S E D A R
Southeast Data, Assessment, and Review
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SEDAR-17-AW-07

Extrapolation of Spanish mackerel bycatch by commercial shrimp trawl fisheries

Prepared by Paul B. Conn, National Marine Fisheries Service, 101 Pivers Island Rd, Beaufort NC 28516

August 2008

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The Caribbean Fishery Management Council
The Gulf of Mexico Fishery Management Council
The South Atlantic Fishery Management Council
NOAA Fisheries Southeast Regional Office
NOAA Fisheries Southeast Fisheries Science Center
The Atlantic States Marine Fisheries Commission
The Gulf States Marine Fisheries Commission

SEDAR Headquarters
The South Atlantic Fishery Management Council
4055 Faber Place #201
North Charleston, SC 29405
(843) 571-4366

INTRODUCTION

Bycatch in shrimp fisheries was thought to be an important source of mortality for young-of-year Spanish mackerel, but estimates of bycatch were only available for eight years (highlighted in Table 1). It was thus important to model bycatch in the assessment model even in years were records were unavailable. Three approaches were considered and evaluated for merit:

- **Option 1:** Relate shrimp bycatch (klb) to shrimp trawl fishery effort (number of trips) and extrapolate back to the beginning of the effort series (1978).
  Pros: If catchability remains constant, effort may be a better predictor of fishing mortality than landings because it is independent of shrimp abundance.
  Cons: Extrapolation only back to 1978 even though substantial shrimp landings occurred previously, catchability in shrimp fishery probably not constant, assumes Spanish mackerel recruitment relatively constant over time, effort not available for 2007.
- **Option 2:** Relate shrimp trawl bycatch (klb) to shrimp landings and extrapolate Spanish mackerel bycatch back to the start of the assessment model (1950)
  Pros: Goes back to “beginning of time,” effort and landings were moderately correlated (0.21; p=0.14).
  Cons: May not reflect effort if shrimp abundance changes over time, assumes Spanish mackerel recruitment relatively constant over time.
- **Option 3:** Express fishing mortality (*F*) associated with shrimp trawl bycatch (klb) as a function of shrimp landings within the assessment model and extrapolate to years where bycatch estimates are unavailable.
  Pros: Goes back to 1950, effort and landings are reasonably well correlated (0.54). Makes no assumptions about recruitment variability.
  Cons: May not reflect effort if shrimp abundance changes over time, appears to lead to extreme instability in assessment model (ostensibly due a single year’s fishing mortality parameter having an effect on all extrapolated years).

Options 2 was selected as the most reasonable for assessment purposes. While option 3 was attractive, it appeared that considerable effort would be needed to implement it correctly (development of an appropriate E-M algorithm, etc).

METHODS

Models

We obtained a shrimp landings database for the U.S. south Atlantic from the NMFS Southeast Fisheries Science Center for the period 1950-2007. The database was queried to isolate only those landings that were obtained in the open ocean and in trawl fisheries, so as to conform better with trips where shrimp fishery observer estimates were obtained. Data on shrimp bycatch was obtained from SEDAR17-DW12.

Preliminary fits of the log of bycatch data to the log of landings using linear regression (Figure 1) showed positive correlation (R^2 = 0.21; p = 0.14), but extrapolation past the region of observed data led to predictions of Spanish mackerel bycatch that were extremely large in certain years (e.g. >50 million individuals in 1995 & 1996). These values were unreasonable because (a) they were approximately six times greater than the highest year of commercial landings, and (b) because a priori one would expect mortality of Spanish mackerel to saturate as shrimp landings increase as a result of some mismatch between productive shrimp fishing areas and Spanish mackerel habitat.

There are several simple models that result in asymptotic behavior. One such model is the logistic function, where Spanish mackerel shrimp bycatch is modeled as a logistic function of shrimp landings, where

$$Bycatch/1000000 = \frac{K}{1+\exp(-r(\log(landings)-\eta))}.$$

Here, K is an asymptote, r is a slope parameter, and η was the value of landings at the inflection point. Sum squares was used to fit this model, which yielded parameter estimates $\hat{K} = 9.03$, $\hat{r} = 16.50$, and $\hat{\eta} = 17.24$ (Figure 2).

This model was not entirely satisfactory, in part because

(i) The estimate of the asymptote K seemed to be somewhat unstable, and
(ii) Spanish bycatch was assumed to be zero for levels of shrimp landings that were still fairly substantial.

Instead, two alternative approaches were considered:

(a) Capping bycatch at the maximum observed level (Figure 2), and
(b) Employing a hockey stick model (e.g., Barrowman and Myers 2000).

Alternative (a) resolves issue (i) somewhat, but failed to resolve issue (ii). In contrast, solution (b) resolves both issues to a large degree. The AW suggested that extrapolations be made on the hockey stick model (Table 2) incorporate an additional assumption about bycatch reduction devices.

Bycatch reduction devices

Recent evidence suggests that bycatch reduction devices (BRDs) in the shrimp trawl fishery have resulted in a 40% reduction in Spanish bycatch. As the shrimp boat observer program was only initiated after BRDs were already in use, these results suggest that shrimp bycatch would have been even higher in earlier years before widespread implementation of BRDs. The following suggestion was made by the AW: set bycatch in year t (B_t) at

$$B_t = a \times f(L_t),$$

where $a = \begin{cases} 1.67 & t \le 1992 \\ 1 + \frac{0.67}{5}(t - 1992) & 1992 < t < 1997 \\ 1.00 & t \ge 1997 \end{cases}$,

and $f(L_t)$ gives the hockey stick model. This choice was made because relatively few shrimp trawls were using BRDs prior to 1993, while they were mandated starting in 1997. In between, there was a transitional period, which we assumed was linear with respect to number of trawls.

REFERENCES

Barrowman, N. J. and R. A. Myers. 2000.. Still more spawner-recruitment curves: the hockey stick and its generalizations. Canadian Journal of Fisheries and Aquatic Sciences 57:665-676.

SAFMC (South Atlantic Fishery Management Council). 2004. Amendment 6 to the Fishery Management Plan for the Shrimp Fishery of the South Atlantic Region. South Atlantic Fishery Management Council, 1 Southpark Cir., Suite 306, Charleston, S.C. 29407-4699. 256p + appendices.

SEDAR17-DW12. Estimation of Spanish mackerel and vermilion snapper bycatch in the shrimp trawl fishery in the South Atlantic. Analysis performed by Kate Andrews, NMFS Southeast Fisheries Science Center.

Table 1. Observed levels of shrimp landings, effort, and extrapolated Spanish mackerel bycatch, together with assumed coefficients of variation (CV). Predicted bycatch is from the hockey stick model, with additional modifications made to reflect the effectiveness of BRDs in years when the observer survey occurred. Values in bold were estimated via delta-glms (Andrews 2008), while the bycatch values in other years are to be calculated via the logistic model.

Year	Shrimp Landings (kLB)	Bycatch (kLB)	CV
1950	36056	11122	1.00
1951	27284	8316	1.00
1952	25284	6343	1.00
1953	32425	11122	1.00
1954	28264	9231	1.00
1955	28303	9267	1.00
1956	25387	6448	1.00
1957	28255	9223	1.00
1958	22198	2969	1.00
1959	25751	6818	1.00
1960	30965	11122	1.00
1961	19664	752	1.00
1962	25936	7003	1.00
1963	15379	752	1.00
1964	17080	752	1.00
1965	25812	6879	1.00
1966	20767	1241	1.00
1967	20192	752	1.00
1968	23869	4850	1.00
1969	26902	7951	1.00
1970	20474	872	1.00
1971	30994	11122	1.00
1972	25129	6184	1.00
1973	24343	5360	1.00
1974	26874	7924	1.00
1975	24711	5749	1.00
1976	25828	6895	1.00
1977	18352	752	1.00
1978	17747	752	1.00
1979	20988	1515	1.00
1980	24583	5614	1.00
1981	16614	752	1.00
1982	25797	6863	1.00
1983	26367	7430	1.00
1984	19169	752	1.00
1985	27108	8149	1.00
1986	25050	6102	1.00
1987	23646	4606	1.00

1988	25150	6205	1.00
1989	35390	11122	1.00
1990	30373	11097	1.00
1991	34703	11122	1.00
1992	26324	7388	1.00
1993	21871	2377	1.00
1994	19307	631	1.00
1995	29686	7983	1.00
1996	16639	511	1.00
1997	24605	3382	1.00
1998	23300	**417**	**0.46**
1999	30267	**7005**	**0.28**
2000	30850	**6341**	**0.21**
2001	18850	**1416**	**0.51**
2002	19304	**266**	**0.37**
2003	17118	**363**	**0.41**
2004	25980	**130**	**0.78**
2005	14832	451	1.00
2006	19957	**116**	**0.55**
2007	19646	451	1.00

† Shrimp landings in the state of Florida were missing this year so were imputed as an average of those in 1977 and 1979.

Figure 1. Fit of linear regression of Spanish mackerel bycatch (log scale) on shrimp landings (log scale). Although the fit seems reasonable, predictions of Spanish bycatch were unreasonably large past the region of observed data.

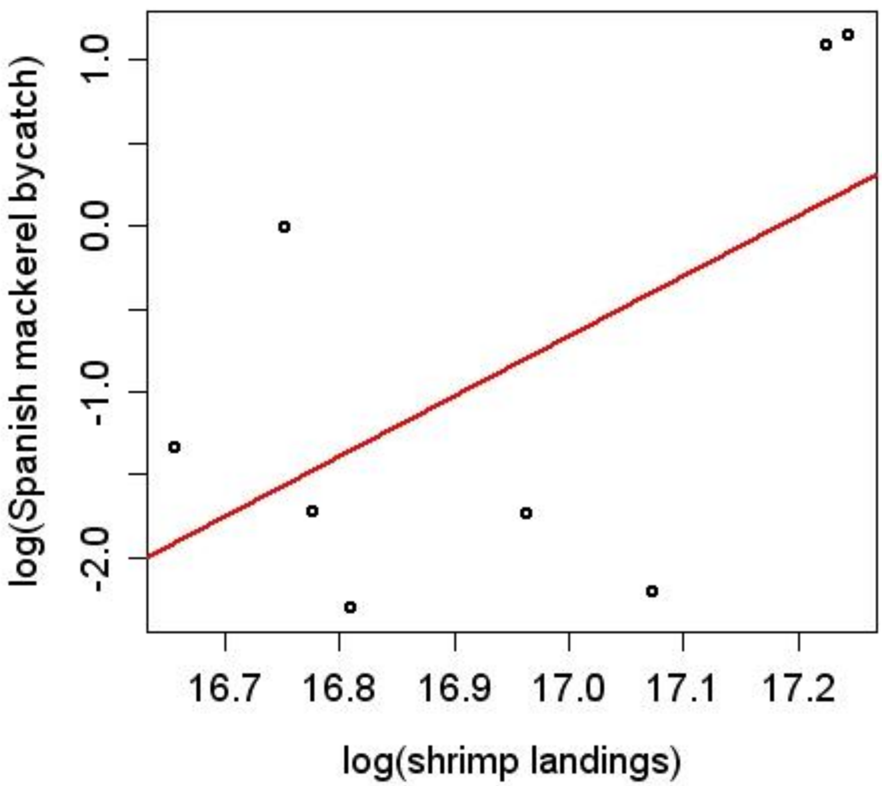

Figure 2. Fit of logistic model relating the observed level of Spanish mackerel bycatch to south Atlantic shrimp landings (log scale). Also shown is the model where predicted bycatch is capped at the maximum observed value.

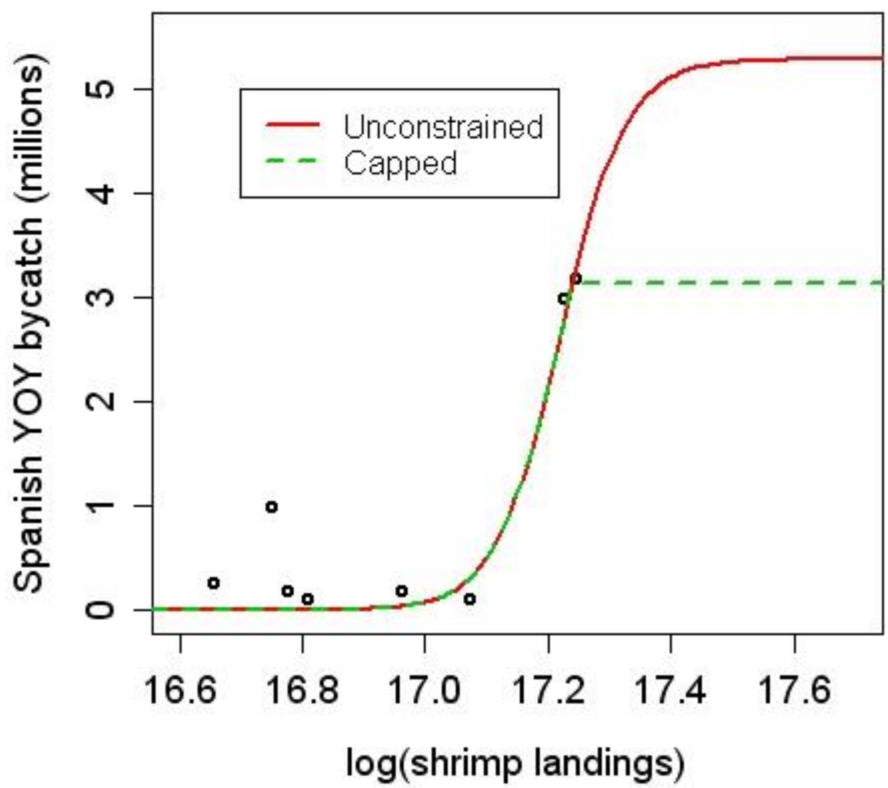

Figure 3. Fit of hockey stick model for observed level of Spanish mackerel bycatch in relation to south Atlantic shrimp landings (log scale).