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King Mackerel Index of Abundance in Coastal US South Atlantic Waters Based on a Fishery-Independent Trawl Survey

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Introduction

Fishery-independent measures of catch and effort with standard gear types and deployment strategies are valuable for monitoring the status of stocks, interpreting fisheries landings data, performing stock assessments, and developing regulations for managing fish resources. Inevitably, tighter management regulations result in fishery-dependent catches reflecting the demographics of a restricted subset of the population, affecting the utility of fishery-dependent data when assessing the current status of the stock. When fisheries are highly regulated, fishery-independent surveys are often the only method available to adequately characterize population size, age and length compositions, and reproductive parameter distributions, all of which are needed to assess the status of stocks. The Southeast Area Monitoring and Assessment Program, South Atlantic (SEAMAP-SA) is a State/Federal program for collection, management and dissemination of fishery-independent data and information in the Atlantic waters of the southeastern United States. The SEAMAP-SA Coastal Survey collects fishery-independent data concerning species abundance, distribution, and habitat which provides valuable fishery information to managers, scientists, and students in the South Atlantic Bight region.

The focus of this report is on the development of an annual abundance index for king mackerel (*Scomberomorus cavalla*) based on the SEAMAP-SA Coastal trawl survey from 1990 to 2012.

Objective

This report presents a summary of the fishery-independent monitoring of king mackerel in the US South Atlantic region. Specifically, it presents annual nominal catch per unit effort (CPUE) and length compositions of king mackerel collected in standardized falcon trawls in relatively shallow water (<20 m). Also included are annual CPUE estimates standardized by a delta-GLM model consistent with the approach utilized in SEDAR 16 (Ingram, 2008) and SEDAR 32 (Ballenger et al., 2013). Both types of model account for the effects of potential covariates on annual CPUE estimates. Data presented in this report are based on the SEAMAP-SA database accessed in November, 2013, and include data collected through the 2012 sampling season. At the writing of this report, field data for the full 2013 survey season had not been finalized.

Methods

Sample Collection

Data presented here were collected as part of the SEAMAP-SA Coastal Survey housed at the South Carolina Department of Natural Resources (SCDNR). Paired 22.9 m mongoose-type Falcon trawl nets (mesh size of net body #15 twine, 1.875 stretch mesh) were deployed from the RV Lady Lisa, a 23 m wooden-hulled, double-rigged, St. Augustine shrimp trawler. Trawls were conducted during daylight hours at target speeds of 2.5 knots and depths between approximately 4 and 10 m for approximately 20 minutes (SEAMAP-SA and SCMRD, 2000). The Coastal Survey conducts trawls at randomly selected stations within 24 latitude- and depth-based strata between Cape Hatteras, NC and Cape Canaveral, FL (Figure 1) in three seasons each year; spring (April-May), summer (July-August), and fall (September-November). The contents of each net are processed independently with all finfish, elasmobranchs, decapod and stomatopod crustaceans, and cephalopods sorted to species (limited exceptions to genus only), counted, and weighed. Abundance, biomass, and length-frequency data is recorded utilizing electronic measuring boards. Length frequency is recorded to the nearest cm for priority species, including king mackerel. Although deployments are paired, only data from one net are used for estimation of abundance, biomass, and length frequency. The Coastal Survey design includes both the shallow-water strata mentioned above and deep water strata in some parts of the region. The deep strata were eliminated from the current analysis because these occur in on some areas of the region and have not been consistently sampled and are not as useful for characterizing abundance trends for king mackerel for the full region.

Data and Treatment

Data and Nominal CPUE Estimation

Available data for each trawl fished included a unique collection number, date of deployment, tow time (in minutes), sampling area, season, deployment depth (m), number of king mackerel captured, and aggregate weight of king mackerel. We used numbers, instead of weight, of king mackerel for all analyses. Annual nominal catch per unit effort (CPUE) was defined as the number of fish caught per trawl per hour tow time divided by the total number of trawls conducted in a given year. Estimates of annual nominal abundance, or CPUE, were normalized to the long-term average nominal CPUE of king mackerel for the time series to produce relative abundance.

Our selection of which data to include varied in a few ways from SEDAR 16. The time series analyzed in SEDAR 16 included 1989. The Florida survey area appears to have been eliminated in SEDAR 16, perhaps due to incomplete coverage in early years. We chose to eliminate 1989 from the current analysis due to inconsistencies in sampling procedures between that year and subsequent years. For the resulting time series (1990-2012), we chose to include the Florida survey area because sampling effort in that area was similar to other areas.

Delta-GLM Standardization

CPUE was standardized among years using the delta-GLM technique described in Dick (2004). Briefly, the standardized CPUE is the product of fitted values from two generalized linear models (GLMs). The first GLM examines the effects of factors or covariates on the presence or absence of a species using the binomial error distribution, referred to as a Bernoulli distribution or Bernoulli sub-model in this case. The second GLM examines the effects of covariates on the CPUE of positive observations using a continuous error distribution (e.g. gamma distribution, Gaussian distribution, lognormal distribution, etc.). In general we refer to the positive sub-model by the error distribution identified as the best-fit to data (either the gamma or lognormal error distribution in this case). For a more detailed discussion of these formulations, see Ballenger et al. (2013).

The covariates selected for examination were based on those examined for the king mackerel assessment conducted in 2008 (Ingram, 2008). Depth, Season, Survey Area, their interactions, and year were included in each initial sub-model. Season was defined as Spring (April, May), Summer (June, July, August), and Fall (October, November), based on the survey schedule employed by SEAMAP-SA. Survey area was defined as above and in Figure 1. The depths at which the survey deploys trawls range from 2 m to 13 m (we eliminated deeper strata as they only occur in a few areas). Most deployments occur between 7 and 10 m, so we elected to assign trawls to bins based on the 50% quartile (< 9 m, ≥ 9 m) as was suggested in SEDARs 32 and 36 (Ballenger et al,. 2013; Ballenger and Smart, 2013). Selection of the covariates included in the final sub-models and the error distribution for the positive model was done based on Akaike's information criterion (AIC; Akaike, 1973). All analyses were performed in R, based primarily on code adapted from Dick (2004).

Length-Frequency

From each trawl, once data are sorted to species and collectively weighed, all individuals of priority species are measured to the nearest cm in fork length (FL). Here, we summarize these data in 1-cm bins (centered on the integer, i.e. 10 cm = 9.5-10.4) in terms of the total number of fish collected each year and % composition of those fish which fall into each length bin in that year.

Results

King mackerel were collected in greater than 10% of all SEAMAP-SA Coastal Survey shallow-water trawls from 1990 to 2012 (Table 1). Nominal CPUE was highly variable from 1990 to 2000, with peaks in 1990, 1993, 1996, and 1998 (Figure 2). Nominal CPUE decreased from 1998 to 2001, recovered until 2008, and again declined through 2012.

Delta-GLM Standardization

King mackerel delta-GLM standardized CPUE followed similar trends to the nominal CPUE, although with reduced within-year variability (Table 1) and between-year variability (Figure 2). Delta-GLM CPUE was lowest in 2012 relative to the full time series. All covariates were initially included in both sub-models of the delta-GLM. However, depth was not significant or selected for in either the Bernoulli or positive sub-models and therefore not included in the final model (Table 3). The lognormal error distribution provided a better fit to the data than the gamma distribution for the positive sub-model. All other covariates were significant in both final sub-models (Table 3). See Figures 3 and 4 for model quantiles and residuals. In many years of the time series, king mackerel CPUE was highest in Florida (FL, area 1) relative to other survey areas, although in a few years CPUE was highest in either Long Bay (LB, area 4) or Onslow Bay (OB, area 5; Figure 5). With few exceptions, king mackerel CPUE was highest in spring relative to other seasons (Figure 6). There was a significant interaction between season and area in both sub-models, similar to SEDAR 16, with CPUE higher in summer than fall in Florida but similar in all other areas among seasons (Figure 7).

Length-Frequency

The total number of king mackerel measured for length frequency for the years 1990 to 2012 was 16,070, ranging from 208 to 1,386 per year (Table 3). Observed lengths ranged from 4 cm to 123 cm with 12-14 cm being observed most frequently.

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Tables

Table 1. Nominal and standardized catch per unit effort (CPUE) of king mackerel in the SEAMAP-SA Coastal Trawl Survey from 1990 to 2012. Number of trawls per year (Collections), number of trawls positive for king mackerel (Positive) and % Positive Collections, nominal CPUE with standard errors (SE), delta-GLM standardized CPUE with SE and nominal and delta-GLM CPUE normalized to the time-series average.

								Normalized			
				Nominal		Delta-GLM		Nominal		Delta-GLM	
Year	Collections	Positive	% Positive	CPUE	SE	CPUE	SE	CPUE	SE	CPUE	SE
1990	231	98	42	13.104	2.44	9.433	1.58	1.754	0.33	2.642	0.44
1991	233	47	20	2.202	0.49	1.854	0.40	0.295	0.07	0.519	0.11
1992	234	46	20	11.615	4.18	3.216	0.76	1.554	0.56	0.901	0.21
1993	234	46	20	3.628	1.40	1.750	0.39	0.486	0.19	0.490	0.11
1994	234	50	21	4.513	1.11	2.729	0.60	0.604	0.15	0.764	0.17
1995	234	66	28	11.397	2.92	4.813	1.01	1.525	0.39	1.348	0.28
1996	234	81	35	15.628	3.36	7.721	1.41	2.091	0.45	2.162	0.39
1997	234	47	20	2.462	0.56	1.944	0.47	0.329	0.07	0.545	0.13
1998	234	65	28	15.821	3.80	6.942	1.53	2.117	0.51	1.944	0.43
1999	234	77	33	4.474	0.86	4.380	0.83	0.599	0.12	1.227	0.23
2000	234	53	23	6.462	1.87	3.128	0.74	0.865	0.25	0.876	0.21
2001	306	53	17	4.731	1.62	1.627	0.40	0.633	0.22	0.456	0.11
2002	306	65	21	2.863	0.56	1.825	0.35	0.383	0.08	0.511	0.10
2003	306	77	25	6.706	1.93	3.642	0.72	0.897	0.26	1.020	0.20
2004	306	74	24	15.912	7.43	4.830	1.02	2.129	0.99	1.353	0.29
2005	306	59	19	10.882	2.86	4.613	0.92	1.456	0.38	1.292	0.26
2006	306	60	20	7.324	1.66	3.735	0.80	0.980	0.22	1.046	0.23
2007	306	69	23	7.304	1.50	4.151	0.79	0.977	0.20	1.162	0.22
2008	306	50	16	10.363	3.05	3.983	0.86	1.387	0.41	1.115	0.24
2009	336	56	17	4.089	1.09	1.859	0.40	0.547	0.15	0.521	0.11
2010	336	45	13	1.866	0.43	1.194	0.27	0.250	0.06	0.335	0.08
2011	336	40	12	5.304	1.34	1.802	0.49	0.710	0.18	0.505	0.14
2012	336	48	14	3.214	1.11	0.953	0.23	0.430	0.15	0.267	0.06

Table 2. Analysis of Variance tables for A. the Bernoulli sub-model and B. the Lognormal sub-model of the delta-GLM analysis.

A. Bernoulli sub-model					
Covariate	d.f.	Deviance	Residual d.f.	Residual	p-value
Year	22	166.64	6339	6467.1	<0.001
Area	5	276.74	6334	6190.3	<0.001
Season	2	726.72	6332	5463.6	<0.001
Area*Season	10	108.94	6322	5354.7	<0.001

B. Lognormal sub-model						
Covariate	d.f.	Deviance	Residual d.f.	Residual	F	p-value
Year	22	197.91	1349	2145.7	6.27	<0.001
Area	5	139.94	1344	2005.8	19.51	<0.001
Season	2	55.51	1342	1950.2	19.35	<0.001
Area*Season	10	37.64	1333	1912.6	2.91	0.002

Table 3. Length % Composition by fork length (FL) of king mackerel from SEAMAP-SA Coastal Survey Falcon trawl catches from 1990 to 2012.

FL (cm)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
4	0.26	0.47	0.00	0.35	0.28	0.11	0.00	0.37	0.00	0.00	0.00	0.63	0.34	0.15	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
5	1.38	0.95	0.11	0.71	0.28	0.00	0.29	1.83	0.15	0.26	0.00	18.33	1.71	0.15	0.06	0.00	0.40	0.00	0.10	2.23	0.00	0.00	0.00
6	0.60	0.47	0.33	0.00	0.28	0.11	0.94	3.66	0.23	0.00	0.38	24.17	5.48	0.58	0.18	0.09	1.06	0.81	0.00	1.22	0.00	0.00	0.00
7	0.77	2.37	0.44	0.00	0.28	1.43	3.17	1.47	0.69	1.05	0.38	5.21	4.45	0.58	0.49	0.55	10.76	0.00	0.00	2.23	0.00	2.01	0.00
8	2.32	2.37	0.11	0.71	1.98	8.25	5.05	3.66	0.46	2.89	2.11	2.50	5.48	1.31	0.49	0.36	5.71	0.00	0.67	5.68	0.00	2.01	0.28
9	4.47	1.90	0.44	1.41	6.21	6.93	4.76	0.37	0.54	6.30	3.26	2.92	4.45	1.17	2.64	0.09	0.66	0.13	0.00	1.22	0.00	2.84	0.00
10	6.19	3.32	1.54	9.19	11.02	1.54	5.92	0.37	1.07	7.61	14.59	6.46	9.59	2.63	3.32	1.45	0.66	1.35	0.67	4.26	5.77	4.52	0.56
11	7.48	4.27	1.76	14.84	7.34	5.17	11.33	0.00	3.21	4.20	20.73	6.25	9.59	3.21	6.95	2.27	3.98	1.62	1.45	5.68	12.02	8.86	3.92
12	9.63	9.95	3.63	22.97	21.47	12.43	14.86	0.00	11.63	2.62	26.49	11.25	2.74	6.42	13.65	8.55	11.29	15.88	16.18	19.47	20.19	18.90	1.68
13	8.08	9.48	12.10	15.55	21.75	9.68	10.97	0.73	19.20	4.72	14.01	2.29	7.53	7.45	19.25	17.55	10.62	20.59	20.04	19.07	18.27	18.06	8.68
14	7.57	11.85	21.01	6.71	11.02	9.46	7.22	0.00	22.42	10.50	5.18	1.88	7.19	8.61	16.17	23.55	11.55	20.59	16.47	10.34	12.50	25.92	12.32
15	5.50	5.69	26.29	2.47	7.63	7.59	4.47	0.00	15.00	5.25	0.58	2.92	5.48	11.39	3.63	21.27	2.79	4.85	14.84	7.30	9.62	8.53	6.44
16	4.90	4.27	13.97	3.18	2.54	4.84	1.73	0.73	11.55	4.72	0.96	1.88	5.48	8.18	3.20	13.82	14.08	7.81	8.48	6.69	8.65	5.35	23.53
17	2.92	1.90	5.50	3.53	0.85	7.48	1.15	0.73	5.74	0.52	0.77	1.25	4.45	6.72	4.61	2.91	3.05	2.29	4.43	3.25	3.37	0.84	5.60
18	1.38	0.95	4.07	2.83	0.00	3.96	0.36	1.10	2.60	1.57	1.92	1.88	1.37	6.28	3.87	0.73	1.73	2.02	6.84	4.06	3.37	1.51	7.00
19	1.38	3.79	2.42	5.30	0.85	1.76	0.43	2.93	1.15	1.31	0.58	0.42	1.37	7.01	1.85	0.27	1.20	2.29	3.28	0.20	2.88	0.17	3.64
20	0.26	0.95	2.31	1.77	0.85	0.77	0.29	6.96	1.30	3.67	0.58	0.42	3.08	6.57	2.52	1.82	0.00	2.83	2.99	0.61	1.44	0.17	6.72
21	0.09	0.00	1.10	0.71	0.00	0.66	1.23	12.82	0.77	2.62	0.77	0.00	2.05	3.94	1.35	0.73	0.40	1.08	0.77	1.62	0.00	0.00	3.36
22	0.60	1.42	1.32	1.41	0.56	2.86	2.02	10.26	0.84	3.41	0.58	0.63	2.05	4.96	2.71	0.27	1.99	5.92	2.22	2.84	0.00	0.00	2.80
23	0.09	0.47	0.55	0.00	0.00	3.19	2.24	6.96	0.38	1.31	0.58	0.00	1.37	1.17	1.78	0.00	0.66	1.88	0.19	0.61	0.00	0.17	6.44
24	1.03	0.00	0.11	1.41	0.00	2.75	3.39	8.79	0.23	3.41	0.00	1.88	3.08	2.04	3.57	0.27	0.00	1.62	0.00	0.00	0.48	0.00	0.56
25	0.52	2.37	0.11	1.41	0.28	4.62	2.45	6.59	0.00	1.84	0.19	0.21	3.08	0.15	1.66	0.00	1.06	0.13	0.10	0.00	0.00	0.00	0.56
26	2.84	0.47	0.00	1.77	0.28	1.65	2.96	6.23	0.08	3.67	0.38	0.42	1.37	1.75	2.40	0.36	1.99	1.62	0.00	0.00	0.48	0.00	2.52
27	2.58	5.21	0.00	0.00	0.85	0.55	3.82	5.86	0.00	2.36	0.38	0.83	1.37	2.19	1.05	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00
28	3.70	3.32	0.00	0.35	0.85	0.99	3.75	4.03	0.46	3.15	0.00	2.92	2.05	1.90	0.18	0.73	0.93	0.00	0.10	0.00	0.48	0.00	0.00
29	4.64	4.74	0.00	0.00	1.13	0.44	1.59	2.20	0.00	2.62	0.38	1.04	0.00	0.00	0.25	0.00	1.99	0.00	0.00	0.20	0.00	0.00	0.28
30	4.30	2.37	0.11	0.35	0.56	0.33	1.08	0.73	0.00	3.67	0.19	0.00	0.34	2.19	0.62	0.64	1.20	0.00	0.00	0.00	0.00	0.00	0.56

31	4.30	2.37	0.11	0.00	0.28	0.22	0.65	1.10	0.15	2.89	0.58	1.04	0.34	0.00	0.25	0.00	1.20	0.13	0.00	0.00	0.48	0.00	0.28
32	4.39	3.32	0.00	0.00	0.00	0.11	0.65	1.10	0.00	3.67	0.77	0.00	1.03	0.44	0.25	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.28
33	2.24	0.95	0.00	0.00	0.00	0.00	0.29	1.83	0.00	1.05	0.38	0.00	1.03	0.15	0.25	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
34	0.86	1.42	0.00	0.35	0.28	0.00	0.07	1.83	0.00	3.67	0.00	0.00	0.00	0.44	0.43	0.00	2.39	1.75	0.10	0.00	0.00	0.00	0.56
35	1.20	0.95	0.00	0.00	0.00	0.00	0.29	1.10	0.00	0.79	0.19	0.00	0.00	0.00	0.06	0.09	1.20	0.00	0.00	0.00	0.00	0.00	0.28
36	0.52	1.90	0.00	0.00	0.00	0.00	0.22	1.10	0.00	1.31	0.77	0.21	0.00	0.00	0.31	0.00	1.99	0.67	0.00	0.00	0.00	0.00	0.28
37	0.26	1.42	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.52	0.19	0.00	0.34	0.15	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.28
38	0.26	0.95	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.26	0.00	0.00	0.00	0.15	0.00	0.18	2.12	0.54	0.00	0.20	0.00	0.00	0.00
39	0.09	0.47	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.26	0.19	0.00	0.00	0.00	0.00	0.09	0.00	0.54	0.00	0.00	0.00	0.00	0.00
40	0.17	0.00	0.11	0.00	0.00	0.00	0.07	0.37	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.36	0.53	0.00	0.00	0.00	0.00	0.00	0.00
42	0.09	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.20	0.00	0.00	0.00
43	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	0.09	0.00	0.11	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.10	0.00	0.00	0.00	0.56
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
96	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
97	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00
99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
101	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
102	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
103	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
107	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
108	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
109	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
110	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
111	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
112	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
113	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
114	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
115	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
116	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
117	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
118	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
121	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
122	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
123	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
Total Fish	1163	211	909	283	354	909	1386	273	1307	381	521	480	292	685	1626	1100	753	743	1038	493	208	598	357
Total Tows	108	57	48	46	52	71	96	53	70	82	57	53	65	77	74	59	60	69	50	56	45	40	48

Figures

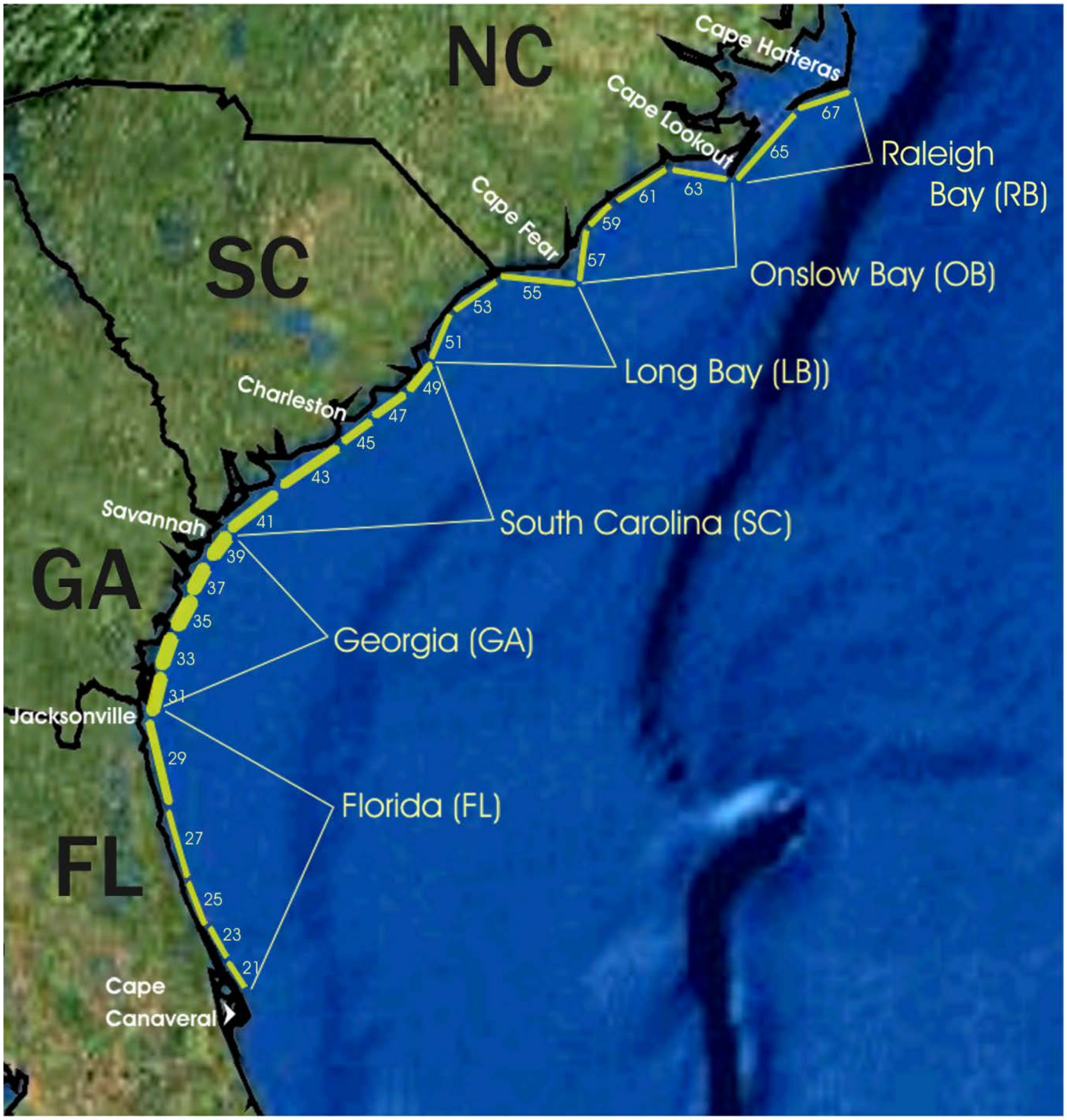


Figure 1. SEAMAP-SA Coastal Trawl Survey regional coverage from 1990 to 2012. Survey areas included in the analysis are Florida (FL, 1), Georgia (GA, 2), South Carolina (SC, 3), Long Bay (LB, 4), Onslow Bay (OB, 5), and Raleigh Bay (RB, 6).

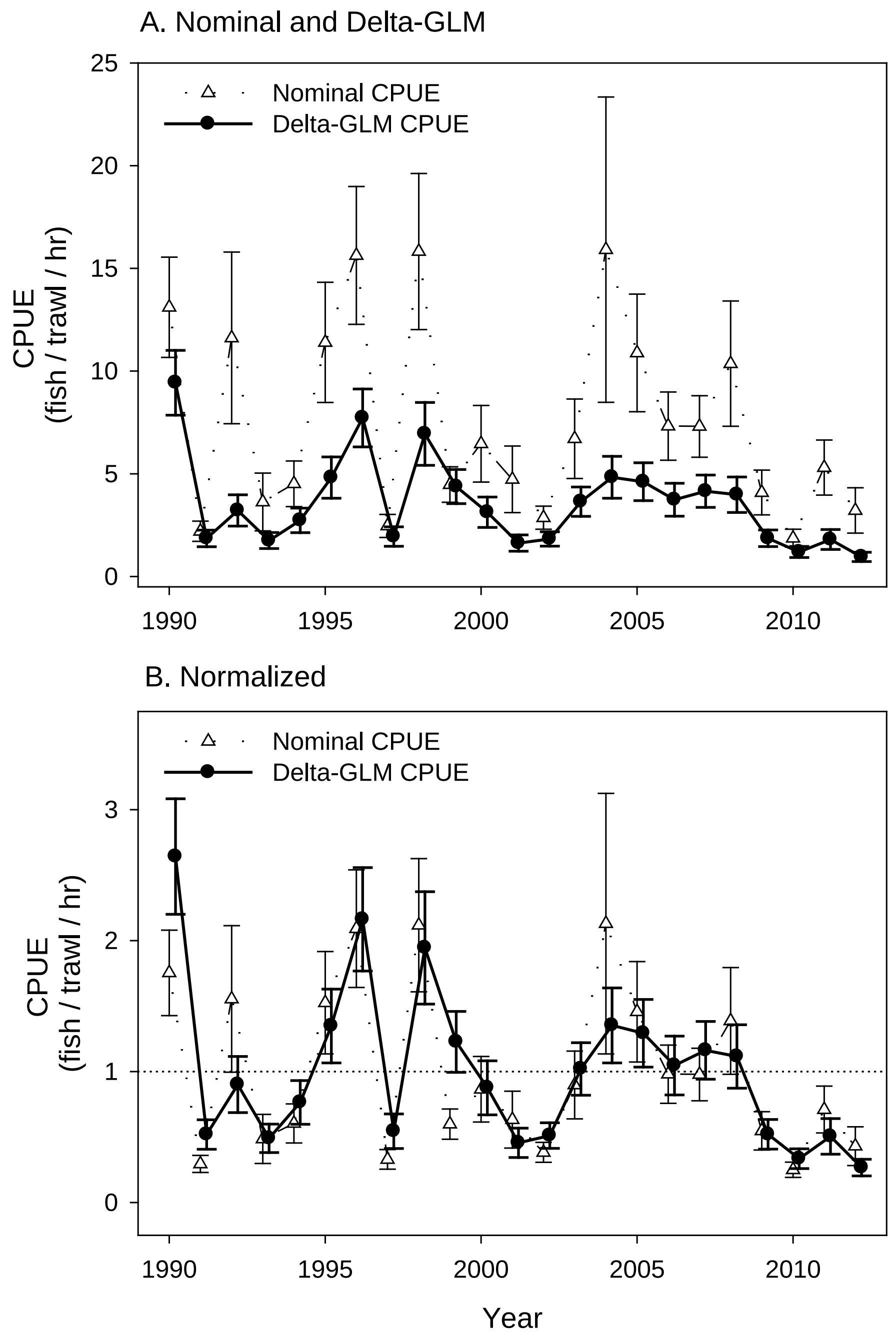
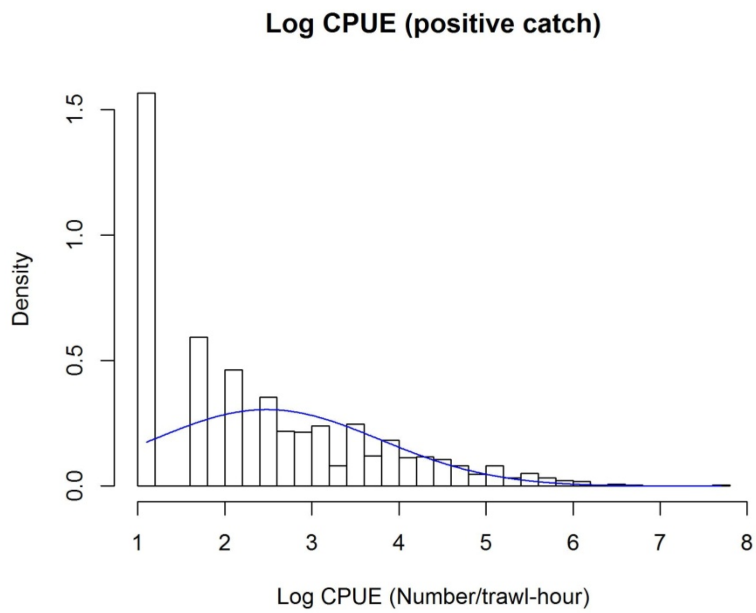


Figure 2. CPUE of king mackerel in the SEAMAP-SA Coastal Trawl Survey from 1990 to 2012. A) Nominal and delta-GLM standardized CPUE and B) CPUE normalized to the time series average. Error bars are the standard error.



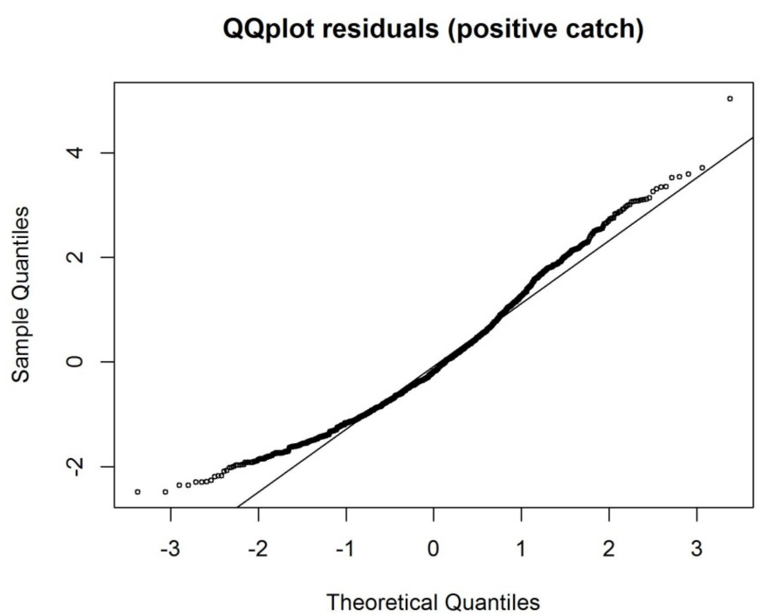
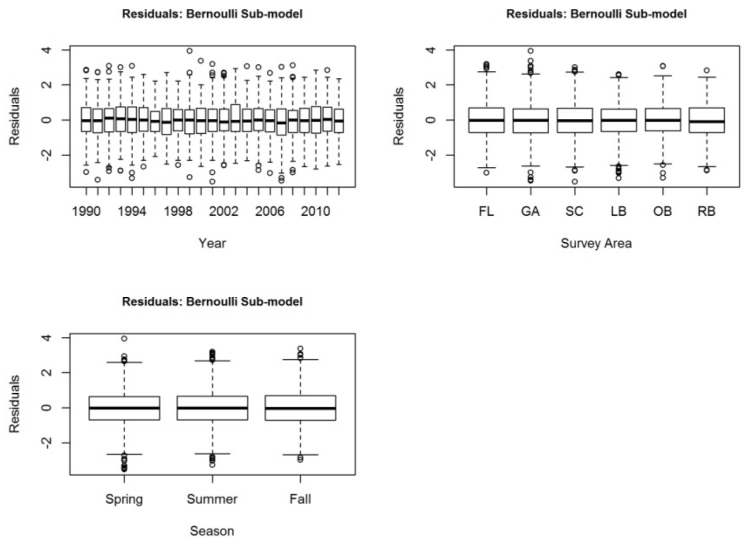


Figure 3. Quantiles and residuals from delta-GLM standardization of king mackerel CPUE.

A. Bernoulli sub-model



B. Lognormal sub-model

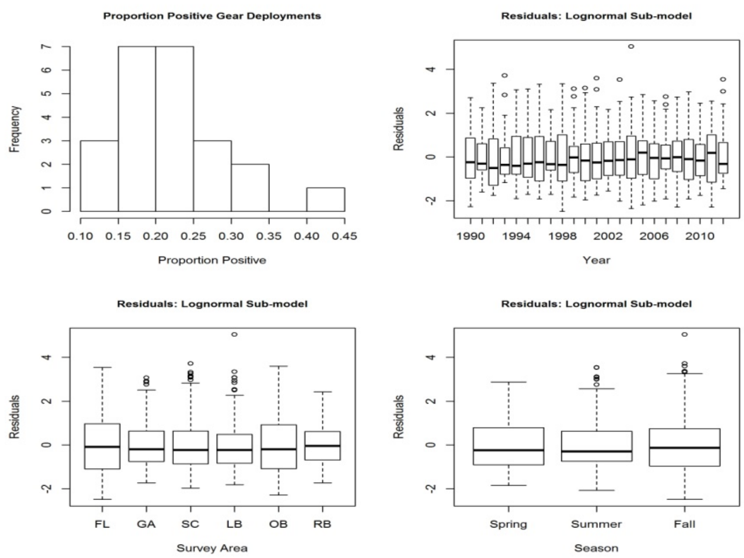


Figure 4. Delta-GLM standardized CPUE residuals for A) the Bernoulli sub-model and B) the lognormal sub-model.

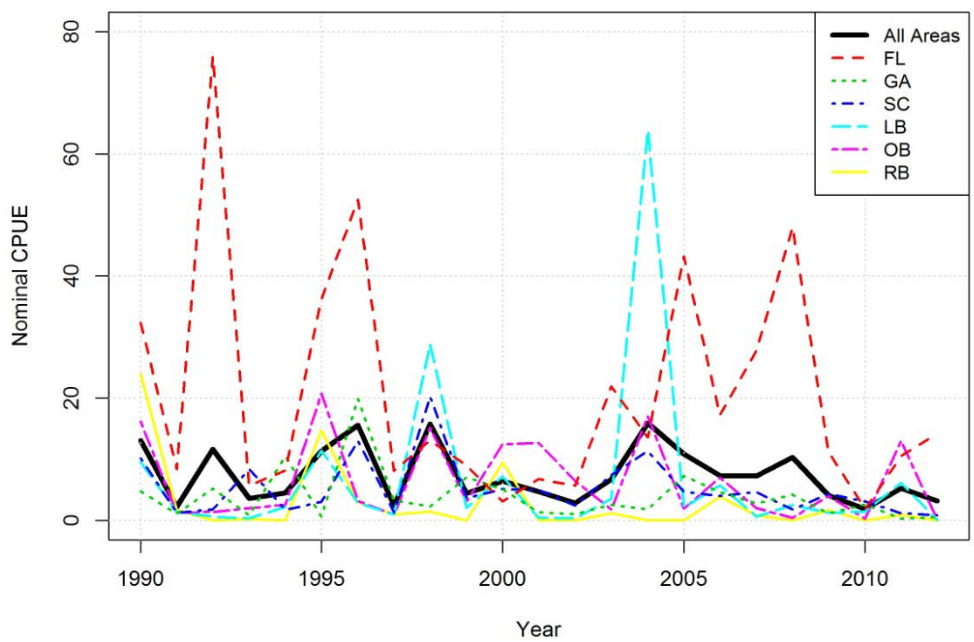


Figure 5. Nominal CPUE of king mackerel in all areas included in the SEAMAP-SA Coastal Trawl Survey from 1990 to 2012.

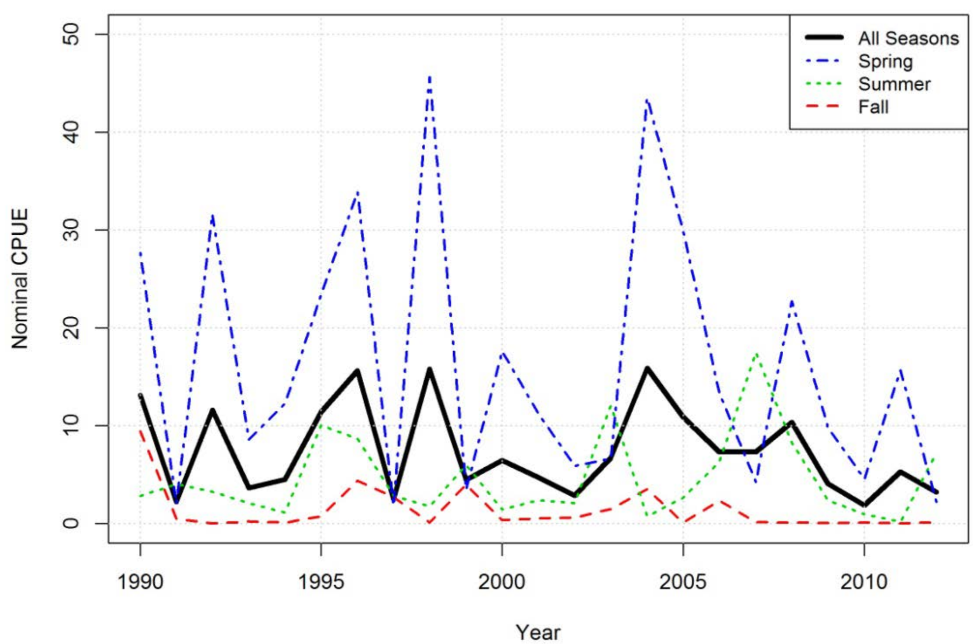


Figure 6. Nominal CPUE of king mackerel in all seasons included in the SEAMAP-SA Coastal Trawl Survey from 1990 to 2012.

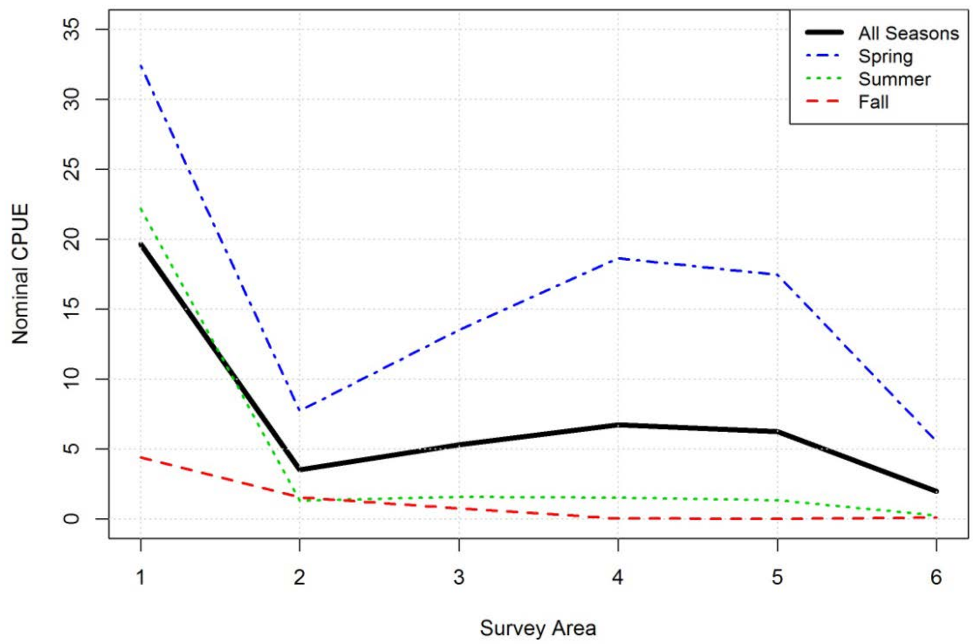


Figure 7. Effects of the interaction between survey area and season on nominal CPUE of king mackerel among years 1990 to 2012.

King Mackerel Index of Abundance in Coastal US South Atlantic Waters Based on a Fishery-Independent Trawl Survey

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Introduction

Fishery-independent measures of catch and effort with standard gear types and deployment strategies are valuable for monitoring the status of stocks, interpreting fisheries landings data, performing stock assessments, and developing regulations for managing fish resources. Inevitably, tighter management regulations result in fishery-dependent catches reflecting the demographics of a restricted subset of the population, affecting the utility of fishery-dependent data when assessing the current status of the stock. When fisheries are highly regulated, fishery-independent surveys are often the only method available to adequately characterize population size, age and length compositions, and reproductive parameter distributions, all of which are needed to assess the status of stocks. The Southeast Area Monitoring and Assessment Program, South Atlantic (SEAMAP-SA) is a State/Federal program for collection, management and dissemination of fishery-independent data and information in the Atlantic waters of the southeastern United States. The SEAMAP-SA Coastal Survey collects fishery-independent data concerning species abundance, distribution, and habitat which provides valuable fishery information to managers, scientists, and students in the South Atlantic Bight region.

The focus of this report is on the development of an annual abundance index for king mackerel (*Scomberomorus cavalla*) based on the SEAMAP-SA Coastal trawl survey from 1990 to 2012.

Objective

This report presents a summary of the fishery-independent monitoring of king mackerel in the US South Atlantic region. Specifically, it presents annual nominal catch per unit effort (CPUE) and length compositions of king mackerel collected in standardized falcon trawls in relatively shallow water (<20 m). Also included are annual CPUE estimates standardized by a delta-GLM model consistent with the approach utilized in SEDAR 16 (Ingram, 2008) and SEDAR 32 (Ballenger et al., 2013). Both types of model account for the effects of potential covariates on annual CPUE estimates. Data presented in this report are based on the SEAMAP-SA database accessed in November, 2013, and include data collected through the 2012 sampling season. At the writing of this report, field data for the full 2013 survey season had not been finalized.

Methods

Sample Collection

Data presented here were collected as part of the SEAMAP-SA Coastal Survey housed at the South Carolina Department of Natural Resources (SCDNR). Paired 22.9 m mongoose-type Falcon trawl nets (mesh size of net body #15 twine, 1.875 cm stretch mesh) were deployed from the RV Lady Lisa, a 23 m wooden-hulled, double-rigged, St. Augustine shrimp trawler. Trawls were conducted during daylight hours at target speeds of 2.5 knots and depths between approximately 4 and 10 m for approximately 20 minutes (SEAMAP-SA and SCMRD, 2000). The Coastal Survey conducts trawls at randomly selected stations within 24 latitude- and depth-based strata between Cape Hatteras, NC and Cape Canaveral, FL (Figure 1) in three seasons each year; spring (April-May), summer (July-August), and fall (September-November). The contents of each net are processed independently with all finfish, elasmobranchs, decapod and stomatopod crustaceans, and cephalopods sorted to species (limited exceptions to genus only), counted, and weighed. Abundance, biomass, and length-frequency data is recorded utilizing electronic measuring boards. Length frequency is recorded to the nearest cm for priority species, including king mackerel. Although deployments are paired, only data from one net are used for estimation of abundance, biomass, and length frequency. Following each trawl, a CTD is deployed to measure bottom temperature and bottom salinity. The Coastal Survey design includes both the shallow-water strata mentioned above and deep water strata in some parts of the region. The deep strata were eliminated from the current analysis because these occur in only some areas of the region and have not been consistently sampled and are not as useful for characterizing abundance trends for king mackerel as the shallow strata for the full region.

Data and Treatment

Data and Nominal CPUE Estimation

Available data for each trawl fished included a unique collection number, date of deployment, tow time (in minutes), sampling area, season, deployment depth (m), number of king mackerel captured, and aggregate weight of king mackerel. We used numbers, instead of weight, of king mackerel for all analyses. Annual nominal catch per unit effort (CPUE) was defined as the number of fish caught per trawl per hour tow time divided by the total number of trawls conducted in a given year. Estimates of annual nominal abundance, or CPUE, were normalized to the long-term average nominal CPUE of king mackerel for the time series to produce relative abundance.

Our selection of which data to include varied in a few ways from SEDAR 16. The time series analyzed in SEDAR 16 included 1989. The Florida survey area appears to have been eliminated in SEDAR 16, perhaps due to incomplete coverage in early years. We chose to eliminate 1989 from the current analysis due to inconsistencies in sampling procedures between that year and subsequent years. For the resulting time series (1990-2012), we chose to include the Florida survey area because sampling effort in that area was similar to other areas and all Florida samples occurred outside of the winter mixing zone boundaries decided upon at the SEDAR 38 Data Workshop.

Delta-GLM Standardization

CPUE was standardized among years using the delta-GLM technique described in Dick (2004). Briefly, the standardized CPUE is the product of fitted values from two generalized linear models (GLMs). The first GLM examines the effects of factors or covariates on the presence or absence of a species using the binomial error distribution, referred to as a Bernoulli distribution or Bernoulli sub-model in this case. The second GLM examines the effects of covariates on the CPUE of positive observations using a continuous error distribution (e.g. gamma distribution, Gaussian distribution, lognormal distribution, etc.). In general we refer to the positive sub-model by the error distribution identified as the best-fit to data (either the gamma or lognormal error distribution in this case). For a more detailed discussion of these formulations, see Ballenger et al. (2013).

The covariates initially selected for examination were based on those examined for the king mackerel assessment conducted in 2008 (Ingram, 2008). Depth, Season, Survey Area, their interactions, and year were included in each initial sub-model. Season was defined as Spring (April, May), Summer (June, July, August), and Fall (October, November), based on the survey schedule employed by SEAMAP-SA. Survey area was defined as above and in Figure 1. The depths at which the survey deploys trawls ranged from 2 m to 13 m (we eliminated deeper strata as they only occur in a few areas). Most deployments occurred between 7 and 10 m, so we elected to assign trawls to bins based on the 50% quartile (< 9 m, ≥ 9 m) as was suggested in SEDARs 32 and 36 (Ballenger et al,. 2013; Ballenger and Smart, 2013). Based on suggestions of the Indices and Environmental working groups during the SEDAR 38 Data Workshop, we also included data from CTD deployments paired with trawls. Quantiles also were used for assigning bottom temperature and bottom salinity to bins (<20, 20-23, 23-26.4, >26.4˚C and <34.2 34.2-35.4, >35.4, respectively). Selection of the covariates included in the final sub-models and the error distribution for the positive model was done based on Akaike's information criterion and backwards selection (AIC; Akaike, 1973). All analyses were performed in R, based primarily on code adapted from Dick (2004).

Length-Frequency

From each trawl, once data are sorted to species and collectively weighed, all individuals of priority species are measured to the nearest cm in fork length (FL). Here, we summarize these data in 1-cm bins (centered on the integer, i.e. 10 cm = 9.5-10.4) in terms of the total number of fish collected each year and % composition of those fish which fall into each length bin in that year.

Results

King mackerel were collected in greater than 10% of all SEAMAP-SA Coastal Survey shallow-water trawls from 1990 to 2012 (Table 1). Nominal CPUE was highly variable from 1990 to 2000, with peaks in 1990, 1993, 1996, and 1998 (Figure 2). Nominal CPUE decreased from 1998 to 2002, recovered until 2008, and again declined through 2012.

Delta-GLM Standardization

King mackerel delta-GLM standardized CPUE generally followed similar trends to the nominal CPUE, although with reduced within-year variability (Table 1) and between-year variability (Figure 2). Delta-GLM CPUE was lowest in 2012 relative to the full time series and peaked in 1990, 1996, 1998, and 2005. All covariates were initially included in both sub-models of the delta-GLM. However, depth was not significant or selected for in the lognormal sub-model and salinity was not selected for either sub-model (Table 4). Area, season, and temperature were included in both sub-models. The interaction between area and year was selected for both sub-models. The lognormal error distribution provided a better fit to the data than the gamma distribution for the positive sub-model. See Figures 3 and 4 for model quantiles and residuals. In many years of the time series, king mackerel CPUE was highest in Florida (FL, area 1) relative to other survey areas, although in a few years CPUE was highest in either Long Bay (LB, area 4) or Onslow Bay (OB, area 5; Figure 5). With few exceptions, king mackerel CPUE was highest in spring relative to other seasons (Figure 6). Paired temperature measurements were significant in both sub-models with generally highest CPUE in 23-26.4˚C (Figure 7). Annual CPUE was either higher at depths greater than or equal to 9 m or similar in both depth categories (Figure 8). The interaction between Survey Area and Season was significant in both sub-models, with CPUE highest in Spring and Summer in Florida (Figure 9).

Length-Frequency

The total number of king mackerel measured for length frequency for the years 1990 to 2012 was 16,070, ranging from 208 to 1,386 per year (Table 6). Observed lengths ranged from 4 cm to 123 cm with 12-14 cm being observed most frequently.

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Tables

Table 1. Nominal and standardized catch per unit effort (CPUE) of king mackerel in the SEAMAP-SA Coastal Trawl Survey from 1990 to 2012. Number of trawls per year (Collections), number of trawls positive for king mackerel (Positive) and % Positive Collections, nominal CPUE with standard errors (SE), delta-GLM standardized CPUE with SE and nominal and delta-GLM CPUE normalized to the time-series average.

									Normalized			
		Positive			Nominal		Delta-GLM		Nominal		Delta-GLM	
Year	Collections	n	%	CPUE	CPUE	SE	CPUE	SE	CPUE	SE	CPUE	SE
1990	231	98	42	13.104	2.44	31.01	5.41	9.433	1.58	1.754	0.33	2.642
1991	233	47	20	2.202	0.49	10.47	1.96	1.854	0.40	0.295	0.07	0.519
1992	234	46	20	11.615	4.18	59.09	19.93	3.216	0.76	1.554	0.56	0.901
1993	234	46	20	3.628	1.40	18.46	6.77	1.750	0.39	0.486	0.19	0.490
1994	234	50	21	4.513	1.11	20.88	4.61	2.729	0.60	0.604	0.15	0.764
1995	234	66	28	11.397	2.92	40.41	9.51	4.813	1.01	1.525	0.39	1.348
1996	234	81	35	15.628	3.36	45.15	8.84	7.721	1.41	2.091	0.45	2.162
1997	234	47	20	2.462	0.56	12.26	2.29	1.944	0.47	0.329	0.07	0.545
1998	234	65	28	15.821	3.80	56.95	12.35	6.942	1.53	2.117	0.51	1.944
1999	234	77	33	4.474	0.86	13.60	2.30	4.380	0.83	0.599	0.12	1.227
2000	234	53	23	6.462	1.87	28.53	7.55	3.128	0.74	0.865	0.25	0.876
2001	306	53	17	4.731	1.62	27.31	8.79	1.627	0.40	0.633	0.22	0.456
2002	306	64	21	2.863	0.56	13.64	2.24	1.825	0.35	0.383	0.08	0.511
2003	306	77	25	6.706	1.93	26.65	7.25	3.642	0.72	0.897	0.26	1.020
2004	306	73	24	15.912	7.43	66.37	30.56	4.830	1.02	2.129	0.99	1.353
2005	306	58	19	10.882	2.86	57.36	13.59	4.613	0.92	1.456	0.38	1.292
2006	306	58	19	7.324	1.66	37.76	7.57	3.735	0.80	0.980	0.22	1.046
2007	306	69	23	7.304	1.50	32.39	5.72	4.151	0.79	0.977	0.20	1.162
2008	306	50	16	10.363	3.05	63.42	16.88	3.983	0.86	1.387	0.41	1.115
2009	336	56	17	4.089	1.09	24.54	5.86	1.859	0.40	0.547	0.15	0.521
2010	336	45	13	1.866	0.43	13.93	2.62	1.194	0.27	0.250	0.06	0.335
2011	336	40	12	5.304	1.34	47.38	10.62	1.802	0.49	0.710	0.18	0.505
2012	336	48	14	3.214	1.11	22.50	7.19	0.953	0.23	0.430	0.15	0.267

Table 2. Distribution of samples among years and factors used in the delta-GLM model.

	Season			Area						Depth (m)		Temperature (̊C)			
Year	Spring	Summer	Fall	FL	GA	SC	LB	OB	RB	<9	≥9	<20	20-23	23-26.4	>26.4
1990	77	78	71	24	48	66	47	29	12	188	38	46	43	63	74
1991	78	78	71	24	48	66	48	29	12	124	103	57	67	32	71
1992	78	78	78	30	48	66	48	30	12	135	99	76	63	48	47
1993	78	78	78	30	48	66	48	30	12	132	102	76	52	42	64
1994	78	78	72	24	48	66	48	30	12	130	98	24	109	45	50
1995	78	78	78	30	48	66	48	30	12	137	97	34	57	72	71
1996	78	73	78	30	48	66	45	28	12	145	84	63	77	42	47
1997	78	77	78	30	48	66	48	29	12	221	12	72	21	67	73
1998	78	78	77	29	48	66	48	30	12	120	113	60	50	55	68
1999	78	78	78	30	48	66	48	30	12	155	79	72	41	58	63
2000	78	78	78	30	48	66	48	30	12	143	91	70	57	45	62
2001	102	94	102	54	80	47	36	54	27	180	118	88	97	44	69
2002	101	102	99	54	86	53	33	49	27	174	128	36	79	89	98
2003	102	101	101	54	86	54	32	51	27	146	158	65	116	107	16
2004	102	102	100	54	78	51	38	53	30	190	114	55	89	112	48
2005	100	100	101	54	76	50	39	52	30	160	141	109	38	66	88
2006	102	100	102	55	81	54	39	48	27	214	90	52	69	100	83
2007	101	102	102	57	74	66	39	45	24	203	102	87	45	63	110
2008	100	102	102	53	84	62	36	45	24	175	129	90	46	97	71
2009	112	112	112	57	81	78	42	51	27	219	117	86	67	75	108
2010	112	112	112	63	90	60	42	54	27	197	139	84	82	92	78
2011	112	112	100	54	93	54	36	57	30	156	168	58	126	45	95
2012	112	112	112	69	84	54	45	57	27	117	219	53	97	82	104

Table 3. Analysis of Variance tables for A. the Bernoulli sub-model and B. the Lognormal sub-model of the delta-GLM analysis.

A. Bernoulli sub-model					
Covariate	**d.f.**	**Deviance**	**Residual d.f.**	**Residual**	**p-value**
Year	22	168.83	6306	6435.9	<0.001
Area	5	274.29	6301	6161.6	<0.001
Season	2	550.14	6396	5376.0	<0.001
Temperature	3	235.48	6298	5926.2	<0.001
Depth	1	4.62	6295	5371.4	0.032
Area*Season	10	79.24	6285	5292.2	<0.001

B. Lognormal sub-model						
Covariate	**d.f.**	**Deviance**	**Residual d.f.**	**Residual**	**F**	**p-value**
Year	22	197.94	1344	2140.2	6.27	<0.001
Area	5	140.25	1339	2000.0	19.54	<0.001
Season	2	35.97	1334	1931.5	12.53	<0.001
Temperature	3	32.49	1336	1967.5	7.54	<0.001
Area* Season	9	29.557	1325	1901.9	2.29	0.015

Table 4. Akaike's Information Criterion scores for final model selection.

	AIC Score	
Model Type	**All Covariates Included**	**Final Covariate Set**
Binomial	5407	5404
Lognormal	4550	4386
Gamma	4648	4644

Table 5. Annual predictions based on each delta-GLM sub-model (Binomial and Lognormal).

	Binomial		Lognormal	
Year	Prediction	Predicted SE	Prediction	Predicted SE
1990	0.690	0.242	13.662	0.533
1991	0.251	0.148	7.401	0.525
1992	0.211	0.163	15.237	1.037
1993	0.228	0.162	7.662	0.415
1994	0.267	0.163	10.211	0.618
1995	0.375	0.205	12.848	0.645
1996	0.460	0.239	16.782	0.723
1997	0.242	0.163	8.030	0.491
1998	0.348	0.208	19.968	0.863
1999	0.511	0.226	8.567	0.447
2000	0.288	0.186	10.861	0.549
2001	0.157	0.160	10.345	0.584
2002	0.222	0.168	8.208	0.393
2003	0.324	0.180	11.242	0.569
2004	0.259	0.191	18.674	0.797
2005	0.182	0.161	25.309	1.064
2006	0.192	0.153	19.417	1.104
2007	0.239	0.175	17.331	0.897
2008	0.149	0.148	26.726	1.629
2009	0.157	0.141	11.831	0.575
2010	0.131	0.128	9.088	0.554
2011	0.089	0.102	20.268	0.864
2012	0.117	0.122	8.182	0.416

Table 6. Length % Composition by fork length (FL) of king mackerel from SEAMAP-SA Coastal Survey Falcon trawl catches from 1990 to 2012.

FL (cm)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
4	0.26	0.47	0.00	0.35	0.28	0.11	0.00	0.37	0.00	0.00	0.00	0.63	0.34	0.15	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
5	1.38	0.95	0.11	0.71	0.28	0.00	0.29	1.83	0.15	0.26	0.00	18.33	1.71	0.15	0.06	0.00	0.40	0.00	0.10	2.23	0.00	0.00	0.00
6	0.60	0.47	0.33	0.00	0.28	0.11	0.94	3.66	0.23	0.00	0.38	24.17	5.48	0.58	0.18	0.09	1.06	0.81	0.00	1.22	0.00	0.00	0.00
7	0.77	2.37	0.44	0.00	0.28	1.43	3.17	1.47	0.69	1.05	0.38	5.21	4.45	0.58	0.49	0.55	10.76	0.00	0.00	2.23	0.00	2.01	0.00
8	2.32	2.37	0.11	0.71	1.98	8.25	5.05	3.66	0.46	2.89	2.11	2.50	5.48	1.31	0.49	0.36	5.71	0.00	0.67	5.68	0.00	2.01	0.28
9	4.47	1.90	0.44	1.41	6.21	6.93	4.76	0.37	0.54	6.30	3.26	2.92	4.45	1.17	2.64	0.09	0.66	0.13	0.00	1.22	0.00	2.84	0.00
10	6.19	3.32	1.54	9.19	11.02	1.54	5.92	0.37	1.07	7.61	14.59	6.46	9.59	2.63	3.32	1.45	0.66	1.35	0.67	4.26	5.77	4.52	0.56
11	7.48	4.27	1.76	14.84	7.34	5.17	11.33	0.00	3.21	4.20	20.73	6.25	9.59	3.21	6.95	2.27	3.98	1.62	1.45	5.68	12.02	8.86	3.92
12	9.63	9.95	3.63	22.97	21.47	12.43	14.86	0.00	11.63	2.62	26.49	11.25	2.74	6.42	13.65	8.55	11.29	15.88	16.18	19.47	20.19	18.90	1.68
13	8.08	9.48	12.10	15.55	21.75	9.68	10.97	0.73	19.20	4.72	14.01	2.29	7.53	7.45	19.25	17.55	10.62	20.59	20.04	19.07	18.27	18.06	8.68
14	7.57	11.85	21.01	6.71	11.02	9.46	7.22	0.00	22.42	10.5	5.18	1.88	7.19	8.61	16.17	23.55	11.55	20.59	16.47	10.34	12.50	25.92	12.32
15	5.50	5.69	26.29	2.47	7.63	7.59	4.47	0.00	15.00	5.25	0.58	2.92	5.48	11.39	3.63	21.27	2.79	4.85	14.84	7.30	9.62	8.53	6.44
16	4.90	4.27	13.97	3.18	2.54	4.84	1.73	0.73	11.55	4.72	0.96	1.88	5.48	8.18	3.20	13.82	14.08	7.81	8.48	6.69	8.65	5.35	23.53
17	2.92	1.90	5.50	3.53	0.85	7.48	1.15	0.73	5.74	0.52	0.77	1.25	4.45	6.72	4.61	2.91	3.05	2.29	4.43	3.25	3.37	0.84	5.60
18	1.38	0.95	4.07	2.83	0.00	3.96	0.36	1.10	2.60	1.57	1.92	1.88	1.37	6.28	3.87	0.73	1.73	2.02	6.84	4.06	3.37	1.51	7.00
19	1.38	3.79	2.42	5.30	0.85	1.76	0.43	2.93	1.15	1.31	0.58	0.42	1.37	7.01	1.85	0.27	1.20	2.29	3.28	0.20	2.88	0.17	3.64
20	0.26	0.95	2.31	1.77	0.85	0.77	0.29	6.96	1.30	3.67	0.58	0.42	3.08	6.57	2.52	1.82	0.00	2.83	2.99	0.61	1.44	0.17	6.72
21	0.09	0.00	1.10	0.71	0.00	0.66	1.23	12.82	0.77	2.62	0.77	0.00	2.05	3.94	1.35	0.73	0.40	1.08	0.77	1.62	0.00	0.00	3.36
22	0.60	1.42	1.32	1.41	0.56	2.86	2.02	10.26	0.84	3.41	0.58	0.63	2.05	4.96	2.71	0.27	1.99	5.92	2.22	2.84	0.00	0.00	2.80
23	0.09	0.47	0.55	0.00	0.00	3.19	2.24	6.96	0.38	1.31	0.58	0.00	1.37	1.17	1.78	0.00	0.66	1.88	0.19	0.61	0.00	0.17	6.44
24	1.03	0.00	0.11	1.41	0.00	2.75	3.39	8.79	0.23	3.41	0.00	1.88	3.08	2.04	3.57	0.27	0.00	1.62	0.00	0.00	0.48	0.00	0.56
25	0.52	2.37	0.11	1.41	0.28	4.62	2.45	6.59	0.00	1.84	0.19	0.21	3.08	0.15	1.66	0.00	1.06	0.13	0.10	0.00	0.00	0.00	0.56
26	2.84	0.47	0.00	1.77	0.28	1.65	2.96	6.23	0.08	3.67	0.38	0.42	1.37	1.75	2.40	0.36	1.99	1.62	0.00	0.00	0.48	0.00	2.52
27	2.58	5.21	0.00	0.00	0.85	0.55	3.82	5.86	0.00	2.36	0.38	0.83	1.37	2.19	1.05	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00
28	3.70	3.32	0.00	0.35	0.85	0.99	3.75	4.03	0.46	3.15	0.00	2.92	2.05	1.90	0.18	0.73	0.93	0.00	0.10	0.00	0.48	0.00	0.00
29	4.64	4.74	0.00	0.00	1.13	0.44	1.59	2.20	0.00	2.62	0.38	1.04	0.00	0.00	0.25	0.00	1.99	0.00	0.00	0.20	0.00	0.00	0.28
30	4.30	2.37	0.11	0.35	0.56	0.33	1.08	0.73	0.00	3.67	0.19	0.00	0.34	2.19	0.62	0.64	1.20	0.00	0.00	0.00	0.00	0.00	0.56
31	4.30	2.37	0.11	0.00	0.28	0.22	0.65	1.10	0.15	2.89	0.58	1.04	0.34	0.00	0.25	0.00	1.20	0.13	0.00	0.00	0.48	0.00	0.28

32	4.39	3.32	0.00	0.00	0.00	0.11	0.65	1.10	0.00	3.67	0.77	0.00	1.03	0.44	0.25	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.28
33	2.24	0.95	0.00	0.00	0.00	0.00	0.29	1.83	0.00	1.05	0.38	0.00	1.03	0.15	0.25	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
34	0.86	1.42	0.00	0.35	0.28	0.00	0.07	1.83	0.00	3.67	0.00	0.00	0.00	0.44	0.43	0.00	2.39	1.75	0.10	0.00	0.00	0.00	0.56
35	1.20	0.95	0.00	0.00	0.00	0.00	0.29	1.10	0.00	0.79	0.19	0.00	0.00	0.00	0.06	0.09	1.20	0.00	0.00	0.00	0.00	0.00	0.28
36	0.52	1.90	0.00	0.00	0.00	0.00	0.22	1.10	0.00	1.31	0.77	0.21	0.00	0.00	0.31	0.00	1.99	0.67	0.00	0.00	0.00	0.00	0.28
37	0.26	1.42	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.52	0.19	0.00	0.34	0.15	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.28
38	0.26	0.95	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.26	0.00	0.00	0.00	0.15	0.00	0.18	2.12	0.54	0.00	0.20	0.00	0.00	0.00
39	0.09	0.47	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.26	0.19	0.00	0.00	0.00	0.00	0.09	0.00	0.54	0.00	0.00	0.00	0.00	0.00
40	0.17	0.00	0.11	0.00	0.00	0.00	0.07	0.37	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.36	0.53	0.00	0.00	0.00	0.00	0.00	0.00
42	0.09	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.20	0.00	0.00	0.00
43	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	0.09	0.00	0.11	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.10	0.00	0.00	0.00	0.56
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00

64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

96	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
97	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00
99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
101	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
102	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
103	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
107	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
108	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
109	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
110	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
111	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
112	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
113	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
114	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
115	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
116	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
117	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
118	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
121	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
122	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
123	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
Total Fish	1163	211	909	283	354	909	1386	273	1307	381	521	480	292	685	1626	1100	753	743	1038	493	208	598	357
Total Tows	108	57	48	46	52	71	96	53	70	82	57	53	65	77	74	59	60	69	50	56	45	40	48

Figures

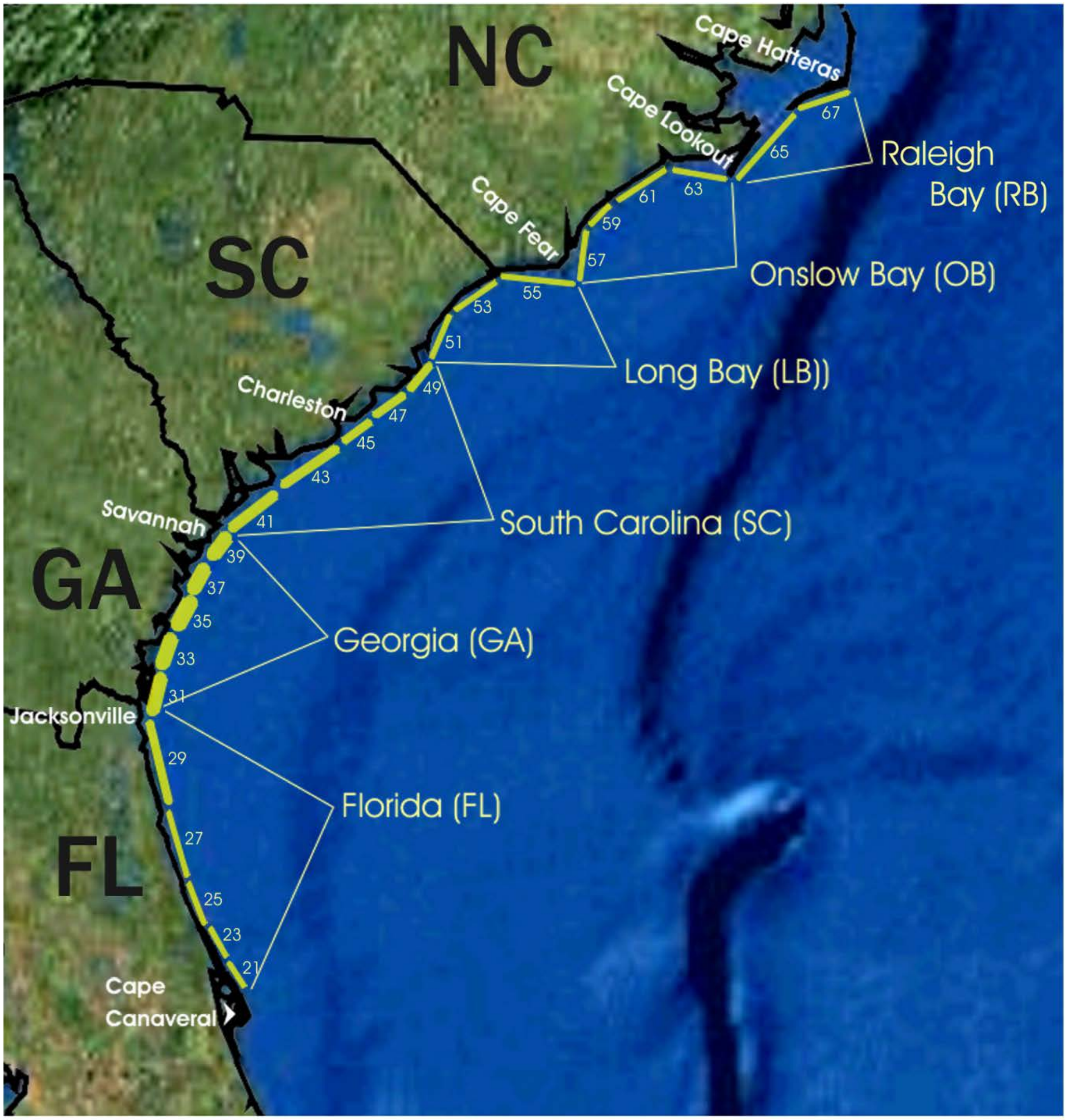


Figure 1. SEAMAP-SA Coastal Trawl Survey regional coverage from 1990 to 2012. Survey areas included in the analysis are Florida (FL, 1), Georgia (GA, 2), South Carolina (SC, 3), Long Bay (LB, 4), Onslow Bay (OB, 5), and Raleigh Bay (RB, 6). All Florida samples collected in Flagler County were removed from analysis.

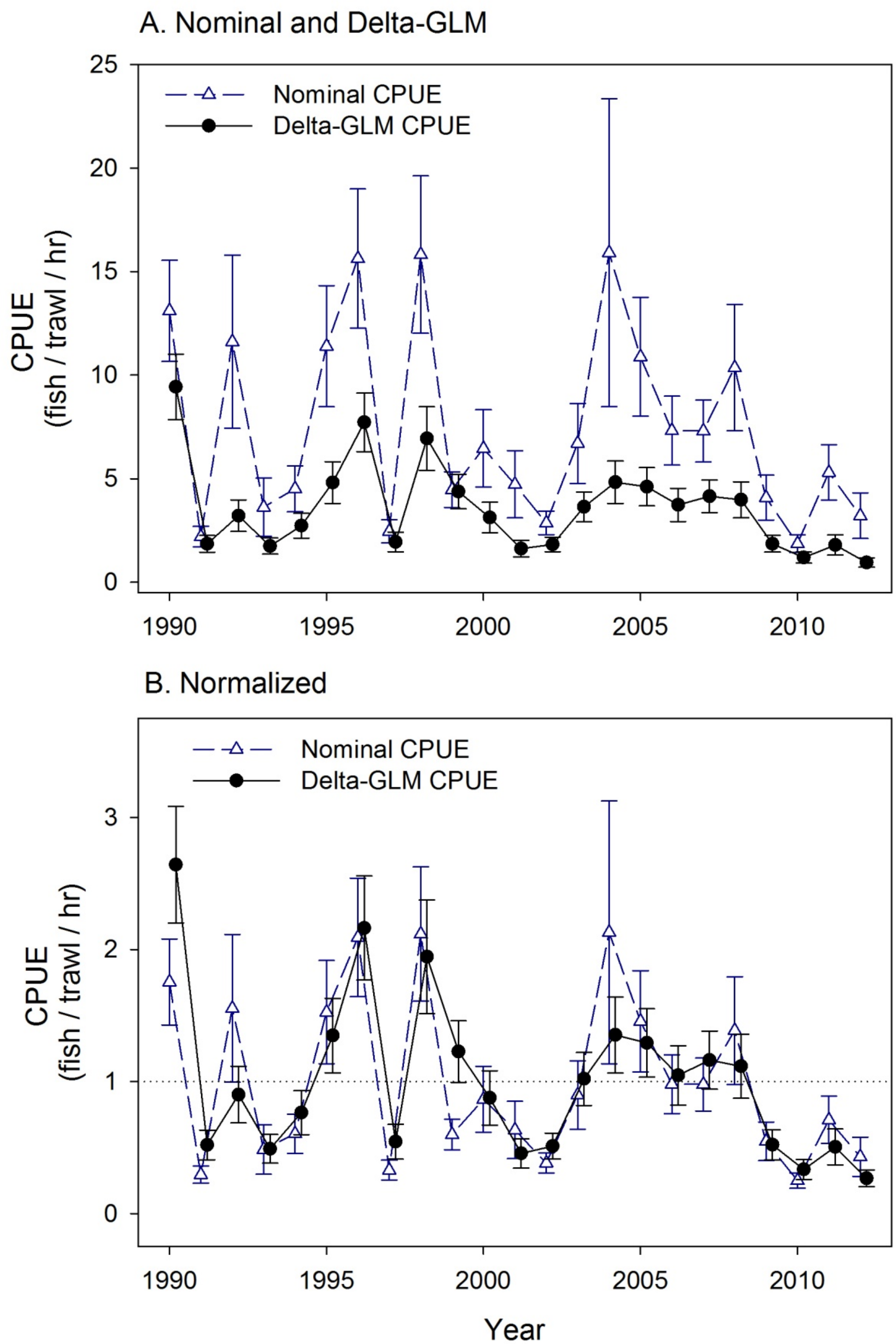


Figure 2. CPUE of king mackerel in the SEAMAP-SA Coastal Trawl Survey from 1990 to 2012. A) Nominal and delta-GLM standardized CPUE and B) CPUE normalized to the time series average. Error bars are the standard error.

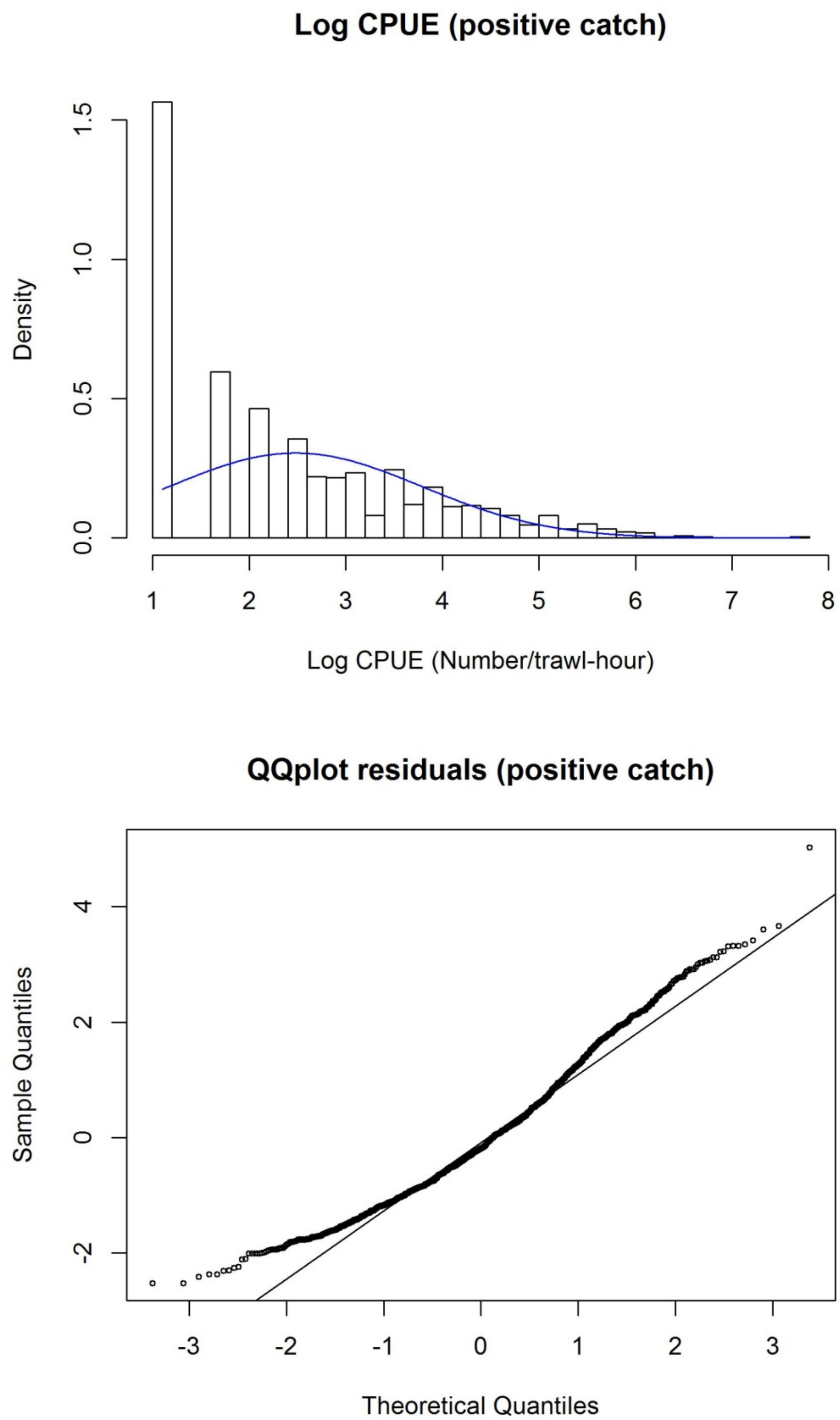
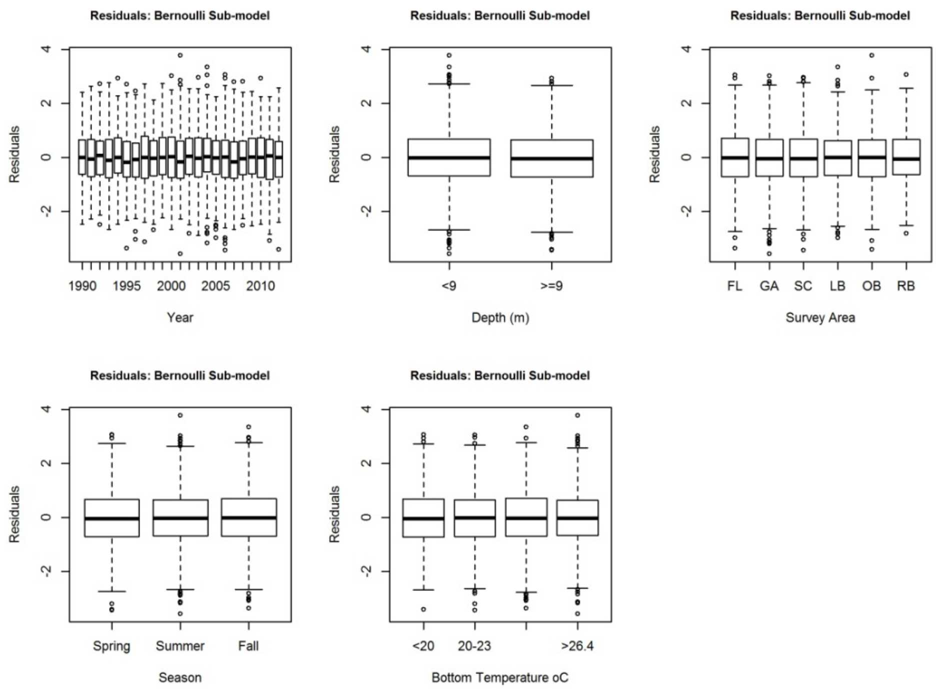


Figure 3. Quantiles from the lognormal model of the delta-GLM standardization of king mackerel CPUE.

A. Bernoulli sub-model



B. Lognormal sub-model

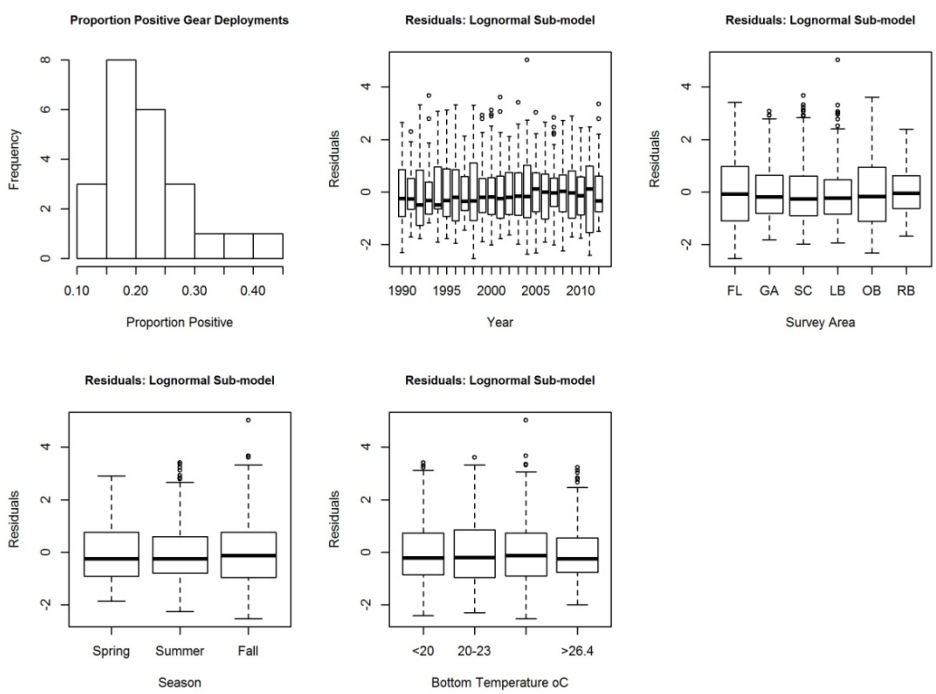


Figure 4. Delta-GLM standardized CPUE residuals for A) the Bernoulli sub-model and B) the lognormal sub-model.

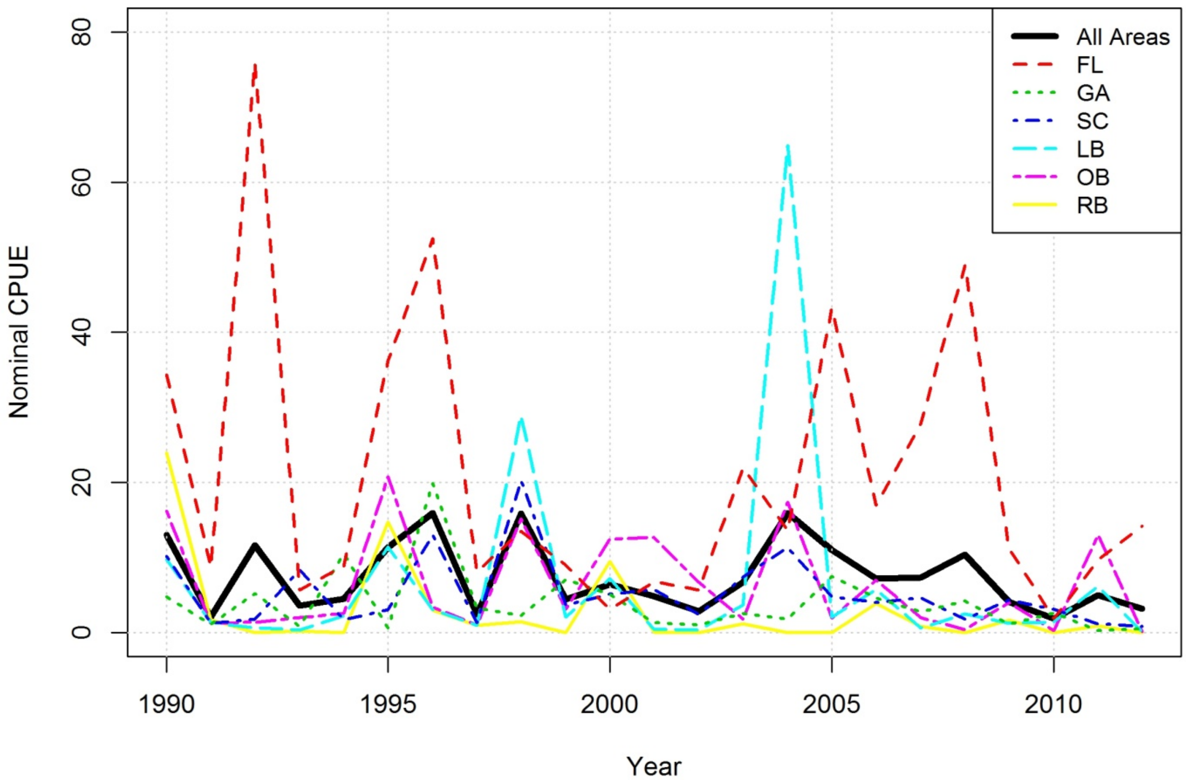


Figure 5. Nominal CPUE of king mackerel in all areas included in the SEAMAP-SA Coastal Trawl Survey from 1990 to 2012.

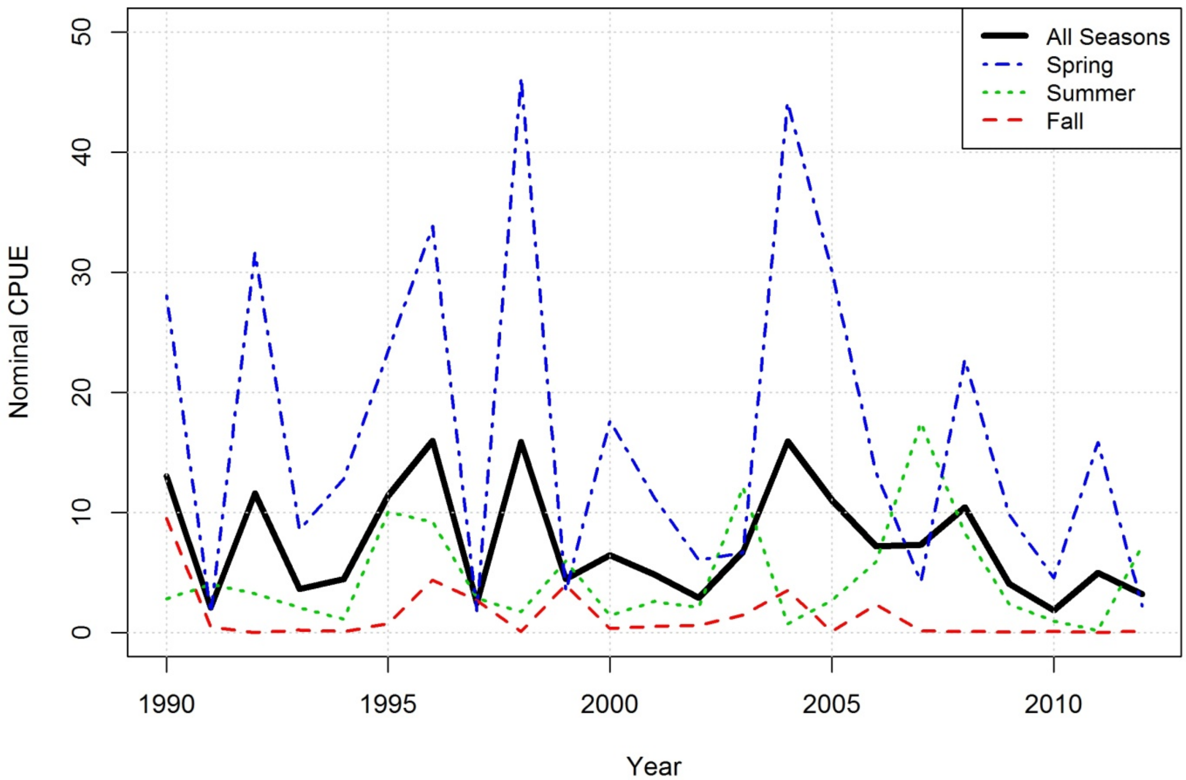


Figure 6. Nominal CPUE of king mackerel in all depths included in the SEAMAP-SA Coastal Trawl Survey from 1990 to 2012.

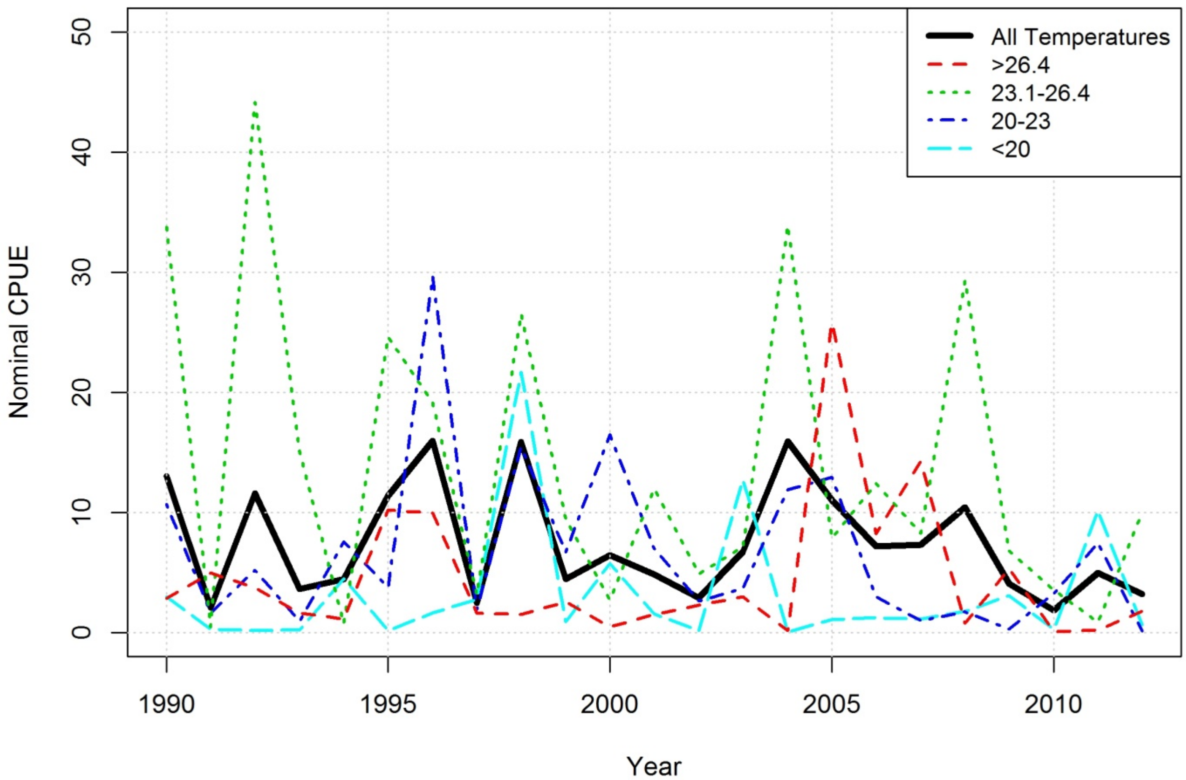


Figure 7. Nominal CPUE of king mackerel in all temperatures included in the SEAMAP-SA Coastal Trawl Survey from 1990 to 2012.

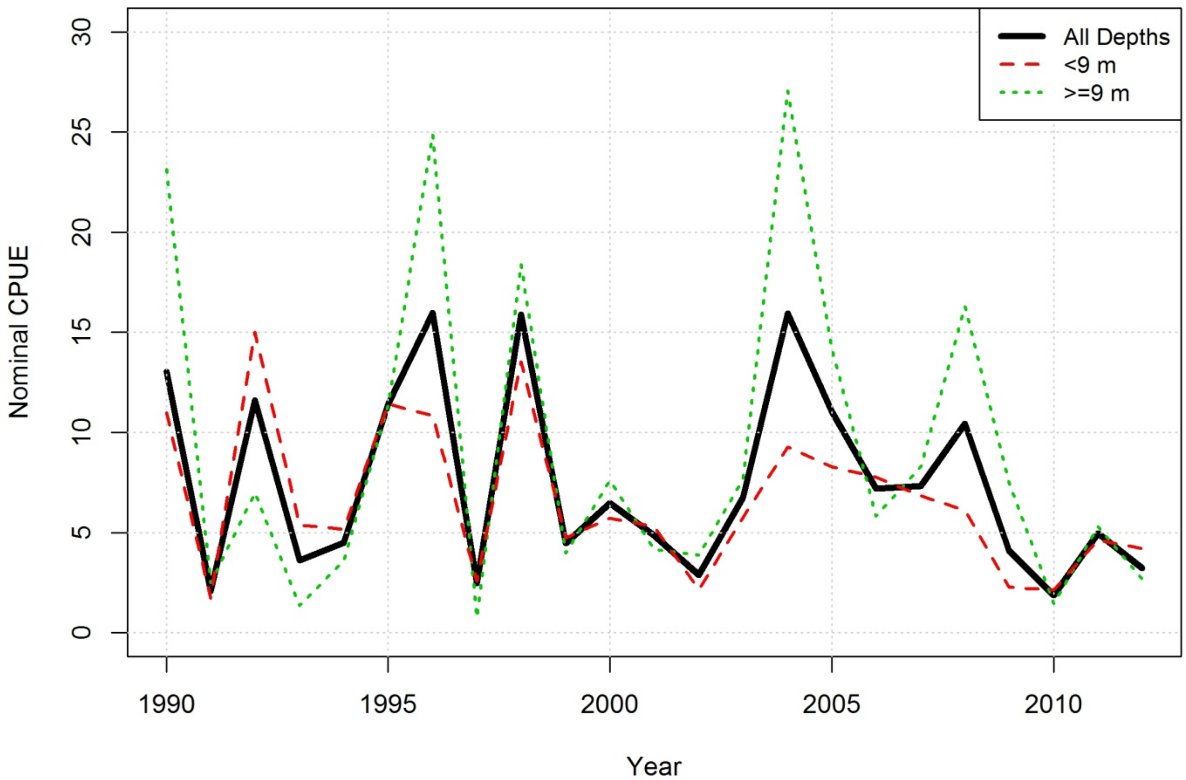


Figure 8. Nominal CPUE of king mackerel in all depths included in the SEAMAP-SA Coastal Trawl Survey from 1990 to 2012.

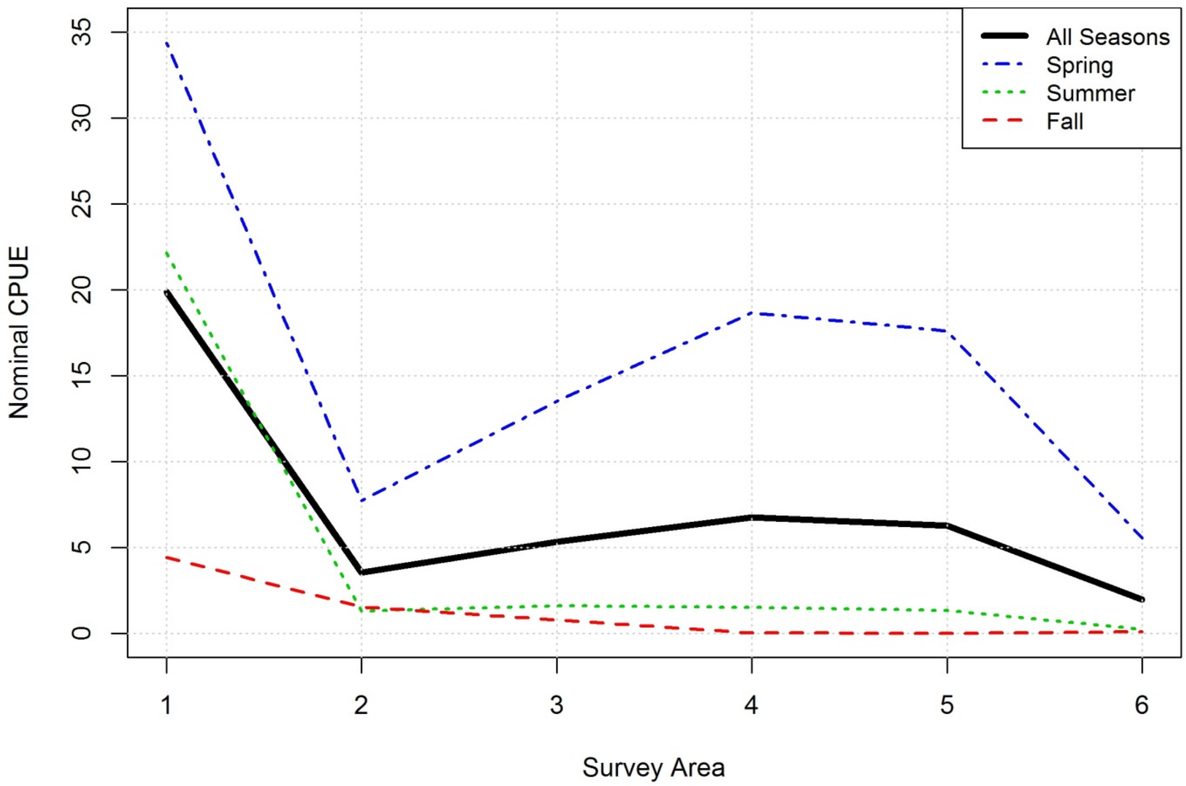


Figure 9. Nominal CPUE of king mackerel in all areas and seasons included in the SEAMAP-SA Coastal Trawl Survey from 1990 to 2012.