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King Mackerel Abundance Indices from NFMS Small Pelagics Surveys in the Northern Gulf of Mexico

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Abstract

The NMFS 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) in order to investigate if the distributional range of many of species collected in SEAMAP groundfish surveys extended beyond the geographical boundaries of the commercial shrimping grounds. By 2004, the survey became a mid to outer shelf and upper slope survey (i.e. between 50 and 500 m station depth) in order to overlap some of the area covered by the SEAMAP groundfish survey. These fisheries independent data were used to develop abundance indices for age 0 king mackerel (Scomberomorus cavalla). Annual abundance indices show a peak of abundance in 2007, with a subsequent decline in 2008 that has remained relatively unchanged through 2012.

Introduction

The NMFS 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). 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 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). While this survey data has not been utilized in previous stock assessments, mainly due to the short duration of the survey, it potentially could provide an important source of fisheries independent information on many commercially and recreationally important species throughout the northern GOM. The purpose of this document is to provide abundance indices for king mackerel (*Scomberomorus cavalla*).

Methodology

Survey Design / Data

The survey methodologies used herein have been presented in detail by Ingram (2008). Trawl sampling was conducted using a 27.4 m (90 foot) high-opening fish trawl. Stations are selected with a proportional allocation based on stratum area with 30% effort between 50 and 110 m, 60% effort between 110 and 200 m and 10 % effort between 200 and 500 m. A total of 1259 stations were sampled from 2002- 2012 (Tables 1). Trawl data was obtained from the NMFS Mississippi Laboratories trawl unit leader (Gilmore Pellegrin).

Data Exclusions

Data was limited to only those stations that did not indicate a problem with the tow, and were outside of shrimp statistical zone 12. There were no king mackerel collected between 200 and 500 m and only three occurrences (< 1% occurrence) in 110 to 200 m, therefore stations in these depths were dropped from the analysis (566 stations), since these depths seem to be past the range of king mackerel collected during the survey. This precluded the use of data from years 2002 and 2003 (132 and 146 stations, respectively), since the vast majority of sampling was done in depths greater than 110 m.

Index Construction

Delta-lognormal modeling methods were used to estimate relative abundance indices for king mackerel (Lo *et al*. 1992). The main advantage of using this method is allowance for the probability of zero catch (Ortiz *et al.* 2000). The index computed by this method is a mathematical combination of yearly abundance estimates from two distinct generalized linear models: a binomial (logistic) model which describes proportion of positive abundance values (i.e. presence/absence) and a lognormal model which describes variability in only the nonzero abundance data (Lo *et al*. 1992).

The delta-lognormal index of relative abundance (I_y) as described by Lo *et al*. (1992) was estimated as:

(1) $$I_y = c_y p_y,$$

where c_y is the estimate of mean CPUE for positive catches only for year y, and p_y is the estimate of mean probability of occurrence during year y. Both c_y and p_y were estimated using generalized linear models. Data used to estimate abundance for positive catches (c) and probability of occurrence (p) were assumed to have a lognormal distribution and a binomial distribution, respectively, and modeled using the following equations:

(2) $$\ln(c) = X\beta + \varepsilon$$

and

(3) $$p = \frac{e^{\mathbf{X\beta+\varepsilon}}}{1+e^{\mathbf{X\beta+\varepsilon}}},$$

respectively, where c is a vector of the positive catch data, p is a vector of the presence/absence data, X is the design matrix for main effects, β is the parameter vector for main effects, and ε is a vector of independent normally distributed errors with expectation zero and variance σ^2. Therefore, c_y and p_y were estimated as least-squares means for each year along with their corresponding standard errors, SE(c_y) and SE(p_y), respectively. From these estimates, I_y was calculated, as in equation (1), and its variance calculated as:

(4) $$V(I_y) \approx V(c_y)p_y^2 + c_y^2 V(p_y) + 2c_y p_y \mathrm{Cov}(c, p),$$

where:

(5) $$\text{Cov}(c, p) \approx \rho_{\text{c,p}} \left[\text{SE}(c_y) \text{SE}(p_y) \right],$$

and $\rho_{c,p}$ denotes correlation of *c* and *p* among years.

The submodels of the delta-lognormal model were built using a backward selection procedure based on type 3 analyses with an inclusion level of significance of $\alpha = 0.05$. Binomial submodel performance was evaluated using AIC, while the performance of the lognormal submodel was evaluated based on analyses of residual scatter and QQ plots in addition to AIC. Variables that could be included in the submodels were:

Submodel Variables (Continuity)

Year: 2004 – 2012
Region: Texas, Louisiana, Mississippi/Alabama, Florida
Time of Day: Day, Night
Depth: 27-60 fathoms (continuous)

Results and Discussion

Age and Size

The distribution of king mackerel is presented in Figure 1, with annual abundance and distribution presented in the Appendix Figure 1. The total number of king mackerel captured ranged from 8 to 51 (Table 3). Of the 188 king mackerel captured during the survey, a total of 152 were measured from 2004 – 2012 with an average total length of 388 mm. The length frequency distribution of king mackerel captured is shown in Figure 3. Aging of otoliths (49) from 2009 to 2012 by the NFMS Panama City Laboratory revealed that the majority of king mackerel collected during the survey were age 0 (46) ranging in size from 235 mm to 463 mm. There were also two age 1 king mackerel (527 mm and 595 mm) and one age 6 (750 mm).

Abundance Index

For the NMFS Small Pelagics abundance index of king mackerel, the nominal CPUE and number of stations with a positive catch are presented in Figure 3. Year, region, time of day and depth were retained in the binomial submodel, while only year was retained in the lognormal submodel. A summary of the factors used in the analysis is presented in Appendix Table 1. Table 4 summarizes the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 2349.0 and 124.2, respectively. There was a slight increase in AIC for the lognormal submodel between runs two, three and four (123.5, 123.4 and 124.4, respectively), however since none of the factors were significant, it was deemed acceptable. The diagnostic plots for the binomial and lognormal submodels are shown in Figures 4-6, and indicated the distribution of the residuals is somewhat divergent from normal. Annual abundance indices are presented in Table 5 and Figure 7.

Considerations

This survey appears to cover the same age class of king mackerel that is covered in the SEAMAP groundfish survey. However this survey does not sample the full range of king mackerel and may be of limited use. In addition, the uptick in the relative abundance index (Figure 7) in 2011 is mainly due to one high catch of king mackerel off south Florida. This catch is actually the highest of the time series (75 fish per hour), and some caution should be exercised since this area has not been consistently sampled over the course of the survey.

Literature Cited

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Table 1. Number of stations sampled by shrimp statistical zone during the NMFS Small Pelagics survey from 2002-2012. (Note: No survey was conducted in 2005 due to Hurricane Katrina and in 2006, the vessel was repurposed to conduct SEAMAP groundfish survey after leg 1)

	Shrimp Statistical Zone																		
Year	2	3	4	5	6	8	9	10	11	13	14	15	16	17	18	19	20	21	***Total***
2002	5	14	19	12	1	18	13	3	2	5	5	7	6	7	4		9	2	***132***
2003		10	21	15	2	18	18	4	4	5	4	8	7	8	5		11	6	***146***
2004			1	7	2	17	12	4	3	4	5	8	6	9	6	1	9	7	***101***
2005																			
2006							5	4	5	5	7	8	6	11	6		9	7	***73***
2007		1	22	18	5	17	12	3	4	7	7	7	7	9	7	1	12	7	***146***
2008	3	16	22	19	5	18	14	4	5	3	7	8	9	8	7		13	6	***167***
2009	1	7	10	9	4	13	13	4	3	4	8	6	6	10	7	1	11	5	***122***
2010	3	13	13	9	2	11	17	1	4	3	4	10	6	9	6	1	13	5	***130***
2011	2	13	16	12	3	12	11	7	1	3	12	8	8	6	7	2	7	1	***131***
2012		9	11	5	2	10	13	2	1	2	5	10	7	10	5	2	11	6	***111***
Total	***14***	***83***	***135***	***106***	***26***	***134***	***128***	***36***	***32***	***41***	***64***	***80***	***68***	***87***	***60***	***8***	***105***	***52***	***1259***

Table 2. Number of stations sampled by shrimp statistical zone used in the analysis during the NMFS Small Pelagics survey from 2002-2012. (Note: No stations were used from 2002 and 2003 because of changes in depth sampled. No survey was conducted in 2005 due to Hurricane Katrina and in 2006, the vessel was repurposed to conduct SEAMAP groundfish survey after leg 1)

	Shrimp Statistical Zone																		
Year	2	3	4	5	6	8	9	10	11	13	14	15	16	17	18	19	20	21	***Total***
2002																			
2003																			
2004					2	3	2	1		2	2	5	4	4	3	1	4	2	***35***
2005																			
2006							1	1	2	2	5	7	3	6	3		7	3	***40***
2007			5	5	2	5	2	1	1	3	3	3	3	4	4	1	5	2	***49***
2008		9	5	5	4	4	1	2	2	1	3	4	4	2	3		5	1	***55***
2009					2		2	3		1	4	2	5	7	5	1	10	3	***45***
2010	3	7	6	4	1		3		2	1	3	8	2	8	4	1	8	4	***65***
2011	1	10	7	8	3	2	3	3	1		5	5	6	2	4	2	6	1	***69***
2012		4	4	3	2	1	3	1	1	2	2	6	6	6	3	2	7	4	***57***
Total	***4***	***30***	***27***	***25***	***16***	***15***	***17***	***12***	***9***	***12***	***27***	***40***	***33***	***39***	***29***	***8***	***52***	***20***	***415***

Table 3. Summary of the king mackerel length data collected during NMFS Small Pelagics surveys conducted between 2002 and 2012. (Note: no survey was conducted in 2005 due to Hurricane Katrina)

Survey Year	*Number of Stations*	*Number of Analyzed Stations*	*Number Collected*	*Number Measured*	*Minimum Fork Length (mm)*	*Maximum Fork Length (mm)*	*Mean Fork Length (mm)*	*Standard Deviation (mm)*
2002	132							
2003	146							
2004	101	35	26	14	292	591	373	74
2005	0							
2006	73	40	8	8	199	794	418	205
2007	146	49	51	51	254	825	392	111
2008	167	55	10	10	148	790	375	242
2009	122	45	12	12	232	999	467	218
2010	130	65	15	15	273	400	336	36
2011	131	69	48	24	26	594	372	142
2012	111	57	18	18	212	750	373	115
Total Number of Years	Total Number of Stations	Total Number of Stations for Analysis	Total Number Collected	Total Number Measured			Overall Mean Fork Length (mm)	
10 (8)	1259	415	188	152			184	

Table 4. Summary of backward selection procedure for building delta-lognormal submodels for king mackerel NMFS Small Pelagics survey index of relative abundance from 1972 to 2012.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 2349.0)*						*Lognormal Submodel Type 3 Tests (AIC 128.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	382	17.52	2.50	0.0144	0.0159	7	36	1.80	0.1182
Region	2	382	15.93	7.96	0.0003	0.0004	2	36	3.25	0.0504
Time of day	1	382	24.23	24.23	<.0001	<.0001	1	36	3.33	0.0763
Depth Zone	1	382	20.55	20.55	<.0001	<.0001	1	36	2.75	0.1058
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 2349.0)*						*Lognormal Submodel Type 3 Tests (AIC 123.5)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	382	17.52	2.50	0.0144	0.0159	7	37	1.93	0.0926
Region	2	382	15.93	7.96	0.0003	0.0004	2	37	2.02	0.1469
Time of day	1	382	24.23	24.23	<.0001	<.0001	1	37	1.63	0.2096
Depth Zone	1	382	20.55	20.55	<.0001	<.0001	dropped			
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 2349.0)*						*Lognormal Submodel Type 3 Tests (AIC 123.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	382	17.52	2.50	0.0144	0.0159	7	38	1.82	0.1118
Region	2	382	15.93	7.96	0.0003	0.0004	2	38	1.86	0.1692
Time of day	1	382	24.23	24.23	<.0001	<.0001	dropped			
Depth Zone	1	382	20.55	20.55	<.0001	<.0001	dropped			
Model Run #4	*Binomial Submodel Type 3 Tests (AIC 2349.0)*						*Lognormal Submodel Type 3 Tests (AIC 124.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	7	382	17.52	2.50	0.0144	0.0159	7	40	1.61	0.1619
Region	2	382	15.93	7.96	0.0003	0.0004	dropped			
Time of day	1	382	24.23	24.23	<.0001	<.0001	dropped			
Depth Zone	1	382	20.55	20.55	<.0001	<.0001	dropped			

Table 5. Indices of king mackerel abundance developed using the delta-lognormal model for NMFS Small Pelagics surveys from 2004-2012. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the 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. (Note: No survey was conducted in 2005 due to Hurricane Katrina)

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
2004	0.08571	35	0.56138	1.02964	0.72696	0.27985	3.78834
2005							
2006	0.12500	40	0.25984	0.47659	0.50570	0.18351	1.23775
2007	0.22449	49	1.77971	3.26424	0.35374	1.64263	6.48671
2008	0.12727	55	0.34650	0.63553	0.38660	0.30128	1.34062
2009	0.13333	45	0.22347	0.40988	0.45456	0.17227	0.97520
2010	0.06154	65	0.14017	0.25709	0.64391	0.07917	0.83492
2011	0.05797	69	0.72722	1.33381	0.68661	0.38484	4.62282
2012	0.14035	57	0.32344	0.59323	0.41020	0.26958	1.30544

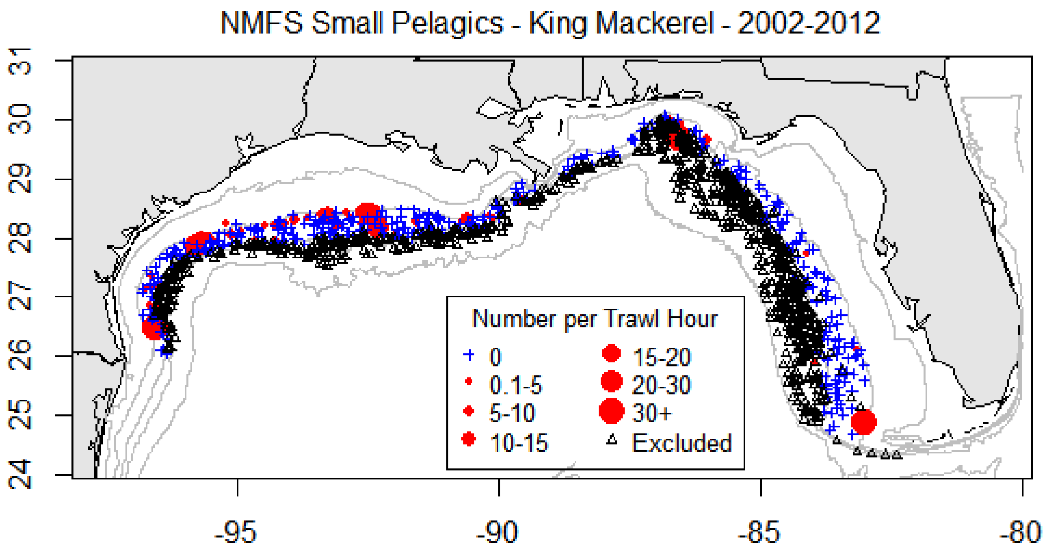


Figure 1. Stations sampled from 2002 to 2012 during the NMFS Small Pelagics Survey with the CPUE for king mackerel.

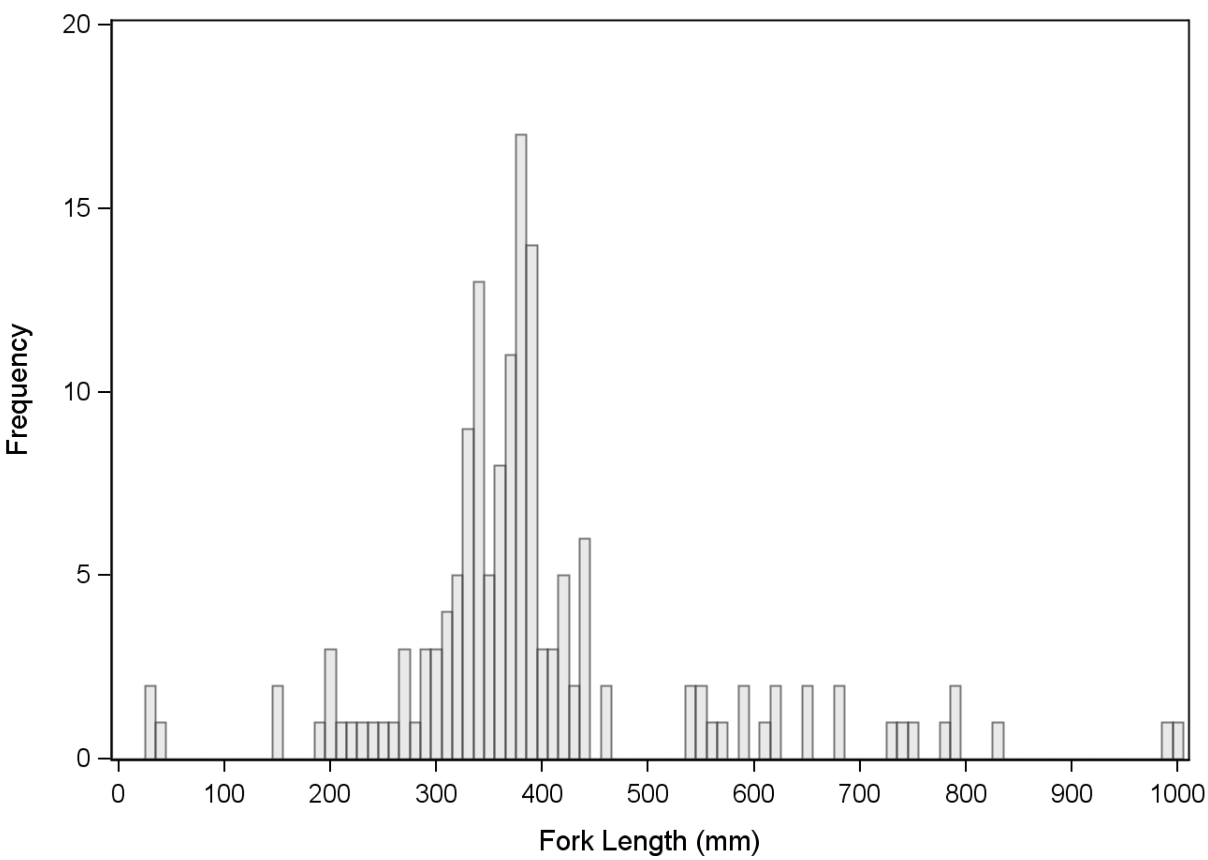


Figure 2. Length frequency histograms for king mackerel captured during NMFS Small Pelagics surveys from 2004-2012.

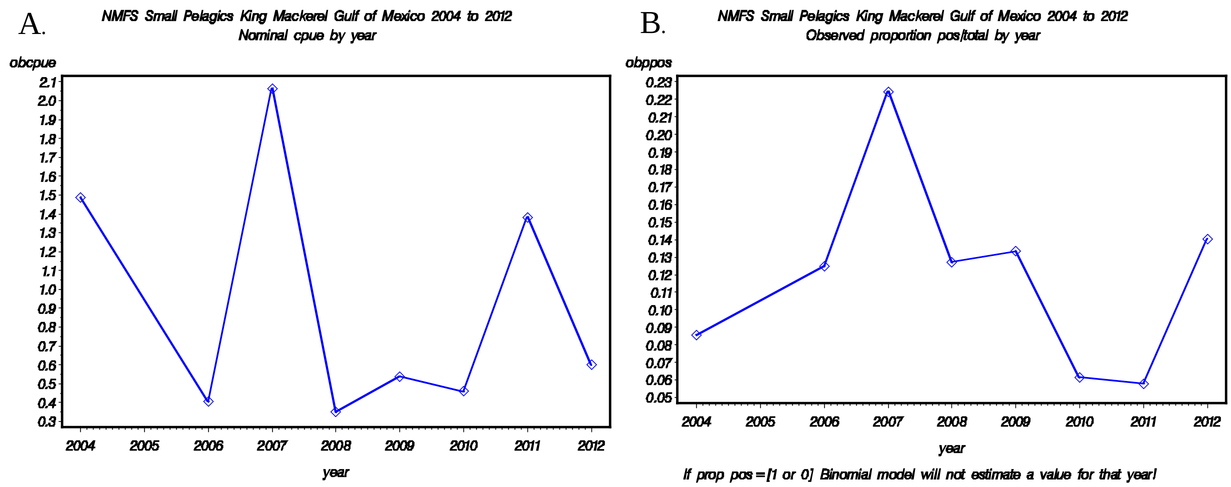


Figure 3. Annual trends for king mackerel captured during NMFS Small Pelagics surveys from 2004 to 2012 in **A.** nominal CPUE and **B.** proportion of positive stations.

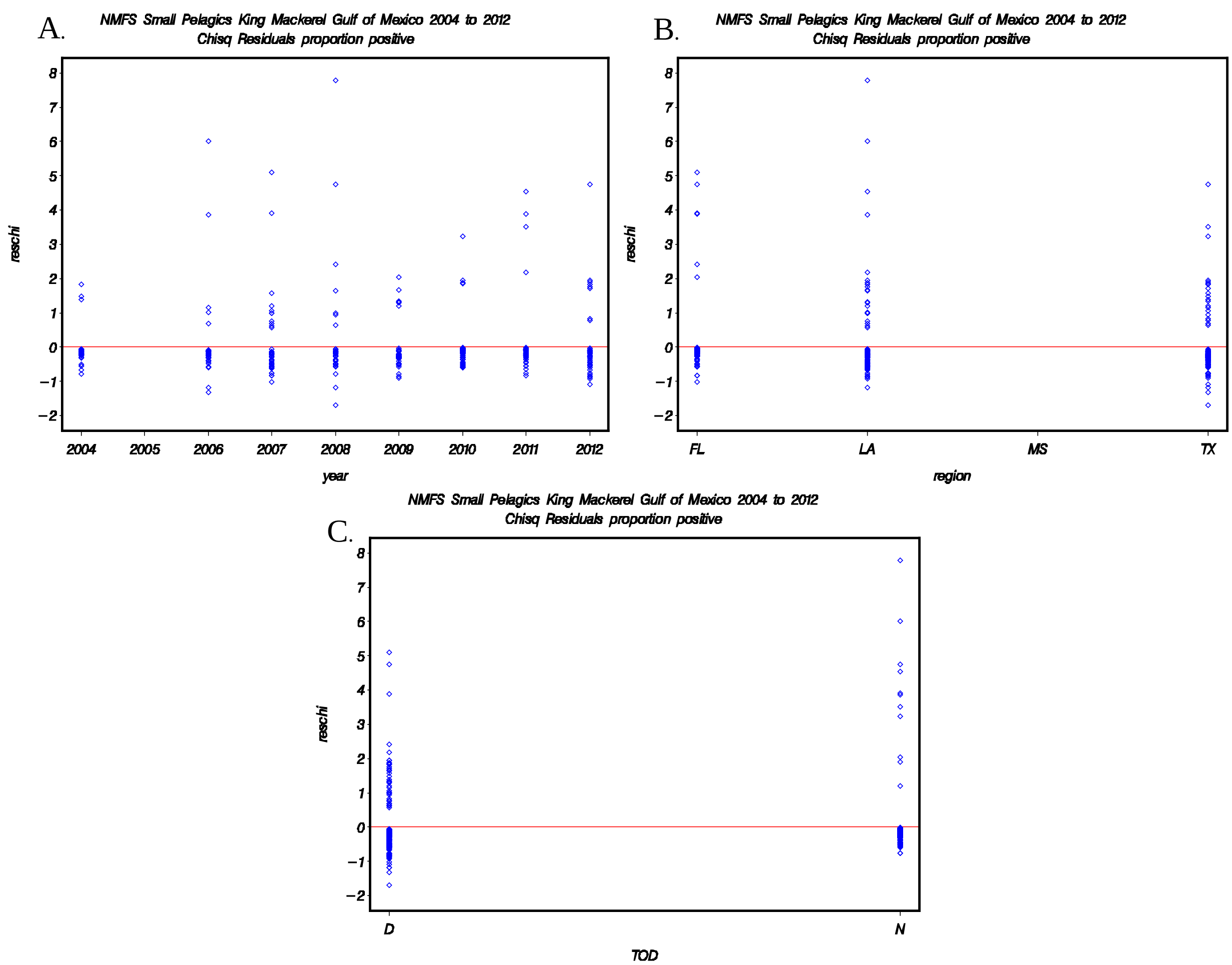


Figure 4. Diagnostic plots for binomial component of the king mackerel NMFS Small Pelagics surveys model: **A.** the Chi-Square residuals by year, **B.** the Chi-Square residuals by region, and **C.** the Chi-Square residuals by time of day.

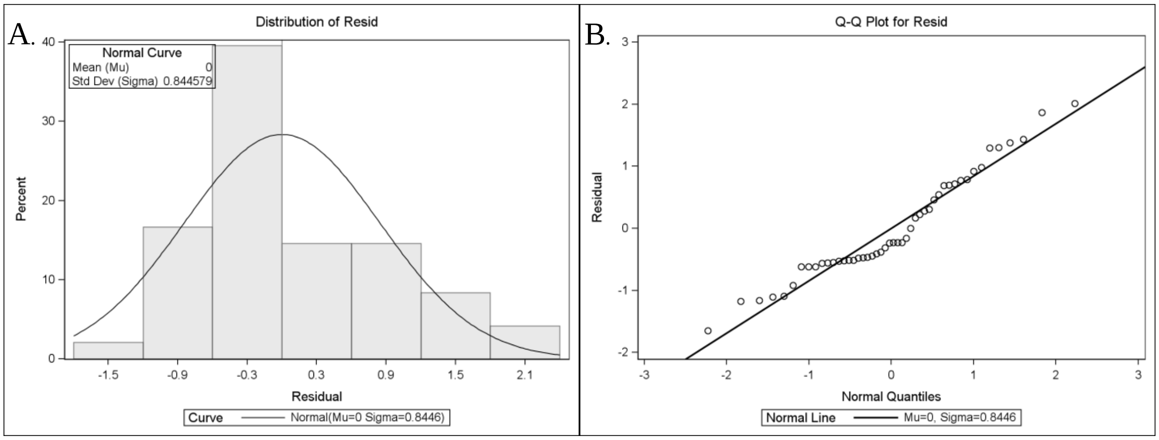


Figure 5. Diagnostic plots for lognormal component of the king mackerel NMFS Small Pelagics surveys model: **A.** the frequency distribution of log(CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

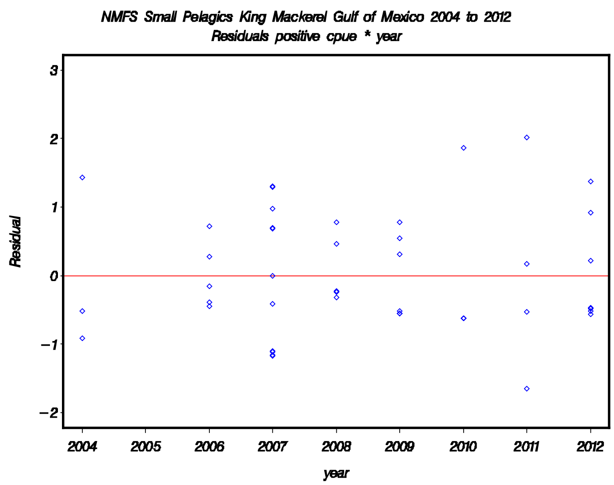


Figure 6. Diagnostic plots for lognormal component of the king mackerel NMFS Small Pelagics surveys model: the Chi-Square residuals by year.

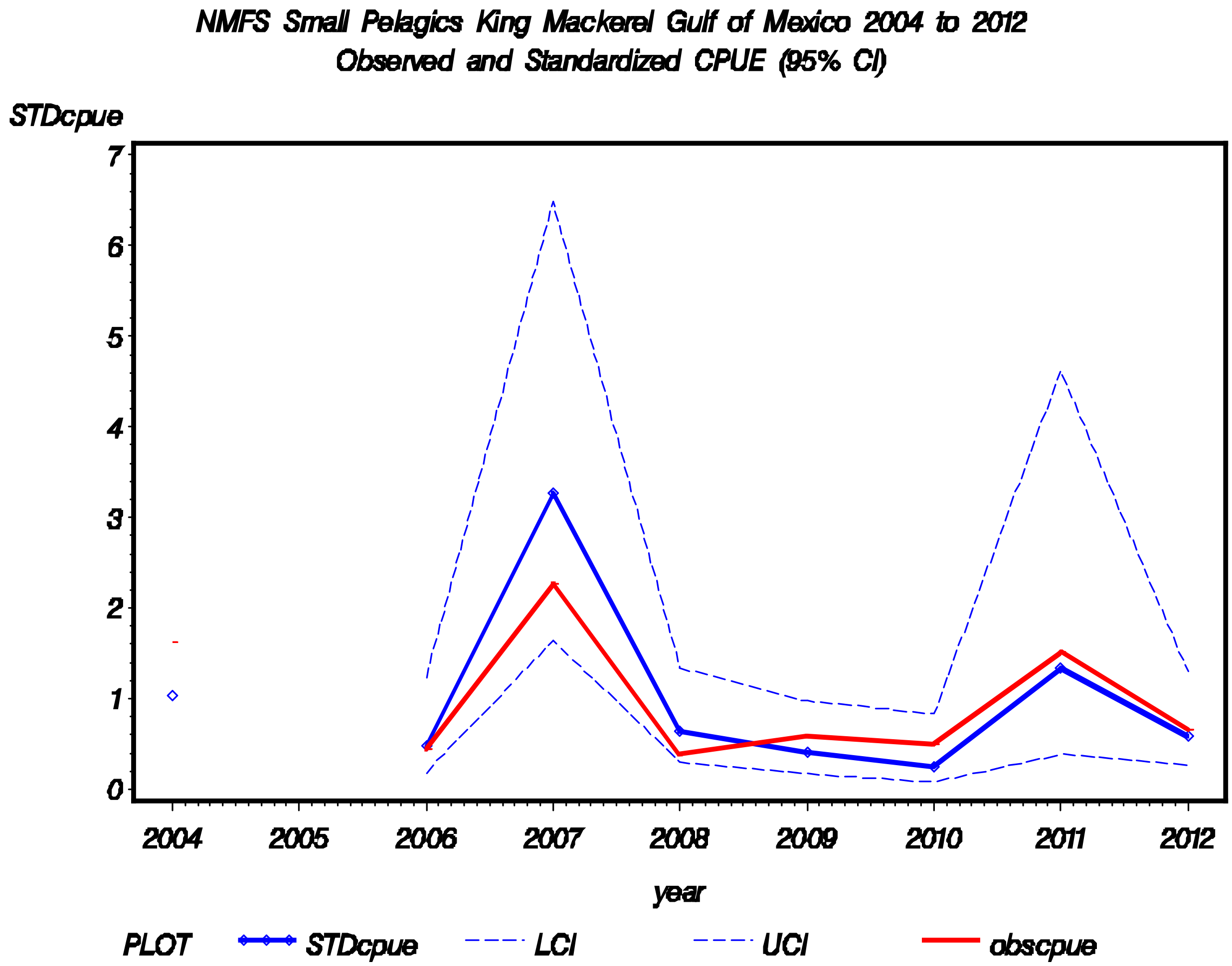


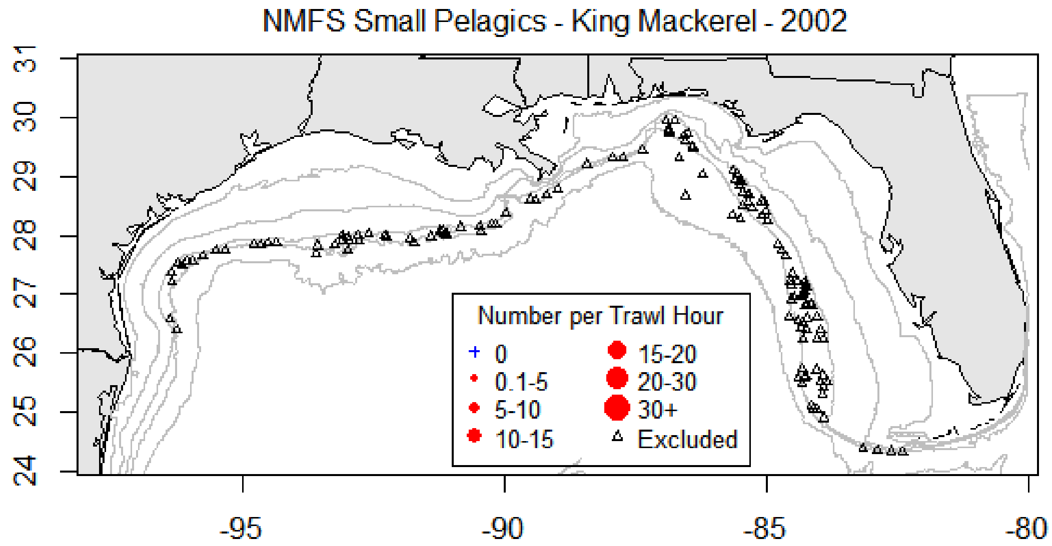
Figure 7. Annual index of abundance for king mackerel from the NMFS Small Pelagics surveys from 2004 – 2012.

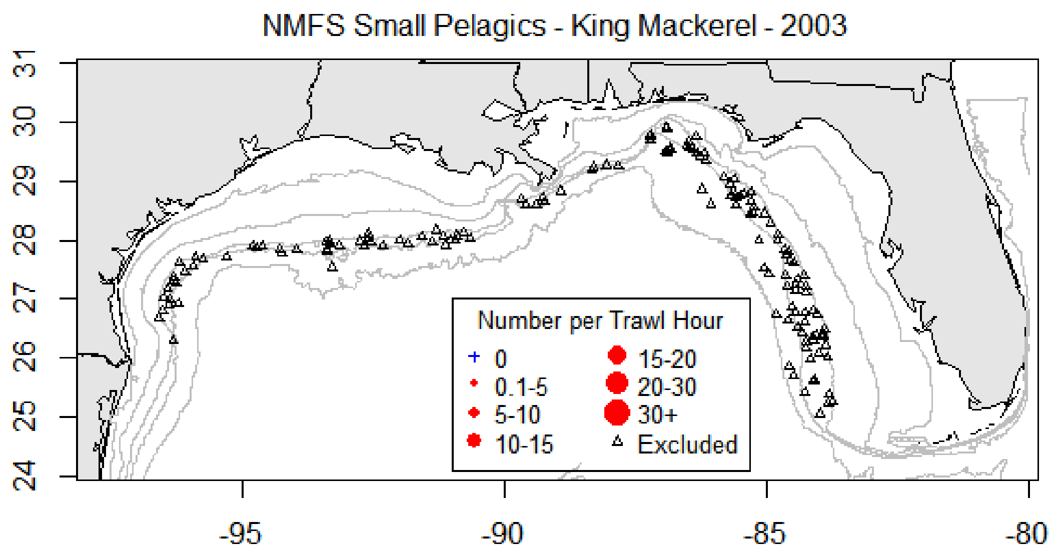
Appendix

Appendix Table 1. Summary of the factors used in constructing the king mackerel abundance index from the NMFS Small Pelagics survey data.

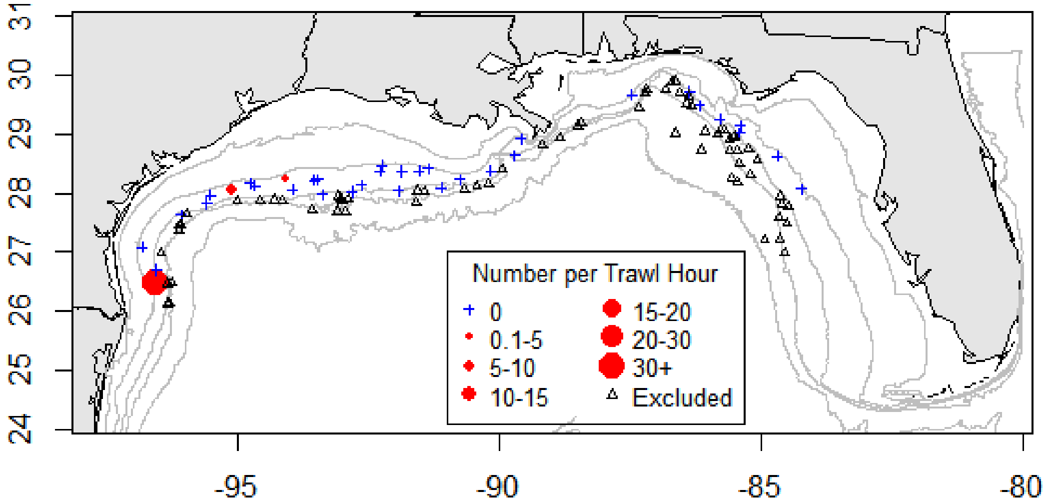
Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Year	2004	35	3	0.08571	1.48571
Year	2006	40	5	0.12500	0.40615
Year	2007	49	11	0.22449	2.06434
Year	2008	55	7	0.12727	0.34996
Year	2009	45	6	0.13333	0.53869
Year	2010	65	4	0.06154	0.46008
Year	2011	69	4	0.05797	1.38248
Year	2012	57	8	0.14035	0.60133
Region	Florida	134	6	0.04478	0.66604
Region	Louisiana	151	22	0.14570	0.92400
Region	Mississippi/Alabama	21	0	0.00000	0.00000
Region	Texas	109	20	0.18349	1.31822
Time of Day	Day	191	37	0.19372	1.61451
Time of Day	Night	224	11	0.04911	0.28610

Appendix Figure 1. Annual survey effort and catch of king mackerel from the NMFS Small Pelagics Survey from 2002 - 2012.

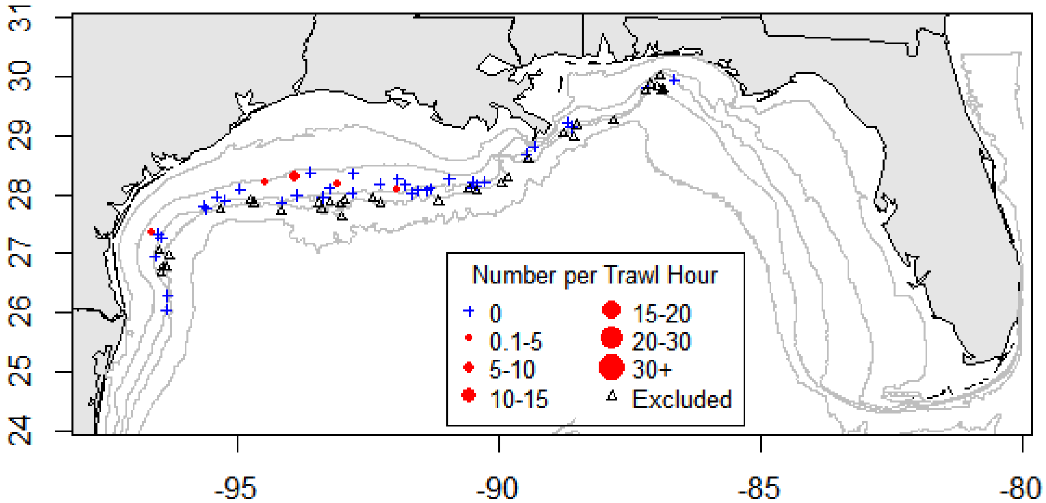




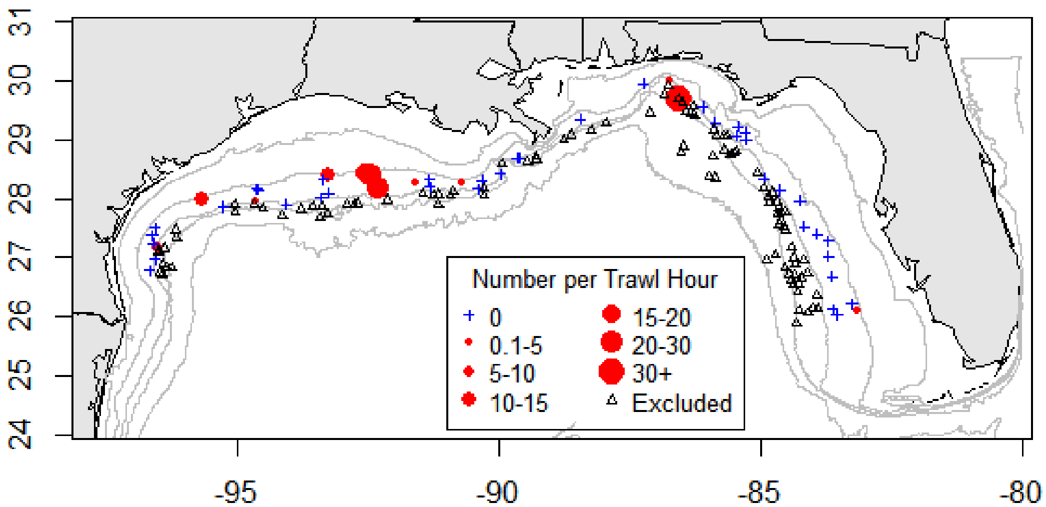
NMFS Small Pelagics - King Mackerel - 2004

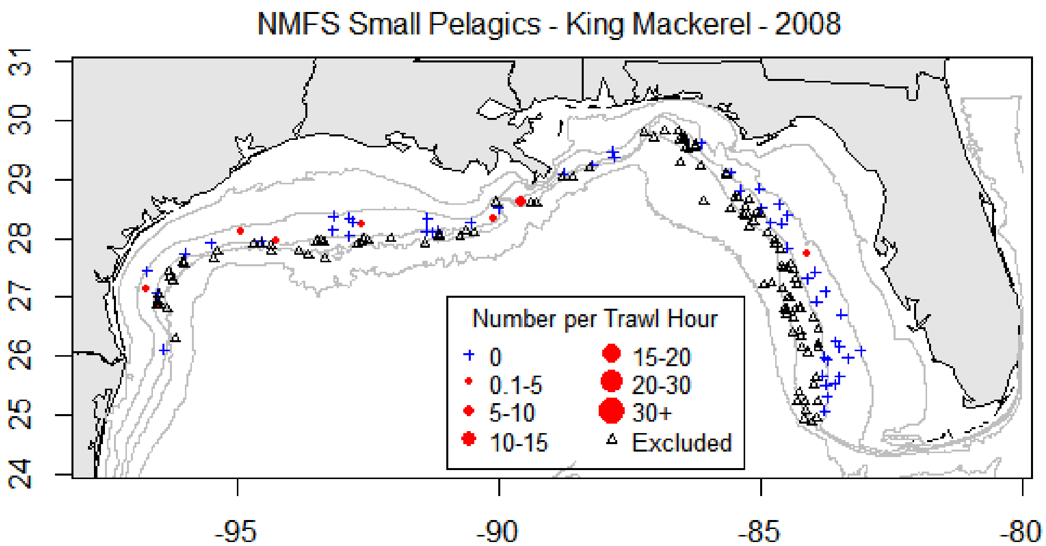


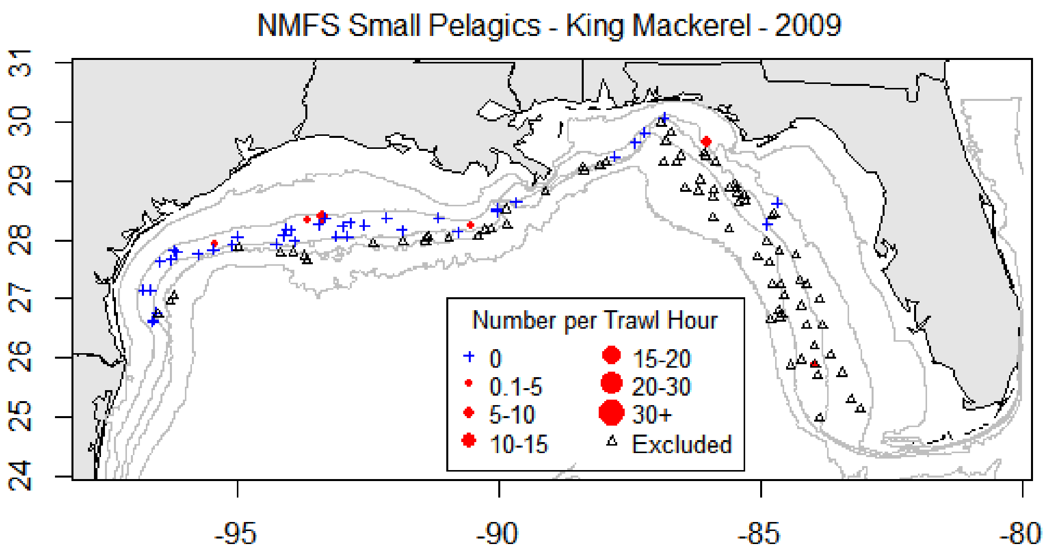
NMFS Small Pelagics - King Mackerel - 2006

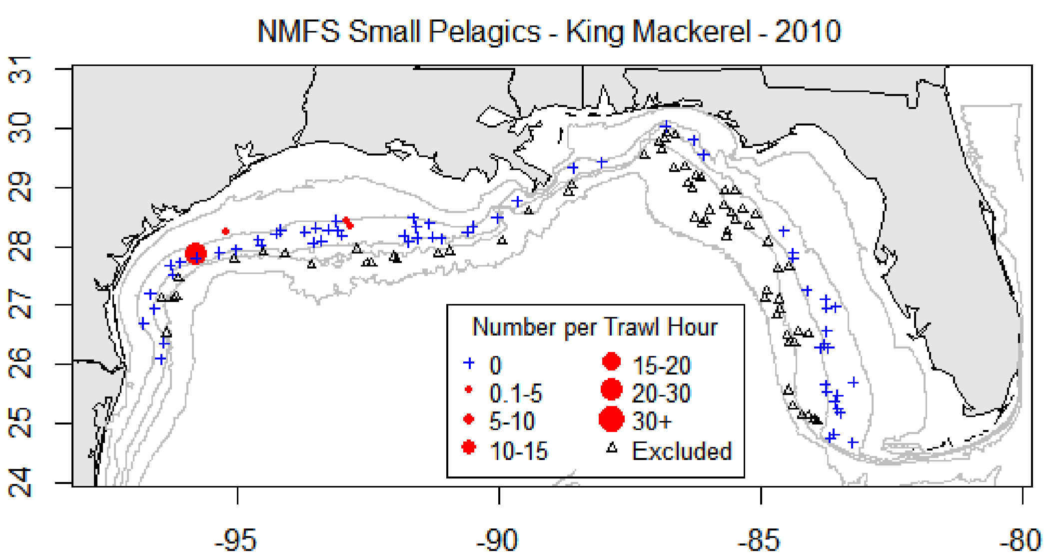


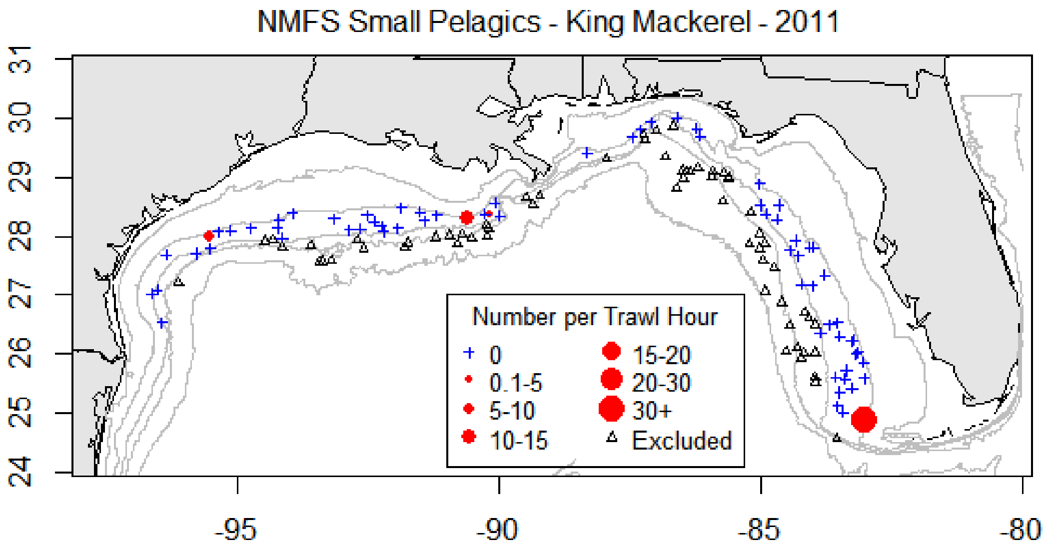
NMFS Small Pelagics - King Mackerel - 2007

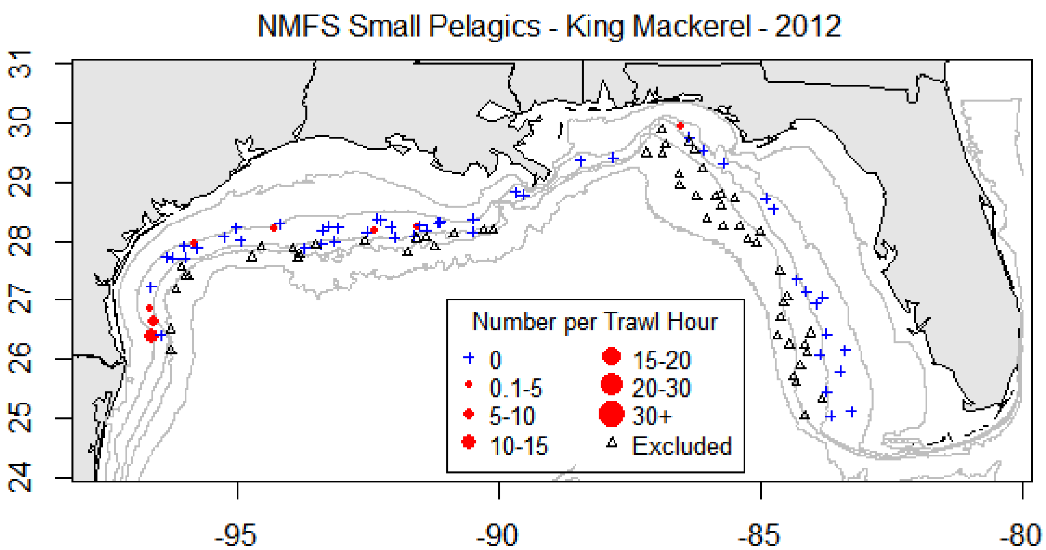



NMFS Small Pelagics - King Mackerel - 2008
Number per Trawl Hour
0
0.1-5
5-10
10-15
15-20
20-30
30+
Excluded
31
30
29
28
27
26
25
24
-95
-90
-85
-80


NMFS Small Pelagics - King Mackerel - 2009
Number per Trawl Hour
0
0.1-5
5-10
10-15
15-20
20-30
30+
Excluded
31
30
29
28
27
26
25
24
-95
-90
-85
-80


NMFS Small Pelagics - King Mackerel - 2010
Number per Trawl Hour
0
0.1-5
5-10
10-15
15-20
20-30
30+
Excluded
31
30
29
28
27
26
25
24
-95
-90
-85
-80


NMFS Small Pelagics - King Mackerel - 2011
Number per Trawl Hour
0
0.1-5
5-10
10-15
15-20
20-30
30+
Excluded
24
25
26
27
28
29
30
31
-95
-90
-85
-80


NMFS Small Pelagics - King Mackerel - 2012
Number per Trawl Hour
0
0.1-5
5-10
10-15
15-20
20-30
30+
Excluded
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