SEDAR 78 Spanish mackerel bycatch estimates from US Atlantic coast shrimp trawls

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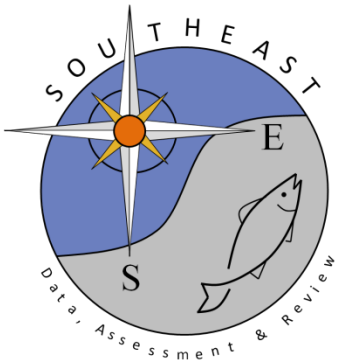

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SEDAR 78 Spanish mackerel bycatch estimates from US Atlantic coast shrimp trawls

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In SEDAR17, Spanish mackerel bycatch from shrimp fishing was estimated, first by fitting a delta-GLM for years with observer coverage, and then by fitting a "hockey stick" model to predict discards from shrimp landings for remaining years (SEDAR17-DW12, SEDAR17-AW07). In SEDAR 28, the approach was reevaluated and modified for simplicity, consistent with comments from the SEDAR17 Review. In SEDAR 78, the Spanish mackerel bycatch estimates from SEDAR 28 were recalculated using updated datasets provided by state data providers.

For SEDAR 78, the estimates were developed using the same methods from SEDAR 28. For additional details regarding methods and results from SEDAR 28 the hyperlink to the SEDAR 28 working paper is SEDAR 28-AW02 and in the Appendix. There were slight differences in values from North and South Carolina but the final updated estimates are very similar to the SEDAR 28 estimates in the overlapping years (r= 0.9995) (Tables 1-4) and Figure 1.

Table 1. Encounter and catch rates from the SAS observer data.

	Encounter Rate		Catch rate (fish/net-hour)	
Year	NC	SC/GA/FL	NC	SC/GA/FL
1978	0.21	0.40	0.79	1.28
1979	0.21	0.40	0.79	1.28
1980	0.21	0.40	0.79	1.28
1981	0.21	0.40	0.79	1.28
1982	0.21	0.40	0.79	1.28
1983	0.21	0.40	0.79	1.28
1984	0.21	0.40	0.79	1.28
1985	0.21	0.40	0.79	1.28
1986	0.21	0.40	0.79	1.28
1987	0.21	0.40	0.79	1.28
1988	0.21	0.40	0.79	1.28
1989	0.21	0.40	0.79	1.28
1990	0.21	0.40	0.79	1.28
1991	0.21	0.40	0.79	1.28
1992	0.21	0.40	0.79	1.28
1993	0.21	0.40	0.79	1.28
1994	0.21	0.40	0.79	1.28
1995	0.21	0.40	0.79	1.28
1996	0.21	0.40	0.79	1.28
1997	0.21	0.40	0.79	1.28
1998	0.21	0.40	0.79	1.28
1999	0.21	0.40	0.79	1.28
2000	0.21	0.40	0.79	1.28
2001	0.21	0.40	0.79	1.28
2002	0.21	0.40	0.79	1.28
2003	0.21	0.40	0.79	1.28
2004	0.21	0.40	0.79	1.28
2005	0.21	0.35	0.79	1.92
2006	0.21	0.40	0.79	1.28
2007	0.21	0.46	0.79	0.97
2008	0.26	0.40	0.80	1.28
2009	0.19	0.19	1.02	0.45
2010	0.18	0.40	0.41	1.28
2011	0.21	0.40	0.79	1.28
2012	0.21	0.40	0.79	1.28
2013	0.21	0.40	0.79	1.28
2014	0.21	0.40	0.79	1.28
2015	0.21	0.40	0.79	1.28
2016	0.21	0.40	0.79	1.28
2017	0.21	0.40	0.79	1.28
2018	0.21	0.40	0.79	1.28
2019	0.21	0.40	0.79	1.28
2020	0.21	0.40	0.79	1.28

Table 2. Number of shrimp trips from the NMFS South Atlantic Shrimp System (light shaded) and state trip ticket programs (unshaded). The dark shading cells are years where either the average of adjacent years (NC) or a 3-year average of the earliest years. NC trips were split into skimmer and bottom trawls for calculation of net-hours.

Year	NC	SC	GA	FL
1978	13277	11374	8270	9002
1979	16485	10986	3283	9002
1980	32753	14333	5819	9002
1981	24542	8802	4844	9002
1982	37981	13696	8526	9002
1983	36829	10322	9614	9002
1984	27237	5406	4308	9002
1985	24243	5351	4772	7582
1986	24260	9757	4164	9865
1987	19388	11161	1786	9559
1988	24945	8245	4516	10007
1989	30273	9989	5855	9746
1990	19549	9651	3730	9643
1991	25056	14520	4538	10344
1992	9660	12997	3977	9949
1993	14564	11793	4078	10496
1994	19468	11362	4198	13217
1995	21028	13232	3809	12091
1996	15417	9896	3361	11109
1997	18107	12228	4000	12031
1998	12933	9403	4642	12962
1999	17081	9710	6475	12475
2000	16102	9231	5879	11430
2001	12226	6610	4192	10362
2002	16238	7096	3963	10591
2003	12206	3489	3538	6994
2004	10377	5776	2811	7157
2005	5594	4090	2502	7349
2006	7003	3452	2133	7038
2007	8256	3129	1761	6546
2008	6903	3370	1788	6250
2009	6530	3007	1836	6266
2010	6649	4167	2258	7562
2011	4657	3125	1932	7004
2012	7249	3835	1889	6906
2013	6835	2667	1389	4577
2014	5281	2912	1617	5447
2015	7007	3564	1494	6283
2016	8698	2972	1107	6297
2017	8416	2221	863	4900
2018	5349	2209	969	4076
2019	5544	1999	1155	3902
2020	5708	2932	1088	3594

Table 3. Average number of nets per vessel from state trip ticket programs (unshaded) and the 3-year average of the first 3 years of estimates (shaded) applied when no data were available. North Carolina skimmer trawls were assumed to use 2 nets per vessel.

Year	NC	SC	GA	FL
1978	2.00	2.61	2.99	1.64
1979	2.00	2.61	2.99	1.64
1980	2.00	2.61	2.99	1.64
1981	2.00	2.61	2.99	1.64
1982	2.00	2.61	2.99	1.64
1983	2.00	2.61	2.99	1.64
1984	2.00	2.61	2.99	1.64
1985	2.00	2.61	2.99	1.64
1986	2.00	2.61	2.99	1.64
1987	2.00	2.61	2.99	1.64
1988	2.00	2.61	2.99	1.64
1989	2.00	2.61	2.99	1.64
1990	2.00	2.61	2.99	1.64
1991	2.00	2.61	2.99	1.67
1992	2.00	2.61	2.99	1.66
1993	2.00	2.61	2.99	1.60
1994	1.97	2.61	2.99	1.65
1995	1.99	2.61	2.99	1.64
1996	2.04	2.61	2.99	1.88
1997	2.11	2.61	2.99	1.81
1998	2.11	2.61	2.99	1.53
1999	2.11	2.61	2.99	1.48
2000	2.09	2.61	2.99	1.42
2001	2.27	2.61	2.99	1.60
2002	2.31	2.61	3.02	1.64
2003	2.32	2.55	2.98	1.89
2004	2.38	2.65	2.98	1.83
2005	2.25	2.63	2.93	1.87
2006	2.47	2.56	3.09	2.03
2007	2.46	2.62	3.17	2.15
2008	2.57	2.53	2.93	1.96
2009	2.43	2.66	3.05	1.88
2010	2.39	2.61	2.92	1.81
2011	2.35	2.56	2.94	1.90
2012	2.25	2.65	3.06	1.87
2013	2.28	2.42	3.13	1.98
2014	2.36	2.75	3.21	2.00
2015	2.17	2.80	3.43	1.96
2016	2.27	2.36	3.28	2.16
2017	2.33	2.33	3.31	2.07
2018	2.31	2.54	3.09	2.18
2019	2.44	2.46	3.07	2.79
2020	2.33	2.50	3.24	2.53

Table 4. Average number of hours fished per trip from state trip ticket data (unshaded) and the average of the first 3 years of data (shaded). The average hours per trip were used to expand SAS estimates of shrimp effort.

Year	NC	SC	GA	FL
1978	20.3	13.2	28.0	18.5
1979	20.3	13.2	28.0	18.5
1980	20.3	13.2	28.0	18.5
1981	20.3	13.2	28.0	18.5
1982	20.3	13.2	28.0	18.5
1983	20.3	13.2	28.0	18.5
1984	20.3	13.2	28.0	18.5
1985	20.3	13.2	28.0	20.7
1986	20.3	13.2	28.0	16.8
1987	20.3	13.2	28.0	17.8
1988	20.3	13.2	28.0	17.9
1989	20.3	13.2	28.0	17.6
1990	20.3	13.2	28.0	18.5
1991	20.3	13.2	28.0	15.1
1992	20.3	13.2	28.0	16.1
1993	20.3	13.2	28.0	16.4
1994	20.5	13.2	28.0	15.7
1995	20.5	13.2	28.0	14.9
1996	19.9	13.2	28.0	13.7
1997	20.3	13.2	28.0	12.4
1998	20.8	13.2	28.0	14.5
1999	17.3	13.2	28.0	13.6
2000	18.7	13.2	28.0	13.3
2001	19.1	13.2	28.0	14.1
2002	18.9	13.2	28.1	14.5
2003	16.5	14.1	28.4	20.5
2004	17.4	12.7	27.7	20.0
2005	16.0	12.7	24.3	19.1
2006	17.8	12.1	24.4	17.3
2007	20.3	10.7	23.8	16.5
2008	23.0	9.9	22.1	15.4
2009	20.7	10.9	23.7	15.3
2010	19.5	11.0	21.8	15.8
2011	20.1	10.8	26.2	17.9
2012	18.7	10.2	28.1	18.8
2013	19.5	9.6	24.3	17.2
2014	21.1	11.4	27.8	17.5
2015	20.5	9.7	35.2	16.0
2016	20.2	10.0	39.6	15.9
2017	22.8	9.2	42.7	17.7
2018	23.8	9.2	32.1	17.3
2019	21.7	10.2	39.8	23.9
2020	22.5	11.2	40.0	23.7

Table 5. Estimates of Spanish mackerel bycatch in number for SEDAR 78 and SEDAR 28. The SEDAR 17 (s17) estimates are included for comparison. In SEDAR 17 the glm approach was used to develop bycatch from 1998-2007.

Year	NC	SC	GA	FL	SEDAR 78	SEDAR 28	SEDAR 17
1978	89180	201578	357895	140619	789273	814445	751667
1979	110727	194708	142076	140619	588129	612640	1515334
1980	219996	254028	251825	140619	866468	899050	5613758
1981	164843	156000	209631	140619	671092	691339	751667
1982	255116	242743	368974	140619	1007452	1038947	6863411
1983	247379	182936	416050	140619	986984	1011160	7430291
1984	182950	95812	186434	140619	605815	618904	751667
1985	162838	94841	206515	132852	597045	609855	8149058
1986	162951	172928	180194	140391	656464	678750	6101833
1987	130227	197809	77292	144429	549757	574800	4606309
1988	167553	146119	195436	151522	660630	679700	6204944
1989	203340	177038	253400	144935	778713	801821	11121667
1990	131306	171047	161421	150877	614650	636455	11097002
1991	168299	257342	196388	134923	756952	789523	11121667
1992	64884	230349	172110	136924	604267	632736	7388148
1993	97824	209010	176481	141654	624969	650540	2377186
1994	130509	201372	181674	176944	690499	714289	631400
1995	141454	234514	164840	151678	692486	719418	7982573
1996	103332	175389	145452	147228	571402	590951	511133
1997	127808	216720	173105	139584	657217	675319	3382461
1998	93290	166652	200889	147653	608483	619669	417000
1999	102109	172093	280214	129452	683868	715529	7005000
2000	103100	163603	254422	111390	632514	649010	6341000
2001	86053	117151	181414	119965	504583	512973	1416000
2002	114087	125764	173402	129469	542723	560166	266000
2003	74834	64600	154169	139950	433553	429277	363000
2004	68618	99830	119467	134889	422804	426003	130000
2005	32477	92167	119568	177008	421220	420179	451000
2006	49191	55155	82852	127296	314493	309807	116000
2007	65934	39290	59307	103917	268449	256348	451000
2008	81496	43366	59777	97322	281961	276588	
2009	61614	7292	11115	15080	95100	86373	
2010	22805	61639	74043	111721	270207	273811	
2011	35938	44060	76132	122239	278369	275246	
2012	49348	52873	83057	124250	309527		
2013	48981	31559	53986	79578	214104		
2014	42426	46604	73654	97447	260132		
2015	50845	49593	92112	100684	293235		
2016	64481	35724	73520	110058	283783		
2017	72871	24250	62275	91793	251189		
2018	47996	26238	49049	78639	201923		
2019	47849	25524	72105	133171	278648		
2020	48744	42056	71971	109902	272673		

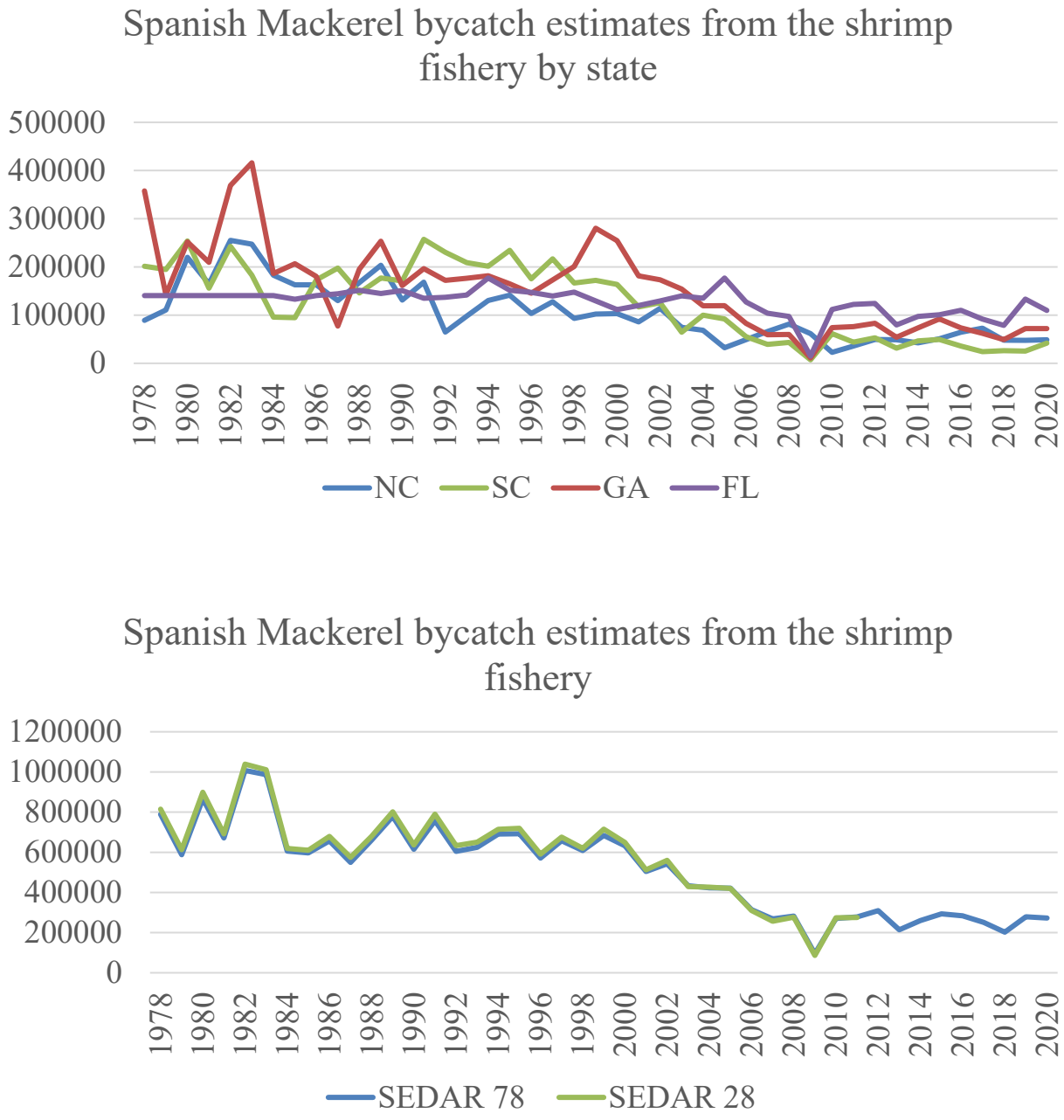

Figure 1. Estimates of Spanish mackerel bycatch by state for SEDAR 78 (upper panel) and a comparison of the total SEDAR 78 and SEDAR 28 estimates (lower panel).

APPENDIX- SEDAR 28-AW02

SEDAR 28 Spanish mackerel bycatch estimates from US Atlantic coast shrimp trawls

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April 11, 2011

In SEDAR17, Spanish mackerel bycatch from shrimp fishing was estimated, first by fitting a delta-GLM for years with observer coverage, and then by fitting a "hockey stick" model to predict discards from shrimp landings for remaining years (SEDAR17-DW12, SEDAR17-AW07). In SEDAR 28, the approach was reevaluated and modified for simplicity, consistent with comments from the SEDAR17 Review.

Encounter rate and catch rate

Evaluation of the shrimp bycatch data from the South Atlantic Shrimp System (SAS) observer data revealed large gaps in the coverage of shrimp effort even when summarized at the state and season levels (Tables 1-3). Trips identified as rock shrimp trips and trips in depths greater than 70 feet were excluded from this analysis (Figure 1). The GLM approach was considered inappropriate given the extremely unbalanced nature of the data. A more simplistic approach was adopted based on the data available. Years with adequate samples spread across the shrimp season were identified and an encounter rate was calculated as the number of positive Spanish mackerel trips divided by the total trips. An empirical mean encounter rate was determined for each area (NC:2008-2010, GA/SC: 2005,2007, and 2009) (Tables 1-3). There was not enough data to determine an encounter rate for Florida. The working group accepted the proposal to borrow the encounter rate for GA/SC to apply to Florida (Table 4).

The annual area-specific catch rate was calculated as the average number of Spanish mackerel caught per trip from positive Spanish mackerel trips (Table 4).

Effort

The estimates of shrimp effort were provided byeach of the states for the most recent period. NMFS SAS estimates of effort were available for earlier years (Table 5). Some of the surveys overlap in the years covered. The data provided by the state representatives was used when available. For all other years the NMFS SAS estimates of shrimp effort were used. The Atlantic Coastal Cooperative Statistics Program (ACCSP) provided effort estimates for each of the states but the working group felt the state data and NMFS data were more reliable. Effort was calculated as net-hours (hours fished multiplied by an estimate of the number of nets per vessel) to match estimates of catch rate from the observer data. This was accomplished differently by state depending on the data provided. The average number of nets/vesses and the average number of hours per trip (Table 6 and 7) were multiplied by the number of trips to get total effort. Because no depth information is available in the effort files, all data sources

excluded deepwater/offshore trawling not likely to encounter juvenile Spanish mackerel by limiting effort estimates to trips fishing in estuaries or out to 3 miles from shore in the ocean.

NC trip ticket

North Carolina shrimp effort data were provided (1994-2010) and summarized by year, month, water body (estuarine and state ocean), and gear. Only the "shrimp trawl" and "skimmer trawl" gear categories were retained. The average number of nets per vessel was provided for 2000-2010 for shrimp trawls. Skimmer trawls were assumed to have 2 nets per vessel. The average number of nets per vessel from 2000-2002 was used for 1994-99 (Table 6). The trip duration was provided was obtained from start and end date of the trip. Almost all commercial shrimping occurs at night in NC. Therfore, half of the trip duration in hours (e.g. 12 hours for a 1-day trip) was used as the hours fished from a trip. The net-hours were calculated as the average number of nets per vessel multiplied by the total annual hours of shrimping. The total hours were calculated as hours per trip (assuming 12 hours fished per day) multiplied by the annual number of trips.

SC trip ticket

South Carolina shrimp effort was provided for 2003-2010 and summarized by year, month, distance (estuarine, 0-3 miles, 3-12 miles, and >12 miles). Only the "shrimp trawl" effort in waters less than 3 miles offshore was retained. A weighted average of the annual number of nets per vessel and the average number of hours fished per vessel was calculated from the data provided. The number of trips for each year, month, and distance was used as the weighting factor. The annual net-hours were calculated as the sum of hours towed times the average number of nets per vessel.

GA trip ticket

Georgia shrimp effort was provided for 2002-2010 and was summarized by year. The net-hours were calculated as the number of trips multiplied by the average number of hours fished per trip and the average number of nets per vessel.

FL trip ticket

Florida shrimp effort was provided for 1985-2010 and was summarized by year. The net-hours were calculated as the number of trips multiplied by the average number of hours fished per trip and the average number of nets per vessel. The number of nets per vessel started in 1991. The average number of nets per vessel from 1991-93 was used for earlier years.

NMFS SAS

The number of shrimp trips was totaled from the South Atlantic Shrimp system effort data provided by NMFS staff. Trips designated as 3-12 and >12 miles from shore were excluded as were all gear types except butterfly nets, skimmer trawls and shrimp trawls. The number of trips was then multiplied by the number of average nets per vessel and average hours fished per trip to get the number of net-hours.

The effort in net-hours was then multiplied by the Spanish mackerel encounter rate and catch rate to get an estimate of the Spanish mackerel bycatch from shrimp trawling (Table 7, Figure 2).

The shrimp observer data for 2011 will not be complete before the SEDAR 28 assessment workshop. Therefore, the 2011 Spanish mackerel bycatch will be calculated using the overall average encounter rates by region applied to 2011 effort estimates provided by each state.

Discussion

Shrimp bycatch depends on two primary factors, shrimping effort and age structure of the Spanish mackerel population. That is, for a given age structure, we would expect more bycatch with more effort, and for a given level of effort, we would expect more bycatch when the population has more young fish (e.g., when strong year classes are present).

The approach taken here applied encounter rates (by area) averaged across years to the total shrimping effort (by area). The exception was 2009 when data were considered sufficient to estimate encounter rates for all areas, such that multi-year averages were not required (Table 3.8). Thus, the approach accounts for one of the important factors (effort) in all years, but both of the important factors in only one year (2009).

The DW discussed how these estimates of shrimping bycatch could be used in the assessment. Some assessment software packages (e.g., Stock Synthesis, ASPIC) require estimated time series of removals by year as input, while other packages (e.g., BAM) allow flexibility for alternative approaches. For example, an alternative approach might estimate annual bycatch mortality rates (F_t) by fitting to observed bycatch in years when those observations are most plausible (e.g., 2009). Those estimates could provide information on catchability (q), such that in other years, bycatch would be predicted by the model but not fitted to observations, by applying $F_t=qE_t$. An advantage to this approach is that predicted bycatch could account for patterns in Spanish mackerel recruitment as well as shrimping effort; a possible disadvantage is the required assumption that bycatch catchability has remained constant. This assumption may not be far from truth, unless substantial changes have occurred in shrimping behavior.

Table 1. North Carolina shrimp observer coverage by month and year. The number of tows observed (top panel), number of tows that caught Spanish mackerel (middle panel), and total number of Spanish mackerel caught (lower panel) are given.

All trips			Month			
Row Labels	6	7	8	9	10	11
2002			9			
2004					18	
2008	8	23	22	7	64	11
2009		38	14	14		3
2010			47	2		
Spanish trips			Month			
YEAR	6	7	8	9	10	11
2002						
2004						
2008		14	14	2	5	
2009		2	4	5		2
2010			9			
Spanish Numbers						
YEAR	6	7	8	9	10	11
2002						
2004						
2008		46	46	5	7	
2009		2	5	11		3
2010			10			

Table 2. Sourth Carolina shrimp observer coverage by month and year. The number of tows observed (top panel), number of tows that caught Spanish mackerel (middle panel), and total number of Spanish mackerel caught (lower panel) are given.

All trips				Month				
Year	5	6	7	8	9	10	11	12
1998				18	24	14	33	8
1999				10				
2000		44						
2004						9	42	
2005	13	28	34	26	25	43		
2006							29	39
2007	12	52	52	9	24	30		
2008		4				25		
2009	20	34			14	7	11	
2010	5	13	3					
2011			30					
Spanish Trips				Month				
YEAR	5	6	7	8	9	10	11	12
1998				4	4			
1999				8				
2000		10						
2004							1	
2005	3	5	3	16	16	16		
2006								
2007	3	13	40	2	5	19		
2008		3				1		
2009	4	8			2	2		
2010	2	1	1					
Spanish Number				Month				
YEAR	5	6	7	8	9	10	11	12
1998				6	4			
1999				23				
2000		24						
2004							4	
2005	11	17	6	74	80	75		
2006								
2007	3	18	116	6	7	108		
2008		6				1		
2009	5	9			2	4		
2010	3	1	1					

Table 3. Florida shrimp observer coverage by month and year. The number of tows observed (top panel), number of tows that caught Spanish mackerel (middle panel), and total number of Spanish mackerel caught (lower panel) are given.

All trips	Month							
Year	2	3	7	8	9	10	11	12
2001						19		
2002	5							
2004			1					
2009				4	1		1	
2010							2	4
2011		1						
Spanish trips	Month							
Year	2	3	7	8	9	10	11	12
2001						4		
2002								
2004								
2009								
2010								
2011								
Spanish Number								
Year	2	3	7	8	9	10	11	12
2001						11		
2002								
2004								
2009								
2010								
2011								

Table 4. Encounter and catch rates from the SAS observer data for years with adequate coverage across months and sample size (unshaded). Average rates across all years by area were applied when data was limited and unlikely to reflect realistic values (shaded).

	Encounter Rate		Catch rate (fish/net-hour)	
Year	NC	SC/GA/FL	NC	SC/GA/FL
1978	0.21	0.40	0.785	1.277
1979	0.21	0.40	0.785	1.277
1980	0.21	0.40	0.785	1.277
1981	0.21	0.40	0.785	1.277
1982	0.21	0.40	0.785	1.277
1983	0.21	0.40	0.785	1.277
1984	0.21	0.40	0.785	1.277
1985	0.21	0.40	0.785	1.277
1986	0.21	0.40	0.785	1.277
1987	0.21	0.40	0.785	1.277
1988	0.21	0.40	0.785	1.277
1989	0.21	0.40	0.785	1.277
1990	0.21	0.40	0.785	1.277
1991	0.21	0.40	0.785	1.277
1992	0.21	0.40	0.785	1.277
1993	0.21	0.40	0.785	1.277
1994	0.21	0.40	0.785	1.277
1995	0.21	0.40	0.785	1.277
1996	0.21	0.40	0.785	1.277
1997	0.21	0.40	0.785	1.277
1998	0.21	0.40	0.785	1.277
1999	0.21	0.40	0.785	1.277
2000	0.21	0.40	0.785	1.277
2001	0.21	0.40	0.785	1.277
2002	0.21	0.40	0.785	1.277
2003	0.21	0.40	0.785	1.277
2004	0.21	0.40	0.785	1.277
2005	0.21	0.35	0.785	1.925
2006	0.21	0.40	0.785	1.277
2007	0.21	0.46	0.785	0.973
2008	0.26	0.40	0.795	1.277
2009	0.19	0.19	1.019	0.449
2010	0.18	0.40	0.410	1.277

Table 5. Number of shrimp trips from the NMFS South Atlantic Shrimp System (light shaded) and state trip ticket programs (unshaded). The dark shading cells are years where either the average of adjacent years (NC) or a 3-year average of the earliest years. NC trips were split into skimmer and bottom trawls for calculation of net-hours.

Year	NC	SC	GA	FL
1978	13277	11374	8270	9002
1979	16485	10986	3283	9002
1980	32753	14333	5819	9002
1981	24542	8802	4844	9002
1982	37981	13696	8526	9002
1983	36829	10322	9614	9002
1984	27237	5406	4308	9002
1985	24243	5351	4772	7582
1986	24260	9757	4164	9865
1987	19388	11161	1786	9559
1988	24945	8245	4516	10007
1989	30273	9989	5855	9746
1990	19549	9651	3730	9643
1991	25056	14520	4538	10344
1992	9660	12997	3977	9949
1993	14479	11793	4078	10496
1994	19299	11362	4198	13217
1995	20833	13232	3809	12091
1996	15131	9896	3361	11109
1997	17900	12228	4000	12031
1998	12556	9403	4642	12962
1999	16895	9710	6475	12475
2000	16052	9231	5879	11430
2001	12202	6610	4192	10362
2002	16275	7096	3963	10591
2003	12140	3489	3538	6994
2004	10367	3972	2811	7157
2005	5638	3977	2502	7349
2006	7041	3337	2133	7038
2007	8294	2867	1761	6546
2008	6990	3222	1788	6250
2009	6578	2710	1836	6266
2010	6696	3748	2258	7554

Table 6. Average number of nets per vessel from state trip ticket programs (unshaded) and the 3-year average of the first 3 years of estimates (shaded) applied when no data were available. North Carolina skimmer trawls were assumed to use 2 nets per vessel. SEDAR 17 used 3.6 nets per vessel from the observer data.

Year	NC	SC	GA	FL
1978	2.24	2.60	2.99	1.64
1979	2.24	2.60	2.99	1.64
1980	2.24	2.60	2.99	1.64
1981	2.24	2.60	2.99	1.64
1982	2.24	2.60	2.99	1.64
1983	2.24	2.60	2.99	1.64
1984	2.24	2.60	2.99	1.64
1985	2.24	2.60	2.99	1.64
1986	2.24	2.60	2.99	1.64
1987	2.24	2.60	2.99	1.64
1988	2.24	2.60	2.99	1.64
1989	2.24	2.60	2.99	1.64
1990	2.24	2.60	2.99	1.64
1991	2.24	2.60	2.99	1.67
1992	2.24	2.60	2.99	1.66
1993	2.24	2.60	2.99	1.60
1994	2.24	2.60	2.99	1.65
1995	2.24	2.60	2.99	1.64
1996	2.24	2.60	2.99	1.88
1997	2.24	2.60	2.99	1.81
1998	2.24	2.60	2.99	1.53
1999	2.24	2.60	2.99	1.48
2000	2.10	2.60	2.99	1.42
2001	2.29	2.60	2.99	1.60
2002	2.32	2.60	3.02	1.64
2003	2.33	2.55	2.98	1.89
2004	2.39	2.58	2.98	1.83
2005	2.25	2.66	2.93	1.87
2006	2.47	2.61	3.09	2.03
2007	2.48	2.60	3.17	2.15
2008	2.58	2.61	2.93	1.96
2009	2.44	2.58	3.05	1.88
2010	2.40	2.55	2.92	2.03

Table 7. Average number of hours fished per trip from state trip ticket data (unshaded) and the average of the first 3 years of data (shaded). The average hours per trip were used to expand SAS estimates of shrimp effort.

Year	NC	SC	GA	FL
1978	18.32	14.84	28.04	18.45
1979	18.32	14.84	28.04	18.45
1980	18.32	14.84	28.04	18.45
1981	18.32	14.84	28.04	18.45
1982	18.32	14.84	28.04	18.45
1983	18.32	14.84	28.04	18.45
1984	18.32	14.84	28.04	18.45
1985	18.32	14.84	28.04	20.70
1986	18.32	14.84	28.04	16.81
1987	18.32	14.84	28.04	17.85
1988	18.32	14.84	28.04	17.89
1989	18.32	14.84	28.04	17.57
1990	18.32	14.84	28.04	18.48
1991	18.32	14.84	28.04	15.14
1992	18.32	14.84	28.04	16.10
1993	18.32	14.84	28.04	16.39
1994	18.32	14.84	28.04	15.69
1995	18.32	14.84	28.04	14.87
1996	18.32	14.84	28.04	13.67
1997	18.32	14.84	28.04	12.40
1998	18.32	14.84	28.04	14.48
1999	18.32	14.84	28.04	13.61
2000	18.03	14.84	28.04	13.34
2001	17.70	14.84	28.04	14.07
2002	19.21	14.84	28.10	14.46
2003	15.56	14.11	28.36	20.48
2004	19.72	17.71	27.66	19.98
2005	16.14	12.71	24.27	19.13
2006	16.46	12.10	24.38	17.27
2007	17.57	10.69	23.83	16.53
2008	21.18	10.01	22.13	15.41
2009	17.79	11.33	23.74	15.34
2010	17.05	11.06	21.78	15.82

Table 8. Estimates of Spanish mackerel bycatch in number. The SEDAR 17 (s17) estimates are included for comparison. In SEDAR 17 the glm approach was used to develop bycatch from 1998-2007.

Year	NC	SC	GA	FL	Total	s17
1978	89894	226037	357895	140619	814445	751667
1979	111612	218333	142076	140619	612640	1515334
1980	221756	284851	251825	140619	899050	5613758
1981	166161	174929	209631	140619	691339	751667
1982	257157	272197	368974	140619	1038947	6863411
1983	249358	205133	416050	140619	1011160	7430291
1984	184414	107438	186434	140619	618904	751667
1985	164140	106348	206515	132852	609855	8149058
1986	164255	193910	180194	140391	678750	6101833
1987	131269	221811	77292	144429	574800	4606309
1988	168893	163849	195436	151522	679700	6204944
1989	204967	198519	253400	144935	801821	11121667
1990	132356	191802	161421	150877	636455	11097002
1991	169645	288567	196388	134923	789523	11121667
1992	65403	258299	172110	136924	632736	7388148
1993	98035	234371	176481	141654	650540	2377186
1994	129865	225806	181674	176944	714289	631400
1995	139931	262970	164840	151678	719418	7982573
1996	101600	196671	145452	147228	590951	511133
1997	119614	243016	173105	139584	675319	3382461
1998	84254	186873	200889	147653	619669	417000
1999	112888	192974	280214	129452	715529	7005000
2000	99745	183455	254422	111390	649010	6341000
2001	80229	131366	181414	119965	512973	1416000
2002	116270	141024	173402	129469	560166	266000
2003	70557	64600	154169	139950	429277	363000
2004	78056	93592	119467	134889	426003	130000
2005	33074	90528	119568	177008	420179	451000
2006	45513	54146	82852	127296	309807	116000
2007	57556	35567	59307	103917	256348	451000
2008	76142	43346	59777	97322	276588	
2009	53557	6621	11115	15080	86373	
2010	20084	54499	74043	125186	273811	

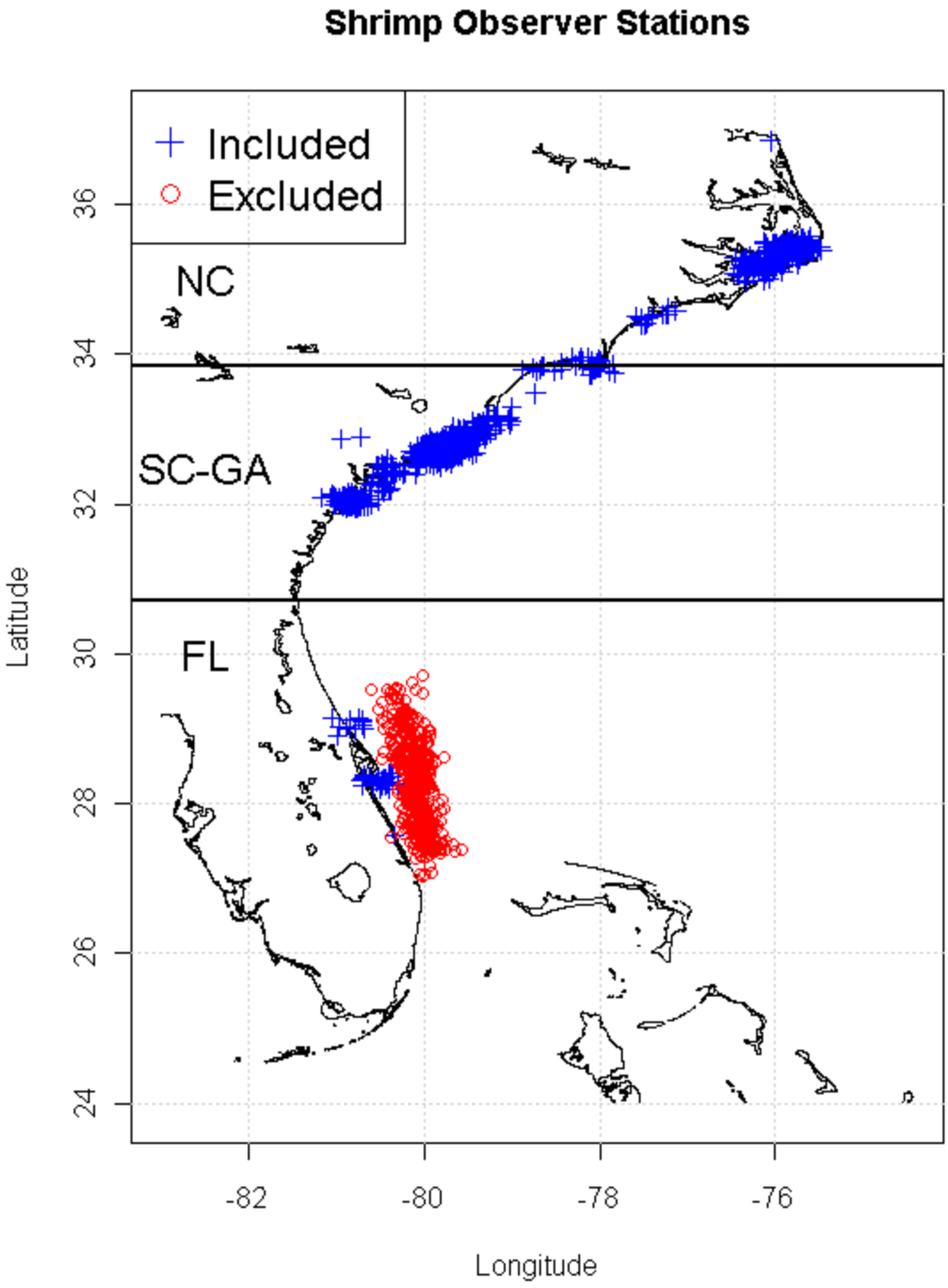

Figure 1. Approximate locations of shrimp observer samples in the Southeast U.S. Latitude and longitude were jittered randomly from 0-6 miles to preserve confidentiality. The excluded stations were either rock shrimp trips or in depths greater than 70 feet.

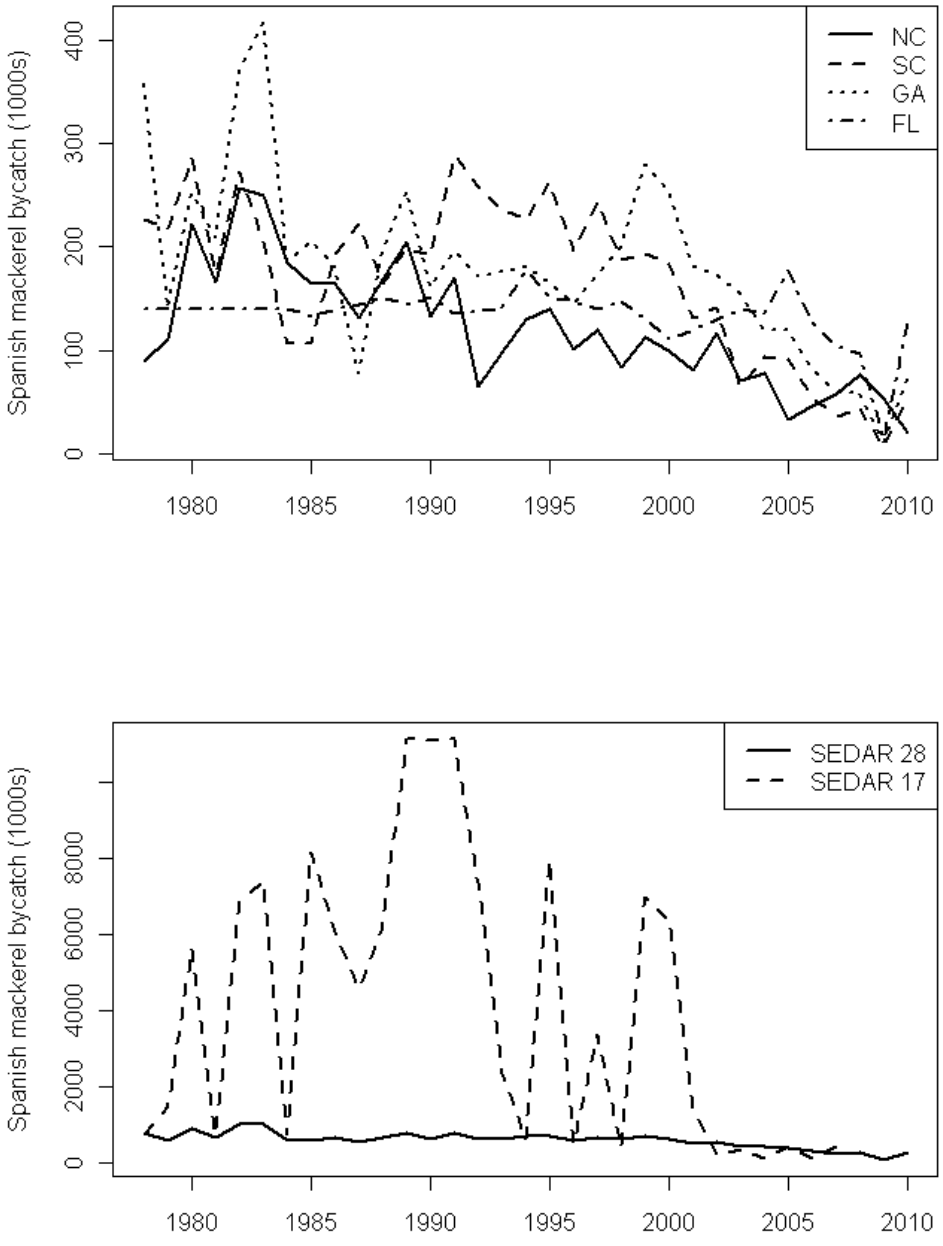

Figure 2. Estimates of Spanish mackerel bycatch by state for SEDAR 28 (upper panel) and a comparison of the total SEDAR 28 and SEDAR 17 estimates (lower panel). The 1998-2004 and 2006 values for SEDAR 17 were based on the GLM analysis.