Preliminary Trials Estimating M1 from Fall and Summer Trawl Surveys

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Introduction

The values of M0 and M1 presently used to assess red snapper originated in the 1995 assessment wherein the age-1 index for red snapper from the Fall Groundfish survey was regressed on the age-1 index from the summer SEAMAP survey to obtain an estimate of Z1 for that 4 month period. The estimate of $Z_1/3$ was 0.473, and it was partitioned into M_0=0.5, and M_1=0.3, and a cumulative bycatch fishing mortality (on ages 0 and 1) that varied slightly with the assumed level of adult mortality. Assuming M=0.1 for ages 2 and older, the bycatch fishing mortality was estimated to be 2.12. These values for M_0 and M_1 were retained in the assessment by Schirripa and Legault (1999).

Bycatch reduction devices (BRDs) were introduced in 1998 to mitigate the bycatch of juvenile redsnapper. This modification to the gear suggests that a comparison between the years without BRDs and years with BRDs could provide an analytical framework from which to derive estimates of M, bycatch F, and a parameter δ that represents the reduction in F due to BRDs.

Trawl surveys in the summer SEAMAP occur in June and July, while the Fall Groundfish survey is conducted in October and November. An age-specific index was developed for both age-1 and age-0 fish (S. Nichols, *personal communication*), and in what follows, the mean index value was used as the observed quantity for that survey. The time span of observations is 1987-2002, thus there are 11 observations pre-BRD implementation, and 5 observations post-BRD implementation. The midpoint between each survey—July1 to November 1—was used to arrive at a time duration of 4 months (or 1/3 year). For the time elapsed between scientific surveys, the average fishing effort by the shrimp fishery, measured in thousands of days fished, is also available.

Analytical Framework

The change in estimated abundance of age-1 fish between Fall and Summer surveys can be represented by:

(1) $$\frac{CPUE_{Fall,y}}{CPUE_{Summer,y}} = \exp(-(M_1 + qf_y)/3)\,,$$

where M_1 is the natural mortality of age-1 fish, q is the catchability (or *bycatchability*) of the shrimp fishery for age-1 red snapper, and f_y is a measure of the shrimp fishery effort between the two surveys.

The predicted CPUE in each period can be written:

(2)
$$CPUE_{SUMMER,y} = \alpha N_y + \varepsilon_{SUMMER}$$

$$CPUE_{FALL,y} = \begin{cases} \alpha N_y \exp(-(M_1 + qf_y)/3) + \varepsilon_{FALL} & (\text{pre} - \text{BRD}) \\ \alpha N_y \exp(-(M_1 + q\delta f_y)/3) + \varepsilon_{FALL} & (\text{post} - \text{BRD}) \end{cases}$$

where N_y is the abundance of the population in year y, α is a proportionality constant that scales population abundance, δ accounts for the effect of BRDs on catchability, and ε_{SUMMER} and ε_{FALL} are the associated observation errors.

Assuming ε_{SUMMER} and ε_{FALL} have the same distribution ($\sigma = \sigma_{SUMMER} = \sigma_{FALL}$), the model negative log-likelihood (L) is proportional to:

(3)
$$L = 0.5\sum_y \left\{ \left(\frac{CPUE_{SUMMER,y} - \alpha N_y}{\sigma} \right)^2 + \left(\frac{CPUE_{FALL,y} - \alpha N_y \exp(-(M_1 + q'f_y))}{\sigma} \right)^2 \right\} + 0.5 \ln \sigma^2$$

where $q' = \delta q$ when a BRD was in place and $q' = q$ otherwise.

The model parameters are αN_y, σ , M_1, q, and δ (y+4 parameters). There are 2y data points (the observed CPUE in spring and fall each year). The term αN_y is a nuisance parameter, and can be eliminated by taking the partial derivative of (3) with respect to N_y, setting the derivative equal to zero, and solving for N_y in terms of the remaining terms. Letting $\theta_y = \alpha N_y$, the MLE for θ_y (given M_1 and q') is:

(4) $$\theta_y = \frac{CPUE_{SUMMER,y} + CPUE_{FALL,y} \exp(-(M_1 + q'f_y)/3)}{1 + \exp(-2(M_1 + q'f_y)/3)}\,.$$

Replacing αN_y with its maximum likelihood estimate θ_y in (3) produces a concentrated likelihood. Estimates for M_1, q, and δ may be obtained by minimizing the concentrated negative log likelihood.

Estimation

The above described model was programmed in ADModel Builder (Otter Research Ltd. 2000) and a set of runs were defined based on the series of years included and the number of parameters being estimated. Six model configurations were evaluated:

Model 1: All data were used (1987-2002), q was fixed at 0, δ was not estimated.
Model 2: All data were used (1987-2002), both q and δ were estimated.
Model 3: Only pre-BRD data were used (1987-1997), q was fixed at 0, δ was not estimated (there is no δ in pre-BRD years).
Model 4: Only pre-BRD data were used (1987-1997), q was estimated.
Model 5: Only post-BRD data were used (1998-2002), q was fixed at 0, δ was not estimated.
Model 6: Only post-BRD data were used (1998-2002), q was estimated, δ was not (q and δ are not separable in this data set).

Results

Runs of models 1-6 were performed with M_1 bounded on [0.1, 2.5], q bounded on [1.0E-9,1.0E+2], and δ bounded on [0.0,1.1]. The bounds on δ allow for the BRD to be completely effective (δ =0, i.e. no bycatch) or to have no effect at all (δ=1). The bounds for q were chosen so as to be unrestrictive.

When q was fixed at 0, the loss in age-1 fish between the summer and fall surveys is all attributed to M_1 in the model. These models therefore provide an upper bound on $M_1/3$, under the implicit assumption that bycatch from shrimp fishing is negligible for that 4 month period.

The estimates for $M_1/3$ when q was fixed at 0 (models 1, 3, and 5) ranged from 0.77 for pre-BRD years to 1.25 for post-BRD years (Table 1). The fits to the CPUE from the trawl surveys are given in Figure 1 for models 1, 3, and 5.

For the models where q was estimated (models 2, 4, and 6), the estimate of $M_1/3$ tended towards its lower bound and δ tended towards its upper bound (Table 1). The fits to the CPUE from the trawl surveys are given in Figure 2. The boundary solutions indicate that there is not enough contrast in the shrimp effort data to be able to estimate M and q (see Fig 3).

Discussion

The lack of contrast in the time series of shrimp effort squelched our anticipation of a lagniappe from the introduction of BRDs. When q was fixed at 0.0, the estimate of M_1 ranged from 0.773 to 1.255, while for the models when q was estimated, M_1 tended to be estimated near zero. The average F=qf over the time period was 0.82 for models 2 and 4, which is rather close to the estimates from models 1 and 3 (about 0.77). Thus, although the forces of natural and fishing mortality cannot at present be separated, an upper bound on the total loss to the age-1 population between summer and fall surveys would be around 0.8.

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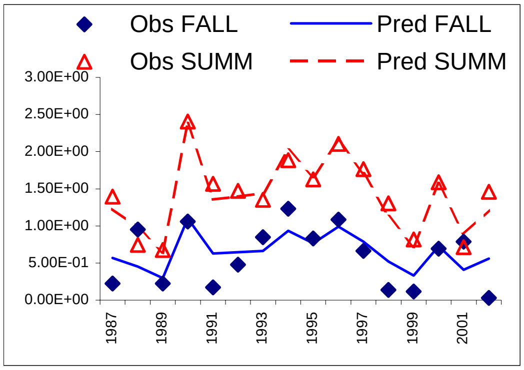
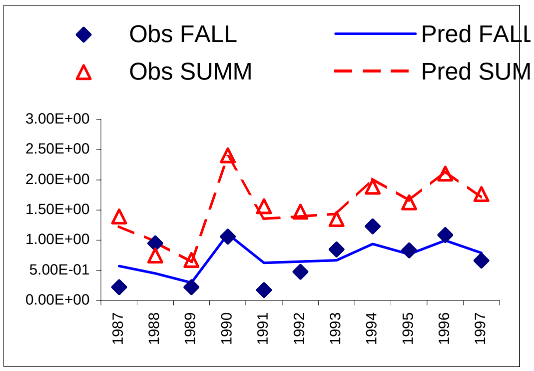
Scott Nichols provided age-specific indices for the summer and fall surveys as well as the estimated shrimp fishery effort.

Table 1. Model results. An asterisk indicates that one or more parameters were estimated at a boundary. When q is set equal to 0, then the parameter δ is not estimated. Also, for models 5 and 6, when only BRD data were used, then q and δ always appear together, so δ was fixed at 1.0 and q was estimated.

Model	**L**	**Nobs**	**Npars**	**AICc**	**1/3 M_1**	**q,** δ
1. q=0, all data	25.79	32	18	118.90	0.773	N/A
2. q estimated, all data	13.63	32	20	143.62	~0 *	0.0533, 1.01
3. q=0, no BRD data	10.17	22	13	91.77	0.770	N/A
4. q estimated, no BRD data	9.09	22	14	106.19	~0 *	0.0532, 1.00
5. q=0, only BRD data	-9.33	10	7	51.34	1.255	N/A
6. q estimated, only BRD data	-9.33	10	8	141.34	1.254	5E-5, N/A

Figure 1. Fits of models 1, 3, 5 to Summer and Fall Groundfish surveys, and residuals. In all models, q was set to 0.





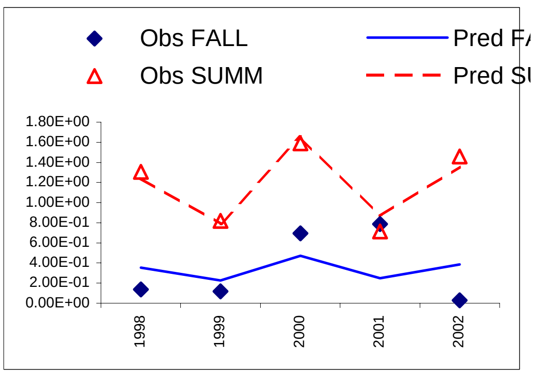


Figure 2. Fits of models 2, 4, 6 to Summer and Fall Groundfish surveys, and residuals. In all models, q was estimated, and δ was estimated in models 2 and 4.

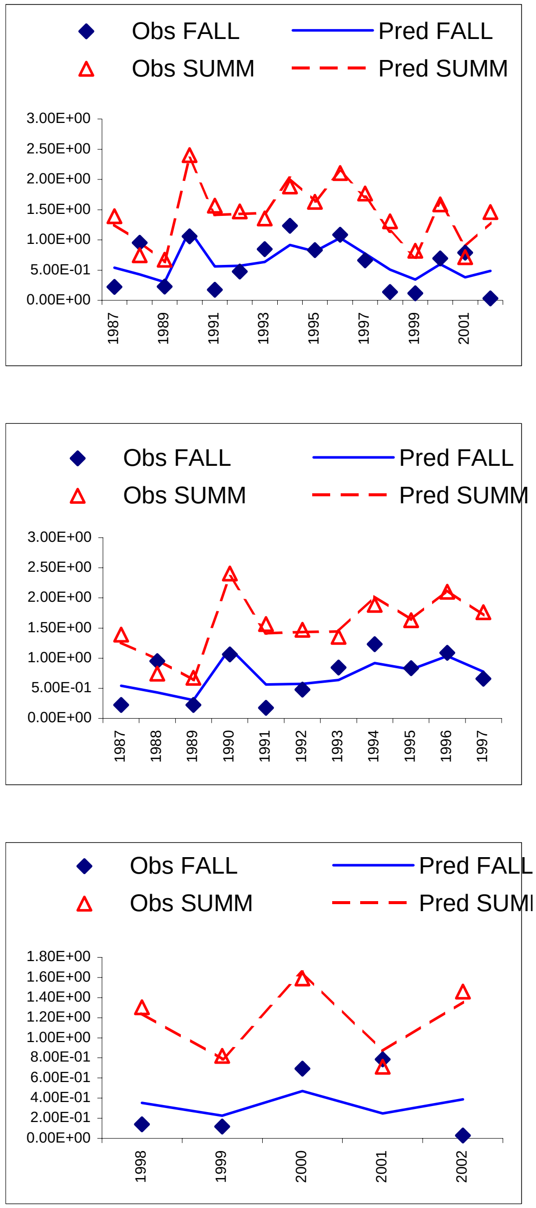


Figure 3. Estimated shrimp fishery effort between the summer SEAMAP and fall groundfish survey. Effort units are in thousands of days fished per month.