort estimates (made at the spatial and temporal resolution of the strata used for the last several analyses of bycatch) was obtained from Galveston – estimates (with uncertainties) were available through 2004. There has apparently not been an update of the Vessel Operating Units files (the source for nets per vessel information) since SEDAR7, so point estimates of nets per vessel were set at 3.1 and 3 for 2003 and 2004, with uncertainty parameters near the average of recent years for 2003, and at the most broad value seen in any year for 2004.

Analytical procedures for the SEDAR7 model here were the same as described in the SEDAR7 papers. Only the model ultimately recommended for SEDAR7 (Model 2 in the SEDAR7-DW-3 paper) was initially considered here. The first runs for gray triggerfish produced numerical nonsense for estimates of the bycatch for the fleet operating with BRDs. A check of the data revealed why – there has never been a gray triggerfish reported caught in a BRD net, thus the model could not find a meaningful distribution for BRD catches. Greater amberjack had the same situation. I therefore modified the model for these species, eliminating the terms and data for nets with BRDs. Thus, the reported estimates are for the fleet as if it were currently fishing without BRDs. We cannot report meaningful estimates of reductions due to BRDs for these species, unless one wished to accept the nominal 100% reduction.

The analyses used the freely available software WINBUGS 1.4, run on the same computer described in SEDAR7-DW-3. Both running time and available memory are limiting to any extended exploration of other modeling ideas. To counteract this limitation somewhat, I lowered the standard number of iterations per run to 15k for the SEDAR7 model, and 10k for the delta model. Occasionally, I ran less than that to save time. (Results comparing shorter and longer runs showed that medians were generally well estimated with only a few thousand iterations, so probably all of the runs were overly long, given the focus of this paper.)

To investigate a WINBUGS implementation of an analyses based on the delta distribution, I kept the overall structure very similar to the SEDAR7 structure, but patched in a parallel set of equations for the presence / absence (0,1) values considered in a delta distribution. The parameters and equations modeling CPUE values become applicable only to CPUEs>0. The lognormal version of a delta analysis was used,

with a hyperpriored, common residual variance (actually parameterized as 1/variance in BUGS). I do not know a theoretical basis for structuring priors for a presence / absence variable (p, essentially the probability of encounter in a random trawl in a cell), but wanting a generally uninformative set, I came up with a procedure largely by trial and error. I used (logarithmic) terms for each of the main effects with normal priors. The sum of the priors chosen produces a logit(p) consistent with a fairly flat distribution of p over the 0,1 range. The BUGS code for the vermilion snapper delta model is listed in the appendix.

After observing some of the problems arising in the SEDAR7 and delta analyses for these species, I decided to resurrect Model 3 from the SEDAR7-DW-3. Instead of adding in a local effect as in the primary SEDAR7 model, this model adds in a term centered on 0, but with a precision equal to the precision of the local term derived via the primary model. This structure is similar to a mixed effects model in a frequentist context, with the main effects fixed, plus a random effect based on the spread of departures (over cells) from the mean main effects predictions. I anticipated a cost to considering this model – variances of the bycatch estimates will increase, and setting the means of the local terms to zero could lead to an overall downward bias. The motivation for this model was different in the red snapper analysis, but here I used it in the hope that it would eliminate some effects of the sparse, and for vermilion snapper, patchy data on the estimates via the local term.

SEDAR7-DW-3 contained a large number of graphs used to explain the properties of the model. This report does not included those graphs, as their inclusion did not seem particularly useful here. Most were generated in the course of the analyses, however, and can be inspected at the data workshop on a computer screen, should anyone want to see any specifically. For this paper, I have concentrated on tables showing the annual estimates, and the problems arising.

RESULTS

Vermilion Snapper

Table 1 shows the annual totals estimated from the SEDAR7 model. Several feautres look quite unrealistic. The estimates for the first 3 years of BRDs (1998-2000) look nonsensical. Even dismissing those, interannual variability looks unrealistically high (less than 2 million to 200 million fish per year in the medians. Within year confidence bands are enormous (from 18x – 1200x). The overall level seems unrealistically high, given that catch rates for vermilion snapper are probably a quarter or less than the rates for red snapper, and that the highest catch rates in the observer data are in the eastern Gulf, not in the center of the shrimp fishery.

There is, of course, no direct way to verify whether estimates returned by the model are biased one direction or another, but I decided to add an evaluation criterion at this point. I took the average CPUE from all observer data (BRD and non-BRD separately) from a SAS Proc Tabulate run, and multiplied by the approximate amount of recent shrimp effort (4 million hours per year and 3 nets per vessel). For vermilion snapper, this value was 7.7M fish per year (no BRD). The median of the medians over years from the model result was 36M fish. I have no measure of how much deviation between these numbers should be before one worries about bias, but as the discrepancy here is almost 5-fold, I concluded these SEDAR7 results are very likely biased upward. (I had noted but not documented the close agreement between the central tendency over years of the annual totals and the 'average CPUE x approximate effort' value for red snapper, as I had not attached any great significance to it. With central tendency over years expressed as median of the annual medians, the central tendencies from the SEDAR7 model and the average CPUE approximation fore red snapper are 27.6M and 26.3M fish per year, respectively.) Lacking a better criterion for evaluating potential for bias, I use this comparison several times in what follows.

Inspection of the input data suggests that sparse, non-random data are the source of the problem with the nonsensical BRD year estimates. There are only 71 BRD data points relevant to vermilion in the 3 offending years. Vermilion are present at 11 of these, with reported catch rates ranging between 37 and 982 fish per hour. I have no reason to doubt these observations. Catch rates reported for other species at the same stations look very reasonable. The unusually high entries appear to be from 2 trips, with stations

in close proximity within each trip. There are just not enough other data to 'smooth out' the effects of these apparent chance encounters with high vermilion snapper concentrations. Similar, smaller concentrations are probably responsible for the wild interannual variations elsewhere in the vermilion bycatch estimates.

Although the sparse, non-random aspects of the particular subset of data examined were largely responsible for the nonsensical results in 1998-2000, those same data illustrate a more generic problem with vermilion snapper – their extreme patchiness. For additional illustration, vermilion snapper average CPUE is about 30% that of red snapper, but vermilion occurs at all in only 4% of the observer stations vs 43% for red snapper. Of those stations with positive catches, 29% of the vermilion catches were over 50 individuals; whereas only 15% of the positive red snapper catches were over 50 individuals. The negative binomial distribution cannot completely describe a frequency distribution with a peak at zero and a non-monotonic change of frequency with increasing number, so the extremely patchy vermilion snapper can lead to a compromise fit, consistent with a large number of potential but unobserved samples with abundances between 0 and any peaks at larger numbers. These samples 'predicted' by the negative binomial may or may not really exist. I believe the 'prediction' of these abundances is the main property responsible for the discrepancy between the median of annual medians and the 'average CPUE' approximation. The negative binomial parameter 'r' that is determined in the analysis was essentially pegged at the 0.03 limited required to keep the analysis out of numerical trouble. It would appear the negative binomial may just not be appropriate for something as patchy as vermilion snapper. This was the motivation for introducing a Bayesian version of the delta distribution structure.

Annual totals from the delta model for vermilion snapper are shown in Table 2. The delta approach has reduced but not eliminated the most extreme estimates for the early years of BRDs, and the general interannual variability is much tamed down (160x, even with the 3 early BRD years included). However, the whole set of estimates has been shifted downward so much that the median of annual medians (1.5M) is now well <u>below</u> the 7.7M 'average CPUE' approximation (again, about a 5x difference), suggesting there may be a strong negative bias with the delta analysis. Despite this range, the confidence bands for the SEDAR7 and delta results for individual years do generally overlap, although often only slightly.

Annual estimates using model 3, the model with a fully random effect added in, are shown in Table 3. Central tendencies intermediate between the primary SEDAR7 and delta models. Interannual variability in the medians is down compared to SEDAR7 model results, but still at a seemingly unrealistic 93-fold. The median of the annual medians was 3.8M fish, still well below the 7.7M statistic from 'average CPUE x approximate effort.' The peak during the first 3 BRD years is less pronounced than in Table 1, but those years' results still seems very unrealistic – model 3 reduced but failed to correct the problem that motivated bringing it in here. Even worse, uncertainties around individual annual estimates have exploded, with the upper (97.5%) confidence bounds over 20,000 times or more the lower (2.5%) bound. A single line passes almost all the annual interquartile bands, and through all 95% confidence bands (Figure1).

Gray Triggerfish

Annual statistics for the SEDAR7 model for gray triggerfish appear in Table 4. (Recall that I have already rejected any ability to estimate catches for the fleet with BRDs. The estimates after 1997 are for the fleet as if no BRD requirement existed.) The variability might seem subdued compared to vermilion snapper, but there is still an unexpectedly high range of values among the medians (130x), and the median of the medians (8.3M) exceeds the 'average CPUE' approximation (3.8M) by a fairly large amount (over 2x). These results suggest some of the problems that plagued the vermilion analysis via the SEDAR7 model also affect triggerfish, but much less dramatically.

Annual total statistics from the delta formulation are shown in Table 5. As with vermilion, values are shifted downward, such that the median of medians (2.2M) is now less than the average CPUE approximation (about 1.7x difference). The confidence bands for the annual estimates from the SEDAR7 and delta analyses usually do overlap, quite substantially for some years. The range of medians covers about 140x, max to min. Individual year 95% confidence bands generally have a 3.9x to 360x range

(which probably depends largely on the number of observations each year, much as seen for red snapper in SEDAR7).

Model 3 results (Table 6) resemble the delta results, although medians for individual years may be quite a bit higher or lower between the two models, either direction. The median of medians is 2 M fish, below the average CPUE approximation by about 1.9x.. The range of medians is about 160x. Confidence bands on individual years run from 810x-1300x.

The data situations that generated the differences among model results for gray triggerfish appear to differ from somewhat from the vermilion snapper situations. Gray triggerfish average CPUEs run about half what vermilion snapper run, but triggerfish were present in 9% of the observer stations, vs 4% for vermilion snapper. The negative binomial 'r' parameter did not peg at the lower numerical limit allowed in the analysis. On the other hand, the amount of observer data for triggerfish relative to vermilion is much smaller. There are only about 2900 stations relevant to triggerfish, vs about 8500 for vermilion snapper in the database. It seems likely that the smaller amount of data, and perhaps secondarily the low abundance, present some problems to the triggerfish analysis, whereas patchiness per se is not particularly a problem.

Greater Amberjack

Table 7 shows the annual results for the SEDAR7 model. Table 8 has results for the delta model, and Table 9 covers model 3. The numbers, of course, are much lower than for the other two species, but many of the patterns are similar. The range among the annual medians from the SEDAR7 model is 88-fold; for the delta medians, 78-fold; and for model 3, 70-fold. Confidence bands for the SEDAR7 and delta models are broad relative to the medians, and there is usually a substantial overlap. The confidence bands for model 3 are extremely large, with a range of 660x-1200x between the lower and upper 95% bounds. The median of annual medians statistics are quite different for the 3 models (140k for SEDAR7, 24k for delta, 73k for model 3), and all three are well above the 'average CPUE x approximate effort' statistic (1.9k) fish.

Greater amberjack are not abundant in trawl samples. The average CPUE leading to the 1.9k fish statistic was 0.00016 fish per hour; rates for the other 2 species are on the order of 2000x higher. There are only 2866 observer data points (commercial shrimping, without BRD) relevant to greater amberjack, less than 1/3 that for red snapper. Of those, catches greater than zero are reported for only 2 records. However, the average catch rate in the research trawls is about 0.036 per hr, about 200x the rate reported by observers. For most species, the catch rates in the our random surveys have exceeded the catch rates for directed shrimp fishing recorded by observers (as one might expect), but the differences seen so far have generally been on the order of 3-4x. To get a 200-fold difference, either the distribution of amberjack must be extremely different from the distribution of shrimp, or amberjack were not recognized as such by many of the observers, perhaps being lumped into unidentified fish. In the research trawl data set, amberjack are most abundant off western Louisiana in 10-20 fm and in south Texas inside 10 fm, but they are found scattered throughout the survey area as well.

DISCUSSION

Clearly, the analyses presented here are not completely satisfactory. When compared to the red snapper analysis of SEDAR7, it appears the lower abundances, the reduced number of observations and for vermilion snapper, the high patchiness lead to more ambiguity in the estimates of bycatch for the three SEDAR9 species. This will probably be a continuing problem as assessments continue on less abundant species.

Although I have used the 'average CPUE x approximate effort' statistic to indicate potential bias, I am reluctant to attach too much significance to the statistic. Major motivations of, first, the GLM models, and now, these Bayesain models were to correct for the unbalanced sampling among cells. To assume that overall, the unbalanced situation balances itself enough to give an accurate global median seems a bit of a stretch. Nevertheless, using the 'average CPUE' statistic as an additional estimate of central tendency is

worthy of serious consideration. The factor of departure from the 'average CPUE' statistic varies among species, but SEDAR7 model median was about same factor above 'average CPUE' statistic as the delta was below for gray triggerfish and vermilion snapper. It is not clear if there is any real significance to that approximate symmetry. The symmetry did not hold for greater amberjack, where all 3 models produced medians of annual medians above the 'average CPUE' statistic. It is unclear whether the amberjack situation is in any way predictable from the level of amberjack abundance being much lower than the other two species.

Appropriateness of the negative binomial may be an issue, and there seem to be two problems related to its use. If the population frequency distribution has a peak at zero, and then one or more peaks above that, the negative binomial may simply be the wrong distribution to use. However, given the generally small (and, remember, non-random) sample sizes within cells; we cannot really tell if the population distribution is monotonic. There has been an additional, numerical problem with fitting the negative binomial for less abundant species, first noticed for king mackerel in SEDAR7-DW-3. Allowed values of the 'r' parameter had to be restricted to r>0.03, or the BUGS routines crash from numerical errors. I did not re-explore the minimum threshold here; I kept it at 0.03.   Both vermilion snapper and greater amberjack return a posterior for r crushed against the 0.03 boundary.   I do not know if keeping the value at 0.03 when the free solution clearly would have been lower produces a bias or not. Indications from king mackerel were that if anything, it might add a downward bias, the opposite direction from the possible bias of the SEDAR7 model. Also, as the gray triggerfish analysis returned a posterior for r centered at 0.07, with the tail dying out well above 0.03, it seems unlikely that the constraint on r is producing any of the undesirable patterns, as those patterns are generally the same for all 3 species.

The delta distribution has always held intuitive appeal to me, but every time I've examined it in a non-Bayesian context, I have concluded its practical problems and less than certain properties recommended against its use. Having now tried it in a Bayesian context, I still make that same conclusion. I have never been certain about the properties of the presence / absence portion of the model in any formulation. What I have set up in BUGS seems to work, but I am concerned about one aspect. The model returns presence / absence and abundance parent distributions that have virtually no correlation (generally +/- 0.05), but really, one would expect they should be strongly correlated. Looking at the main effects suggests there may be too much freedom – some cells that have lower abundances relative to the others seem to be compensated by higher presence / absence terms, and vice versa. Basically, the SEDAR7 main effects seemed to make reasonable sense as 'partial derivatives,' whereas the delta main effects often do not. This presents no problem in fitting existing data, but it can be a very undesirable feature for predicting catch rates in empty cells, which is a major requirement of this analysis. I did not investigate other versions of the delta, such as replacing the lognormal distribution with a gamma. (That seemed unlikely to improve things.) I did make an abbreviated run with the delta model on red snapper. The delta medians were below the SEDAR7 and the 'CPUE average" by about 2x. As this direction has been repeated for every species examined so far, I suspect it is a property of the delta model, and not just a consequence of the particular underlying data. Remember, too, that the delta only uses data for CPUE>0 in its separate analysis of abundance when present. For the SEDAR9 species, this means extremely small, even zero, sample sizes in many cells, no matter how many observer stations actually occurred. I do not see this necessarily producing a direction, but the reliability of the predictions certainly must suffer.

In this paper, I did not address many of the issues I covered in the SEDAR7 papers. I did examine the posteriors and the iteration histories in much the same manner, and again found no particular concerns. Other than needing the restriction r>0.03 and some conservative choices for some initial values, there do not appear to be any convergence, mixing, numerical accuracy, or other performance problems with the BUGS implementations. I did not run any of the (time-consuming) goodness of fit analyses covered at length in SEDAR7. In SEDAR7, I noted that different models all tended to fit existing data similarly – it was the predictions for cells with little or no data that differed among models, and that pattern probably held for all alternative models considered by any number of people over the last 15 years. I expected that pattern to hold here as well, and concentrated on other issues.

Are there any other analytical options that could improve on the present situation? I suspect not. Adding more parameters might tighten the fits to data where they exist, but that would not guarantee better

predictions in the empty cells. Also, adding more parameters would quickly collide with the limits to computer memory available. Other structures might work, but probably couldn't address the fundamental problem of sparse, unbalanced, and non-random data any better than the current models do. We were fortunate that the analysis of the much more abundant red snapper did settle down to reasonable consistency, but that success looks unlikely to happen for any of much less abundant species.

So, what should we use to describe the shrimp fleet bycatch, and its uncertainty, for the SEDAR9 species? We have several options:

> Pick one of the methods reported here, and use its results for all 3 species
> Pick a method for each species, not necessarily the same for each
> Pick separate sources of central tendency and uncertainties
> Pick a central tendency over all years, and construct a confidence band incorporating interannual variation, uncertainty among models, and within model uncertainty

There are other combinations as well, but this covers a range of ideas. I have never been comfortable philosophically with using different models for different species, but there may be little choice. These species may not have much in common with the red snapper situration, with 40k observations, with presence in almost 40% of them, to justify the same analytical choice. My opening recommendation to the Data Workshop would be along the lines of the 4th option listed above, but I think the topic is open for debate.

We also have some options to consider within the assessment models, which might affect the choices. Goodyear incorporated bycatch removals in earlier versions of the red snapper assessments without letting the bycatch estimates affect the population sizes in the directed fishery (essentially via a VPA with an age 2 terminal N). He noted a reasonable agreement between shrimper F and effort in the result, suggesting it was evidence for some measure of success. It might be advisable to build a similar separation into the more modern assessment models that may be used in SEDAR9.

LITERATURE CITED

All references are to documents listed in the SEDAR7 DW and AW series.

Note on revisions made during the DW, 6/22/05: In checking the written results against the direct computer output during the DW, I found several transcription errors in the medians and ranges in the version of DW-26 originally submitted. Those errors have been corrected in this version, and I also took the opportunity to change awkward wordings and typos.

Table 1. Annual statistics for vermilion snapper from the SEDAR7 model. (million fish)

	2.50%	25.00%	median	75.00%	97.50%	sample
1972	12.42	71.3	201.1	631.9	8426	32000
1973	4.283	24.14	65.96	203.7	2758	32000
1974	0.9519	5.477	15.1	46.22	634.2	32000
1975	0.7473	4.036	11.3	35.39	491	32000
1976	0.3052	1.666	4.729	15.79	261.6	32000
1977	0.3346	1.617	4.493	14.26	231.2	32000
1978	3.19	8.429	16.32	34.98	240.1	32000
1979	2.876	20.63	65	222.6	3434	32000
1980	0.481	1.59	3.402	8.28	71.7	32000
1981	2.568	9.494	23.54	71.5	985.1	32000
1982	0.8486	4.64	12.87	40.99	564.8	32000
1983	1.075	6.657	18.83	59.32	839.2	32000
1984	2.8	16.84	46.85	145.1	1966	32000
1985	2.726	14.62	40.17	123.8	1621	32000
1986	6.235	35.03	95.93	290.1	3875	32000
1987	7.64	44.77	125.9	386.9	5129	32000
1988	2.512	15.85	45.56	140.8	1880	32000
1989	3.606	21.88	60.69	190.4	2704	32000
1990	5.859	35.08	100.2	317.5	3877	32000
1991	12.68	71.69	195.1	588.6	7499	32000
1992	1.59	4.465	9.961	29.23	487.6	32000
1993	0.6151	1.149	1.803	3.328	30.2	32000
1994	0.723	1.216	1.739	2.857	12.76	32000
1995	5.6	10.59	16.06	26.86	131.5	32000
1996	2.216	8.758	20.63	54.74	605	32000
1997	3.391	15.05	36.44	104.5	1282	32000
1998	80.3	281.4	662.2	1871	23470	32000
1999	53.89	325.1	920.5	2970	41260	32000
2000	33.76	213.6	606.3	1918	26740	32000
2001	9.868	40.17	110.3	380.5	6514	32000
2002	3.393	5.82	8.783	16.35	163.8	32000
2003	11.57	23.97	40.45	80.34	766.1	32000
2004	0.7724	1.451	2.47	5.804	97.11	32000

Table 2. Annual statistics for vermilion snapper from the delta model. (million fish)

	2.50%	25.00%	median	75.00%	97.50%	sample
1972	0.7618	2.382	4.302	7.681	23.56	39000
1973	0.8583	2.325	3.811	6.161	14.86	39000
1974	0.1397	0.4552	0.8294	1.498	4.569	39000
1975	0.1012	0.3082	0.5673	1.048	3.504	39000
1976	0.1621	0.4385	0.7422	1.265	3.683	39000
1977	0.1747	0.5064	0.8766	1.524	4.548	39000
1978	4.612	7.106	8.861	11.14	17.81	39000
1979	0.007102	0.06443	0.1966	0.5966	4.98	39000
1980	0.1383	0.3484	0.5627	0.8992	2.336	39000
1981	0.4376	1.187	1.989	3.344	9.482	39000
1982	0.08332	0.3042	0.6029	1.188	4.179	39000
1983	0.07114	0.2529	0.4963	0.961	3.485	39000
1984	0.2392	0.7566	1.367	2.512	7.879	39000
1985	0.1505	0.5195	0.9947	1.888	6.348	39000
1986	0.4422	1.36	2.451	4.328	12.26	39000
1987	0.3961	1.217	2.207	3.905	11.31	39000
1988	0.05535	0.2205	0.4541	0.9258	3.468	39000
1989	0.1517	0.5058	0.9454	1.739	5.369	39000
1990	0.3693	1.135	2.015	3.57	10.09	39000
1991	0.97	2.551	4.212	6.786	16.5	39000
1992	0.7421	1.089	1.341	1.668	2.732	39000
1993	0.4209	0.595	0.715	0.863	1.308	39000
1994	0.4882	0.7441	0.9272	1.166	1.875	39000
1995	4.562	6.147	7.2	8.449	11.56	39000
1996	0.5282	1.067	1.561	2.319	5.448	39000
1997	0.5776	1.236	1.821	2.68	5.673	39000
1998	13.44	23.04	30.53	40.61	71.78	39000
1999	0.4099	1.272	2.279	4.068	11.87	39000
2000	0.3213	1.065	1.952	3.579	10.85	39000
2001	1.32	1.962	2.498	3.277	6.048	39000
2002	1.608	2.114	2.469	2.911	4.293	39000
2003	5.742	7.906	9.308	10.95	15.08	39000
2004	0.4191	0.633	0.7966	1.028	1.927	39000

Table 3. Annual statistics for vermilion snapper from Model 3. (million fish)

	2.50%	25.00%	median	75.00%	97.50%	sample
1972	0.08638	2.605	15.15	89.56	2651	12000
1973	0.05356	1.526	8.563	51.11	1503	12000
1974	0.01274	0.4307	2.548	15.1	441.8	12000
1975	0.006696	0.1953	1.114	6.414	168.7	12000
1976	0.006164	0.1941	1.042	6.152	156.6	12000
1977	0.005745	0.1669	0.931	5.361	153	12000
1978	0.008091	0.2379	1.321	7.795	219.4	12000
1979	0.02	0.5971	3.802	23.72	751	12000
1980	0.003666	0.1029	0.58	3.383	88.6	12000
1981	0.01695	0.4761	2.669	16.02	453.1	12000
1982	0.008159	0.2373	1.378	7.878	219.4	12000
1983	0.009698	0.2631	1.534	8.83	259.5	12000
1984	0.02445	0.7218	4.055	24.09	702.2	12000
1985	0.01941	0.5617	3.216	19.39	550	12000
1986	0.0426	1.321	7.555	46.01	1409	12000
1987	0.04606	1.465	8.729	51.88	1604	12000
1988	0.01739	0.5122	3.094	17.99	599.5	12000
1989	0.02739	0.8391	4.933	29.28	818.8	12000
1990	0.04632	1.418	7.876	47.52	1322	12000
1991	0.0982	3.112	17.76	104.3	2933	12000
1992	0.0163	0.4632	2.651	14.91	408.1	12000
1993	0.004917	0.1405	0.7649	4.312	115.4	12000
1994	0.0055	0.1622	0.8731	5.07	131.3	12000
1995	0.01297	0.3393	1.938	10.98	300.4	12000
1996	0.03815	1.161	6.808	40.44	1112	12000
1997	0.04751	1.454	8.065	46.75	1355	12000
1998	0.3141	9.581	54.19	325.1	9423	12000
1999	0.2852	8.661	52.13	303.6	9327	12000
2000	0.1608	5.47	33.34	199.8	6156	12000
2001	0.1271	3.68	20.5	117.7	3105	12000
2002	0.06538	1.89	10.38	59.04	1595	12000
2003	0.03102	0.9231	4.799	28.23	736	12000
2004	0.01134	0.3272	1.772	10.14	265.5	12000

Table 4. Annual statistics for gray triggerfish from the SEDAR7 model. All entries are estimates for a fleet without BRDs.   (million fish)

	2.50%	25.00%	median	75.00%	97.50%	sample
1972	1.87	6.404	12.63	25.12	106.7	32000
1973	0.7375	1.863	3.216	5.85	22.23	32000
1974	0.9545	2.493	4.257	7.701	28.22	32000
1975	0.5101	1.281	2.163	3.862	14.94	32000
1976	0.4998	0.8353	1.132	1.607	4.206	32000
1977	1.111	1.861	2.554	3.726	9.961	32000
1978	3.559	5.766	7.822	11.19	28.01	32000
1979	1.83	6.582	13.39	27.12	123	32000
1980	3.859	5.712	7.3	9.673	20.61	32000
1981	2.522	5.021	7.723	12.85	46.33	32000
1982	3.137	7.297	12.09	20.86	78.42	32000
1983	1.009	2.56	4.37	7.814	29.3	32000
1984	1.82	4.776	8.305	15.26	60.04	32000
1985	0.8732	2.369	4.193	7.745	30.61	32000
1986	2.416	7.152	13.06	24.72	102	32000
1987	3.405	9.568	17.05	31.7	127.2	32000
1988	2.67	7.434	13.28	25.05	101.3	32000
1989	2.98	8.758	15.82	30.12	118.9	32000
1990	1.516	4.252	7.642	14.18	59.05	32000
1991	7.397	20.45	36.85	68.39	268.9	32000
1992	2.239	3.501	4.713	6.901	21.49	32000
1993	4.624	6.831	8.593	11.19	22.59	32000
1994	2.248	5.029	8.14	14.16	53.89	32000
1995	3.588	10.74	19.48	36.95	142.7	32000
1996	4.732	13.6	24.32	45.21	179.2	32000
1997	2.878	8.182	14.91	28.63	117.1	32000
1998	0.8771	2.665	5.024	9.688	39.83	32000
1999	4.096	11.57	20.37	37.43	144.4	32000
2000	1.605	4.67	8.428	15.77	62.08	32000
2001	11.16	34.22	63.33	120.9	501.5	32000
2002	2.724	7.616	13.82	26.29	111.4	32000
2003	0.53	1.662	3.173	6.196	26.25	32000
2004	0.07057	0.2417	0.4778	0.9808	4.466	32000

Table 5. Annual statistics for gray triggerfish from the delta model. All entries are estimates for a fleet without BRDs. (million fish)

	2.50%	25.00%	median	75.00%	97.50%	sample
1972	0.7378	1.561	2.305	3.371	6.802	10200
1973	0.4633	0.8935	1.23	1.696	3.051	10200
1974	0.4163	0.753	1.006	1.352	2.411	10200
1975	0.32	0.6126	0.8623	1.225	2.323	10200
1976	0.1392	0.2625	0.3579	0.4864	0.9129	10200
1977	0.5982	0.9336	1.179	1.488	2.335	10200
1978	2.702	4.055	5.039	6.225	9.319	10200
1979	0.3313	0.7844	1.239	1.953	4.546	10200
1980	1.407	2.063	2.508	3.064	4.556	10200
1981	1.327	2.256	2.971	4.011	7.293	10200
1982	1.058	1.962	2.704	3.735	7.229	10200
1983	0.4532	0.896	1.294	1.85	3.791	10200
1984	0.5483	1.141	1.678	2.441	5.064	10200
1985	0.3122	0.6466	0.9513	1.407	3.01	10200
1986	0.8283	1.71	2.433	3.511	7.183	10200
1987	0.8037	1.533	2.167	3.027	5.64	10200
1988	0.5578	1.12	1.609	2.276	4.44	10200
1989	0.9889	1.935	2.732	3.877	7.414	10200
1990	0.495	1.011	1.454	2.079	4.143	10200
1991	2.199	3.957	5.351	7.183	12.62	10200
1992	1.289	1.634	1.856	2.111	2.705	10200
1993	3.732	4.517	5.01	5.6	7.08	10200
1994	1.427	2.32	2.974	3.811	6.282	10200
1995	0.9356	1.792	2.491	3.42	6.086	10200
1996	1.03	1.931	2.737	3.82	7.039	10200
1997	0.7674	1.532	2.175	3.019	5.406	10200
1998	0.1534	0.3355	0.5015	0.753	1.61	10200
1999	1.25	2.351	3.27	4.485	7.968	10200
2000	0.7678	1.593	2.292	3.307	6.59	10200
2001	3.692	6.757	9.203	12.45	21.83	10200
2002	1.344	2.488	3.455	4.796	8.667	10200
2003	0.1386	0.3381	0.5334	0.8471	2.015	10200
2004	0.003299	0.02412	0.06716	0.1826	1.176	10200

Table 6. Annual statistics for gray triggerfish from Model 3. All entries are estimates for a fleet without BRDs. (million fish)

	2.50%	25.00%	median	75.00%	97.50%	sample
1972	0.07389	0.7594	2.539	8.423	84.19	12000
1973	0.03161	0.297	0.9754	3.087	29.42	12000
1974	0.04001	0.3742	1.204	3.858	36.55	12000
1975	0.02203	0.1954	0.6369	2.054	20.31	12000
1976	0.009728	0.08824	0.2847	0.8936	8.197	12000
1977	0.02331	0.211	0.6752	2.107	20.37	12000
1978	0.05668	0.5001	1.601	5.094	47.19	12000
1979	0.04361	0.4484	1.514	5.195	51.46	12000
1980	0.05865	0.5201	1.663	5.265	49.32	12000
1981	0.0655	0.6153	1.996	6.29	59.91	12000
1982	0.09192	0.864	2.734	8.793	81.32	12000
1983	0.03234	0.3062	0.9807	3.073	31.27	12000
1984	0.05478	0.5003	1.642	5.152	51.1	12000
1985	0.02691	0.2628	0.8565	2.66	26.78	12000
1986	0.07543	0.7163	2.365	7.493	75.09	12000
1987	0.1018	1.003	3.266	10.53	98.51	12000
1988	0.07984	0.7622	2.495	8.117	82.12	12000
1989	0.09732	0.9172	3.014	9.596	94.51	12000
1990	0.04966	0.4667	1.503	4.889	46.97	12000
1991	0.2287	2.169	6.978	22.91	211.2	12000
1992	0.06009	0.5343	1.7	5.35	48.44	12000
1993	0.07669	0.6856	2.136	6.635	63.18	12000
1994	0.0835	0.7405	2.361	7.497	69.34	12000
1995	0.1115	1.033	3.397	11.06	105	12000
1996	0.1267	1.242	4.041	13.19	131.4	12000
1997	0.09044	0.8274	2.729	9.031	89.79	12000
1998	0.02833	0.2575	0.806	2.701	26.05	12000
1999	0.1186	1.151	3.656	11.89	112.1	12000
2000	0.05071	0.4998	1.607	5.158	51.52	12000
2001	0.4173	4.108	12.85	42.24	421.3	12000
2002	0.1124	1.065	3.436	10.82	103.1	12000
2003	0.01879	0.1827	0.5982	1.966	20.46	12000
2004	0.002237	0.02235	0.07853	0.2575	2.822	12000

Table 7. Annual statistics for greater amberjack from the SEDAR7 model. All entries are estimates for a fleet without BRDs. (million fish)

	2.50%	25.00%	median	75.00%	97.50%	sample
1972	0.01512	0.06216	0.1344	0.297	1.401	32000
1973	0.007875	0.02801	0.05469	0.1064	0.4414	32000
1974	0.02676	0.07214	0.1294	0.2378	0.9031	32000
1975	0.01584	0.04315	0.07555	0.1378	0.5834	32000
1976	0.006418	0.01861	0.03274	0.0599	0.242	32000
1977	0.005494	0.01563	0.02769	0.05021	0.197	32000
1978	0.009392	0.02518	0.04247	0.07226	0.2178	32000
1979	0.02511	0.1225	0.2562	0.5454	2.599	32000
1980	0.01174	0.03258	0.05695	0.1033	0.3858	32000
1981	0.004692	0.01646	0.03094	0.06012	0.2618	32000
1982	0.009754	0.03289	0.06191	0.1233	0.5477	32000
1983	0.01129	0.03912	0.0781	0.1602	0.8471	32000
1984	0.0335	0.1053	0.1918	0.3668	1.56	32000
1985	0.04642	0.1438	0.268	0.5248	2.238	32000
1986	0.05991	0.1987	0.3848	0.7622	3.319	32000
1987	0.04661	0.1634	0.3206	0.6435	2.719	32000
1988	0.02596	0.0889	0.1786	0.3639	1.562	32000
1989	0.01901	0.06845	0.1393	0.2853	1.33	32000
1990	0.1656	0.4868	0.8952	1.677	6.675	32000
1991	0.4887	1.364	2.447	4.533	18.1	32000
1992	0.01565	0.04025	0.06773	0.1199	0.4891	32000
1993	0.01438	0.03419	0.05417	0.08667	0.2524	32000
1994	0.02718	0.07588	0.1277	0.2263	0.8226	32000
1995	0.1436	0.4272	0.7957	1.57	7.532	32000
1996	0.0539	0.1751	0.3397	0.6811	3.331	32000
1997	0.4376	1.305	2.366	4.506	17.56	32000
1998	0.02104	0.08445	0.1774	0.3869	2.022	32000
1999	0.3927	1.123	1.984	3.716	14.89	32000
2000	0.01509	0.05706	0.1153	0.2386	1.131	32000
2001	0.1634	0.5506	1.047	2.057	9.029	32000
2002	0.0758	0.2156	0.3891	0.7332	2.844	32000
2003	0.02645	0.09482	0.1901	0.4001	1.917	32000
2004	0.01321	0.05217	0.1068	0.2271	1.107	32000

Table 8. Annual statistics for greater amberjack from the delta model. All entries are estimates for a fleet without BRDs. (million fish)

	2.50%	25.00%	median	75.00%	97.50%	sample
1972	3.09E-04	0.003108	0.01042	0.03435	0.3303	29000
1973	2.06E-04	0.001991	0.006394	0.02002	0.1781	29000
1974	0.001549	0.00731	0.0165	0.03727	0.1848	29000
1975	0.002268	0.01017	0.0224	0.04913	0.2404	29000
1976	6.39E-04	0.003557	0.008757	0.02182	0.1234	29000
1977	2.14E-04	0.00194	0.005999	0.01838	0.1521	29000
1978	0.002448	0.01285	0.03044	0.07114	0.3659	29000
1979	4.83E-04	0.005	0.01666	0.05546	0.5532	29000
1980	0.001725	0.009505	0.02336	0.05646	0.3281	29000
1981	2.50E-04	0.002353	0.007353	0.02265	0.199	29000
1982	2.66E-04	0.002367	0.007489	0.02346	0.2097	29000
1983	2.88E-04	0.002704	0.008746	0.02769	0.25	29000
1984	0.002629	0.01338	0.03225	0.07701	0.4413	29000
1985	0.002295	0.0127	0.03075	0.0763	0.425	29000
1986	0.006785	0.03236	0.07354	0.1677	0.8096	29000
1987	0.003124	0.01997	0.05241	0.138	0.8659	29000
1988	7.88E-04	0.005107	0.01341	0.03522	0.2291	29000
1989	4.55E-04	0.004716	0.01575	0.05011	0.4701	29000
1990	0.01956	0.07517	0.1538	0.3197	1.341	29000
1991	0.0662	0.2319	0.4655	0.9332	3.7	29000
1992	0.003103	0.01228	0.02442	0.0483	0.1932	29000
1993	0.00813	0.03354	0.06993	0.1485	0.6514	29000
1994	0.01006	0.03654	0.07204	0.1435	0.5851	29000
1995	0.01451	0.05396	0.1073	0.2196	0.8877	29000
1996	0.003739	0.01808	0.04062	0.09389	0.4602	29000
1997	0.04768	0.1812	0.3638	0.7379	2.974	29000
1998	6.04E-04	0.005794	0.01876	0.06081	0.5977	29000
1999	0.04528	0.1601	0.3135	0.6167	2.392	29000
2000	4.33E-04	0.004282	0.01363	0.04477	0.4269	29000
2001	0.01747	0.07873	0.1759	0.3985	1.955	29000
2002	0.01642	0.06193	0.1256	0.2552	1.046	29000
2003	0.002088	0.01321	0.03485	0.09113	0.5632	29000
2004	3.85E-04	0.003956	0.01285	0.04236	0.3959	29000

Table 9. Annual statistics for greater amberjack from Model 3. All entries are estimates for a fleet without BRDs. (million fish)

	2.50%	25.00%	median	75.00%	97.50%	sample
1972	0.001571	0.01661	0.05421	0.1856	1.904	12000
1973	7.32E-04	0.006815	0.02174	0.06843	0.6573	12000
1974	0.002221	0.0184	0.0556	0.1748	1.549	12000
1975	0.001575	0.01283	0.0372	0.114	1.068	12000
1976	6.00E-04	0.005197	0.01564	0.04883	0.4249	12000
1977	4.68E-04	0.004381	0.01339	0.04221	0.4094	12000
1978	0.001023	0.007877	0.02319	0.07029	0.6774	12000
1979	0.003619	0.03476	0.1121	0.3531	3.882	12000
1980	0.001277	0.01079	0.03271	0.09835	0.8801	12000
1981	5.64E-04	0.005197	0.01608	0.05065	0.518	12000
1982	8.67E-04	0.007519	0.02422	0.07394	0.735	12000
1983	0.00113	0.009967	0.03178	0.09694	0.9782	12000
1984	0.003416	0.02812	0.08378	0.2505	2.445	12000
1985	0.004064	0.03562	0.1066	0.3343	3.401	12000
1986	0.004889	0.04608	0.1423	0.4391	4.332	12000
1987	0.004404	0.03869	0.1198	0.3783	3.568	12000
1988	0.002595	0.02358	0.07686	0.2363	2.398	12000
1989	0.001718	0.01585	0.05055	0.1682	1.874	12000
1990	0.0129	0.1113	0.3383	1.04	9.846	12000
1991	0.03884	0.3132	0.9407	2.837	25.75	12000
1992	0.001555	0.01316	0.03836	0.1161	1.15	12000
1993	0.001383	0.01237	0.03662	0.1066	0.9644	12000
1994	0.003012	0.02603	0.07805	0.2385	2.218	12000
1995	0.01313	0.1101	0.3395	1.05	11.78	12000
1996	0.00513	0.04464	0.1372	0.4284	4.429	12000
1997	0.03708	0.3109	0.9158	2.824	27.68	12000
1998	0.002261	0.02266	0.0726	0.2349	2.701	12000
1999	0.0317	0.2701	0.8159	2.508	23.27	12000
2000	0.001638	0.01451	0.04663	0.1473	1.548	12000
2001	0.01517	0.1347	0.4074	1.242	12.25	12000
2002	0.007704	0.06275	0.1924	0.5995	5.658	12000
2003	0.002488	0.02395	0.07553	0.233	2.51	12000
2004	0.001369	0.01288	0.0438	0.1407	1.43	12000

Figure 1. Annual estimates of bycatch of vermilion snapper from model 3 on a log scale.
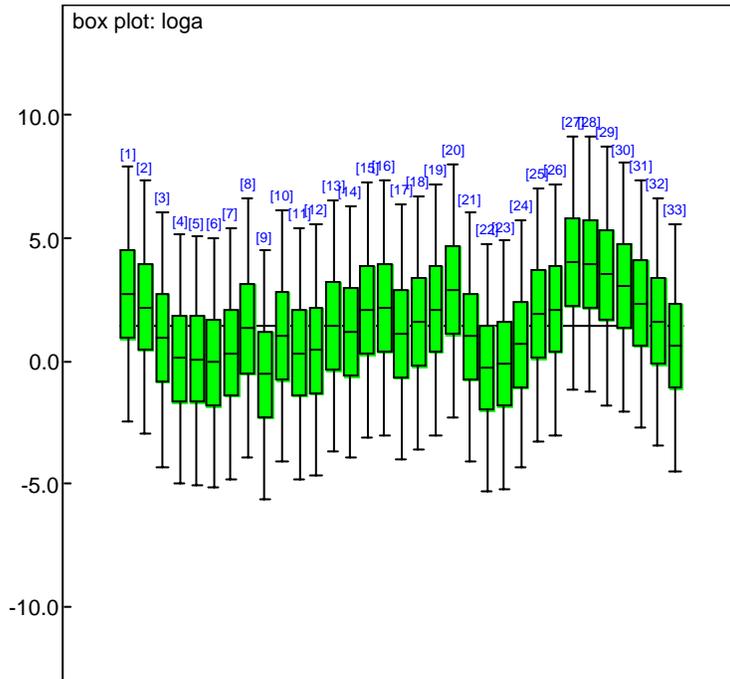
Appendix. BUGS code for the delta implementation. Code for the other two models remained very close to the listings in SEDAR7-DW-3 and 54.

```
model S9delta01 {

residtau~dlnorm(0,3)
tau~dlnorm(0,3.5)
taup~dlnorm(0,5)

for (i in 1:33) {
  yx[i]~dnorm(1,0.7)
  yp[i]~dnorm(0,0.5)
  }
for (j in 1:3) {
  sraw[j]~dnorm(0,1)
  sx[j]<-sraw[j]-mean(sraw[])
  sp[j]~dnorm(0,2)
  }
for (k in 1:4) {
  araw[k]~dnorm(0,0.2)
  ax[k]<-araw[k]-mean(araw[])
  ap[k]~dnorm(0,2)
  }
for (l in 1:2) {
  zraw[l]~dnorm(0,0.2)
  zx[l]<-zraw[l]-mean(zraw[])
  zp[l]~dnorm(0,2)
  }
for (m in 1:3) {
  draw[m]~dnorm(0,1)
  dx[m]<-draw[m]-mean(draw[])
  dsp[m]~dnorm(0,3)
  }
for (i in 1:33) {
  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)
          locp[i,j,k,l,m]~dnorm(0,taup)
          logy[i,j,k,l,m]<-yx[i]+sx[j]+ax[k]+zx[l]+dx[m]+local[i,j,k,l,m]
          logit(p[i,j,k,l,m])<-yp[i]+sp[j]+ap[k]+zp[l]+dsp[m]+locp[i,j,k,l,m]
          y[i,j,k,l,m]<-p[i,j,k,l,m]*exp(logy[i,j,k,l,m])
          }
        }
      }
    }
  }
for (h in 1:1149) {
  cpue[h]~dlnorm(logy[yr[h],seas[h],ar[h],dp[h],ds[h]], residtau)
  }
for (g in 1:39867) {
 pa[g]~dbern(p[pyr[g],pseas[g],par[g],pdp[g],pds[g]])
 }

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 28:33)  {
  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 1:33) {
  annual[i]<-sum(take[i,,])
  loga[i]<-log(annual[i])
 }
for (i in 1:33) {
  for (j in 1:3)   {
    trimester[i,j]<-sum(take[i,j,,])
    logt[i,j]<-log(trimester[i,j])
   }
  }
 }
list(tau=0.1, taup=1.2)
list(tau=1.2, taup=0.1)
```