Response to comments on:

Age Composition, Growth and Density-Dependent Mortality in Juvenile Red Snapper Estimated from Observer Data from the Gulf of Mexico Penaeid Shrimp Fishery

Bill Gazey, Benny Gallaway, and John Cole

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Response to comments on:

Age Composition, Growth and Density-Dependent Mortality in Juvenile Red Snapper Estimated from Observer Data from the Gulf of Mexico Penaeid Shrimp Fishery

William J. Gazey
W.J. Gazey Research, 1214 Camas Court, Victoria, British Columbia, V8X 4R1, Canada

Benny J. Gallaway
and
John G. Cole
LGL Ecological Research Associates, Inc., 1410 Cavitt Street, Bryan, Texas 77801, USA

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We will first address the last point made by the Comment Letter (the claimed misuse of terminology) in order to clarify apparent misconceptions of model parameters and to avoid confusion in terminology.

Our model was fit to length frequency and standardized catch-per-unit-effort data obtained from post-1998 observers on penaeid shrimp fishery in the Western Gulf of Mexico. The data did not contain measures of absolute abundance (e.g., catch). Sample size (number of measured fish) did not reflect abundance or shrimp effort. Sample size was used only for the calculation of likelihood of the length frequency data based on robustified multinomial or Dirichlet distributions. Absolute estimates of recruitment were not made. As stated in our paper, the quantity estimated was the recruitment deviation in log-space ($\Delta R_{y(i)}$). The contribution to the objective function (sum of the negative log probability functions) was proportional to the sum of squared recruitment deviations (see equation 11) which impels that $\sum \Delta R_{y(i)} = 0$ when the contribution is at a minimum (note that the sum of the logged recruitment indices found in Table 7 is 0). Therefore, our terminology is correct. Also note that the subtraction of the mean recruitment deviation in equation (1a) is redundant when the objective function is at a minimum;

however, the standardization helps stabilize trial values of total mortality when AD Model searches for a solution (i.e., the objective function is not at minimum and $\sum \Delta R_{y(i)} \neq 0$).

We next address the issues as encountered in the Comment Letter. The Comment states that it is unreasonable to assume constant total mortality because of the known changes in shrimp fishing effort. However, if mortality is strongly density-dependent then fishing and other sources of mortality will offset each other such that changes in shrimp effort will have little influence on total mortality. In other words, large variation of total mortality could be generated by changes in abundance but these changes would be impervious to changes in shrimp fishing effort. If shrimp fishing mortality is independent of abundance and an important component of total mortality (and if fishing effort is correlated with recruitment) then we acknowledge that our analysis would find a better fit to the data with the density-dependent model. For example, the current management paradigm for red snapper assumes density independence and predicts a strong stock response and subsequent recruitment of red snapper from shrimp effort reduction. Our analysis could incorrectly declare density-dependent mortality the better fit if such data were obtained. However, the estimate of the coefficient of density dependence would have a negative value (mortality inversely related to recruitment). This was not the case (see Gazey et al. 2012).

Length frequency data with the same monthly sample sizes as in our paper were simulated to investigate the behavior of the model following the concerns raised by the Comment (mortality is a function of fishing effort and independent of abundance and recruitment). Natural mortality was assumed to be constant at 1.0 and 0.6 for age-0 and age-1, respectively. Additive shrimping mortality was set proportional to the 1999 to 2006 shrimping effort (statistical areas 10 to 21 and depths 10 to 30 fathoms, see Table 1) such that mean total mortality agreed with that reported in lower panel of Table 7 in our paper (von Bertalanffy growth with density-independent mortality). Logged recruitment deviations were generated from a normal distribution of mean 0 and standard deviation of 0.2. All other parameters were set as listed by the lower panel in Table 7. These parameters with population dynamics defined in our paper were used to produce simulated predicated length frequencies. Randomness was introduced through a random multivariate logistic distribution with a coefficient of variation of 0.4. No indices of abundance were generated. The simulated length frequency data were fit to the density independent and dependent models as described in our paper but without the abundance index component. The density-independent model correctly recovered all parameters. The density-dependent model fit the data slightly better and correctly recovered all parameters (including the trend in annual total mortality) with the exception of the recruitment deviations and the coefficient of density dependence (estimated value of approximately 1.0 with a standard deviation of 0.8 instead of the expected value of 0.0). As predicted by the Comment the density-dependent model varied total mortality over time by changing the recruitment deviation to find a better fit to the model. If small recruitment deviations were input to the simulation model then the subsequent estimates of the deviations mimicked the trend in shrimping effort. Conversely, if large recruitment deviations were input to the simulation then the subsequent estimates of recruitment deviation were closer to the input values and the coefficient of density dependence was near 0.0. The inference from this simulation exercise is that recruitment deviations change to fit changes in mortality; therefore, the statistical support for density-dependent mortality reported in Gazey et al. (2008) and Gazey et al. (2012) is not correct.

The Comment recommends the comparison of 1) a density-dependent natural mortality estimate that can vary with recruitment to 2) a constant density-independent natural mortality estimate where fishing mortality has been accounted for in both the density-dependent and density-independent estimates. There are difficulties with this suggestion. First, under density-dependence not only does fishing mortality replace natural mortality (some fish are destined to die) but natural mortality may be inversely related to shrimp effort (e.g., if fish are removed then those remaining have a better chance of survival). We are not aware of a concise model that would represent these dynamics. Second, estimation of natural mortality with age structured population models is notoriously difficult (Hilborn and Walters 1992) and will likely be particularly difficult for the red snapper population (Forrest et al. In Review). For example, if mortality is portrayed as $M + q_a E_i$ in our model (where E_i is relative shrimp effort for month i and the estimated parameters are natural mortality, M, and catchability coefficient, q_a, for age-a) then subsequent estimates of the q's approach 0.0. This does not mean that fishing mortality is 0 but it may imply that the parameters are confounded.

In order to provide some insight on the behaviour of juvenile red snapper total mortality with shrimping effort we applied the model as described in Gazey et al. (2008) with total mortality stratified by year and age to the updated observer juvenile red snapper data described by Gazey et al. (2012). In other words, mortality was assumed to be constant for the sampled months nested within a year for each of the two age-classes. The subsequent total mortality estimates for age-0 and age-1 during 1999-2011 are listed in Table 1. Because of the added parameters (13 years by 2 ages), there is a substantial uncertainty in these estimates (mean CV is approximately 0.4 and 0.5 for age age-0 and age-1, respectively). Shrimp fishing effort from Statistical Areas 10-21 and depths 10 to 30 fathoms, viewed by the Fishery Management Council as the best indicator of effort directed on juvenile red snapper, is also listed in Table 1. Figure 1 plots the mortality estimates versus scaled shrimp effort (mean=1). In this approach we are looking for evidence of at least some positive relationship between mortality and shrimping effort. No correlation would indicate very strong density-dependence. The estimated probability for zero correlation between mortality and shrimping effort was 0.21 for age-0 and 0.93 for age-1. The trend lines suggest at least some response in age-0 mortality from changes in shrimp fishing effort and strong density-dependence for age-1. Figure 2 compares the estimated recruitment index (estimated recruit deviation in log space exponentiated and then re-scaled such that the 1999-2011 mean was 1.0) with the SEAMAP Western Gulf of Mexico age-0 selectivity fall abundance index (Pollack et a. 2012, Table 51; re-scaled such that the 1999-2011 mean was 1.0). The agreement was poor for 1999 to 2005 but was good for 2006 to 2011.

The Comment questions our assertion that age-0 total mortality generally exceeds that reported by SEDAR7 (2007) because “the results of this study have large variability over time and invalid assumptions that undermine the authors’ suggestions”. The Comment points out that our smallest annual age-0 mortality estimate is in fact smaller than that reported by SEDAR7. We acknowledge that age-0 mortality is highly variable; however, the scale or mean (1999-2006) of the mortality rates was substantially greater than the SEDAR7 benchmark 2001-2003 mean regardless of the alternative models applied (see Table 7). The simulation exercise conducted for this response and simulations by Forrest et al. (In Review) found estimation of scale parameters (e.g., total mortality) by density-dependent models to be very robust even when applied to density-independent generated data.

As noted in our paper the estimated recruitment deviations followed the recruitment trends calculated by SEDAR7 (Porch 2005, his Figure 7). However, as noted in the Comment, the recruitment estimates made by the SEDAR Update (after our paper was published) were quite different (see Figure 3). Further, note that the SEAMAP abundance index has little agreement with the SEDAR Update results over any period of time (see Figure 4). The SEDAR Update report acknowledged these differences (between SEDAR7, the Update and SEAMAP) and attributes them to addition of new data, issues with model convergence and choice of data sets used in the SEDAR models. The point is that estimates of age-0 recruitment are volatile. We believe that comparison of models and trying to determine the causal mechanisms for differences in recruitment is good practice. However, these discrepancies are poor evidence for model invalidation.

In summary, we acknowledge that the density dependent model found in Gazey et al. (2008) can modify recruitment deviations to fit total mortality. We concur with the Comment Letter that the ability of the density-dependent model to respond to variations in mortality, whereas the density-independent model cannot respond to variations in mortality, calls into question the statistical validity of the comparison. All other assertions made by the Comment (incorrect terminology, total mortality must respond to changes in fishing effort even under density-dependence, invalid estimates of mean total mortality, and model invalidation through the comparison of recruitment estimates) we rebut. The analysis conducted above for this response provided some support for density dependence in juvenile red snapper. We believe that the density dependent model as presented by Gazey et al (2008) and Gazey et al. (2012) provides a good description of juvenile red snapper population dynamics and robust estimates of mortality.

The upcoming assessment needs to address the impact of substantial reduction in shrimp fishing after 2002. To date, responses in the SEAMAP abundance indices (Figure 4), shrimp fishery observer indices of juvenile red snapper abundance (Gazey et al. 2012, Figure 1), or estimated mortality (Gazey et al 2012, Figure 5) have not been detected. We believe density-dependent mortality from habitat limitation explains the lack of relationship.

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Table 1. Estimated instantaneous total mortality and recruitment deviation as well as SEAMAP index of age-0 abundance and shrimp fishing effort.

	Z Age-0[1]		Z Age-1[1]		Z Total[2]		Recruit Dev[1]		Recruit Index		Effort[5]	
Year	Est.	SD	Est.	SD	Est.	SD	Est.	SD	All Strata[3]	SEAMAP[4]	Est.	Scaled
1999	3.027	0.379	1.233	0.892	4.260	0.969	0.835	0.326	1.922	1.277	203,747	1.441
2000	0.962	0.743	0.800	0.570	1.762	0.937	0.827	0.340	1.908	0.833	232,671	1.645
2001	2.447	0.542	1.913	1.239	4.360	1.353	0.370	0.356	1.208	0.574	251,318	1.777
2002	0.001	0.001	0.947	0.532	0.948	0.532	-0.560	0.351	0.477	0.913	279,331	1.975
2003	3.104	0.549	2.762	0.928	5.866	1.078	-0.624	0.278	0.447	1.417	230,342	1.629
2004	2.188	0.840	1.802	0.572	3.990	1.016	-0.488	0.400	0.512	1.832	154,552	1.093
2005	1.675	0.542	2.409	0.731	4.084	0.910	-0.251	0.380	0.649	1.128	104,778	0.741
2006	0.686	0.807	1.609	0.501	2.295	0.949	0.125	0.360	0.945	1.025	88,213	0.624
2007	0.001	0.000	1.667	0.948	1.668	0.948	0.213	0.363	1.033	1.087	57,480	0.406
2008	1.269	0.854	0.699	0.589	1.968	1.037	-0.102	0.368	0.753	0.125	43,273	0.306
2009	0.547	0.642	2.420	0.738	2.967	0.978	0.858	0.347	1.968	1.845	58,937	0.417
2010	1.237	0.629	1.640	1.573	2.877	1.694	-1.344	0.419	0.218	0.324	49,619	0.351
2011	1.401	0.642	0.001	0.002	1.402	0.642	0.141	0.405	0.960	0.619	84,038	0.594
Mean	1.427	0.170	1.531	0.233	2.958	0.289	0.000	0.101	1.000	1.000	141,408	1.000

Notes:

1 - Parameter estimates using the Gazey et al. (2008) model with total mortality stratified by year and age of red snapper.

2 - Age-0 and age-1 total mortality estimates summed.

3 - The estimated recruit deviation was exponentiated and then re-scaled such that the 1999-2011 mean was 1.0.

4 - SEAMAP Western Gulf of Mexico age-0 selectivity fall abundance index (Pollack et a. 2012, Table 51) re-scaled such that the 1999-2011 mean was 1.0.

5 - Nominal shrimp effort net-days in Statistical Areas 10 to 21 and depth 10 to 30 fathoms.

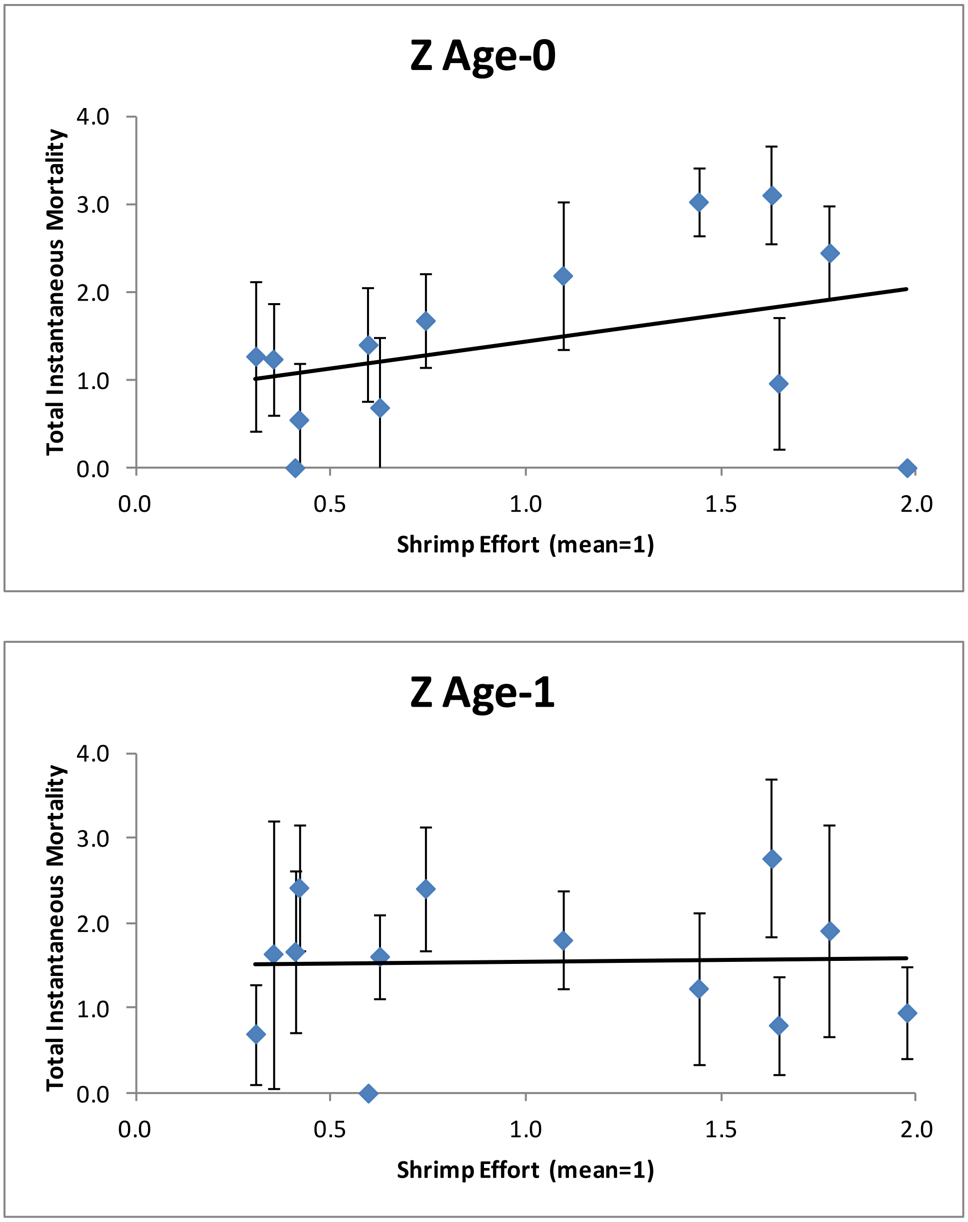

Figure 1. Total juvenile red snapper mortality estimates for 1999 to 2011 versus scaled shrimp effort. Top panel plots age-0 and lower panel plots age-1. The error bars represent plus/minus one standard deviation.

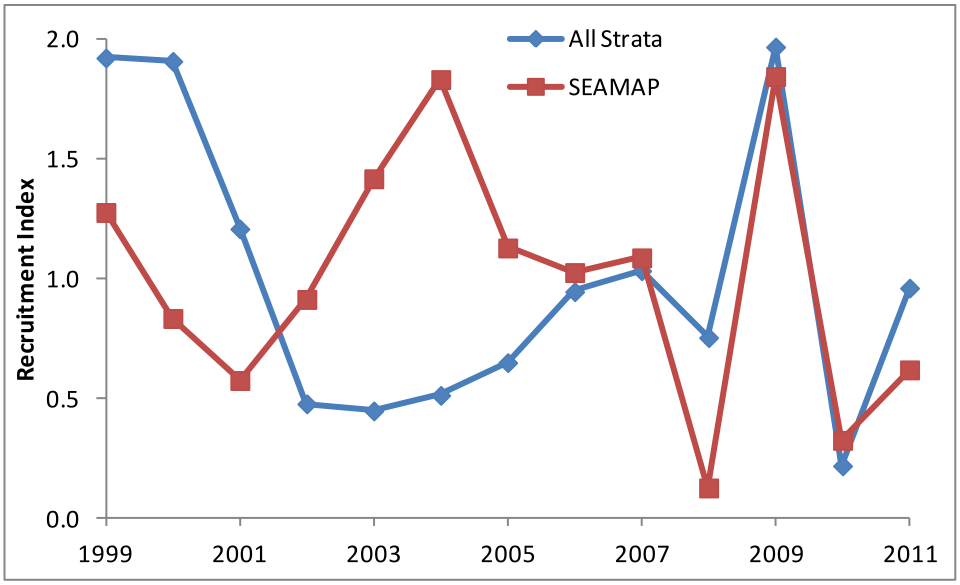

Figure 2. Estimated recruitment index (all strata) and the SEAMAP Western Gulf of Mexico age-0 selectivity fall abundance index (Pollack et a. 2012, Table 51). Both series were re-scaled such that the 1999-2011 mean was 1.0.

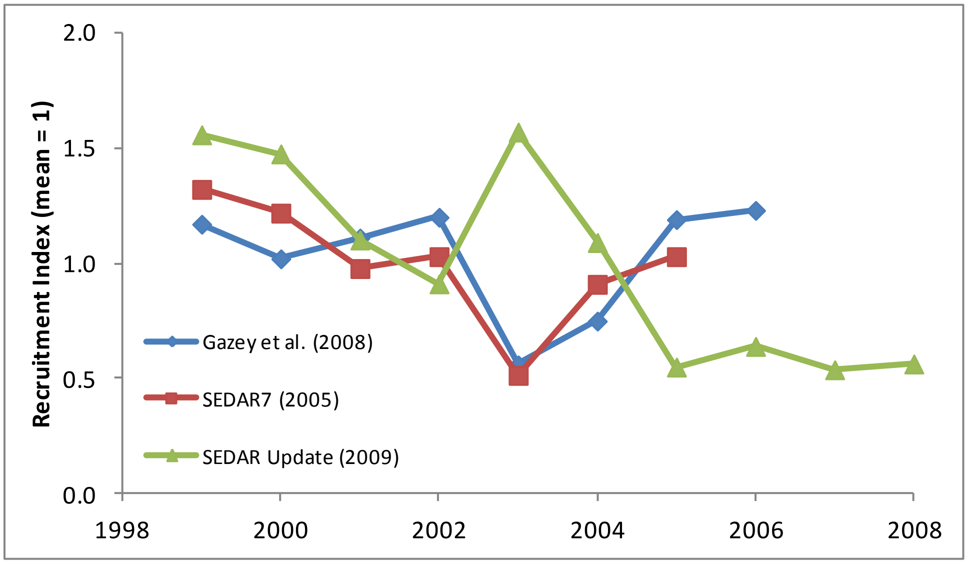

Figure 3. Estimated recruitment trends from Gazey et al. (2008), Porch (2005) and the SEDAR Update (2009).

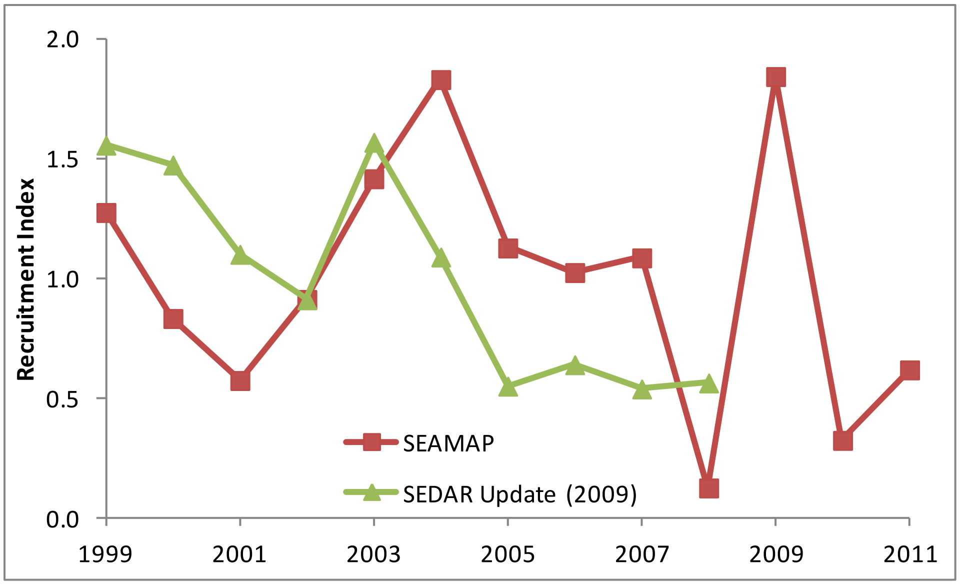

Figure 4. SEAMAP Western Gulf of Mexico age-0 selectivity fall abundance index (Pollack et a. 2012, Table 51) and SEDAR Update (2009) recruitment index. Both series standardized to a mean of 1.0.