Data Summary of King Mackerel (*Scomberomorus cavalla*) Collected During Small Pelagic Trawl Surveys in the U.S. Gulf of Mexico, 1988 – 1996 and 2002-2007

G. Walter Ingram, Jr.
NOAA Fisheries, Southeast Fisheries Science Center, Mississippi Laboratories
Pascagoula, Mississippi

Introduction and Methods

In the early 1980s, the National Marine Fisheries Service (NMFS) initiated a program to investigate the abundance and distribution of the U.S. Gulf of Mexico (GOM) coastal pelagics species complex. Early efforts centered around the development of fishing gear effective at capturing pelagic species, since the use of standard groundfish trawling gear and techniques was believed to be inappropriate for capturing the schooling, fast-swimming pelagics (Link et al. 2000). By the late 1980s, it was determined that large, high-opening trawls offered the best potential for capturing these fishes in deeper waters (Gledhill 1989, Reese 1993), and sampling continued until 1996 (Table 1).

The current small pelagics survey began in October of 2002 as an outer shelf and upper slope survey (i.e. between 110 and 500 m station depth, Table 2). The distributional range of many of species collected in SEAMAP groundfish trawls was suspected to extend well beyond the geographical boundaries of the commercial shrimping grounds where most of NMFS trawling efforts were concentrated. Therefore, in order to more effectively evaluate these extensions of distributional range, trawling stations began to be allocated in shallower depth strata (Table 2) to allow geographic overlap with SEAMAP groundfish effort. By 2004, the survey became a mid to outer shelf and upper slope survey (i.e. between 50 and 500 m station depth, Table 2). Also, due to consistent gear damage in statistical zones 1-3, these areas were dropped in 2004, resulting in coverage between Brownsville, Texas and Sarasota, Florida.

For the historic survey, a total of 15 cruises were conducted from 1988 to 1996, primarily during spring and fall (Table 1). These data are highly imbalanced both spatially and temporally (Table 1) due to varying cruise objectives, temporal constraints, mechanical difficulties, and similar logistical considerations. For the current survey, a total of 5 cruises were conducted between 2002 and 2007 (Table 2). These data are more temporally and spatially balanced than those of the historic survey. This is due to proportional allocation and random placement of trawling stations within strata (Table 2).

During the historic survey, trawling was done with a 27.5 m small pelagics trawl and a 37.5 m Shuman trawl from the NOAA vessel *Chapman.* Sampling designs were either stratified random, two dimensional systematic or systematic random, spanned the entire U.S. Gulf of Mexico (Link et al. 2000, Gledhill 1989, Reese 1993; Table 1), including depths from 10 to 420 m. Bottom trawls were conducted for approximately 30 minute at each station, and total catch per unit effort was standardized to one hour. Cruises associated with the historic small pelagics program that were related to gear development or that were directed sampling were also omitted from this analysis (Link et al. 2000). A comparison between the two types of gear mentioned above was conducted with paired trawls in 1991 indicated that the two gears exhibited no significant

differences in catch rates (Gledhill, unpubl. data). However, gear type was used in this analysis to confirm these results for king mackerel, specifically.

During the current survey, trawling was done with a 27.5 m small pelagics trawl from the NOAA vessel *Gordon Gunter*. The sampling design, in which stations were proportionally allocated, spanned the entire U.S. Gulf of Mexico between Brownsville, Texas and Sarasota, Florida, including depths from 50 to 500 m (see Table 2). Bottom trawls were conducted for approximately 30 minute at each station, and total catch per unit effort was standardized to one hour.

Once onboard, the entire trawl catch was weighed and then subsampled if the catch was greater than 150 kg. Subsamples (or the entire catch if less than 150 kg) were sorted, identified, enumerated, weighed, and measured to the nearest mm following standard NMFS and Southeast Area Monitoring and Assessment Program (SEAMAP) protocols (Link et al. 2000). Environmental data were collected at each station.

A previous study (Link et al. 2000) provided an initial analysis of the historic data that included information on the distribution, abundance, geographic range, catch frequency, and size composition of the most common pelagic species collected during these surveys. The object of this document was to likewise summarize the distribution, abundance, catch frequency, and size composition of GOM king mackerel, *Scomberomorus cavalla*, collected during these studies.

I present results of analyses in which annual abundance indices of catch per unit effort (CPUE, number per trawl-hour) were derived using a backward selection procedure (based on type 3 analysis with an inclusion significance of $\alpha = 0.05$) and the delta-lognormal (DL) approach (Lo et al. 1992; see SEDAR16-DW-08) across combinations of depth and geographic strata, which were assigned *a posteriori*. The strata consisted of East and West GOM geographic regions (i.e., GOM divided at 89.25˚ west longitude) and Stratification by depth and shrimp statistical zone combinations [i.e. four depth strata within each statistical zone (depth stratum 1: <50 m; depth stratum 2: 50-110 m; depth stratum 3: 110-200 m; depth stratum 4: 200-500 m)]. Measurements of bottom temperature, bottom salinity and bottom oxygen concentration were also used in model development. Finally, a length frequency histogram was developed to determine which portion of the stock was represented in these analyses.

Results and Discussion

The data used in these analyses are summarized in Table 3. The number of stations sampled per survey year ranged from 53 in 1991 to 158 in 1993. The number of specimens collected per year ranged from 0 to 219, and ranged in length from 55 to 1270 mm fork length with an overall mean fork length of 469 mm. King mackerel occurred throughout the western and central GOM primarily in waters of less than 200 m in depth (Figure 1). No king mackerel were collected in depth stratum 4, and in depth stratum 3 frequency of occurrence was 0.4 %; therefore, I dropped the data associated with strata 3 and 4 from the analyses. This precluded the use of data from years 2002 and 2003, since the vast majority of sampling was done in depths greater than 110 m. Also, due to the spatially concentrated effort in the De Soto Canyon area in 1991 (see Figure 2), I dropped the data collected during that year from the analysis. The many charts of Figure 2 reiterate the highly imbalanced nature, both spatially and temporally, of effort during the historic survey.

Figure 3 is a length frequency histogram of king mackerel collected in this survey. The bimodal length frequency distribution for all king mackerel measured in this study indicated that the majority of king mackerel captured were between 170 and 470 mm fork length and between 550 and 850 mm fork length (Figure 3). The length frequency distribution itself is skewed to the right with several larger specimens being captured (Figure 3). The median and mean (± standard deviation) fork length of the 401 king mackerel collected and measured during this study was 384 mm and 474 (± 197) mm, respectively (Figure 3). According to findings summarized by Brooks and Ortiz, 2004 (SEDAR5-AW1), the mean sizes of age-0, age-1, age-2 and age-3 king mackerel in the Gulf of Mexico are approximately 517, 621, 711 and 790 mm fork length, respectively. When comparing these age-specific mean lengths to the length frequency distribution of king mackerel collected and measured in the survey (Figure 3), the indices, developed from this survey, index the abundance of age-0, age-1 and age-2 king mackerel in the GOM.

The variables that were retained in the binomial submodel were year, geographic region, season, and bottom temperature. Table 4 summarizes the type 3 analyses of the parameters used in the final binomial submodel and their significance. For the lognormal submodel, the year, depth zone, season, and bottom temperature variables were retained (Table 5). Figure 4 indicates the distribution of the residuals of the lognormal submodel is approximately normal. Table 6 and Figure 5 summarize indices of age-0, age-1 and age-2 king mackerel (number per trawl-hour) developed from the delta-lognormal model.

Due to the aforementioned highly imbalanced nature trawling effort during these surveys, abundance indices show much standardization when compared to nominal CPUE and frequency of occurrence values (Table 6 and Figure 5). However, the coefficients of variation (CVs) are not astronomic (Table 6). The main weakness of this database would be the large data holidays during the central part of the time series (Table 6 and Figure 5). Therefore, the use of this data for abundance indices could be problematic. However, the data do provide insight into the distribution of age-0, age-1 and age-2 king mackerel to 110 m in depth in the GOM. Since 2004, the current small pelagics survey has been conducted in depths from 50 to 500 m, and in the future this survey could prove valuable in providing indices for young king mackerel.

Literature Cited

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Table 1. Summary of trawling effort for historic small pelagics trawl surveys (from Link et al. 2000). Latitudes and longitudes are in degrees and minutes North and West respectively. Gear size is the headrope length, in meters, of the trawl. SysRdm=systematic random, 2DSys=two-dimensional systematic, StratRdm=stratified random.

Year	88	89	90	91	92	93	94	95	96
Cruise	88-03	89-04	90-02,90-03	91-01	92-01	93-03	94-02	95-07	96-06
Months	3,4	8,9	3,4,5	1,2	3,4	3,4	3,4	10,11	10,11
Survey Design	SysRdm	StratRdm	SysRdm,2DSys	StratRdm	SysRdm	SysRdm	SysRdm	StratRdm	StratRdm
Cruise	88-08	89-05	90-08	--	92-06	93-07	--	--	--
Months	10,11	10,11	10,11	--	10,11	10,11	--	--	--
Survey Design	2DSys	SysRdm	SysRdm	--	SysRdm	SysRdm	--	--	--
Total # Stations	154	65	118	53	123	158	81	67	92
Max Latitude	30°59.46'	29°58.48'	30°59.90'	29°59.48'	30°59.84'	29°59.79'	30°59.60'	30°58.12'	29°59.48'
Min Latitude	27°00.09'	27°00.92'	27°00.15'	29°35.44'	27°00.45'	26°00.01'	27°00.00'	27°00.97'	26°00.41'
Max Longitude	96°59.95'	91°59.48'	94°58.92'	87°48.58'	93°56.85'	97°59.90'	91°58.50'	97°57.79'	97°59.11'
Min Longitude	83°00.09'	85°02.69'	85°01.73'	86°19.54'	82°00.30'	88°01.00'	83°00.40'	84°01.83'	84°00.26'
Gear Size	37.5	37.5	37.5	37.5,27.5	27.5,37.5	27.5,37.5	27.5	27.5	27.5

Table 2. Current small pelagics trawl surveys.

Year	Cruise	Survey Dates	Depth Range of Survey	Number of Trawl Stations Allocated for Sampling	Number of Trawl Stations Attempted	Allocation Methodology	Comments
2002	Gordon Gunter, 0206	10/10/02-11/21/02	110-500 m	153	153	Shrimp statistical zones extended through depth strata (i.e. 110 to 200 m and 200 to 500 m). Proportional allocation based on stratum area with 90 % effort between 110 and 200 m and 10 % between 200 and 500 m.	10 stations deemed untrawlable
2003	Gordon Gunter, 0304	10/07/03-11/17/03	90-500 m	153	153	Shrimp statistical zones extended through depth strata (i.e. 90 to 110 m, 110 to 200 m and 200 to 500 m). Proportional allocation based on stratum area with 80 % effort between 110 and 200 m and 10 % between 200 and 500 m and 10% between 90 and 110 m.	11 stations deemed untrawlable
2004	Gordon Gunter, 0405	10/07/04-11/19/04	50-500 m	155	96	Shrimp statistical zones extended through depth strata (i.e. 50 to 110 m, 110 to 200 m and 200 to 500 m). Proportional allocation based on stratum area with 60 % effort between 110 and 200 m and 10 % between 200 and 500 m and 30% between 50 and 110 m.	Remaining stations lost due to change in cruise objectives (i.e. assisted with SEAMAP fall groundfish survey).
2005				0			Hurricane Katrina, no Survey. Vessel assisted with SEAMAP fall groundfish survey.
2006	Gordon Gunter, 0605	10/12/06-11/19/06	50-500 m	155	104	Shrimp statistical zones extended through depth strata (i.e. 50 to 110 m, 110 to 200 m and 200 to 500 m). Proportional allocation based on stratum area with 60 % effort between 110 and 200 m and 10 % between 200 and 500 m and 30% between 50 and 110 m.	Remaining stations lost due to change in cruise objectives (i.e. assisted with SEAMAP fall groundfish survey).
2007	Gordon Gunter, 0706	10/09/07-11/21/07	50-500 m	155	155	Shrimp statistical zones extended through depth strata (i.e. 50 to 110 m, 110 to 200 m and 200 to 500 m). Proportional allocation based on stratum area with 60 % effort between 110 and 200 m and 10 % between 200 and 500 m and 30% between 50 and 110 m.	9 stations deemed untrawlable

Table 3. Summary of the data used in these analyses.

Survey Year	Total Number of Stations	Number of Stations Used in Analyses	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation
1988	154	56	0					
1989	65	34	54	19	223	1000	578	209
1990	118	60	88	32	214	1032	669	213
1991	53	0	0					
1992	123	67	100	49	351	1270	631	193
1993	158	112	219	104	260	890	453	189
1994	81	53	26	13	226	437	368	51
1995	67	53	100	47	283	834	530	171
1996	92	49	124	62	264	586	339	47
2002	143	0	0					
2003	127	0	0					
2004	102	36	52	14	292	591	373	74
2006	77	39	16	8	57	794	354	229
2007	145	46	134	53	55	903	395	153
Total Number of Years when Sampling Occurred 14 years	Total Number of Stations 1505	Total Number of Stations Used in Analyses 605	Total Number Collected 913	Total Number Measured 401			Overall Mean Fork Length (mm) 474	Overall Standard Deviation 197

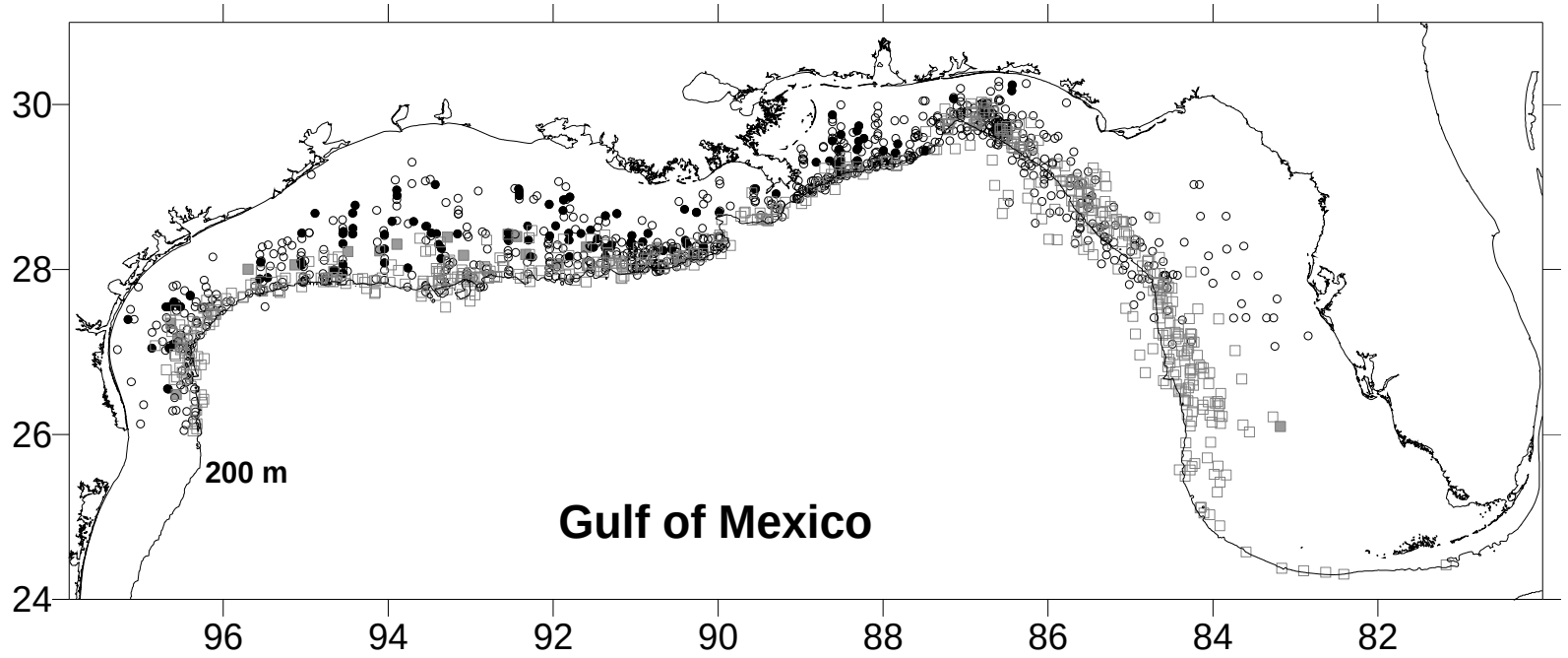


Figure 1. Trawling effort included in this study (black open circles represent historic survey effort, 1988-1996; gray open squares represent current survey effort, 2002-2007) and stations where king mackerel were collected (closed black circles and closed gray squares). The horizontal axis is in degrees west longitude, and the vertical axis is in degrees north latitude.

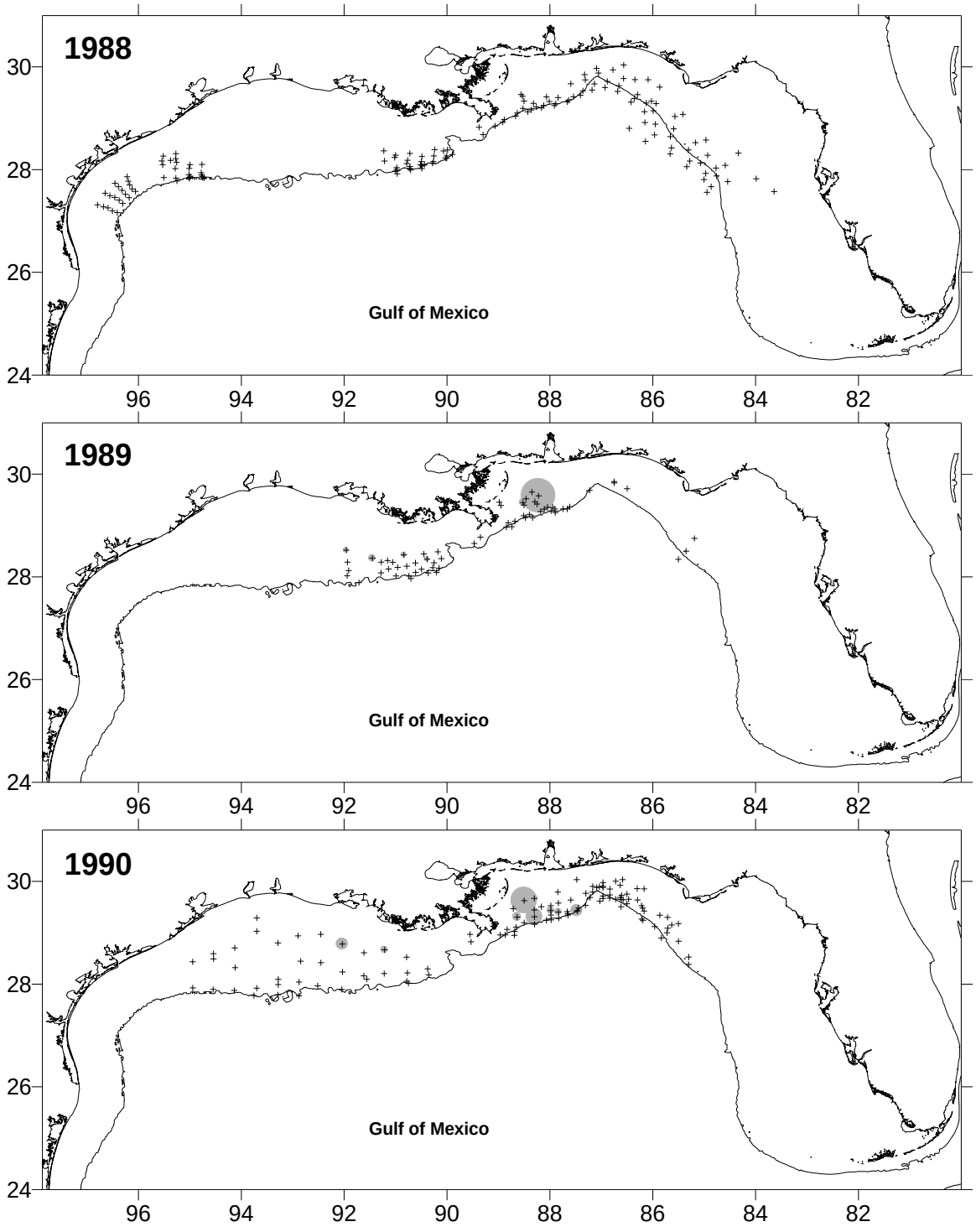
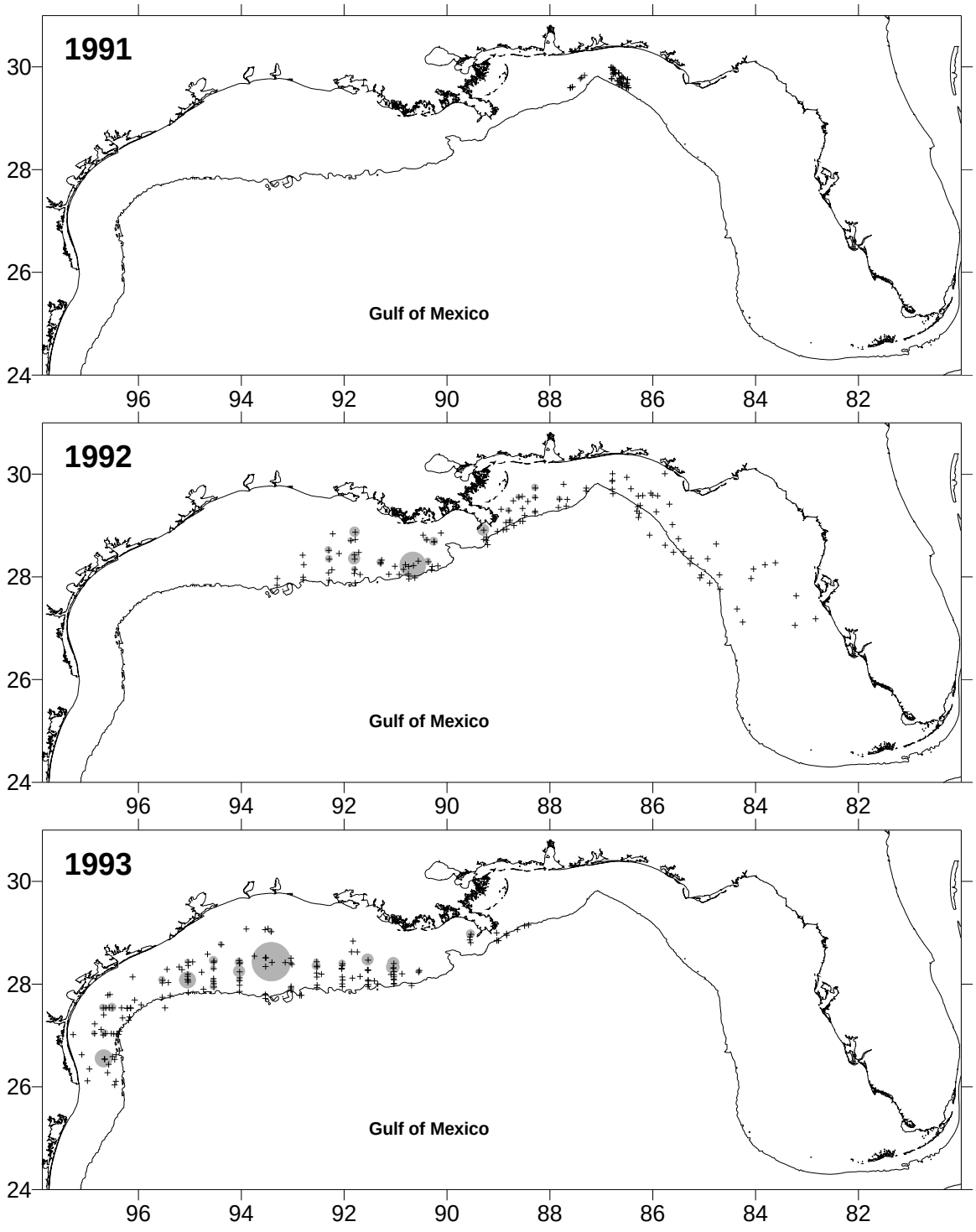


Figure 2. This figure consists of 14 charts each depicting trawling effort (crosses) and stations where king mackerel were collected (gray circles, linearly related to CPUE, ranging from 2 to 44 fish per trawl hour) for each year of this study. The horizontal axes are in degrees west longitude, and the vertical axes are in degrees north latitude.



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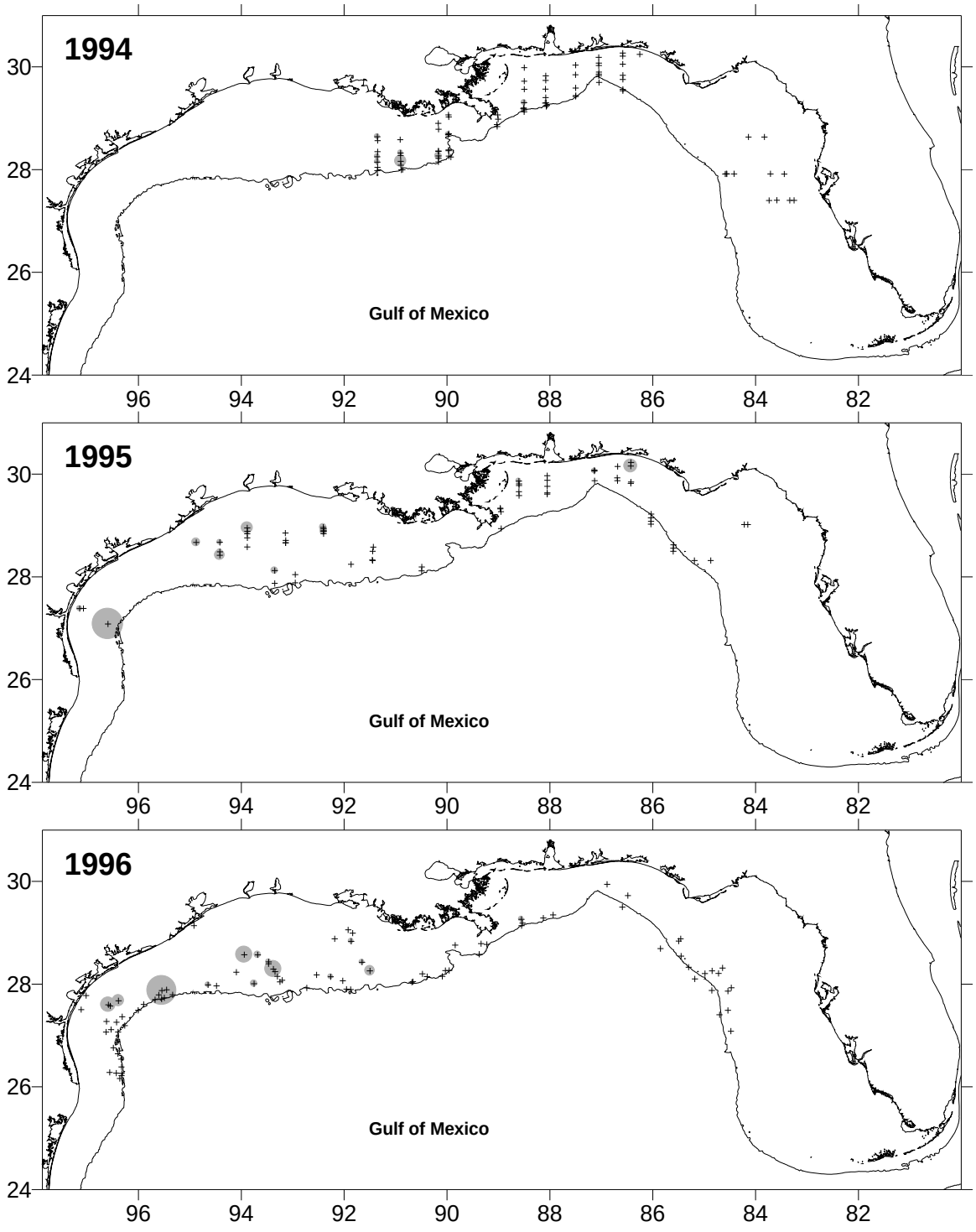

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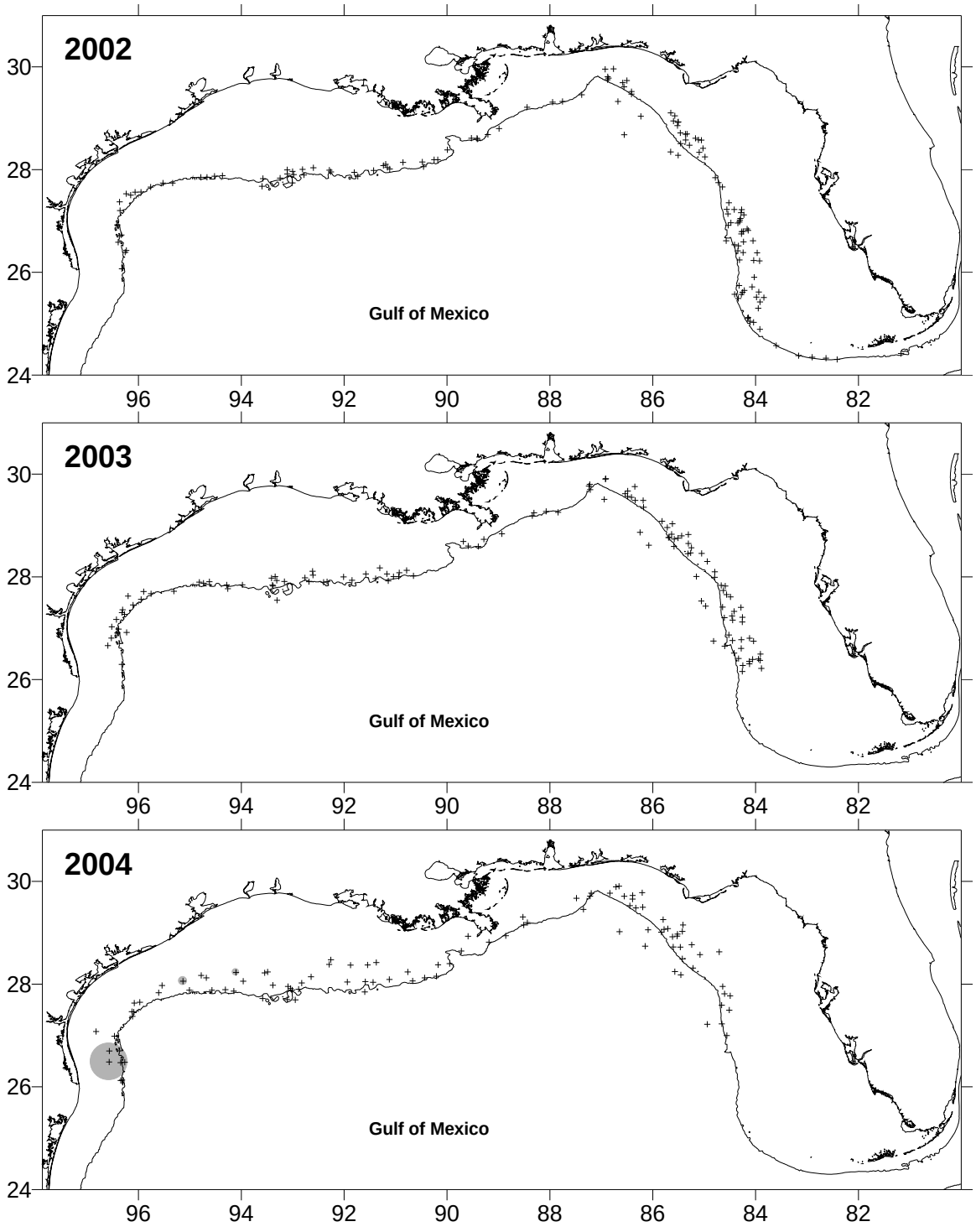

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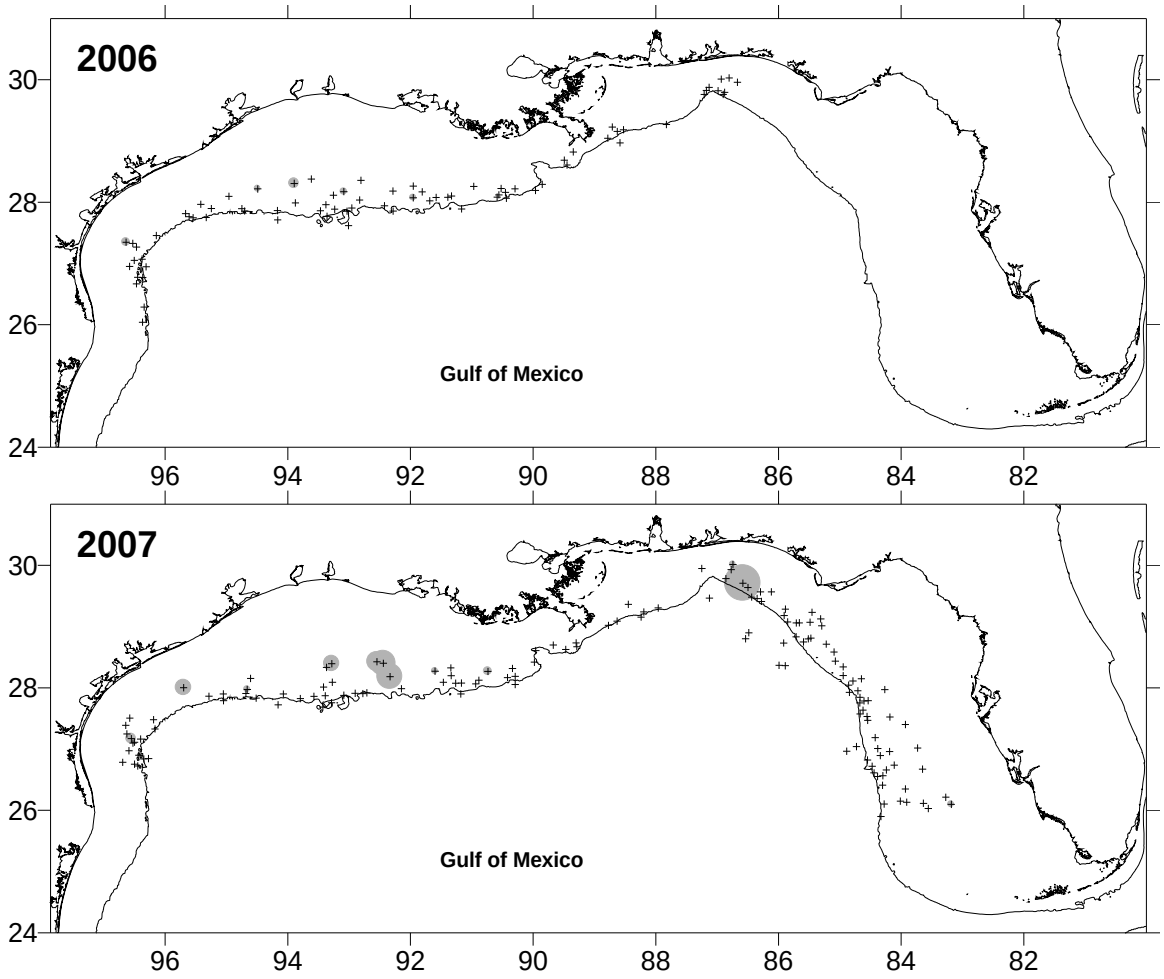

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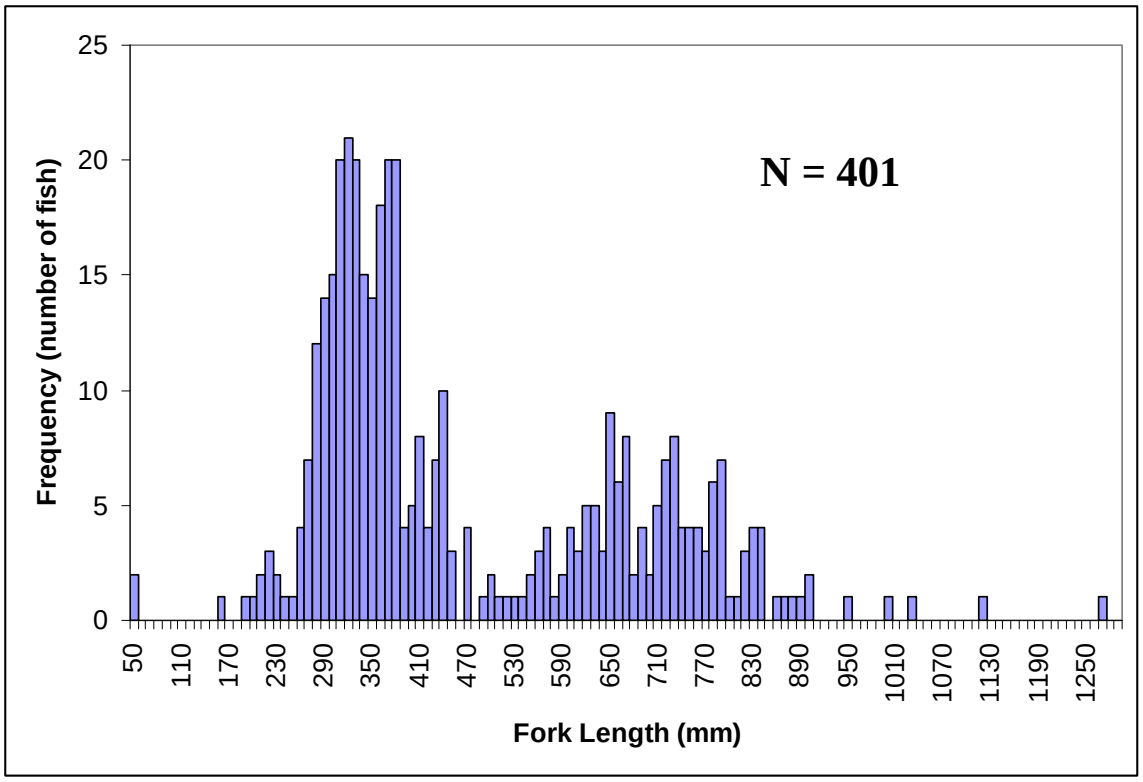

Figure 3. Length frequency of king mackerel collected during this study.

Table 4. Type 3 tests of fixed effects for the binomial submodel.

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
Year	9	498	24.61	2.73	0.0034	0.0040
Region	1	498	11.36	11.36	0.0007	0.0008
Season	1	498	11.38	11.38	0.0007	0.0008
Temperature	1	498	12.03	12.03	0.0005	0.0006

Table 5. Type 3 tests of fixed effects for the lognormal submodel.

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	9	102	1.21	0.2967
Depth Zone	1	102	5.62	0.0196
Season	1	102	4.77	0.0313
Temperature	1	102	6.10	0.0152

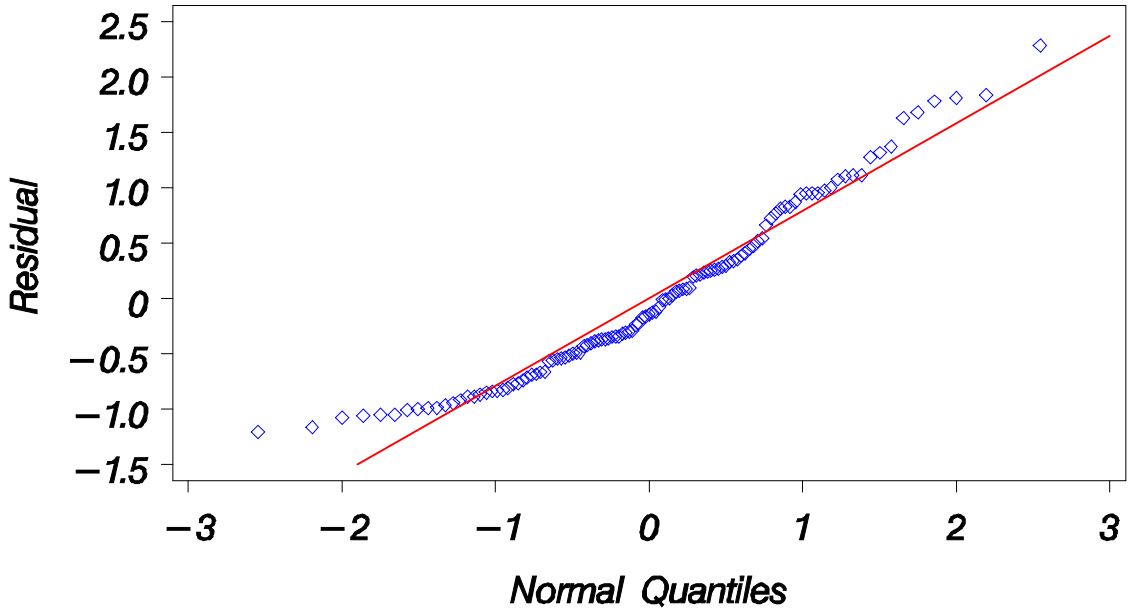

Figure 4. QQ plot of residuals of the lognormal submodel.

Table 6. Indices of age-0 king mackerel collected in small pelagics trawl surveys in the U.S. Gulf of Mexico developed using the delta-lognormal (DL) model. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the nominal and DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	*Frequency*	*N*	*DL Index*	*Scaled Nominal*	*Scaled Index*	*CV*	*LCL*	*UCL*
1988	0.00000	56	0.00000	0.00000	0.00000			
1989	0.20588	34	0.64063	1.13227	0.78408	0.65380	0.23779	2.58544
1990	0.16667	60	1.94133	1.04407	2.37605	0.42874	1.04484	5.40331
1992	0.28358	67	1.52445	1.06404	1.86582	0.35091	0.94380	3.68859
1993	0.28571	112	0.91564	1.39666	1.12068	0.35187	0.56588	2.21939
1994	0.13208	53	1.06608	0.32475	1.30481	0.53591	0.47765	3.56436
1995	0.30189	53	0.65051	1.34251	0.79617	0.46514	0.32855	1.92934
1996	0.32653	49	0.36461	1.80222	0.44626	0.57531	0.15316	1.30027
2004	0.08333	36	0.32786	1.02885	0.40128	0.86658	0.08982	1.79281
2006	0.12821	39	0.23336	0.29697	0.28562	0.71202	0.07935	1.02807
2007	0.23913	46	0.50594	1.56766	0.61924	0.52336	0.23147	1.65663

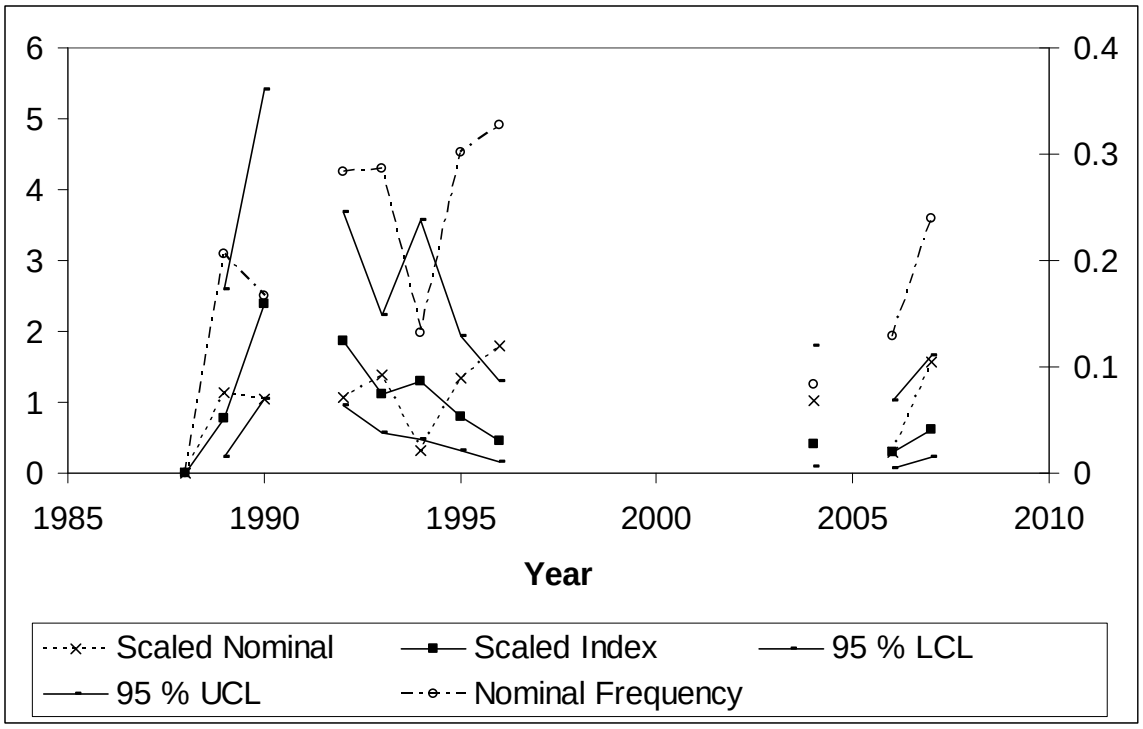

Figure 5. Index of relative abundance of age-0 king mackerel collected in small pelagics trawl surveys in the U.S. Gulf of Mexico. The left vertical axis represents relative CPUE units. Both the index values and the nominal values are scaled to mean of one across the time series. The right vertical axis represents nominal frequency of occurrence.