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ANNUAL INDICES OF SPAWNING BIOMASS OF LITTLE TUNNY (*EUTHYNNUS ALLETTERATUS*) AND COMMON DOLPHIN (*CORYPHAENA HIPPURUS*) BASED ON LARVAL SURVEYS IN THE GULF OF MEXICO (1982-2015)

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SUMMARY

*Fishery-independent indices of spawning biomass of little tunny (*Euthynnus alletteratus*) and common dolphin (*Coryphaena hippurus*) in the Gulf of Mexico are presented utilizing NOAA Fisheries ichthyoplankton survey data collected from 1982 through 2015 in the Gulf of Mexico. Indices for little tunny were developed using catch rates of larvae sampled with both neuston and bongo gear, while those for dolphin were developed using catch rates of larvae sampled with only neuston gear. A delta-lognormal modeling approach was utilized, including the following covariates: time of day, season, area sampled, year, and gear.*

RÉSUMÉ

*Des indices, indépendants des pêcheries, de la biomasse reproductrice de la thonine commune (*Euthynnus alletteratus*) et de la coryphène commune (*Coryphaena hippurus*) dans le golfe du Mexique sont présentés en utilisant les données de la prospection d'ichthyoplanctons réalisée par NOAA de 1982 à 2015 dans le golfe du Mexique. Les indices pour la thonine commune ont été développés à l'aide des taux de capture des larves échantillonnées avec des filets à neuston et l'engin bongo, tandis que les indices pour la coryphène commune ont été développés à l'aide de taux de capture de larves échantillonnées uniquement avec des filets neuston. Une approche de modélisation delta-lognormale a été utilisée, y compris les covariables suivantes : heure du jour, saison, zone échantillonnée, année et engin.*

RESUMEN

Se presentan los índices independientes de la pesquería de la biomasa reproductora de bacoreta (Euthynnus alletteratus) y dorado (Coryphaena hippurus) en el golfo de México utilizando datos de la prospección de ictioplancton de la NOAA recopilados desde 1982 hasta 2015 en el golfo de México. Los índices para la bacoreta se desarrollaron utilizando tasas de captura de las larvas muestreadas con artes neuston y bongo, mientras que los de dorado se desarrollaron utilizando tasas de captura de las larvas muestreadas sólo con artes neuston. Se utilizó un enfoque de modelado delta lognormal, que incluía las siguientes covariables: hora del día, temporada, área muestreada, año y arte.

KEYWORDS

Mathematical models, fish larvae

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1. Introduction and Methodology

The objective of this paper is to present annual indices of bongo- and neuston-collected little tunny (LTA) larvae and neuston-collected common dolphin (DOL) larvae developed using delta-lognormal models. These indices are based upon larval catch rates obtained during fishery-independent surveys conducted by NOAA Fisheries in the Gulf of Mexico from 1982 to 2015. Methodologies concerning general ichthyoplankton surveys conducted by NOAA Fisheries in the Gulf of Mexico have been extensively reviewed (Richards and Potthoff 1980; McGowan and Richards, 1986). Likewise, the evolution of the use of this time series of ichthyoplankton data to index other ICCAT species, such as Atlantic bluefin tuna, skipjack tuna, and Atlantic swordfish is detailed in numerous documents (i.e. Ingram *et al*. 2010, Ingram 2015, Ingram 2017, respectively), and the current methodologies, concerning the development of indices based on delta-lognormal models, are detailed by Ingram *et al*. (2006, 2008) and Ingram *et al*. (2010).

DOL is a cosmopolitan, highly migratory, pelagic fish found in warm waters of the Atlantic, Pacific, and Indian Oceans (Gibbs *et al*. 1959, Díaz-Jaimesa *et al*. 2010), and in the western Atlantic Ocean, the spawning season is reported to be protracted. Gibbs *et al*. (1959) reported that DOL breed in the summer in the Gulf Stream, and earlier in the Caribbean. Beardsley (1967) indicates the spawning season in the area of the Florida Current extends from November through July and is at its peak in March. Schwenke *et al*. (2008) reported that back-calculated hatching dates from age-0 DOL and prior reproductive studies on the east coast of Florida indicate that DOL spawning occurs year round off the U.S. east coast and highest levels range from January through June.

Likewise, LTA is a widespread species and common in tropical and subtropical waters of the Atlantic Ocean, Mediterranean Sea, Black Sea, Caribbean Sea and the Gulf of Mexico (Collette and Nauen, 1983). It also has a protracted spawning period. De Sylva *et al*. (1961) found ripe males from Cape Hatteras, North Carolina to Cape Canaveral, Florida from February through November, and ripe females from January through November. In the Gulf of Mexico, previous studies have collected LTA larvae from May, September, and November (Allman and Grimes 1998).

Ichthyoplankton surveys were conducted from numerous NOAA vessels during the spring, summer, and fall seasons from 1982 through 2015 in the offshore waters of the U.S. Gulf of Mexico. Sampling station locations were usually located on a 30-nautical-mile grid. For the summer and fall seasons, stations were typically located on the shelf (i.e. < 200 m), while in the spring they were off the shelf (i.e. > 200 m). A neuston net tow was made at each station. This was a surface tow taken at a speed of 1.5 kt for 10 min duration. The net was fished from the side of the vessel, outside of the vessel's wake, and the cable paid out was adjusted to insure the net fished the top 0.5 m of the water. The frame of the net was a 1 by 2 m rectangle, and the mesh was 0.950 mm. Single neuston tows were performed from 1982-1988 and 2003-2015, while double neuston (side-by-side, dual frame) tows were performed from 1989-2002, with only the right side being sorted. A double oblique bongo tow was conducted at every station through 1983 and at every other station from 1984 through 2011. Each tow was conducted to 200 m or to within 1-5 m of the bottom if the water depth is less than 200 m and was made using a paired 61-cm bongo net plankton sampler with a 0.335 mm mesh. Ship speed during the tow was maintained at approximately 1.5 kt to maintain a 45° wire angle on the deployment cable. A flow meter inside the mouth of each bongo net was used to determine the volume of water sampled. Only those specimens collected in the right side bongo were used. Identifications and measurements of larvae were obtained by the Polish Plankton Sorting and Identification Center in Szczecin, Poland. Therefore, these data from the SEAMAP Ichthyoplankton Surveys, conducted annually in the U.S. Gulf of Mexico, were used to index LTA and DOL spawning biomass.

For bongo-collected LTA, the mean number of larvae under 100 m^2 at 3 mm body length, and for neuston-collected LTA and DOL, the mean number of larvae per 10-min tow at 3 mm body length for each station sampled each season and each year of the time series (1982-2015) were estimated and used to index abundance. These were estimated as:

(1) $$I_{s,y} = \frac{\sum_{i=1}^{k} R_L e^{-Z\left(L_{s,y,i-1}\right)}}{A_{s,y}}$$

where y indexes year, s indexes sampling station, i (= 1,..., n) indexes individual larvae, A the surface area sampled, Z the larval loss rate by length, L the larval body length, and R, the gear efficiency estimate applied. Since neuston catches are not calculated as densities, A is dropped from equation (1), for that gear. Estimates were constructed using the method as described in Ingram (2015), which adjusts the density or catch estimates at sampling stations for estimated larval loss rates and gear efficiency. Season-specific length frequency histograms of bongo- and neuston-collected LTA larvae (**Figures 1 and 2, respectively**) and neuston-collected DOL larvae (**Figure 3**) were employed to calculate the larval loss rate by length (*Z*). The decay in the number of larvae per mm length-class was estimated using the following equation:

(2) $$N = N_0 e^{-Z(L)}$$

where *Z* is the larval loss rate by length, *L* the larval body length-class, *N* the frequency of larvae within a certain length-class, and N_0 the theoretical number of larvae at the zero mm length-class. The Z, N_0, and *R*, varied depending on season and gear, and at what length the decay curve was initiated and are listed with **Table 1**. In order to use data from both bongo and neuston to index LTA larvae, data from gear type was scaled to a mean of one. This allowed the combination of those data, since they no longer had differing catch units. Also, the gear type was used as a variable in the delta-lognormal (DL) model for LTA. For DOL, only neuston data were used, and were not scaled as with LTA. Finally, outliers of both length and catch data were removed using the median absolute deviation (MAD) approach (Rousseeuw and Croux 1993). With these station-, season-, and year-specific estimates of larval catch, the annual index value (and variability) were developed using the DL method.

The DL index of relative abundance (I_y) as described by Lo *et al*. (1992) is estimated as

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

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

(4) $$\ln(\mathbf{c}) = \mathbf{X\beta} + \boldsymbol{\varepsilon}$$

and

(5) $$\mathbf{p} = \frac{e^{\mathbf{X\beta}+\boldsymbol{\varepsilon}}}{1+e^{\mathbf{X\beta}+\boldsymbol{\varepsilon}}}, \text{ respectively,}$$

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 are 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 is calculated, as in equation (5), and its variance calculated as

(6) $$V(I_y) \approx V(c_y) p_y^2 + c_y^2 V(p_y).$$

The GENMOD procedure in SAS (v. 9.4, 2012) was used to develop the DL model. The covariates considered were: time of day (two categories: night and day, depending on solar altitude), season (three categories: spring, summer, and fall), survey area [four categories: eastern survey area (survey area between 84˚ and 86˚ longitude); central survey area (survey area between 86˚ and 91˚ longitude); western survey area (survey area between 91˚ and 94˚ longitude); far western survey area (survey area west of 94˚ longitude)], gear type (bongo or neuston), and year. These variables were chosen to adjust the index values to account for any temporal or spatial loss in survey effort during a particular survey year. Also, for LTA, interaction terms between time of day and gear type (**Figure 4**) and between sampling season and sampling area (**Figure 5**) were included in the DL, based on nominal patterns in these data. For DOL, only the interaction term between sampling season and sampling area were included in the DL, since only neuston data were used (**Figure 6**). Model performance was evaluated using AUC (Area Under Curve) methodology presented by Steventon *et al*. (2005) and residual analyses.

2. Results and Discussion

Summaries of the number of bongo and neuston tows used in these analyses, nominal catch rates, and charts showing bongo and neuston effort and number of specimens collected per station for each year in the time series are provided in the **Appendix**. There were several years where surveys were started late or ended early due to mechanical, meteorological and/or other logistical factors.

For the DL model of LTA larvae, all variables and interaction terms were retained in the binomial submodel, and likewise, with the lognormal submodel, save for the interaction term of season and sampling area (**Table 2**). The binomial submodel for LTA had an AUC = 0.767. The AUC statistic provides information on the model's lack-of-fit, and in this case it means that in 77 out of 100 instances, a station selected at random from those with larvae had a higher predicted probability of larvae being present than a station randomly selected from those that had no larvae. For the DL model of DOL larvae, all variables and interaction terms were retained in the binomial submodel, whereas only year and season variables were retained in the lognormal submodel (**Table 3**). The binomial submodel for DOL had an AUC = 0.699. **Figure 7** provides residual plots by the variables used in the modeling process, and the QQplot of the residuals for the binomial submodel of LTA. **Figure 8** provides residual plots by the variables used in the modeling process, and the QQplot of the residuals for the lognormal submodel of LTA. **Figure 9** provides residual plots by the variables used in the modeling process, and the QQplot of the residuals for the binomial submodel of DOL. **Figure 10** provides residual plots by the variables used in the modeling process, and the QQplot of the residuals for the lognormal submodel of DOL. **Table 4** and **Figure 11** summarize the indices of larval LTA developed from the DL model. Index values were variable throughout the time series. The highest index values occurred in 1995 and 2002, while the lowest was in 2015. **Table 5** and **Figure 12** summarize the indices of larval DOL developed from the DL model. Index values were variable throughout the time series. The lowest index values occurred in 1987, 1988 and 2001, while the highest were in 2013 and 2015.

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Table 1. Z, N_0, and *R*, varied depending on species, season and gear, and at what length the decay curve was initiated.

Species	LTA	LTA	LTA	LTA	LTA	LTA	DOL	DOL	DOL
Gear	Bongo	Bongo	Bongo	Neuston	Neuston	Neuston	Neuston	Neuston	Neuston
Season	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
N_0	376.1	2849.6	5170.6	12270.7	3793.1	9793.9	428.0	197.7	796.6
Z	0.385	0.499	0.631	0.781	0.515	0.628	0.118	0.132	0.189
R (Length Class)									
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	1.110	1.029	2.279	34.707	5.544	6.393	4.351	12.089	26.608
3	1.000	1.000	1.000	1.709	1.000	1.000	1.686	6.474	11.705
4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	4.862	9.693
5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	5.592	8.285
6	1.000	1.000	1.000	1.000	1.000	1.000	1.000	8.710	7.596
7	1.000	1.000	1.000	1.000	1.000	1.000	1.000	4.041	6.774
8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.543	3.392
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.648	2.047
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.359	1.923
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.900	1.506
12	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.429
13	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.778
14	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.306
15	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.558
>15	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 2. Results of DL model development for LTA.

LR Statistics For Type 3 Analysis for the Binomial Submodel

Source	*DF*	*Chi-Square*	*Pr > ChiSq*
year	33	248.24	<.0001
season	2	633.42	<.0001
area	3	46.62	<.0001
gear	1	269.98	<.0001
time of day	1	318.17	<.0001
*season*area*	6	49.54	<.0001
*time of day *gear*	1	251.30	<.0001

LR Statistics For Type 3 Analysis for the Lognormal Submodel

Source	*DF*	*Chi-Square*	*Pr > ChiSq*
year	33	60.99	0.0021
season	2	10.37	0.0056
area	3	22.40	<.0001
gear	1	31.85	<.0001
time of day	1	16.60	<.0001
*time of day *gear*	1	5.76	0.0164

Table 3. Results of DL model development for DOL.

LR Statistics For Type 3 Analysis for the Binomial Submodel

Source	*DF*	*Chi-Square*	*Pr > ChiSq*
year	33	377.18	<.0001
season	2	129.96	<.0001
area	3	16.21	0.0010
time of day	1	223.26	<.0001
*season*area*	6	45.03	<.0001

LR Statistics For Type 3 Analysis for the Lognormal Submodel

Source	*DF*	*Chi-Square*	*Pr > ChiSq*
year	33	75.67	<.0001
season	2	432.67	<.0001

Table 4. Indices (with 95% confidence limits) larval LTA developed from the DL model.

Survey Year	*Index*	*CV*	*LCL*	*UCL*
1982	0.027105	0.30622	0.014894	0.04933
1983	0.019789	0.35721	0.009895	0.03958
1984	0.035284	0.25283	0.021447	0.05805
1986	0.084535	0.25210	0.051456	0.13888
1987	0.075162	0.16700	0.053944	0.10473
1988	0.092057	0.17135	0.065509	0.12936
1989	0.088058	0.21978	0.057032	0.13596
1990	0.038721	0.20962	0.025576	0.05862
1991	0.043944	0.19582	0.029813	0.06477
1992	0.048033	0.20643	0.031924	0.07227
1993	0.053848	0.17314	0.038185	0.07594
1994	0.059796	0.17705	0.042080	0.08497
1995	0.080744	0.18323	0.056140	0.11613
1996	0.099710	0.16765	0.071471	0.13911
1997	0.069137	0.16714	0.049606	0.09636
1998	0.067694	0.18733	0.046692	0.09814
1999	0.028421	0.26621	0.016841	0.04796
2000	0.060218	0.15786	0.044000	0.08241
2001	0.055009	0.17170	0.039118	0.07735
2002	0.074895	0.16241	0.054238	0.10342
2003	0.084439	0.14266	0.063570	0.11216
2004	0.067200	0.17831	0.047174	0.09573
2005	0.072393	0.17736	0.050914	0.10293
2006	0.030152	0.24425	0.018630	0.04880
2007	0.089472	0.15607	0.065606	0.12202
2008	0.068560	0.15055	0.050821	0.09249
2009	0.053518	0.19983	0.036027	0.07950
2010	0.071037	0.14279	0.053466	0.09438
2011	0.062425	0.15809	0.045592	0.08547
2012	0.073597	0.15655	0.053915	0.10046
2013	0.046981	0.13375	0.035997	0.06132
2014	0.054851	0.14416	0.041173	0.07307
2015	0.036471	0.16673	0.026189	0.05079

Table 5. Indices (with 95% confidence limits) larval DOL (occurrence per 10-min neuston tow) developed from the DL model.

Survey Year	*Index*	*CV*	*LCL*	*UCL*
1982	0.023651	0.18174	0.016492	0.033919
1983	0.011841	0.28560	0.006763	0.020730
1984	0.006377	0.31408	0.003453	0.011776
1986	0.014692	0.41622	0.006605	0.032678
1987	0.023858	0.19057	0.016353	0.034809
1988	0.002966	0.49303	0.001167	0.007538
1989	0.006832	0.30593	0.003756	0.012427
1990	0.026084	0.18991	0.017901	0.038007
1991	0.025219	0.16219	0.018271	0.034809
1992	0.018818	0.19324	0.012831	0.027598
1993	0.018826	0.19917	0.012690	0.027931
1994	0.024985	0.16664	0.017944	0.034788
1995	0.028805	0.17462	0.020368	0.040739
1996	0.023745	0.15827	0.017336	0.032523
1997	0.020453	0.18659	0.014127	0.029610
1998	0.041739	0.15923	0.030416	0.057277
1999	0.009196	0.20300	0.006153	0.013745
2000	0.021900	0.15618	0.016055	0.029874
2001	0.016558	0.17788	0.011633	0.023567
2002	0.000221	0.92067	0.000046	0.001058
2003	0.016872	0.20848	0.011169	0.025487
2004	0.030918	0.20715	0.020520	0.046586
2005	0.025611	0.20280	0.017142	0.038266
2006	0.035607	0.16974	0.025418	0.049880
2007	0.026089	0.16595	0.018763	0.036277
2008	0.023975	0.17307	0.017003	0.033804
2009	0.021545	0.17690	0.015166	0.030606
2010	0.020196	0.18008	0.014129	0.028870
2011	0.019893	0.21042	0.013120	0.030165
2012	0.023475	0.18224	0.016354	0.033699
2013	0.026602	0.16362	0.019219	0.036821
2014	0.044570	0.13713	0.033922	0.058559
2015	0.017311	0.19458	0.011773	0.025455

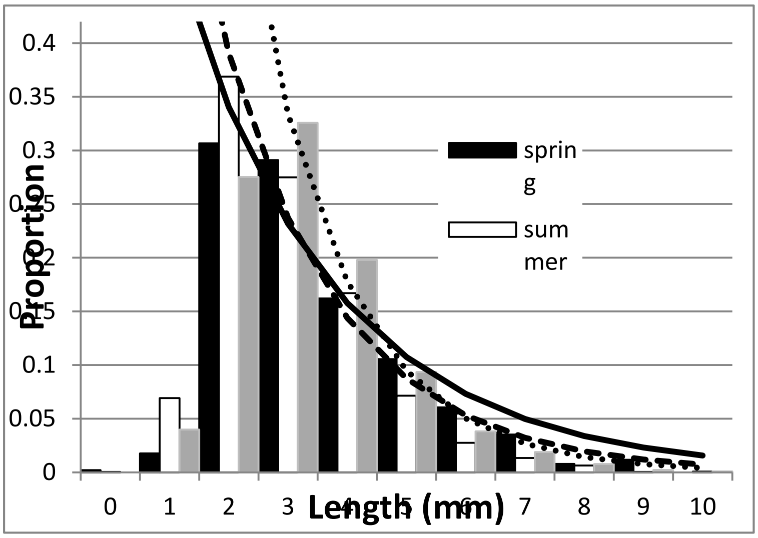


Figure 1. Length frequency distribution of bongo-collected LTA by sampling season with associated decay curves. Frequencies shown in proportion for ease of comparison, and associated with the following season-specific length sample sizes: spring (N = 512), summer (N = 2688), and fall (N = 2333). Decay curve parameters shown in **Table 1** (decay curve model R^2 = 0.985345).

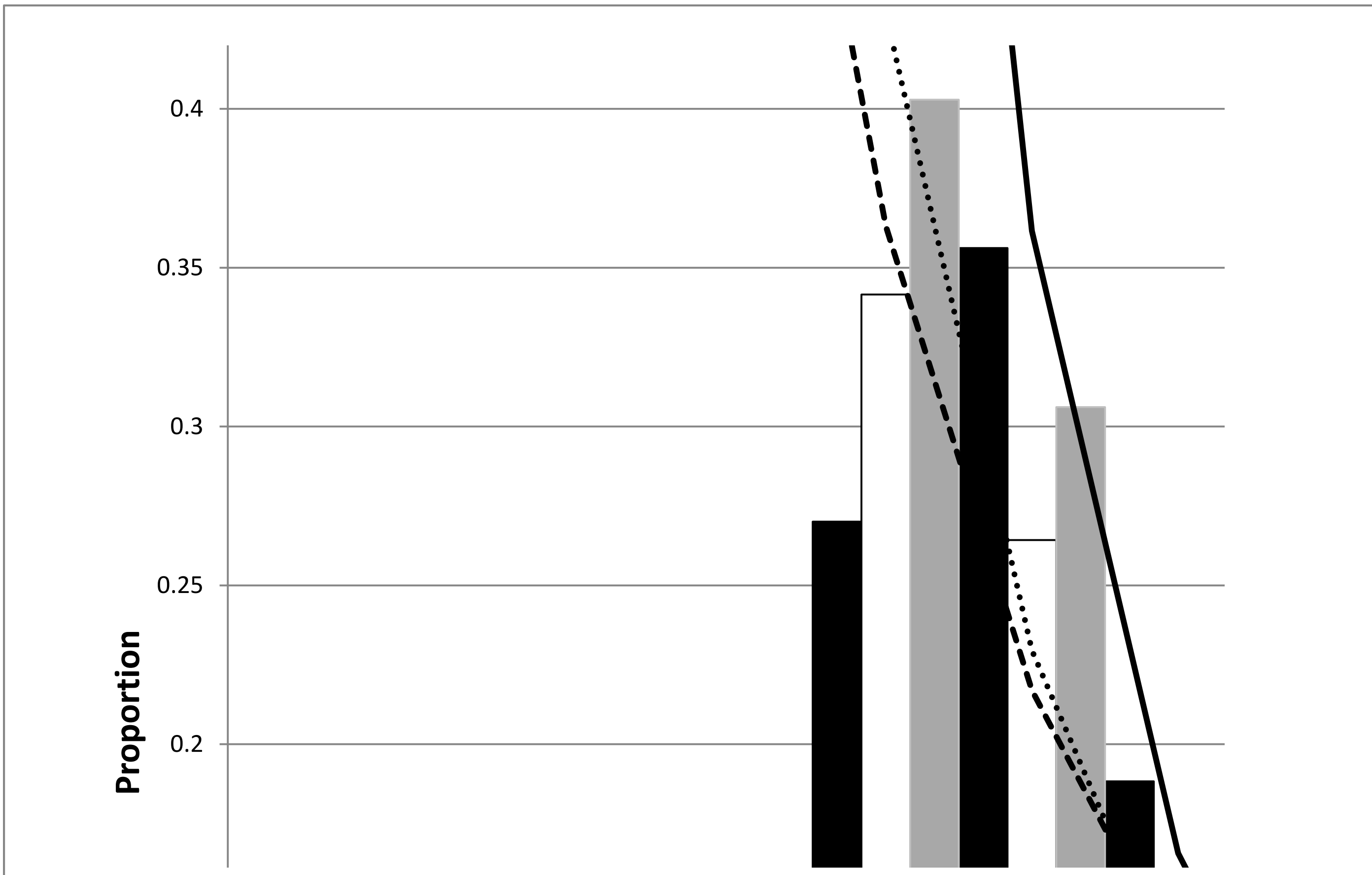


Figure 2. Length frequency distribution of neuston-collected LTA by sampling season with associated decay curves. Frequencies shown in proportion for ease of comparison, and associated with the following season-specific length sample sizes: spring (N = 685), summer (N = 1332), and fall (N = 1849). Decay curve parameters shown in **Table 1** (decay curve model R^2 = 0.966721).

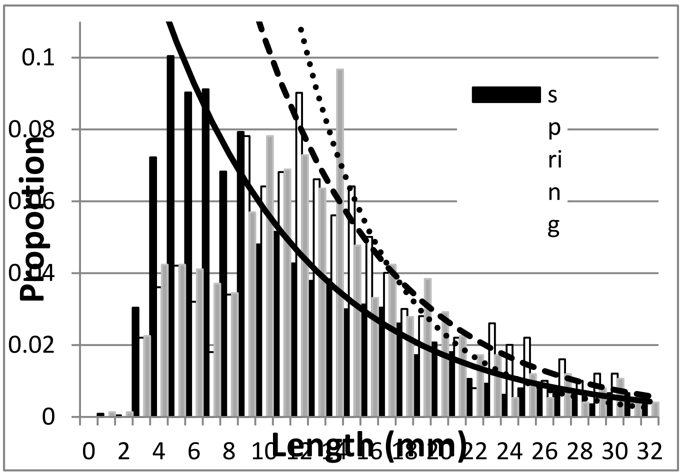
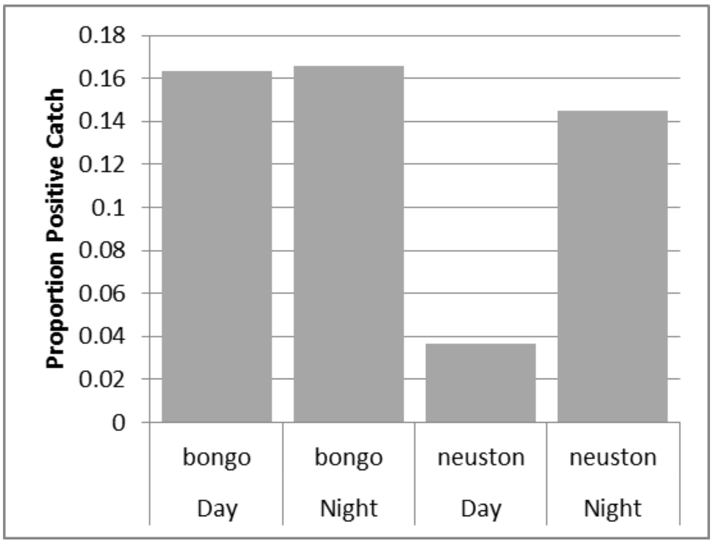
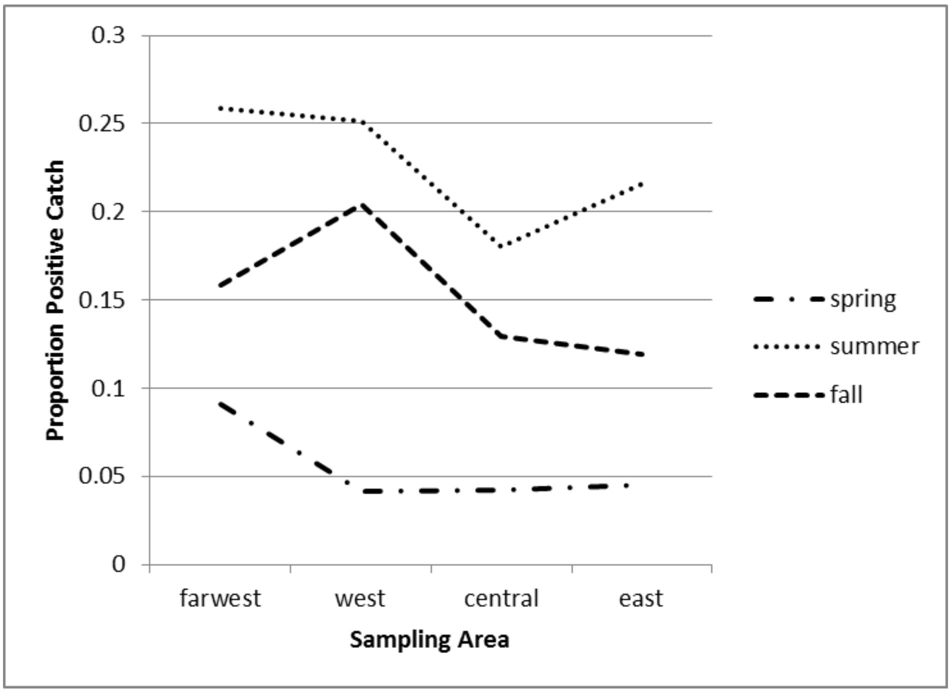


Figure 3. Length frequency distribution of neuston-collected DOL by sampling season with associated decay curves. Frequencies shown in proportion for ease of comparison, and associated with the following season-specific length sample sizes: spring (N = 2270), summer (N = 499), and fall (N = 755). Decay curve parameters shown in **Table 1** (decay curve model R^2 = 0.984021).



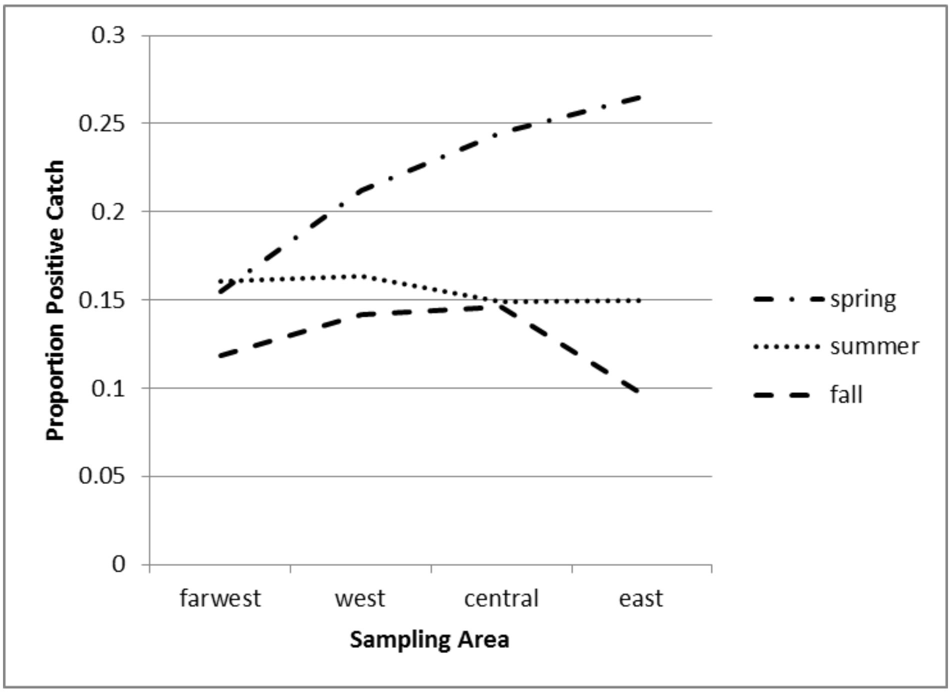
Time of Day	*Gear*	*Stations*	*Positive Stations*
Day	bongo	5143	841
Night	bongo	4106	680
Day	neuston	5851	215
Night	neuston	4839	701

Figure 4. Proportion positive catch of LTA by gear and time of day.



Sampling Area	*Season*	*Stations*	*Positive Stations*
far west	spring	705	64
west	spring	1720	71
central	spring	3601	152
east	spring	2382	108
far west	summer	1282	332
west	summer	1107	278
central	summer	992	179
east	summer	560	121
far west	fall	1466	232
west	fall	1775	362
central	fall	1845	239
east	fall	2504	299

Figure 5. Proportion positive catch of LTA by sampling area and season.



Sampling Area	*Season*	*Stations*	*Positive Stations*
farwest	spring	427	66
west	spring	1056	224
central	spring	2300	563
east	spring	1352	359
farwest	summer	605	97
west	summer	514	84
central	summer	462	69
east	summer	267	40
farwest	fall	736	87
west	fall	868	123
central	fall	891	130
east	fall	1214	117

Figure 6. Proportion positive catch of DOL by sampling area and season.

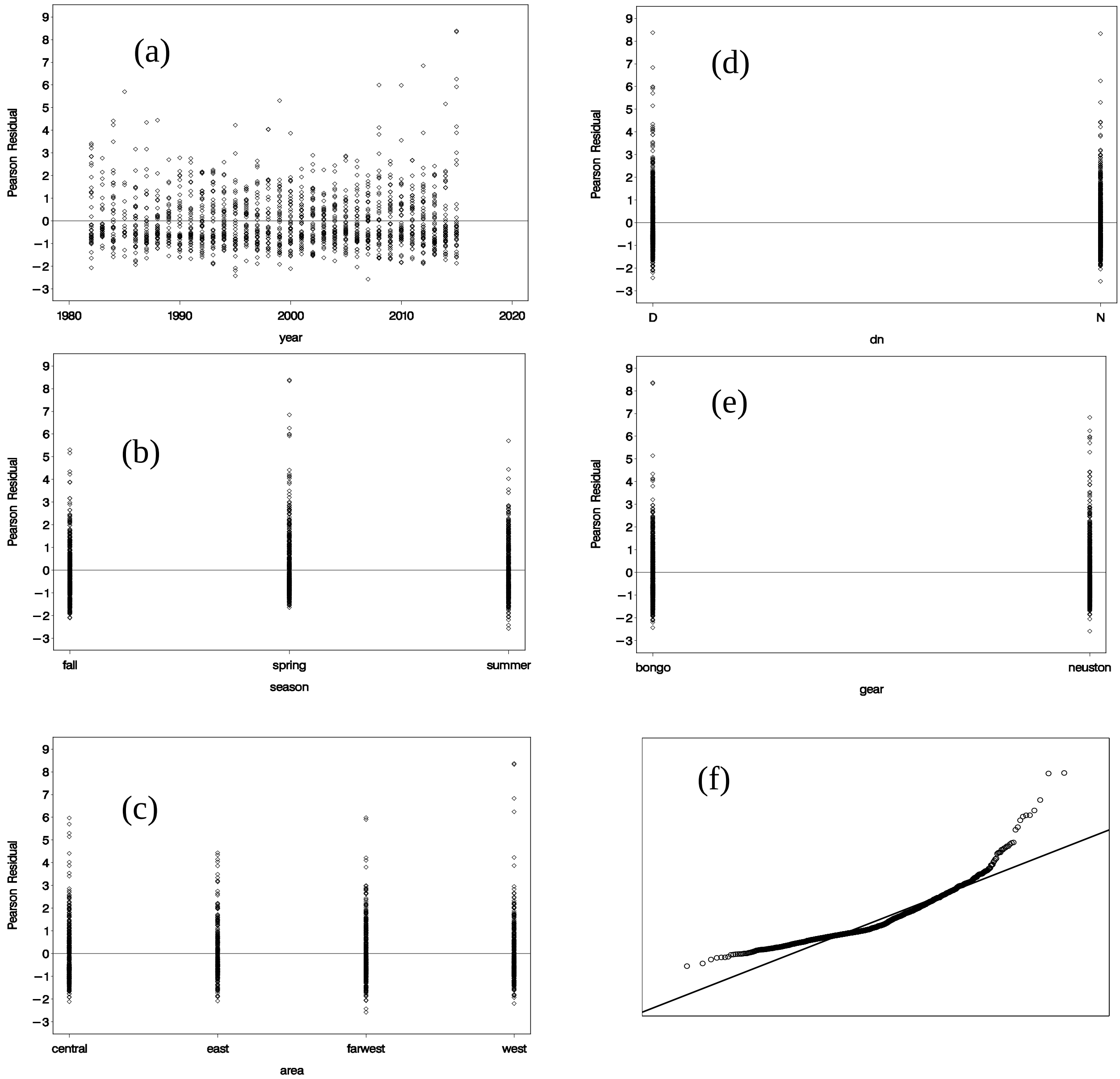


Figure 7. Residual plots of the binomial submodel for LTA larvae collected in bongo and neuston tows. Plot **a** is a plot of residuals versus survey year; plot **b** is of residuals versus season; plot **c** is a plot of residuals versus the survey area variable; plot **d** is a plot of residuals versus the time of day variable; plot **e** is a plot of residuals versus the gear variable; plot **f** is a QQ plot of the residuals.

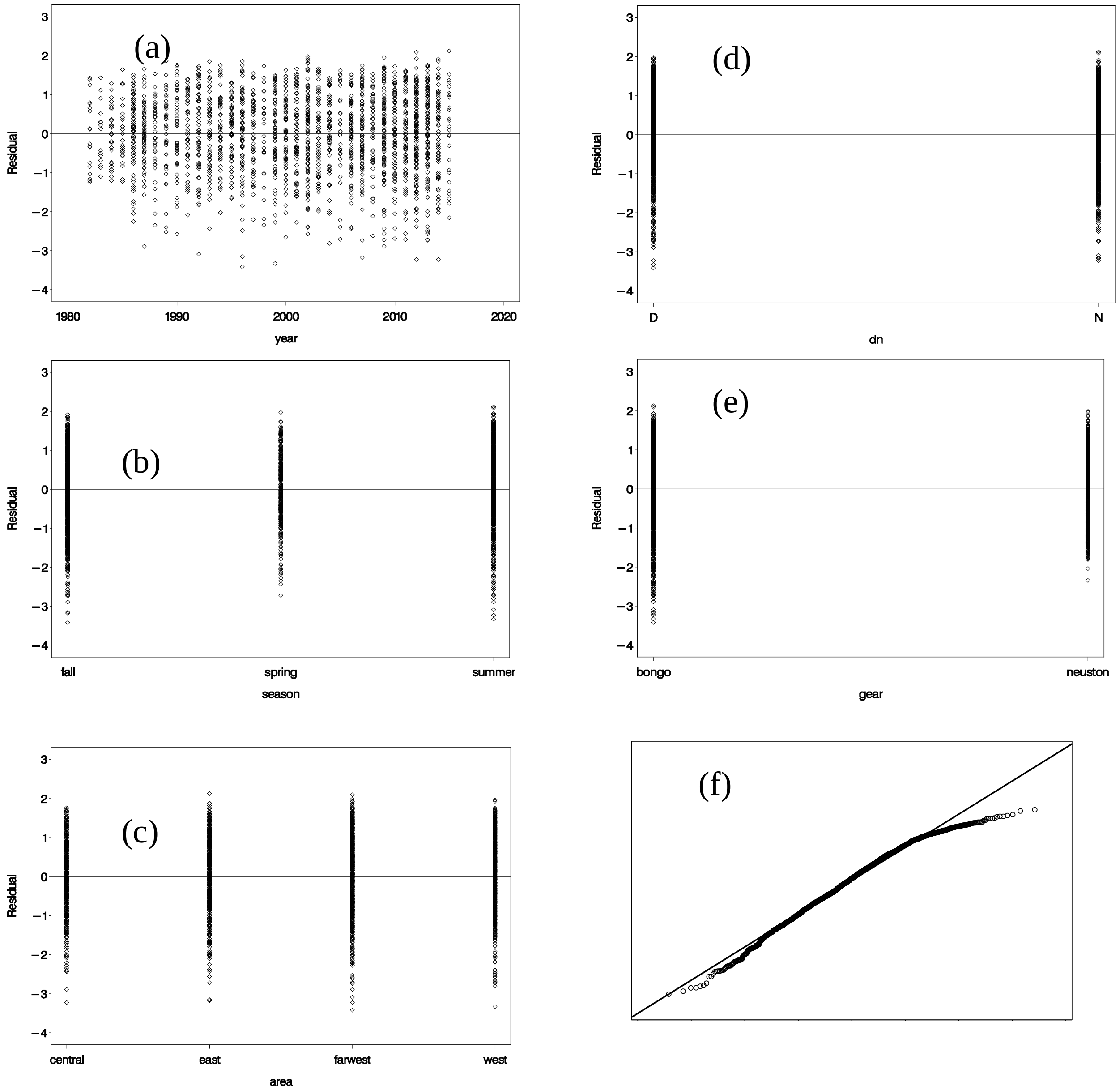


Figure 8. Residual plots of the lognormal submodel for LTA larvae collected in bongo and neuston tows. Plot **a** is a plot of residuals versus survey year; plot **b** is of residuals versus season; plot **c** is a plot of residuals versus the survey area variable; plot **d** is a plot of residuals versus the time of day variable; plot **e** is a plot of residuals versus the gear variable; plot **f** is a QQ plot of the residuals.

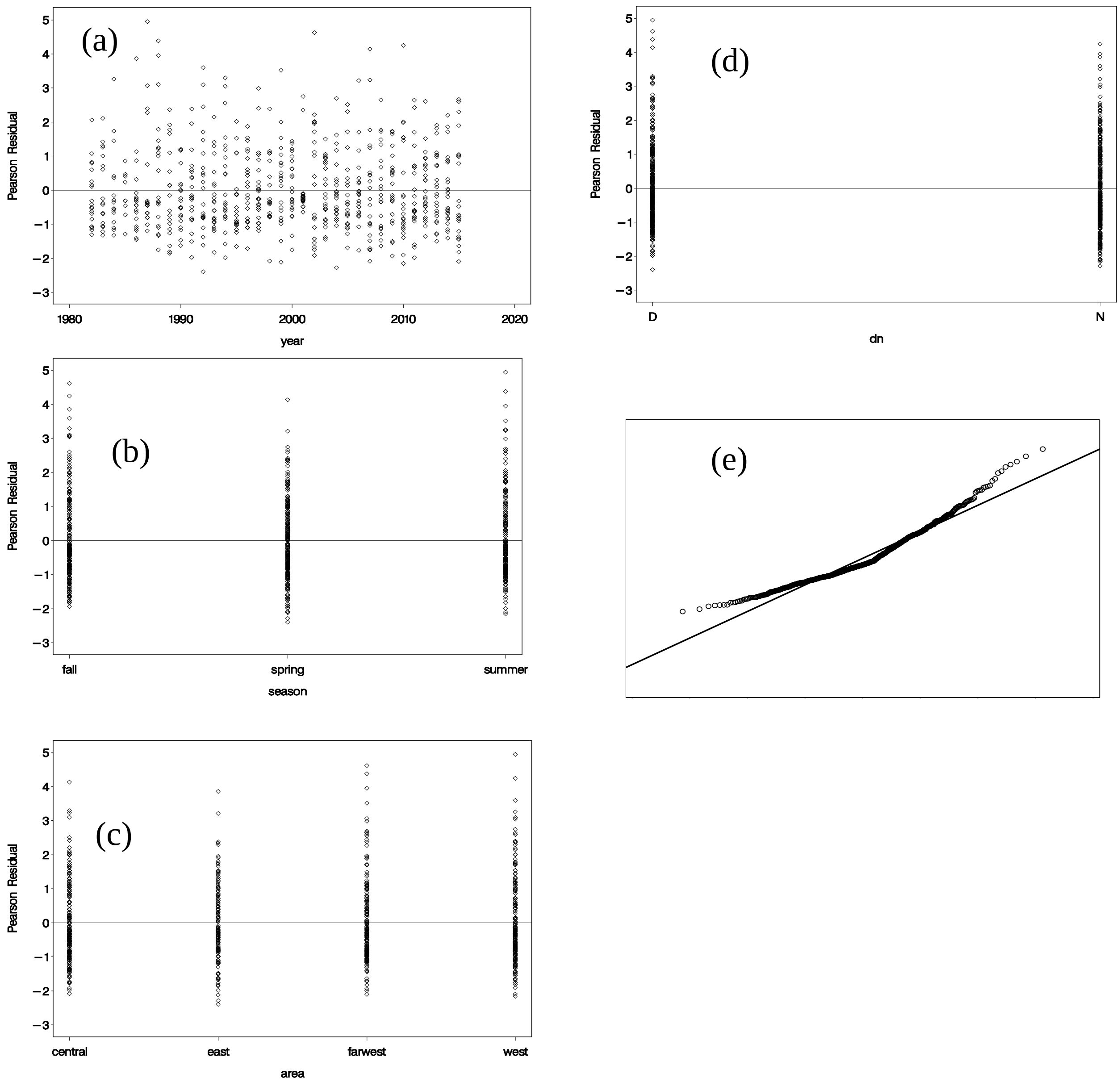


Figure 9. Residual plots of the binomial submodel for DOL larvae collected in neuston tows. Plot **a** is a plot of residuals versus survey year; plot **b** is of residuals versus season; plot **c** is a plot of residuals versus the survey area variable; plot **d** is a plot of residuals versus the time of day variable; plot **e** is a QQ plot of the residuals.

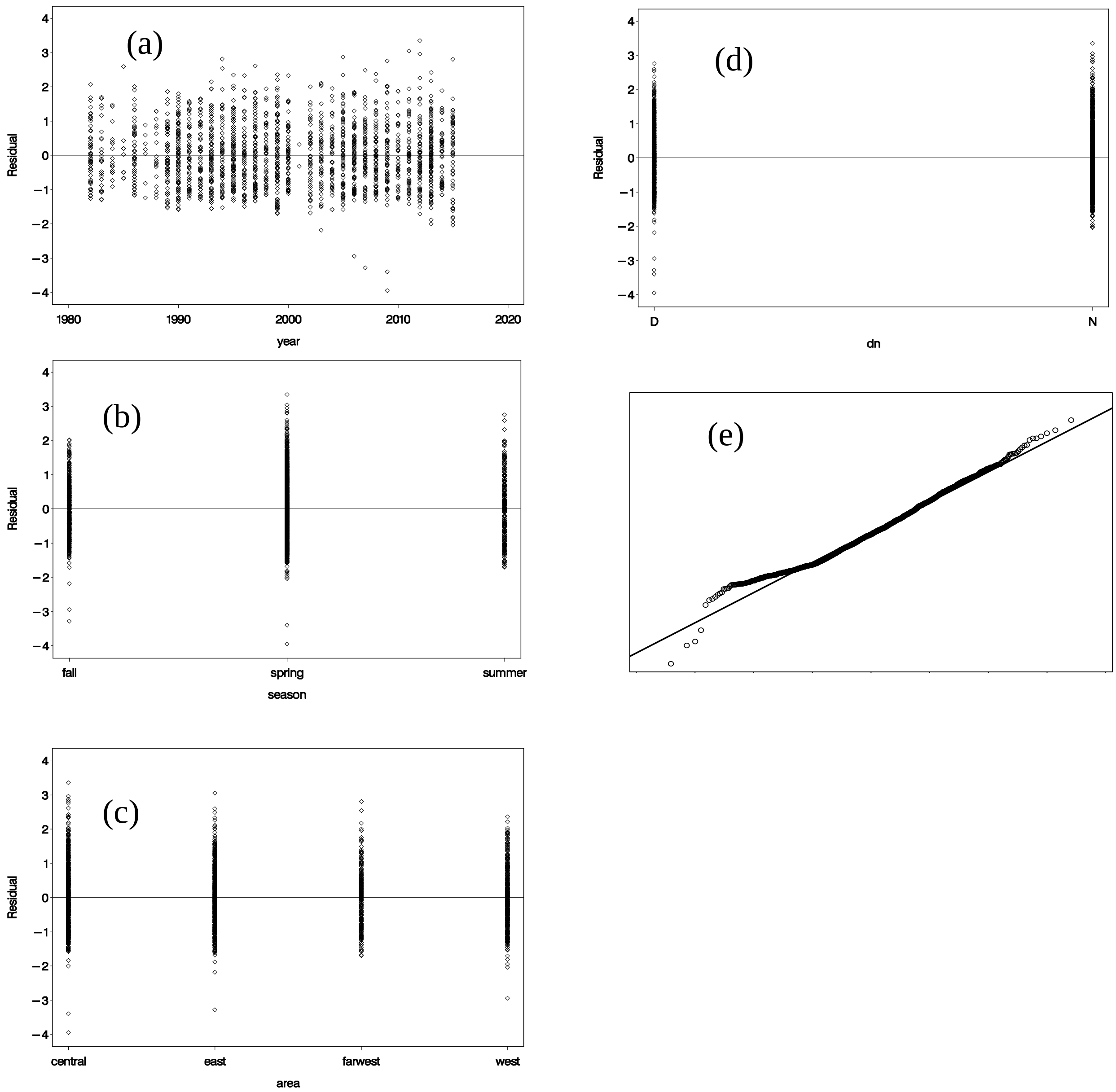


Figure 10. Residual plots of the lognormal submodel for DOL larvae collected in neuston tows. Plot **a** is a plot of residuals versus survey year; plot **b** is of residuals versus season; plot **c** is a plot of residuals versus the survey area variable; plot **d** is a plot of residuals versus the time of day variable; plot **e** is a QQ plot of the residuals.

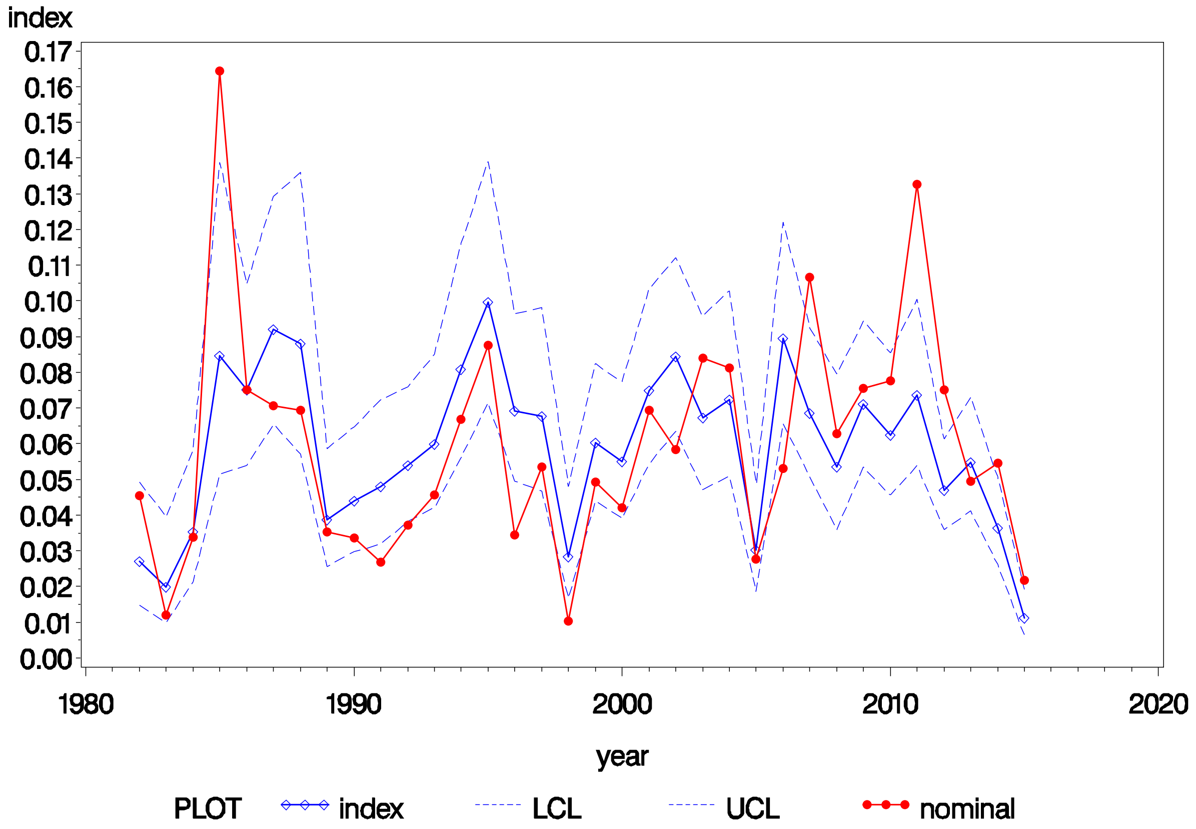


Figure 11. Annual indices (with 95% confidence limits) and nominal means of LTA developed from the DL model.

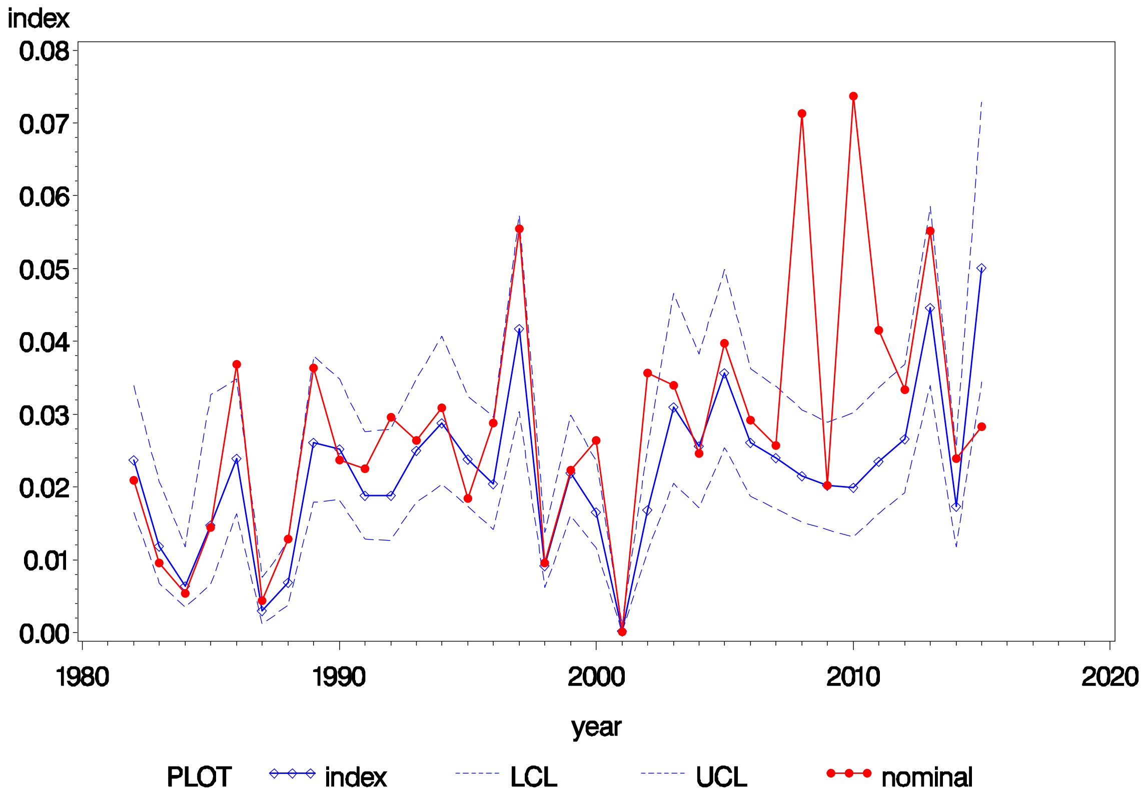
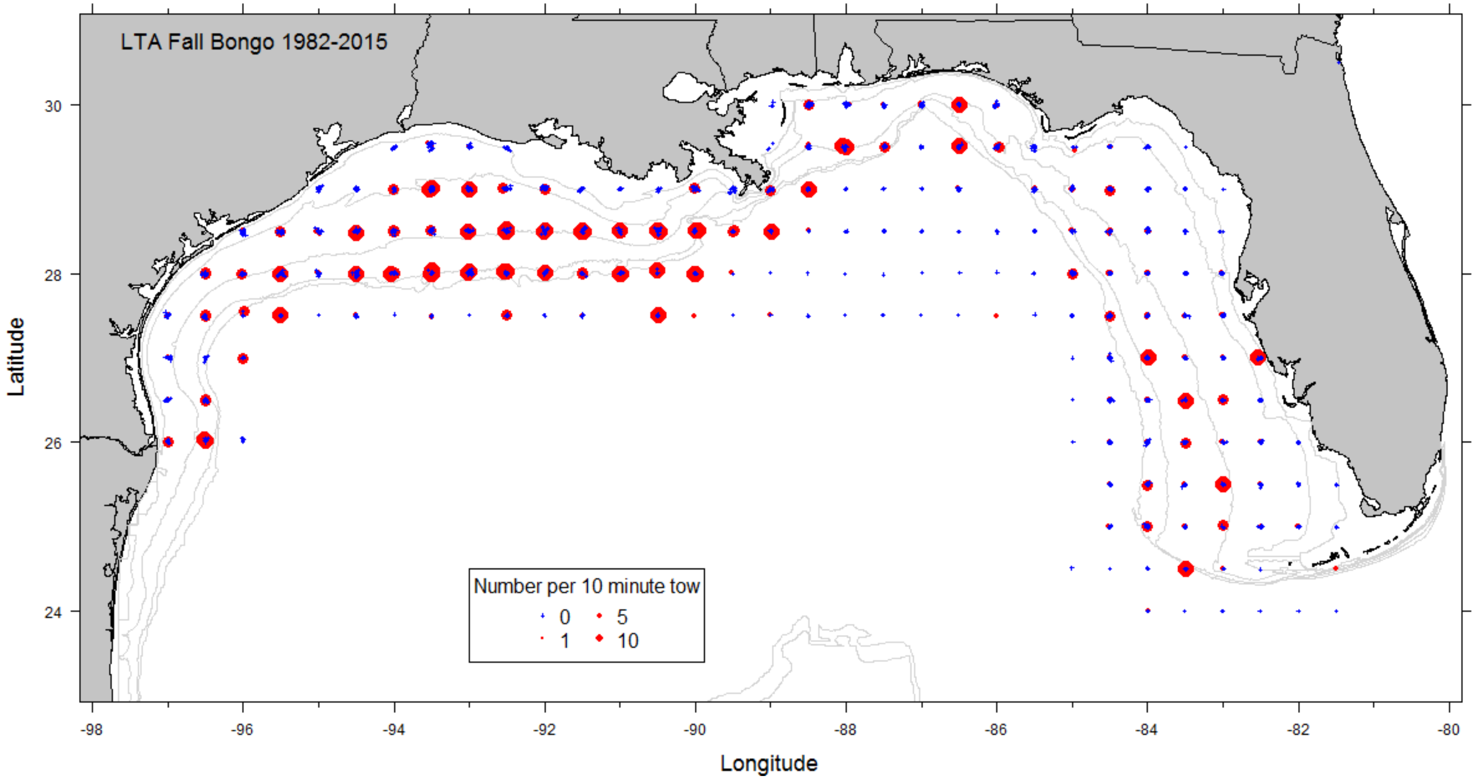
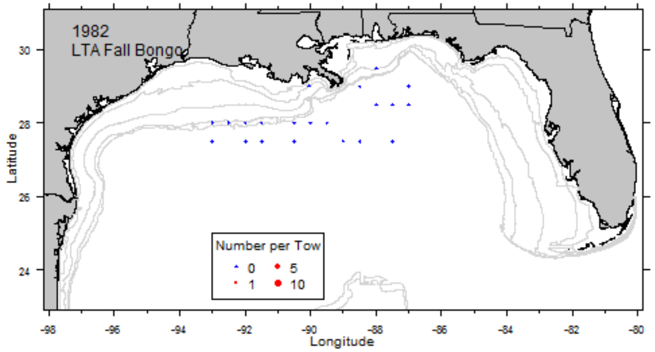


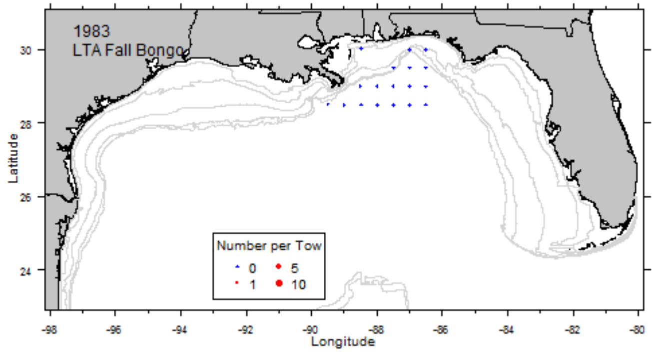
Figure 12. Annual indices (with 95% confidence limits) and nominal means of DOL developed from the DL model.

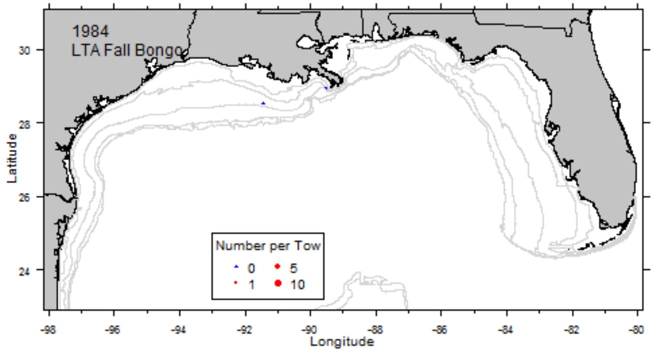
Appendix

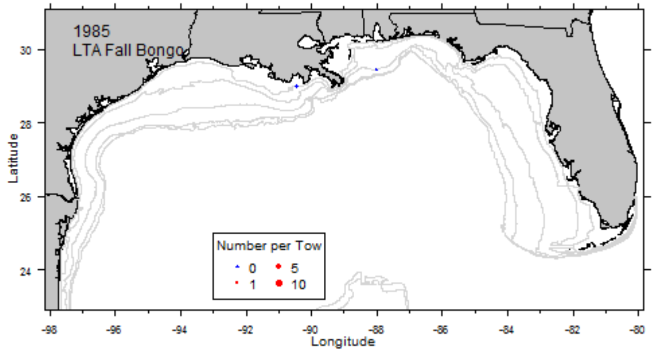
Charts showing bongo and neuston effort and number of specimens collected per station for each year and season in the time series and for all years combined by season.

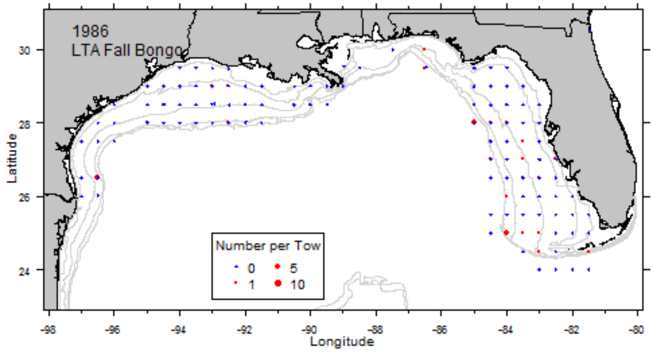


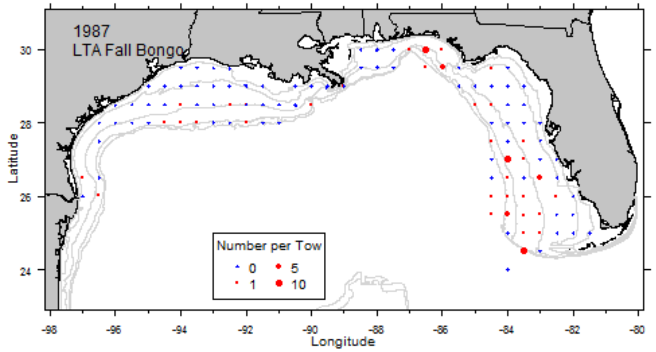

1982
LTA Fall Bongo
Number per Tow
0 5
1 10
Latitude
Longitude

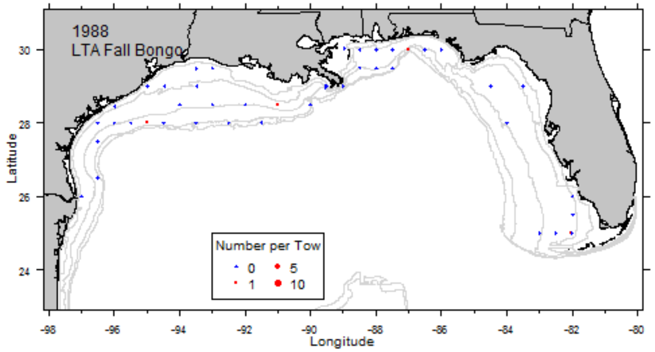

1983
LTA Fall Bongo
Number per Tow
0 5
1 10
Latitude
Longitude

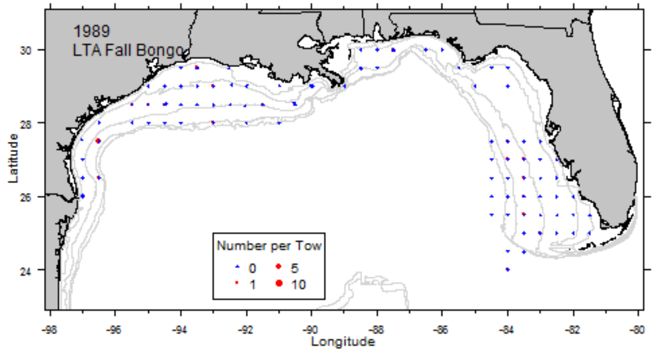

1984
LTA Fall Bongo
Number per Tow
0 5
1 10
Latitude
Longitude

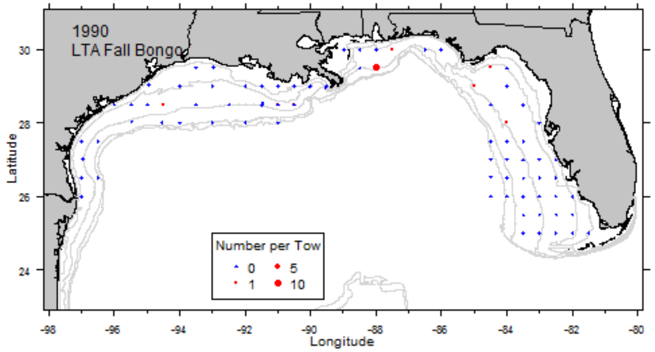

1985
LTA Fall Bongo
Number per Tow
0 5
1 10
Latitude
Longitude

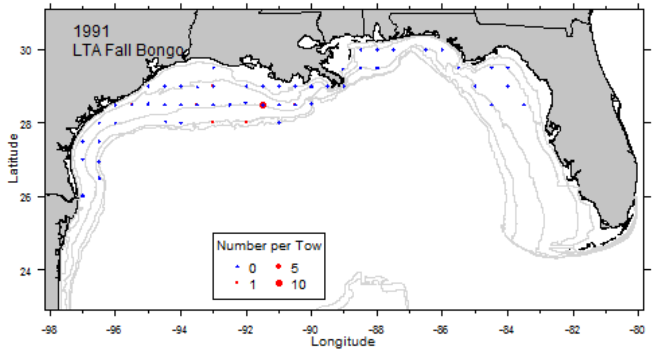

1986
LTA Fall Bongo
Number per Tow
0 5
1 10
Latitude
Longitude

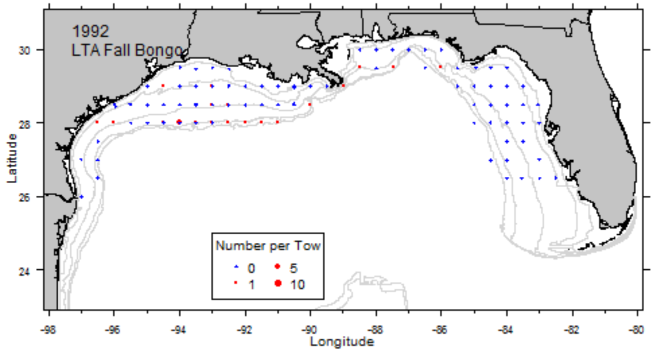

1987
LTA Fall Bongo
Number per Tow
0 5
1 10
Latitude
Longitude


1988
LTA Fall Bongo
Number per Tow
0 5
1 10
Latitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80
Longitude


1989
LTA Fall Bongo
Number per Tow
0 5
1 10
Latitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80
Longitude


1990
LTA Fall Bongo
Number per Tow
0 5
1 10
Latitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80
Longitude


1991
LTA Fall Bongo
Number per Tow
0 5
1 10
Latitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80
Longitude


1992
LTA Fall Bongo
Number per Tow
0 5
1 10
Latitude
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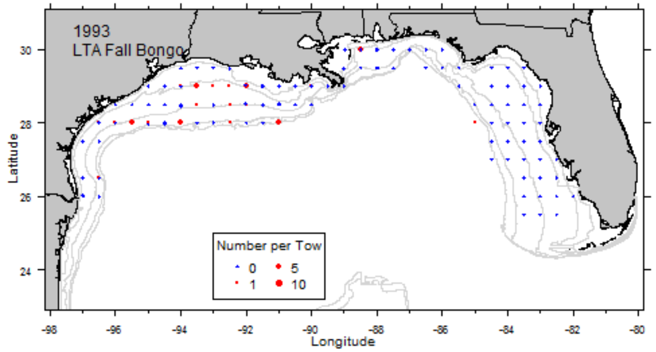
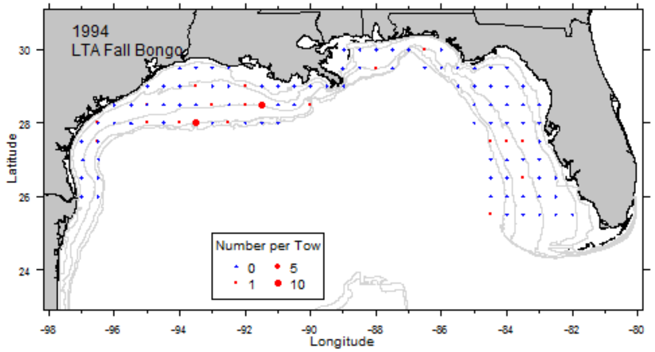
Longitude


1993
LTA Fall Bongo
Number per Tow
0 5
1 10
Latitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80
Longitude


1994
LTA Fall Bongo
Number per Tow
0
5
1
10
Latitude
Longitude
30
28
26
24
-98
-96
-94
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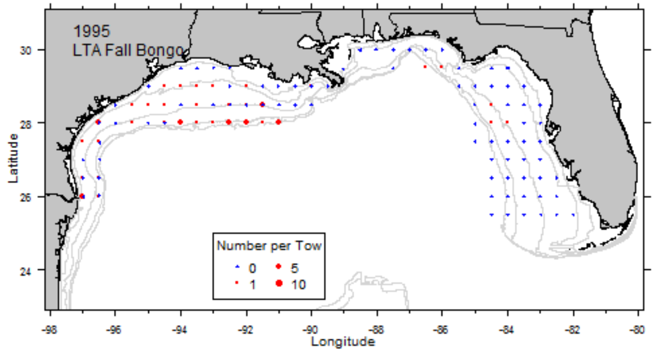
-86
-84
-82
-80


1995
LTA Fall Bongo
Number per Tow
0
5
1
10
Latitude
Longitude
30
28
26
24
-98
-96
-94
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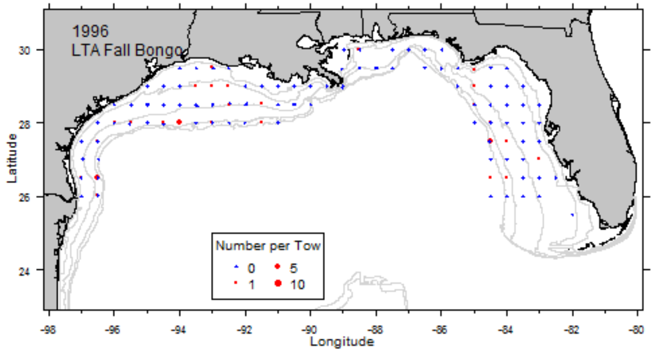
-86
-84
-82
-80


1996
LTA Fall Bongo
Number per Tow
0
5
1
10
Latitude
Longitude
30
28
26
24
-98
-96
-94
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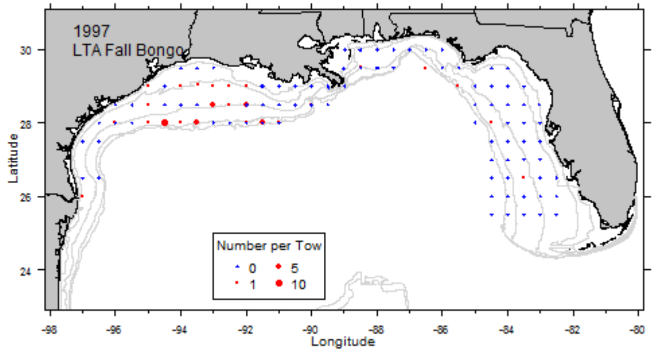
-86
-84
-82
-80


1997
LTA Fall Bongo
Number per Tow
0
5
1
10
Latitude
Longitude
30
28
26
24
-98
-96
-94
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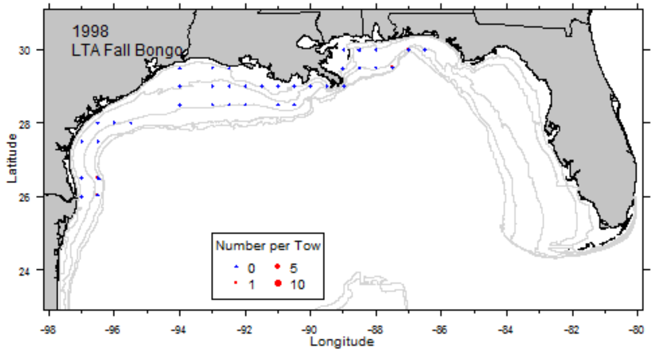
-86
-84
-82
-80


1998
LTA Fall Bongo
Number per Tow
0
5
1
10
Latitude
Longitude
30
28
26
24
-98
-96
-94
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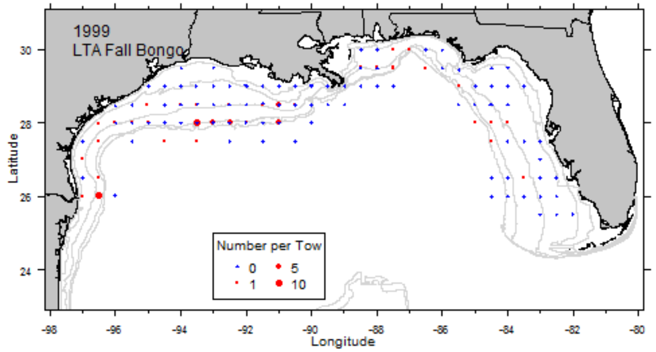
-86
-84
-82
-80


1999
LTA Fall Bongo
Number per Tow
0
5
1
10
Latitude
Longitude
30
28
26
24
-98
-96
-94
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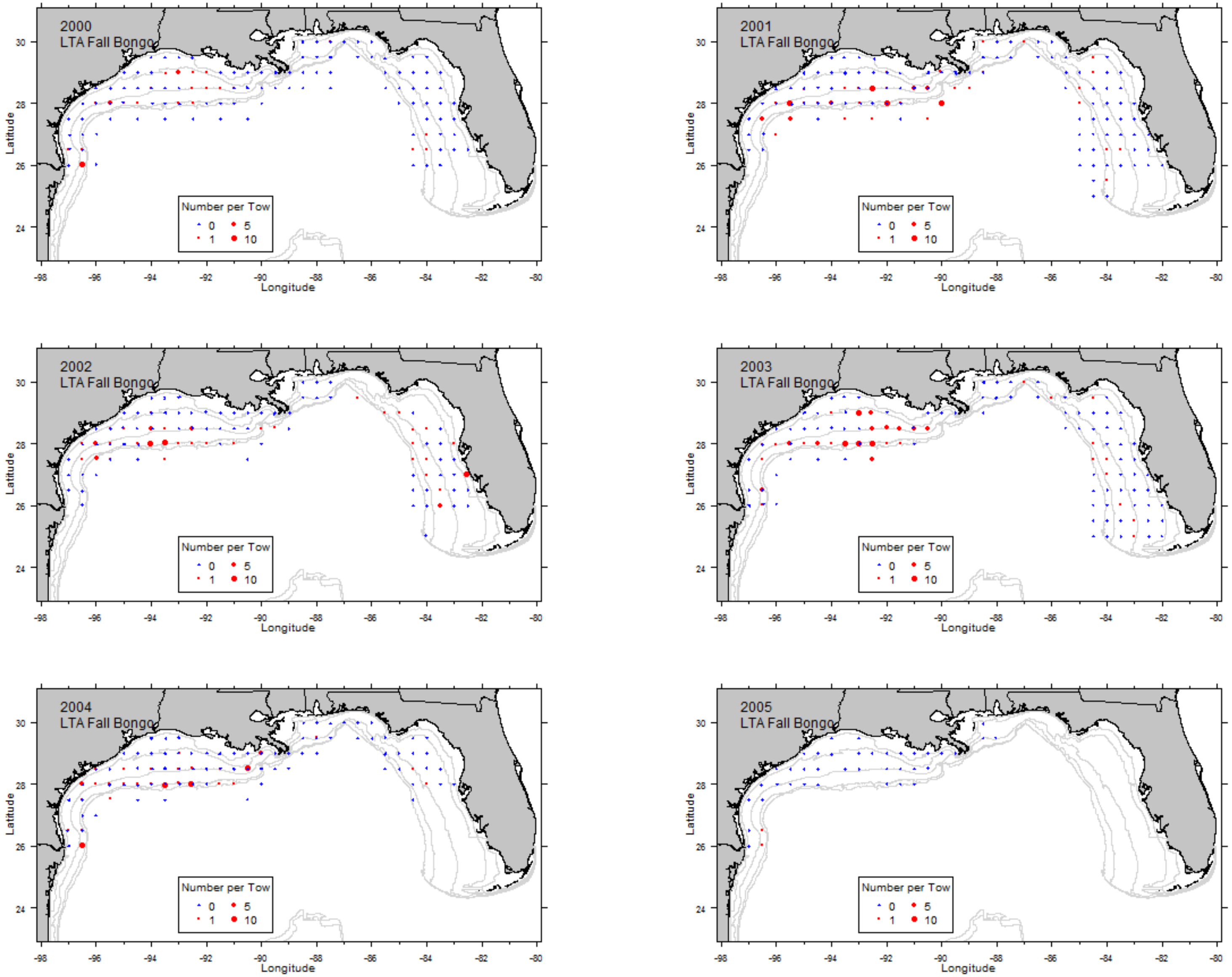
-86
-84
-82
-80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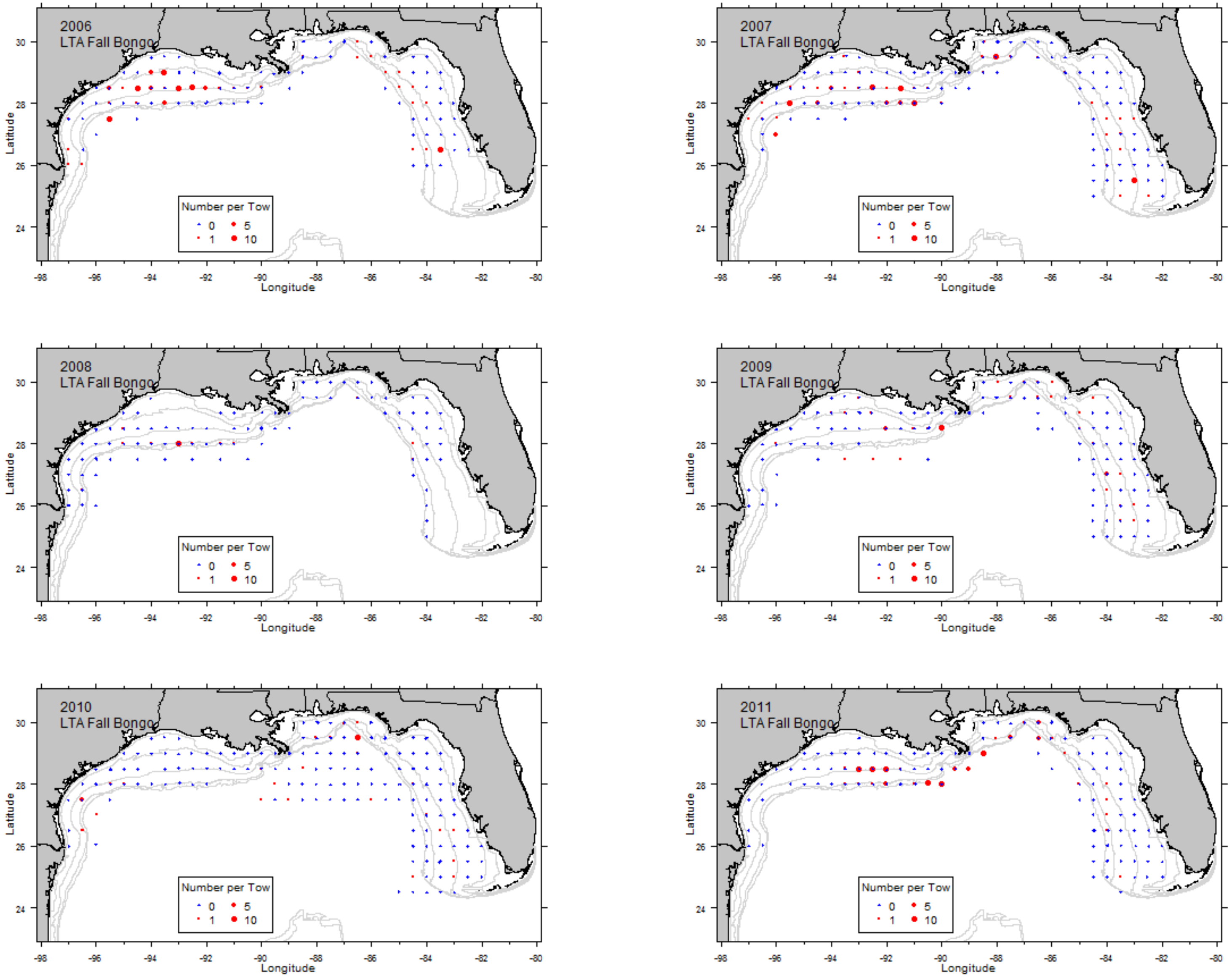
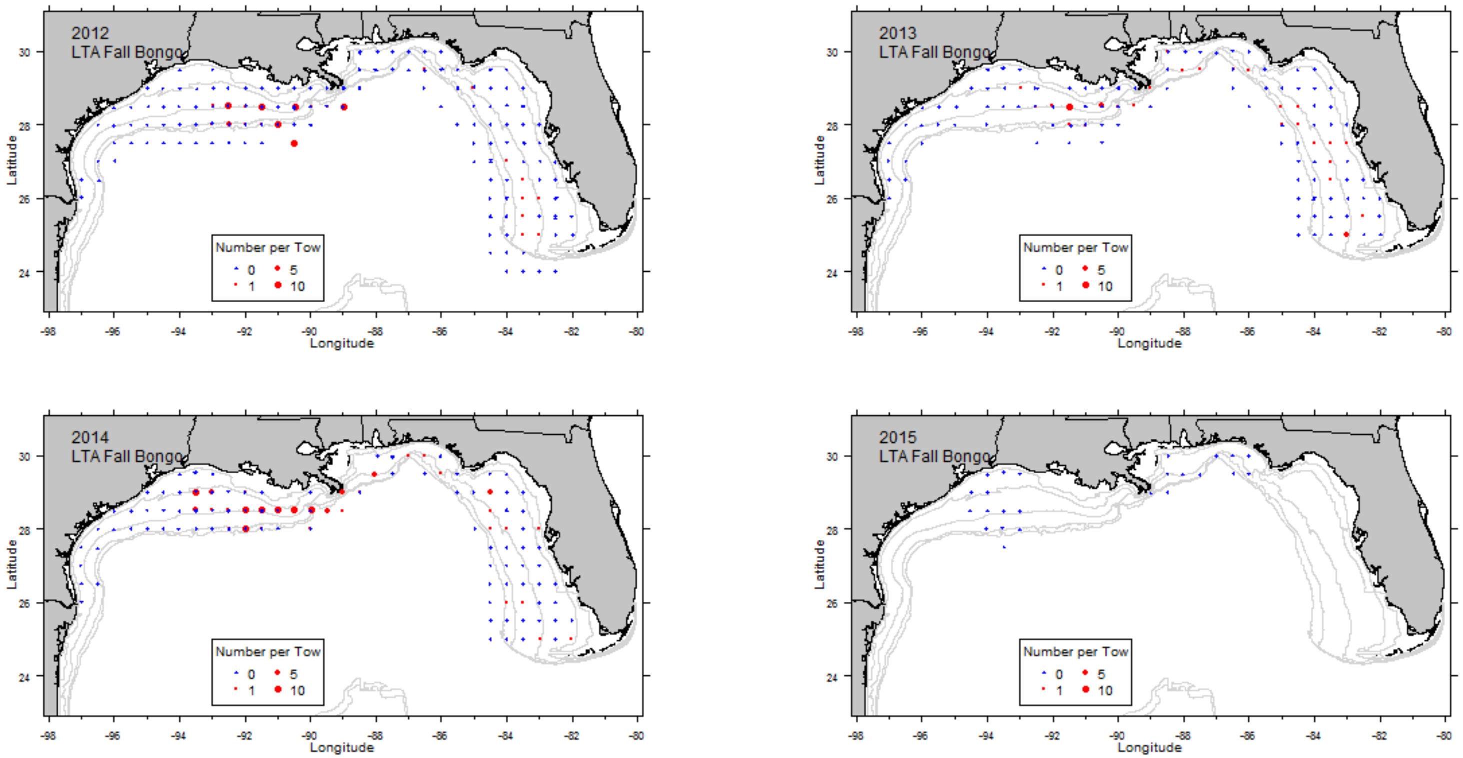
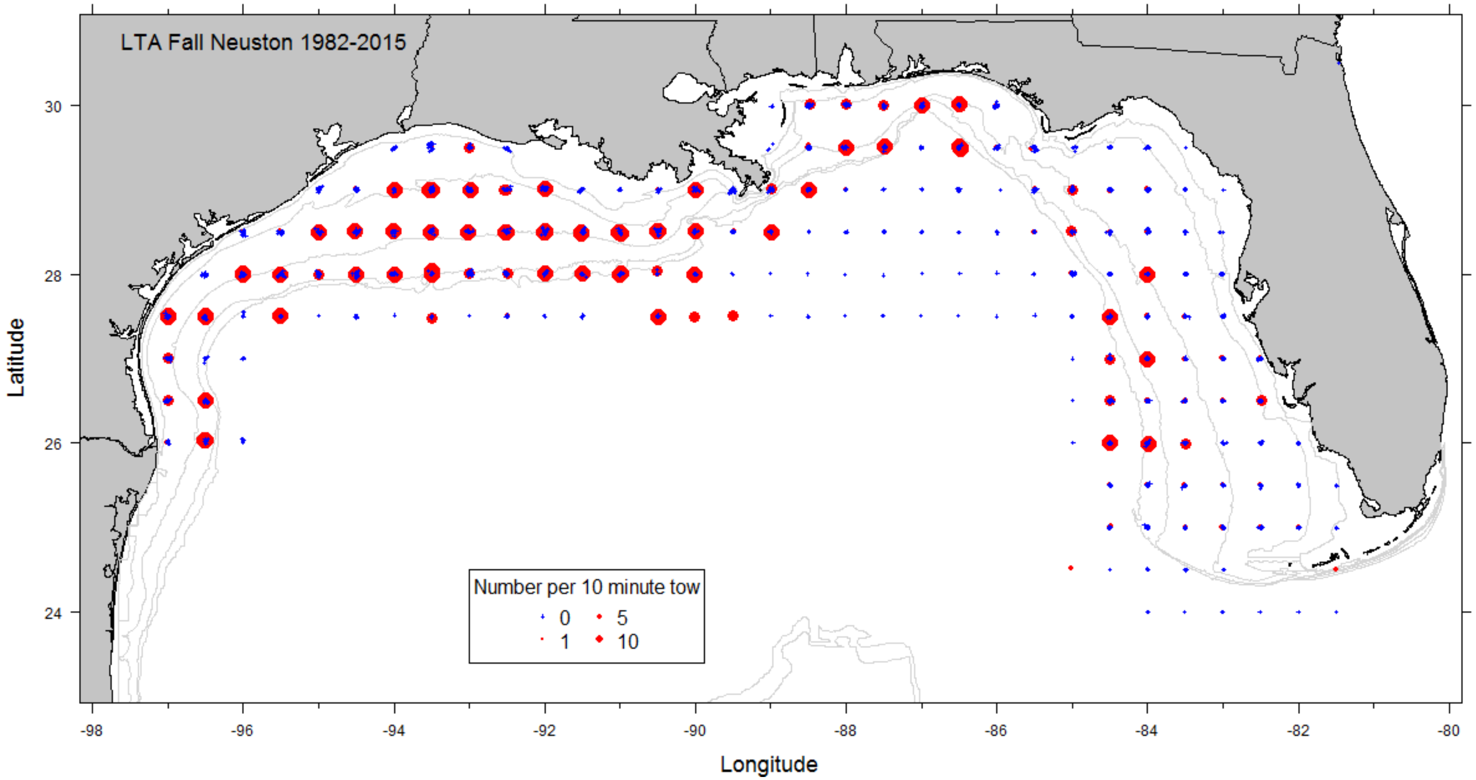
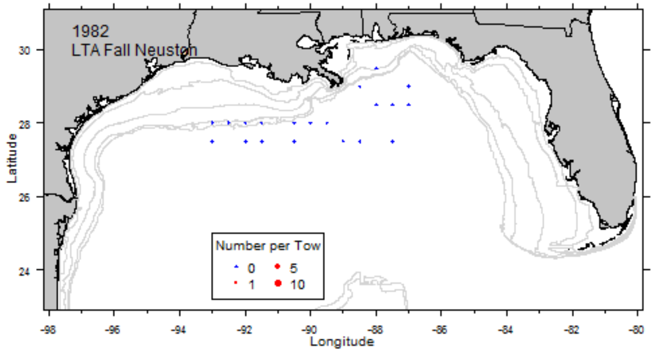
2001
LTA Fall Bongo
2002
LTA Fall Bongo
2003
LTA Fall Bongo
2004
LTA Fall Bongo
2005
LTA Fall Bongo
Number per Tow
0
1
5
10
Latitude
Longitude
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80
24 26 28 30


2006
LTA Fall Bongo
2007
LTA Fall Bongo
2008
LTA Fall Bongo
2009
LTA Fall Bongo
2010
LTA Fall Bongo
2011
LTA Fall Bongo
Number per Tow
0
5
1
10
Latitude
Longitude
30
28
26
24
-98
-96
-94
-92
-90
-88
-86
-84
-82
-80


2012
LTA Fall Bongo
Number per Tow
0
5
1
10
Latitude
Longitude
30
28
26
24
-98
-96
-94
-92
-90
-88
-86
-84
-82
-80
2013
LTA Fall Bongo
2014
LTA Fall Bongo
2015
LTA Fall Bongo


LTA Fall Neuston 1982-2015
Latitude
Longitude
30
28
26
24
-98
-96
-94
-92
-90
-88
-86
-84
-82
-80
Number per 10 minute tow
0
5
1
10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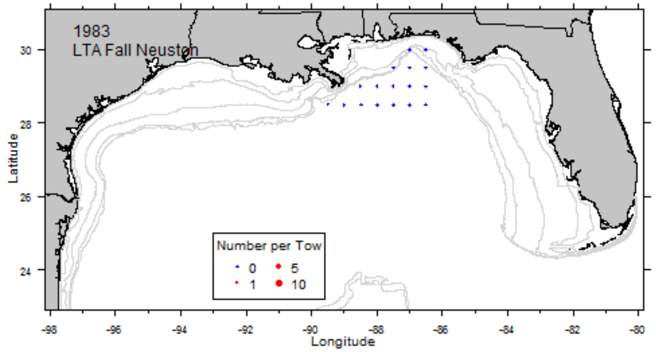
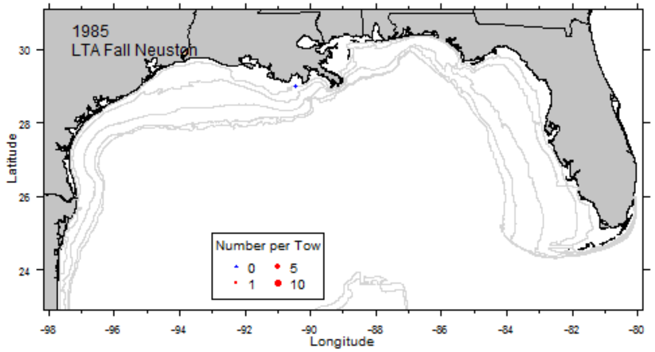
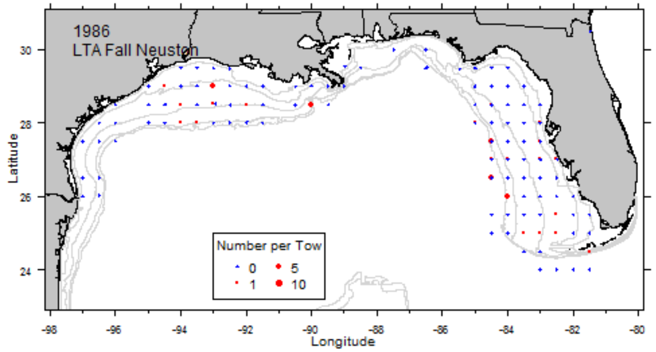
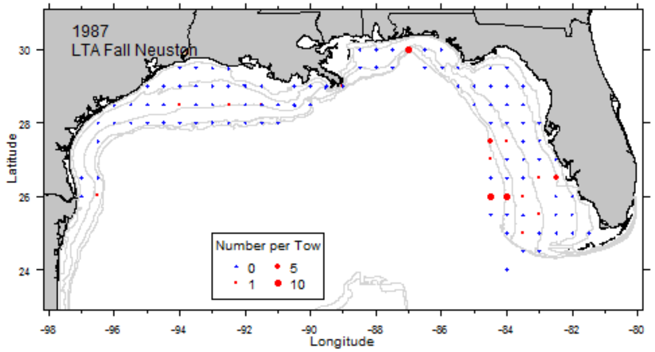
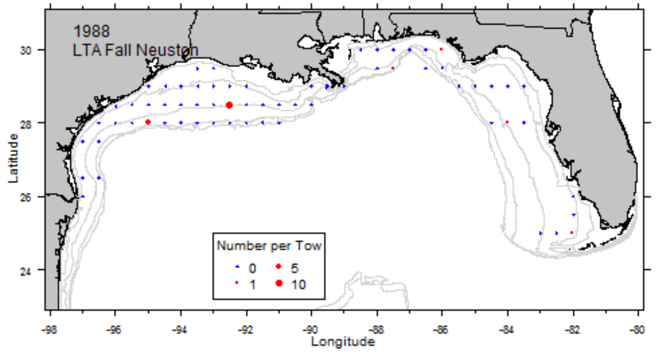
LTA Fall Neuston
Number per Tow
0
5
1
10
Latitude
Longitude

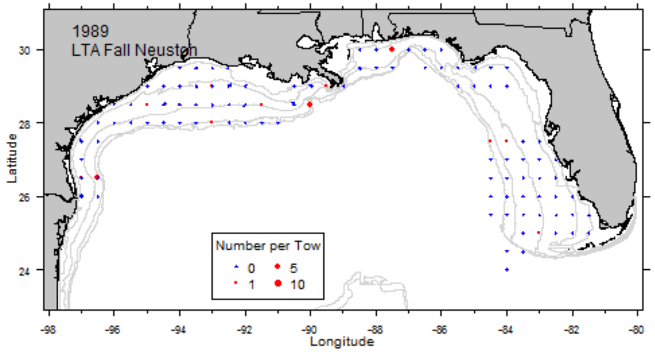

1983
LTA Fall Neuston
Number per Tow
0
5
1
10
Latitude
Longitude

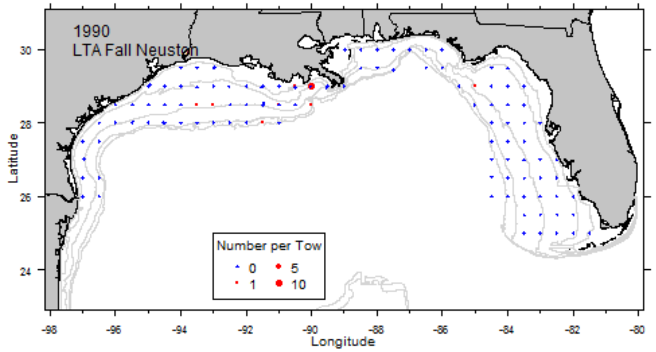

1985
LTA Fall Neuston
Number per Tow
0
5
1
10
Latitude
Longitude

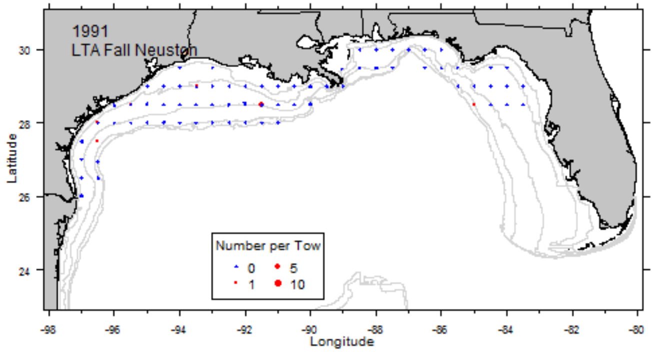

1986
LTA Fall Neuston
Number per Tow
0
5
1
10
Latitude
Longitude

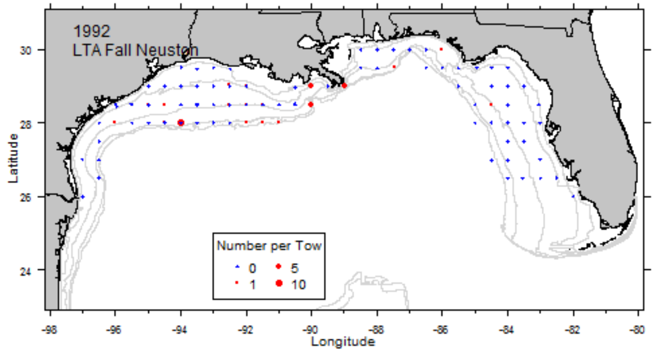

1987
LTA Fall Neuston
Number per Tow
0
5
1
10
Latitude
Longitude

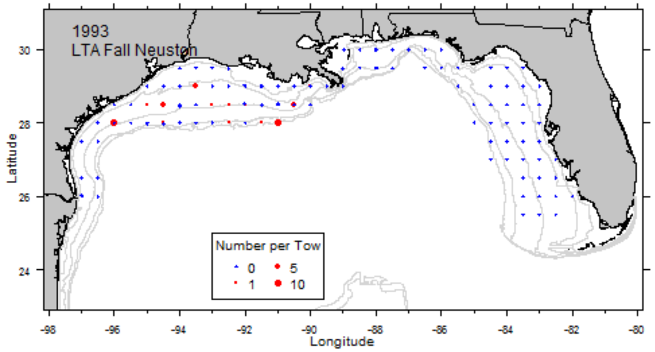

1988
LTA Fall Neuston
Number per Tow
0
5
1
10
Latitude
Longitude

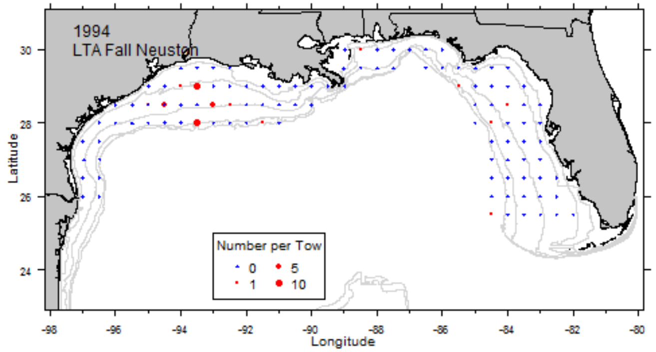

1989
LTA Fall Neuston
Number per Tow
0 5
1 10
Latitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80
Longitude

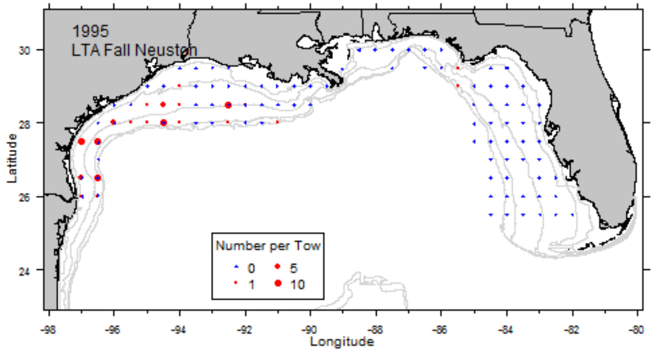

1990
LTA Fall Neuston
Number per Tow
0 5
1 10
Latitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80
Longitude

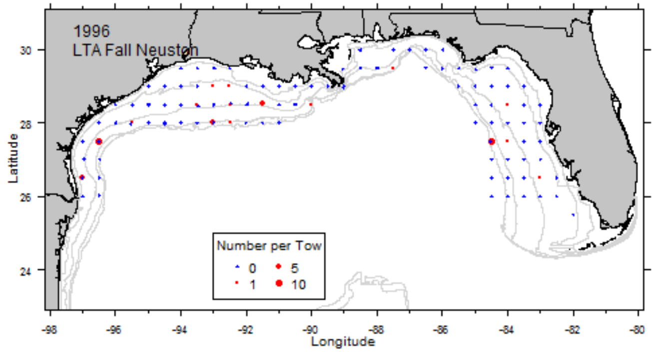

1991
LTA Fall Neuston
Number per Tow
0 5
1 10
Latitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80
Longitude


1992
LTA Fall Neuston
Number per Tow
0 5
1 10
Latitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80
Longitude


1993
LTA Fall Neuston
Number per Tow
0 5
1 10
Latitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80
Longitude


1994
LTA Fall Neuston
Number per Tow
0 5
1 10
Latitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80
Longitude


1995
LTA Fall Neuston
Number per Tow
0 5
1 10
Latitude
30
28
26
24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80
Longitude


1996
LTA Fall Neuston
Number per Tow
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1 10
Latitude
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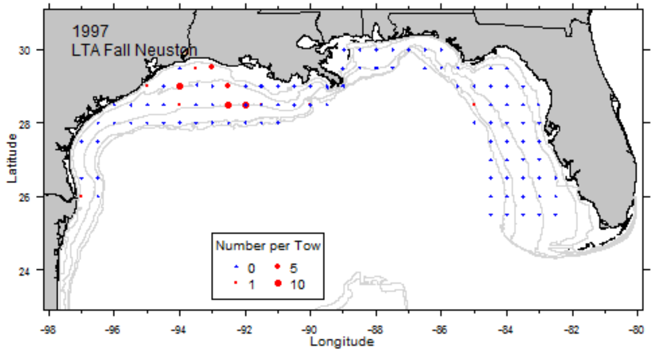
Longitude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Number per Tow
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Latitude
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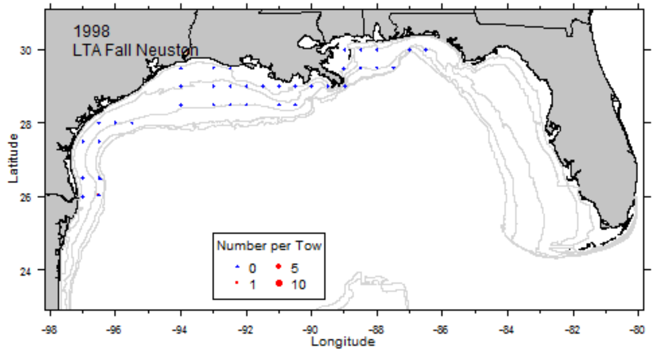
Longitude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Number per Tow
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Latitude
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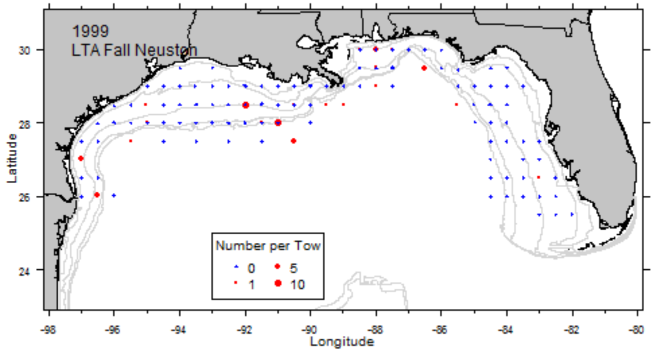
Longitude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Number per Tow
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Latitude
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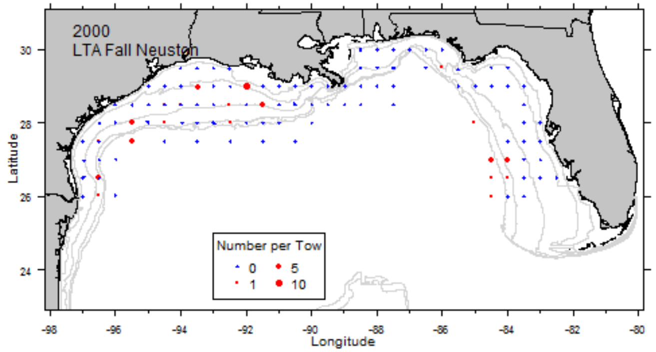
Longitude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Number per Tow
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Latitude
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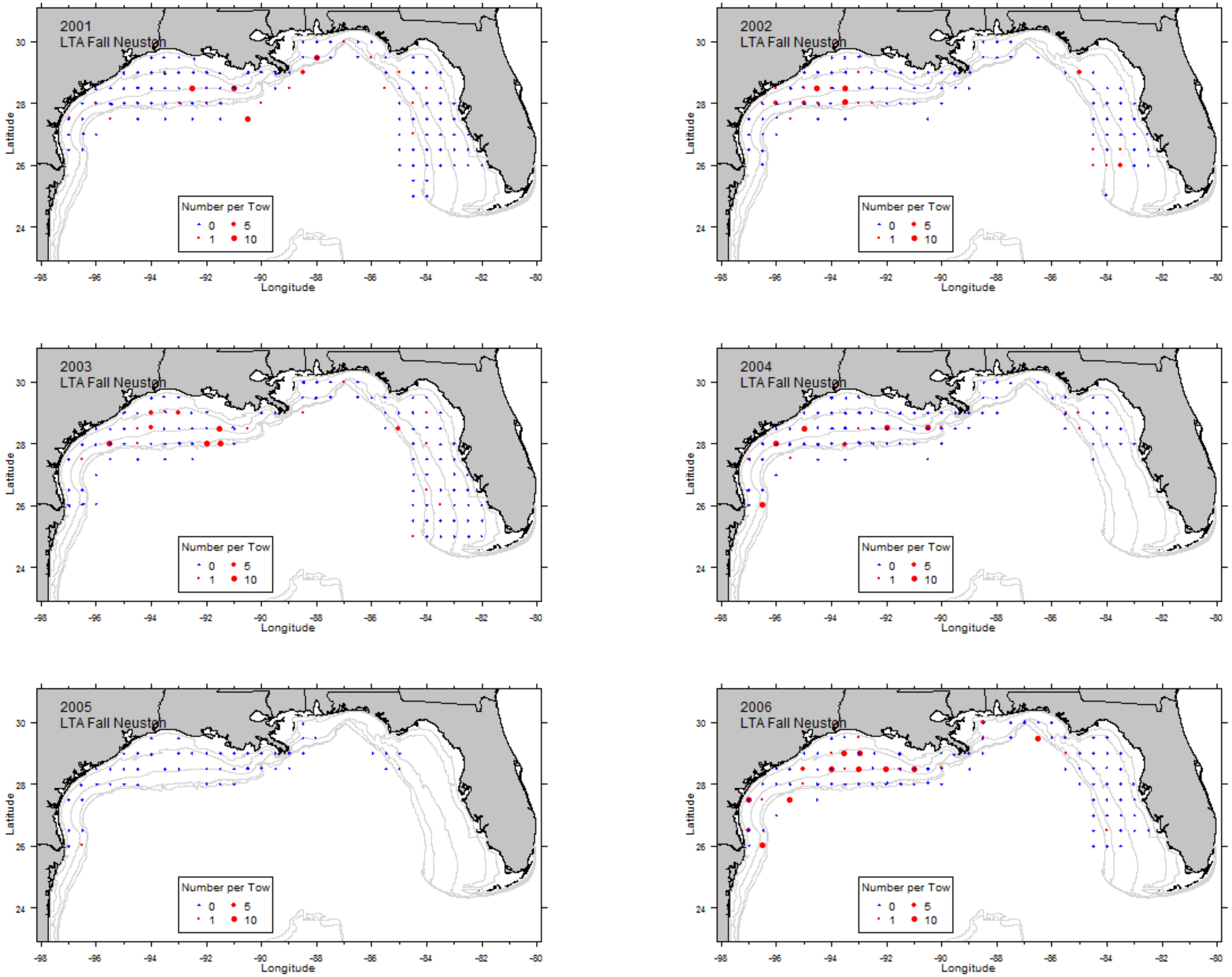
Longitude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2002
LTA Fall Neuston
2003
LTA Fall Neuston
2004
LTA Fall Neuston
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LTA Fall Neuston
2006
LTA Fall Neuston
Number per Tow
0
5
1
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Latitude
Longitude
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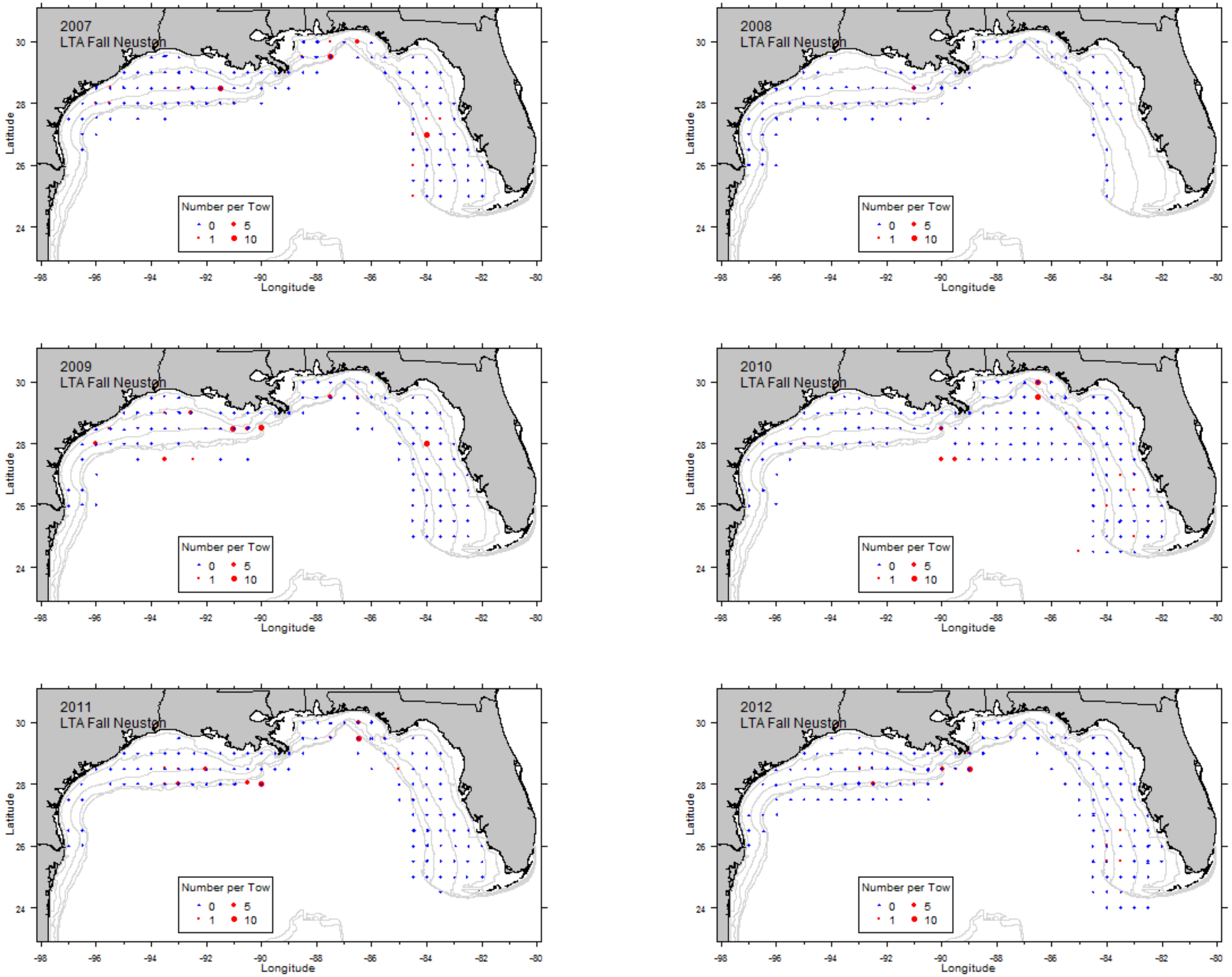
2007
LTA Fall Neuston
2008
LTA Fall Neuston
2009
LTA Fall Neuston
2010
LTA Fall Neuston
2011
LTA Fall Neuston
2012
LTA Fall Neuston
Number per Tow
0
1
5
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Latitude
Longitude
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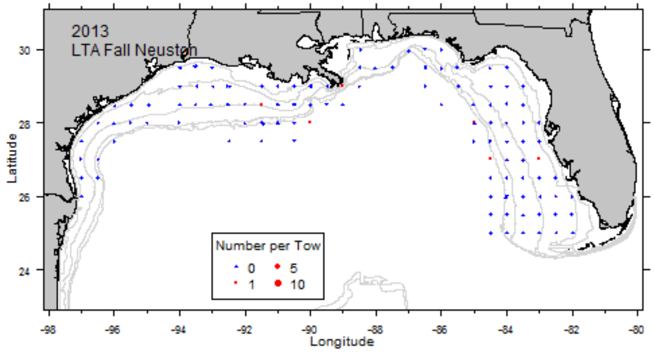
2013
LTA Fall Neuston
Number per Tow
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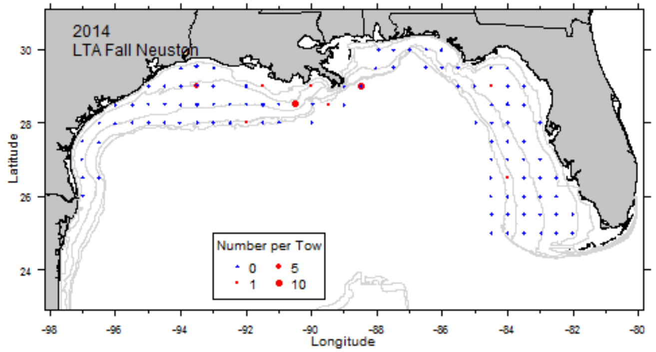
Latitude
Longitude


2014
LTA Fall Neuston
Number per Tow
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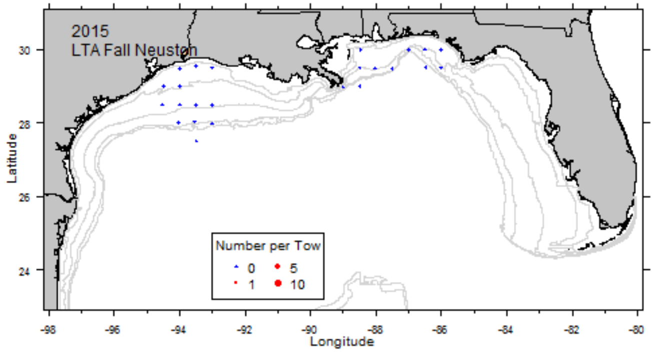
Longitude


2015
LTA Fall Neuston
Number per Tow
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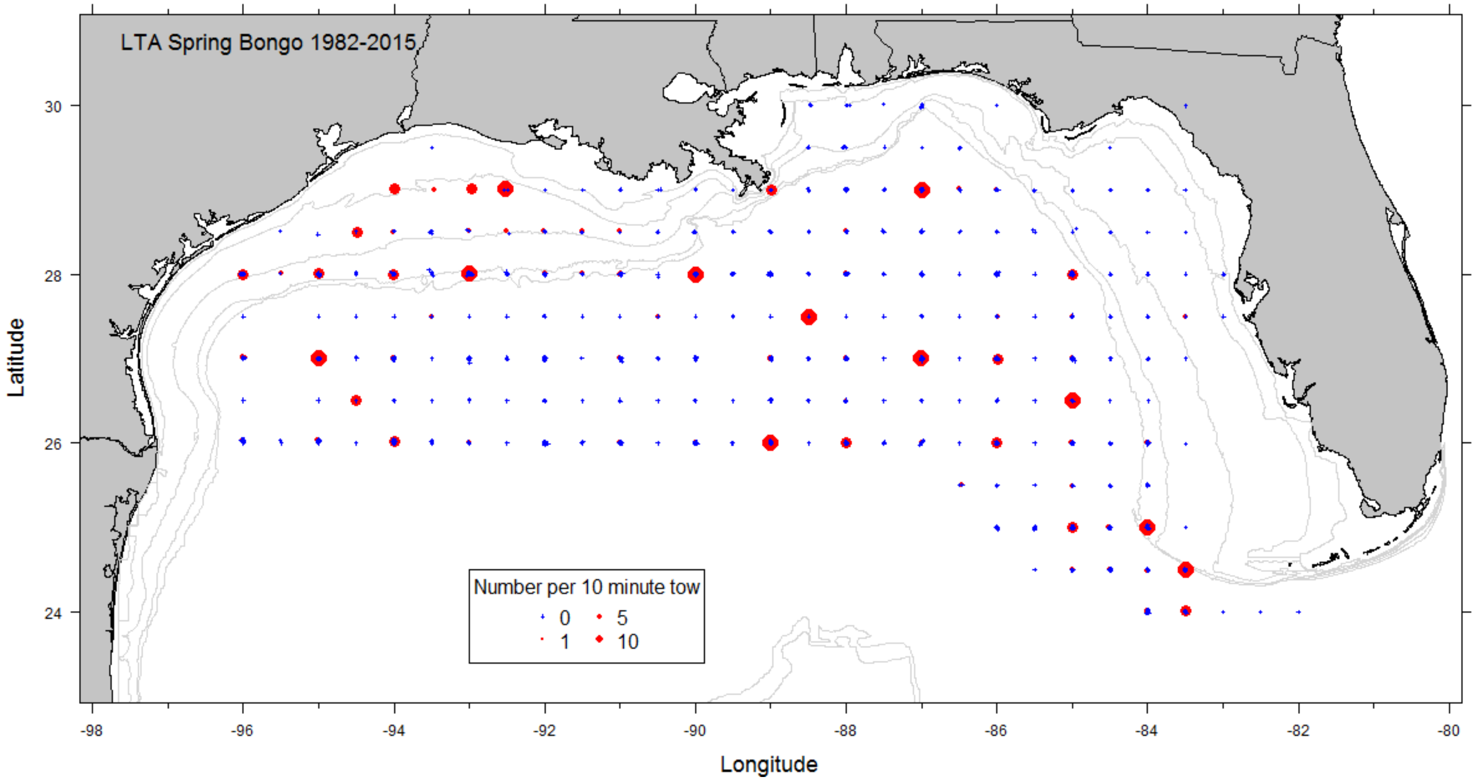
Latitude
Longitude


LTA Spring Bongo 1982-2015
Number per 10 minute tow
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5
1
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Latitude
Longitude
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-86
-84
-82
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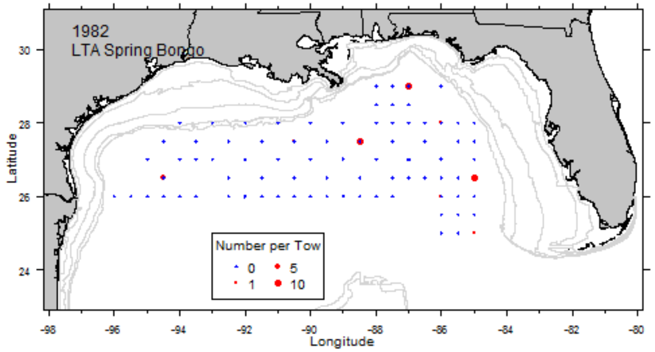
1982
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Number per Tow
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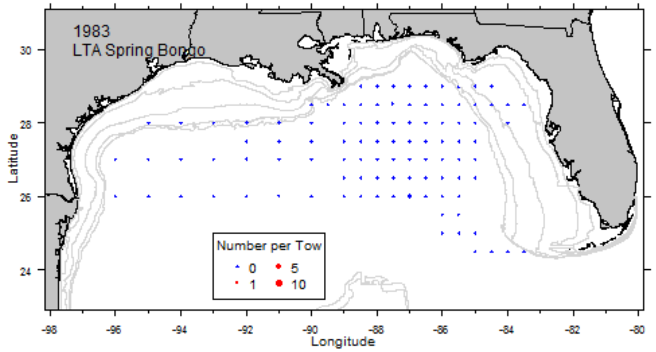
Latitude
Longitude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Number per Tow
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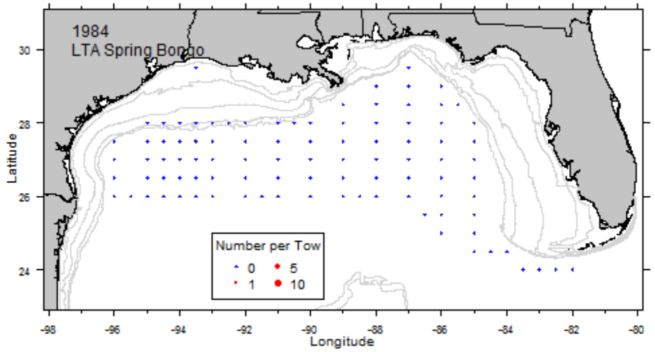
Latitude
Longitude


1984
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Number per Tow
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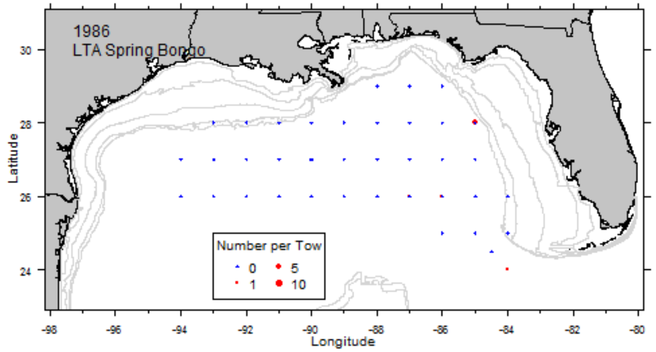
Latitude
Longitude


1986
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Number per Tow
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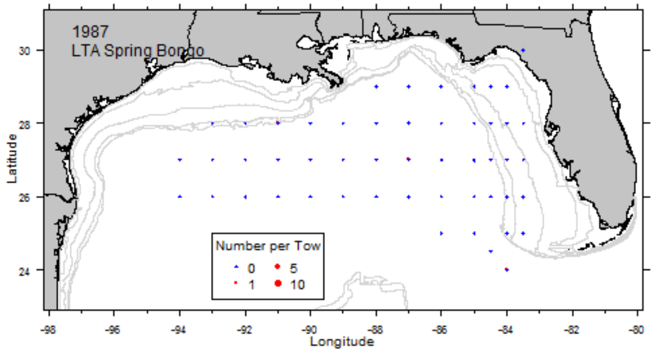
Latitude
Longitude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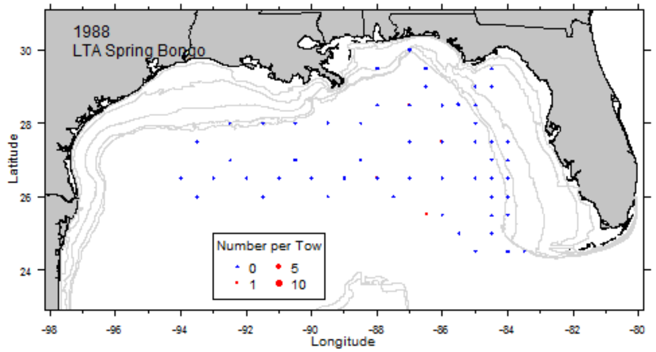
Latitude
Longitude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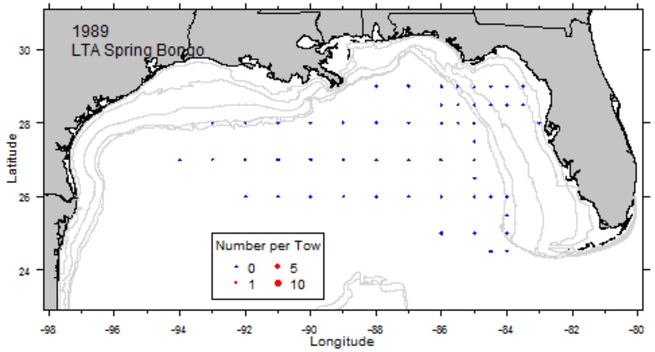
Latitude
Longitude


1989
LTA Spring Bongo
Number per Tow
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Latitude
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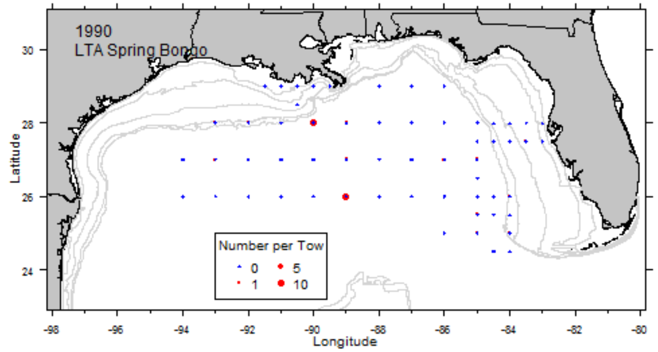
Longitude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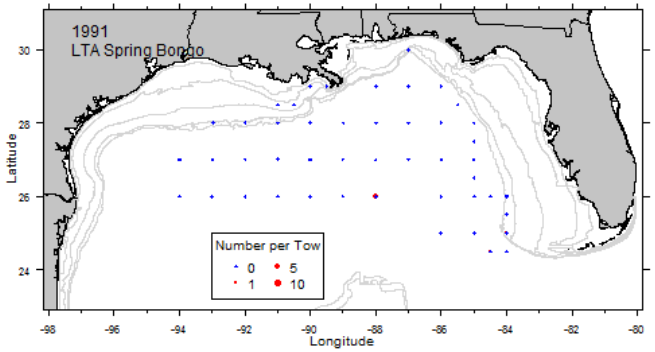
Longitude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Latitude
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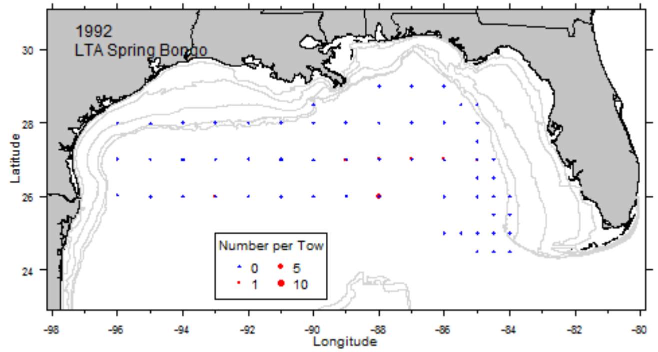
Longitude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Latitude
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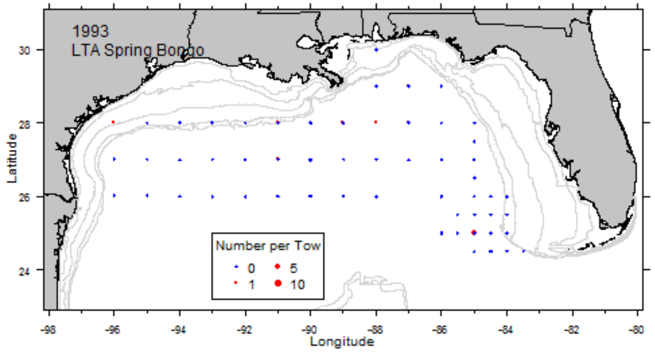
Longitude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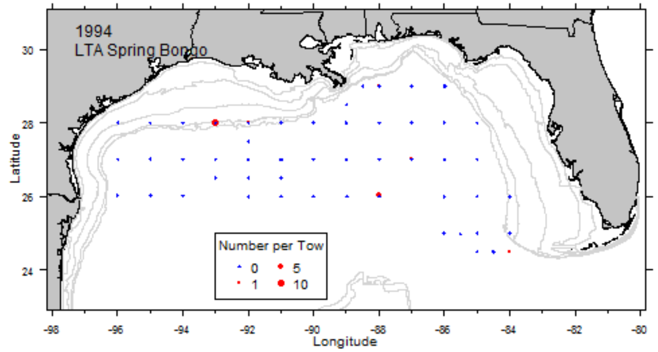
Longitude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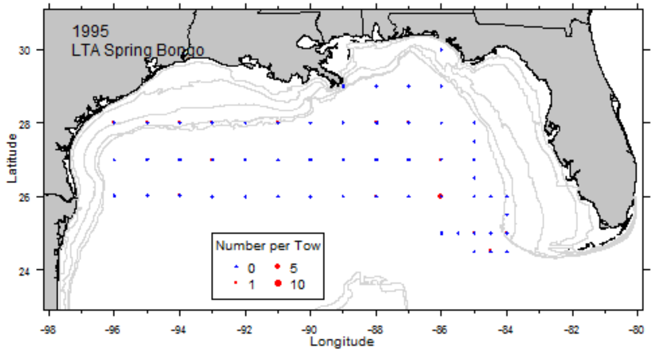
Longitude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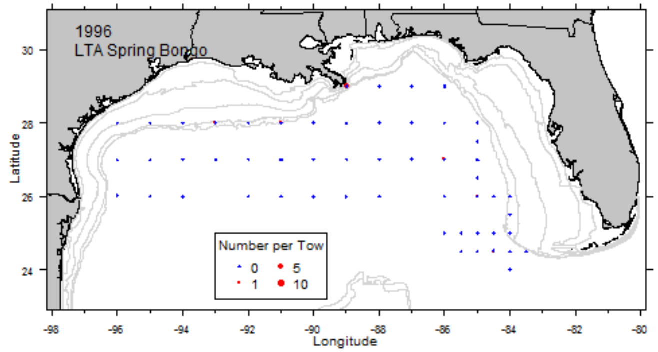
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Number per Tow
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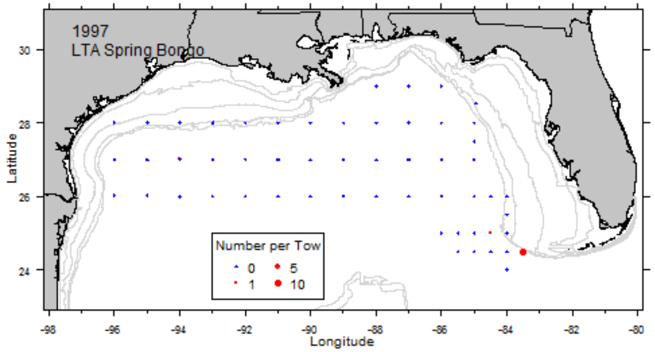
Longitude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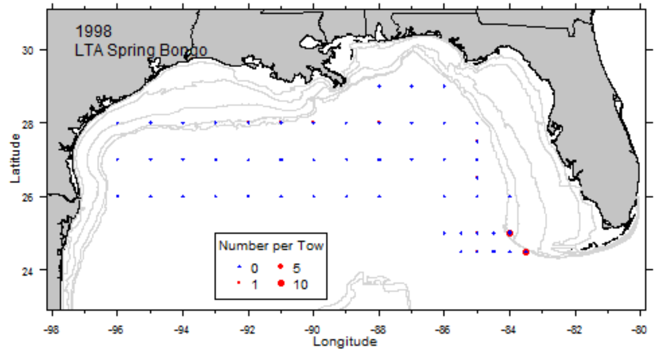
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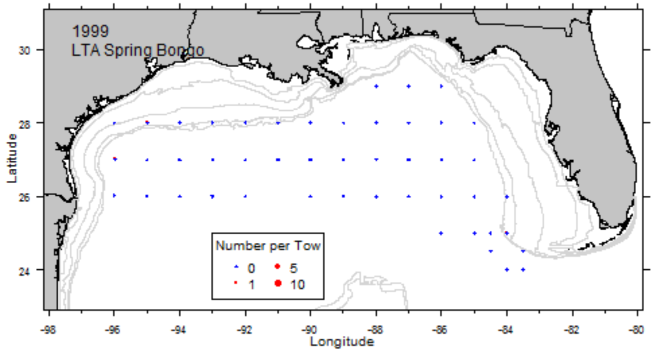
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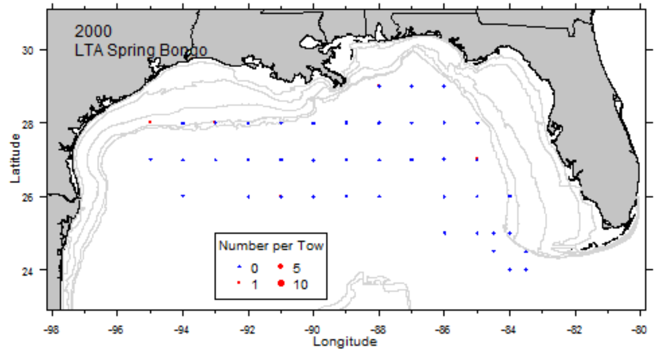
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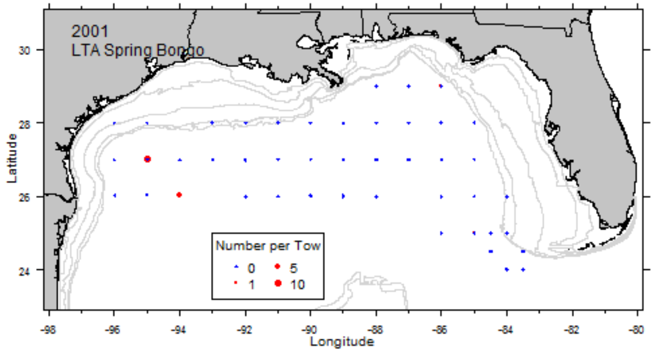
2001
LTA Spring Bongo
Number per Tow
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Longitude
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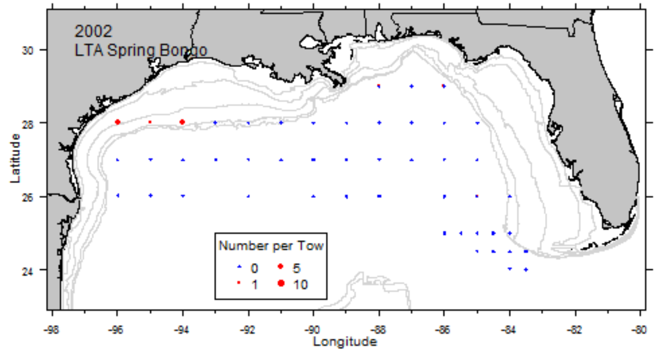
2002
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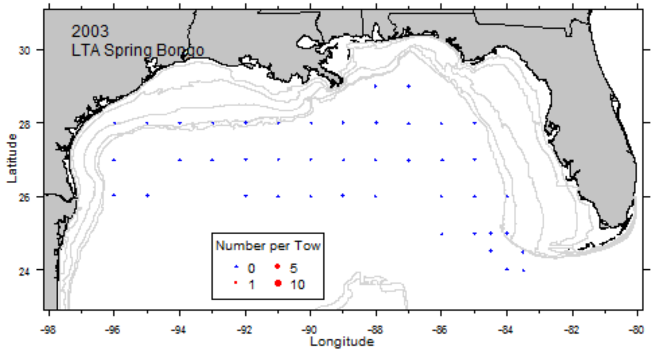
2003
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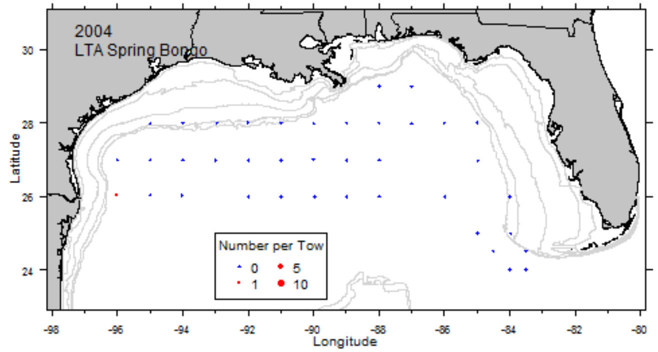
2004
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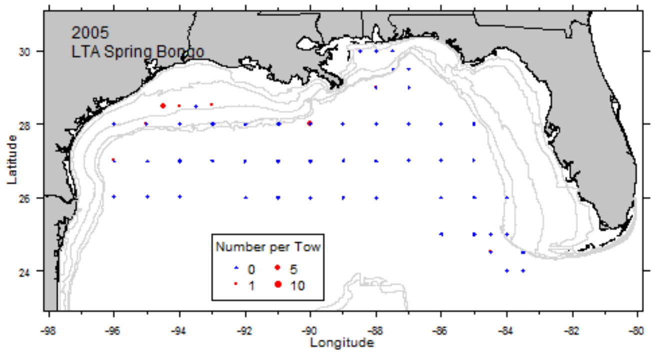
2005
LTA Spring Bongo
Number per Tow
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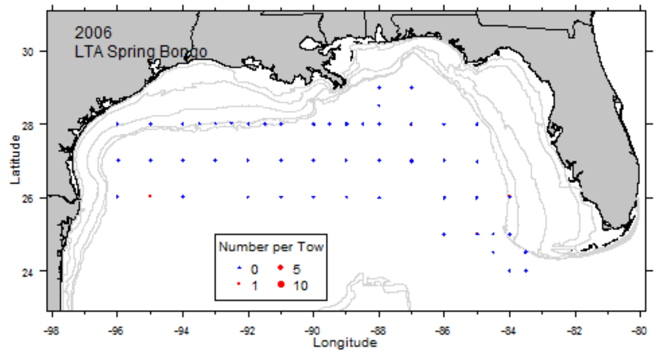
2006
LTA Spring Bongo
Number per Tow
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Latitude
Longitude
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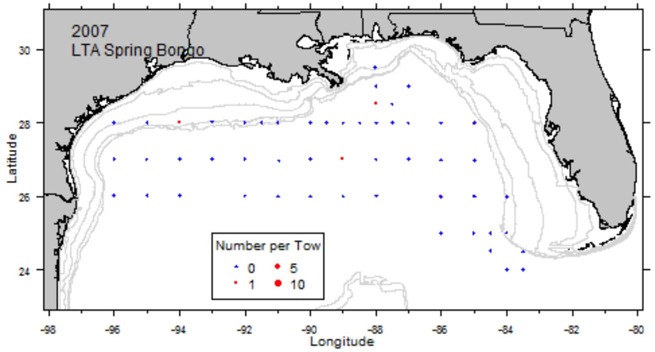
2007
LTA Spring Bongo
Number per Tow
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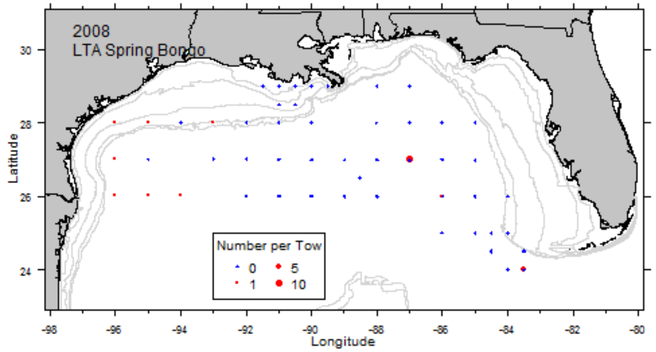
Latitude
Longitude


2008
LTA Spring Bongo
Number per Tow
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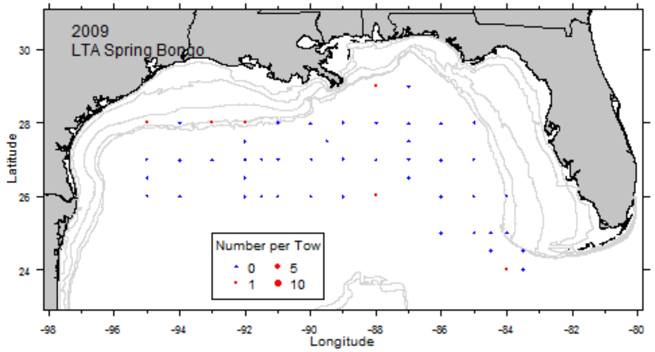
Latitude
Longitude


2009
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Number per Tow
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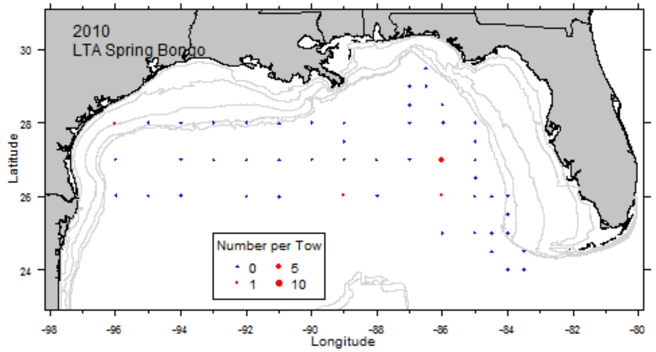
Latitude
Longitude


2010
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Number per Tow
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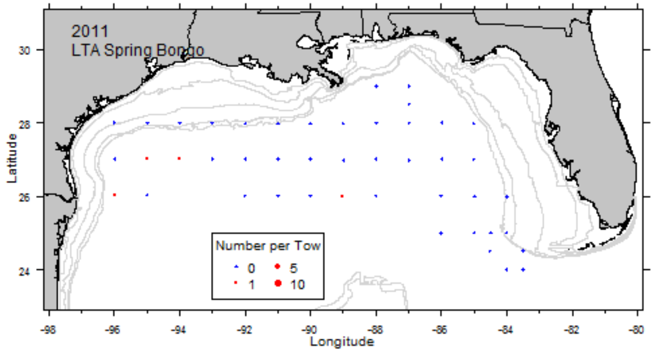
Latitude
Longitude


2011
LTA Spring Bongo
Number per Tow
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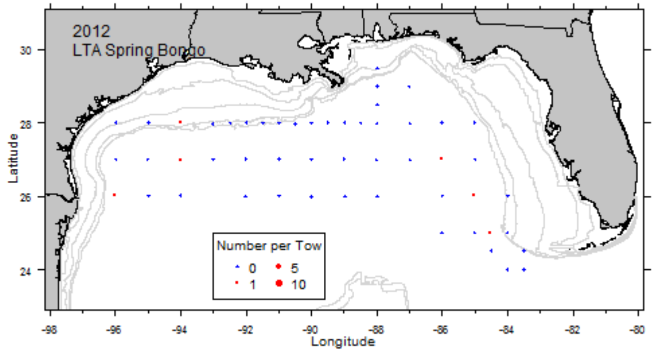
Latitude
Longitude


2012
LTA Spring Bongo
Number per Tow
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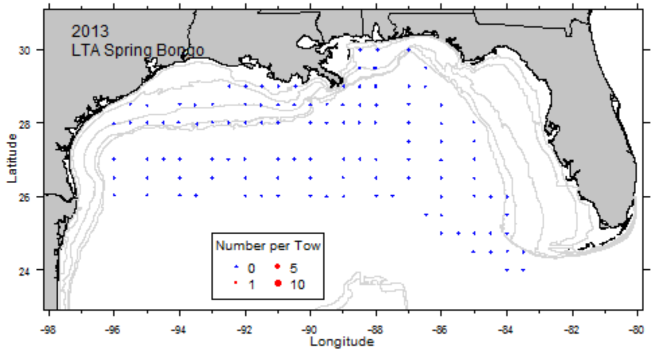
1 10
Latitude
Longitude


2013
LTA Spring Bongo
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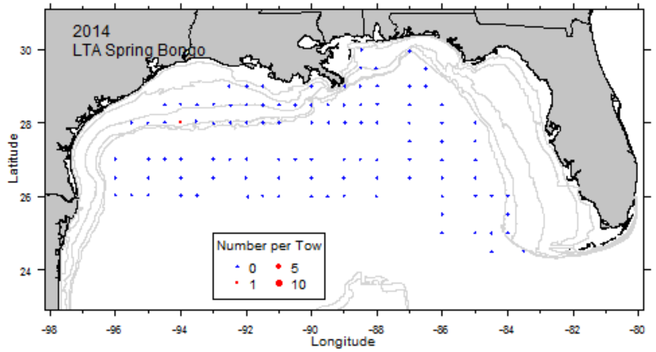
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LTA Spring Bongo
Number per Tow
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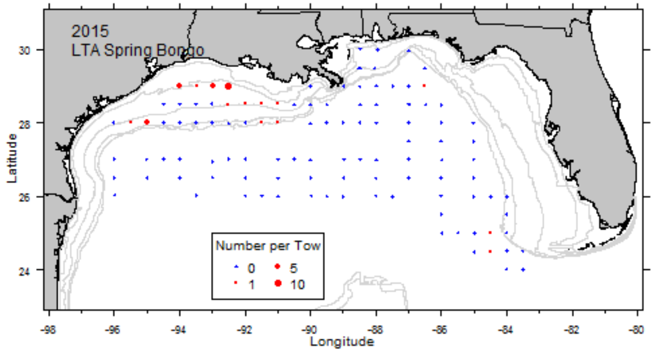
2015
LTA Spring Bongo
Number per Tow
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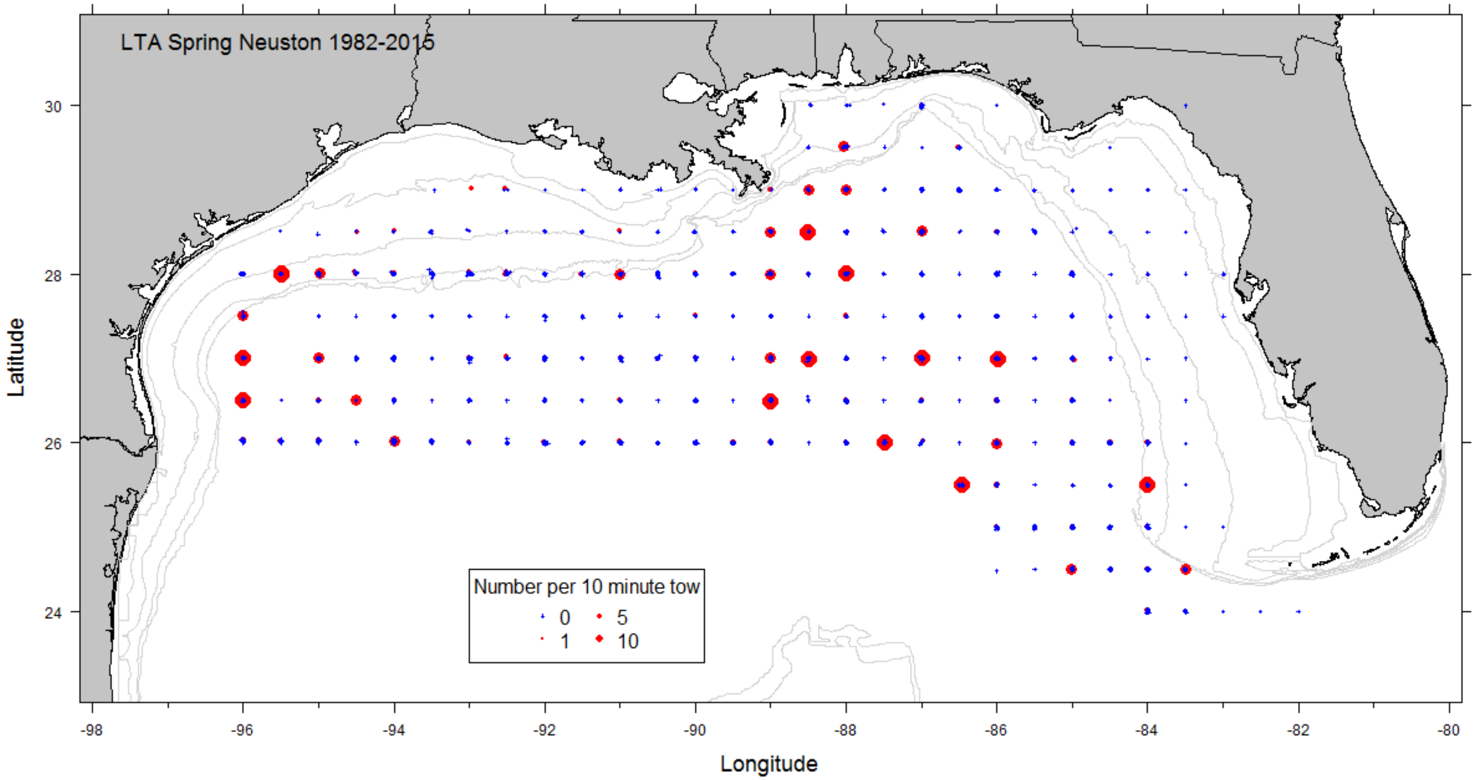
Latitude
Longitude



LTA Spring Neuston 1982-2016
Number per 10 minute tow
0
1
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Latitude
Longitude
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28
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24
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-96
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-90
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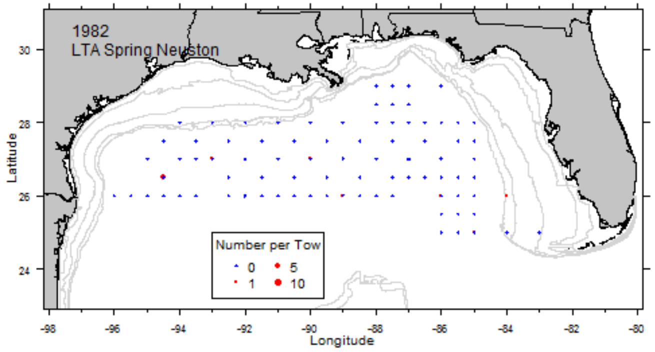
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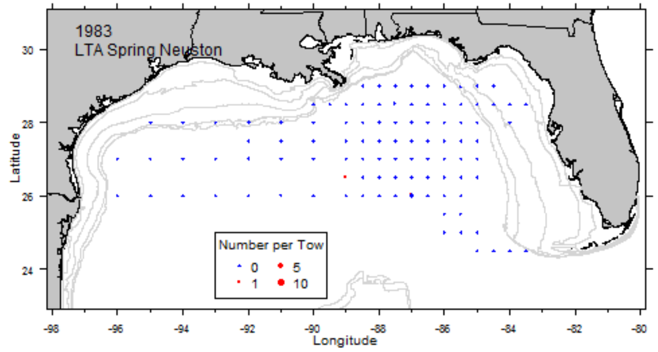
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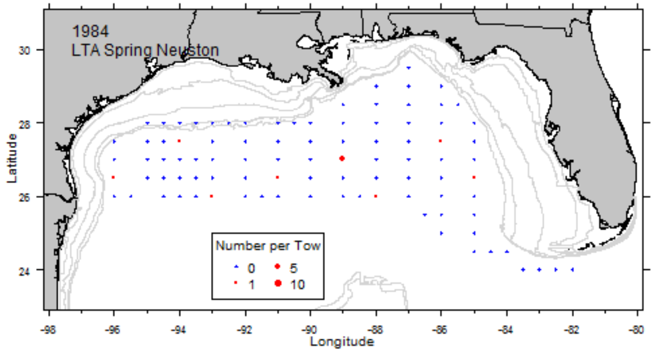
1984
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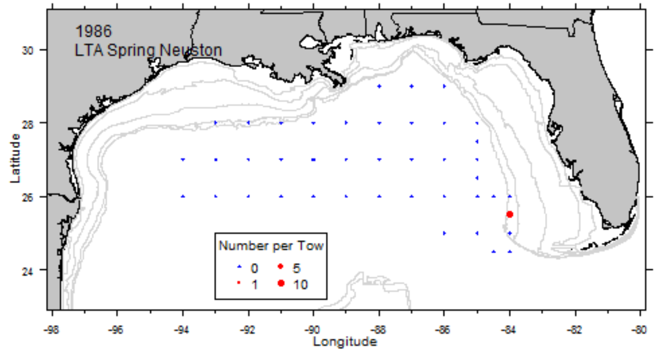
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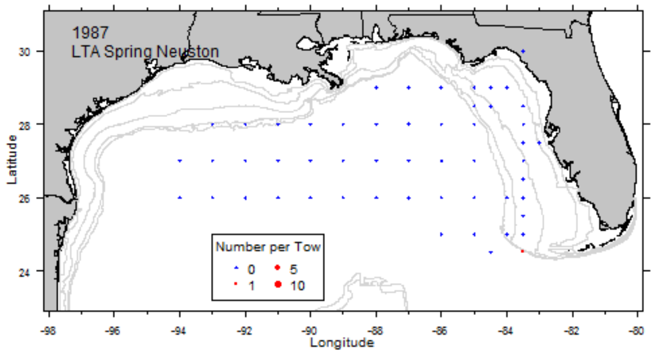
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Latitude
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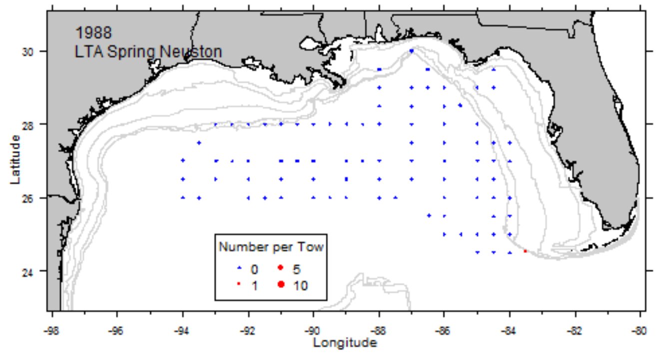
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LTA Spring Neuston
Number per Tow
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Longitude
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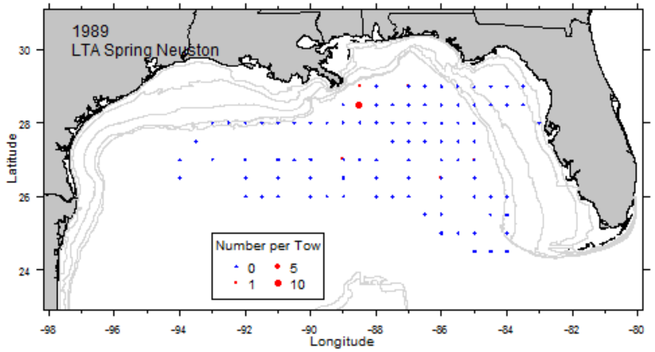
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Latitude
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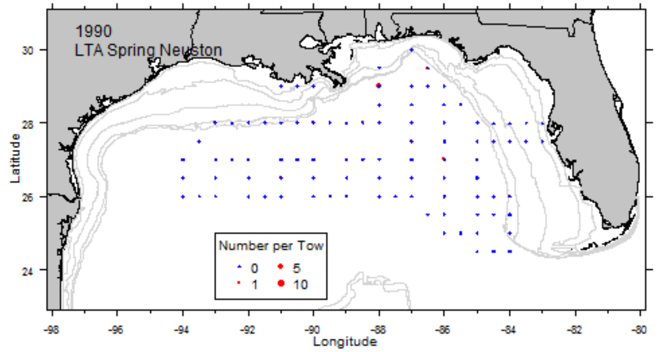
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Longitude
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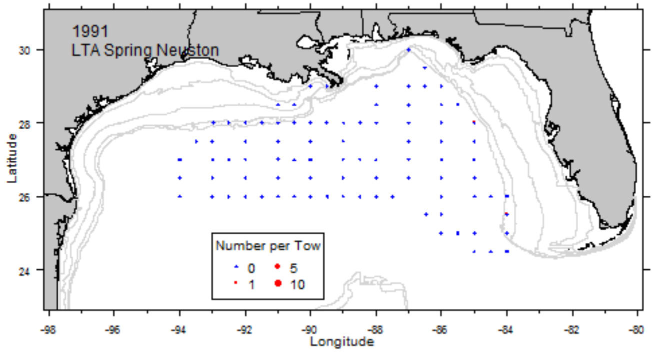
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Number per Tow
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Latitude
Longitude
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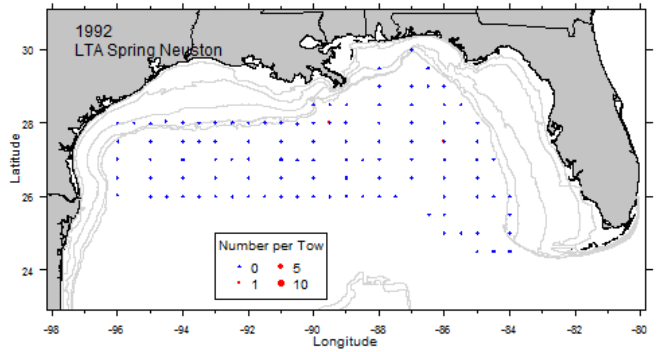
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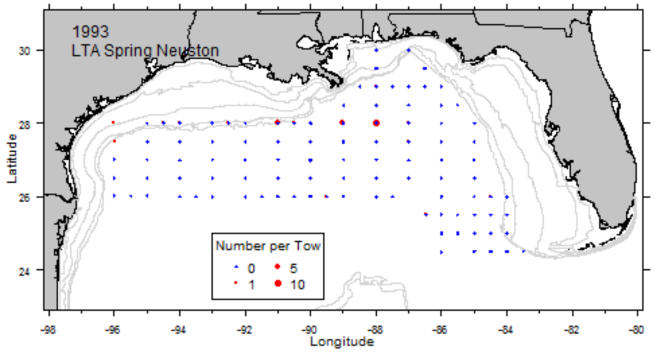
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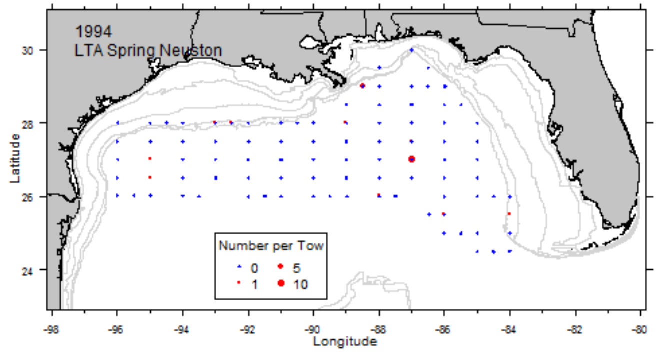
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Latitude
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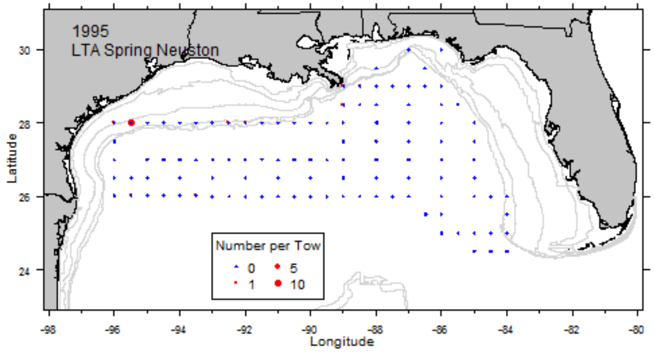
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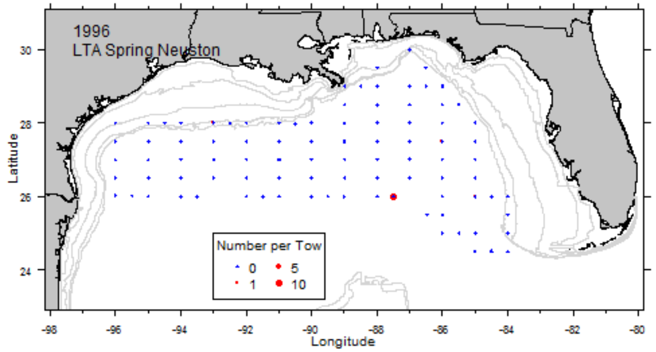
1996
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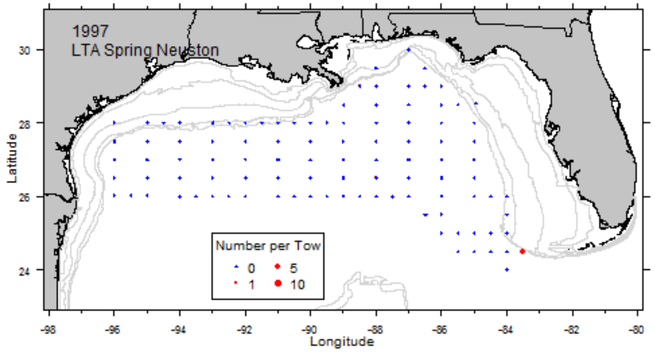
1997
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Number per Tow
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Latitude
Longitude
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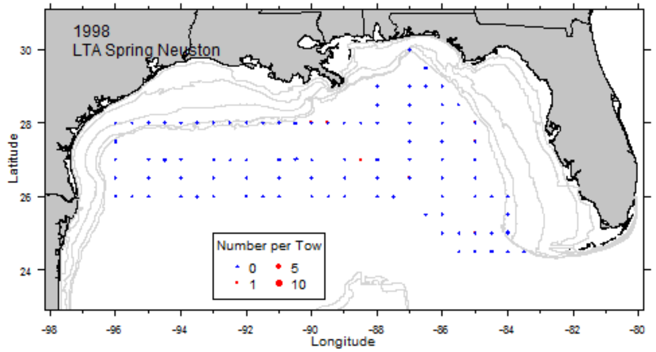
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Number per Tow
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Latitude
Longitude
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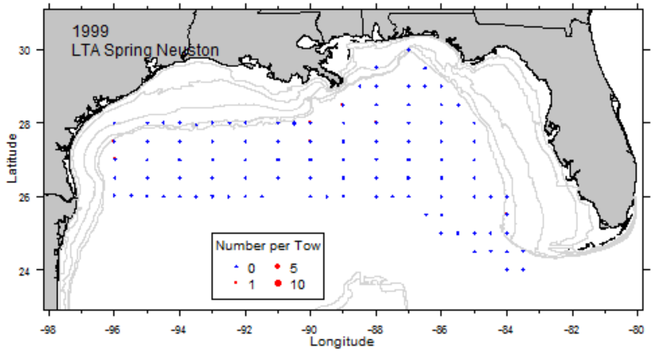
1999
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Number per Tow
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Latitude
Longitude
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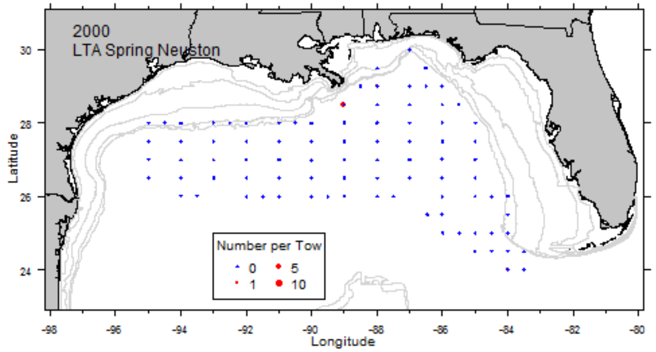
2000
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Number per Tow
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1 10
Latitude
Longitude
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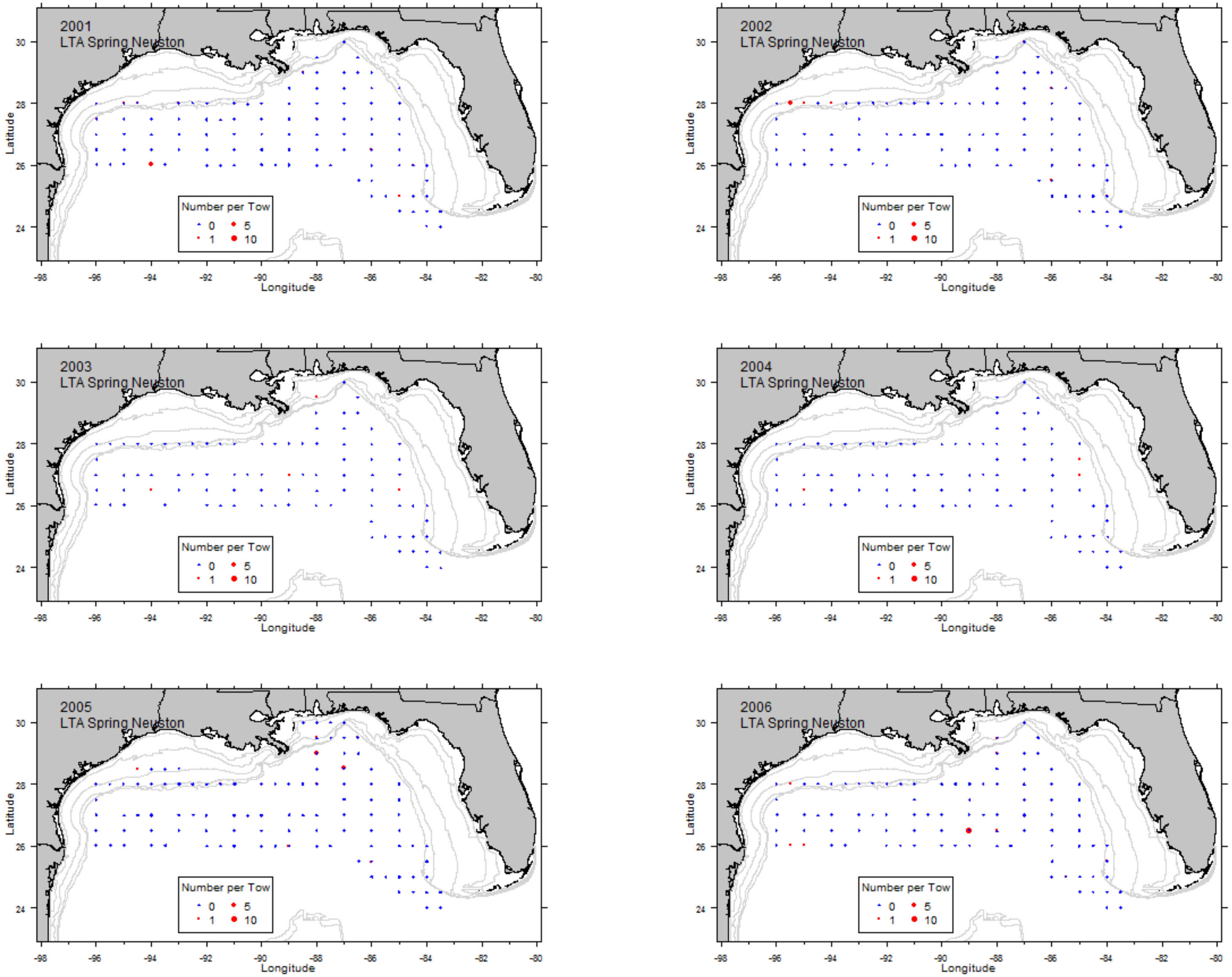
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80


2001
LTA Spring Neuston
2002
LTA Spring Neuston
2003
LTA Spring Neuston
2004
LTA Spring Neuston
2005
LTA Spring Neuston
2006
LTA Spring Neuston
Number per Tow
0
1
5
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Longitude
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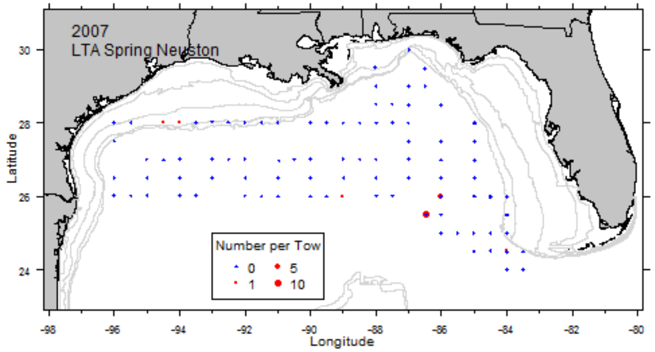
2007
LTA Spring Neuston
Number per Tow
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Latitude
Longitude
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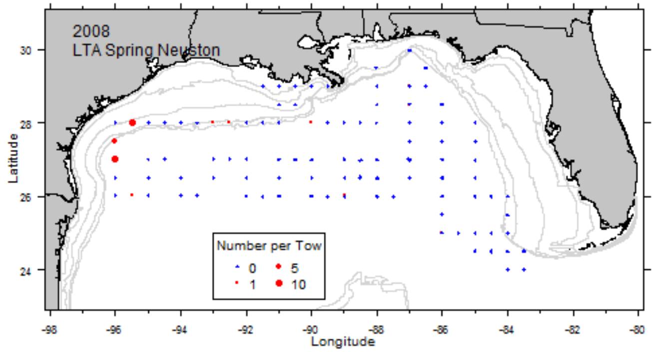
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80


2008
LTA Spring Neuston
Number per Tow
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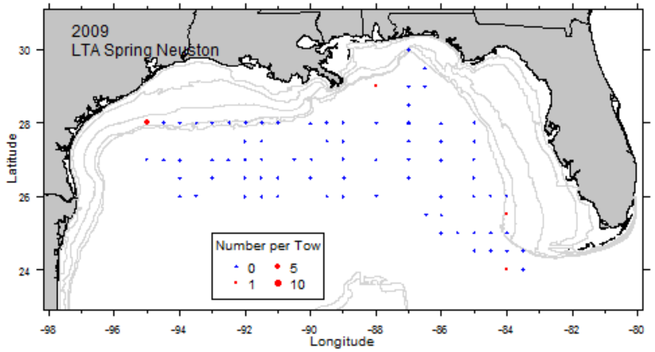
Latitude
Longitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80


2009
LTA Spring Neuston
Number per Tow
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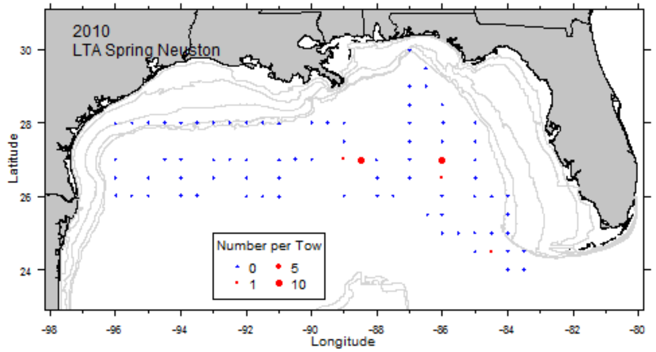
1 10
Latitude
Longitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80


2010
LTA Spring Neuston
Number per Tow
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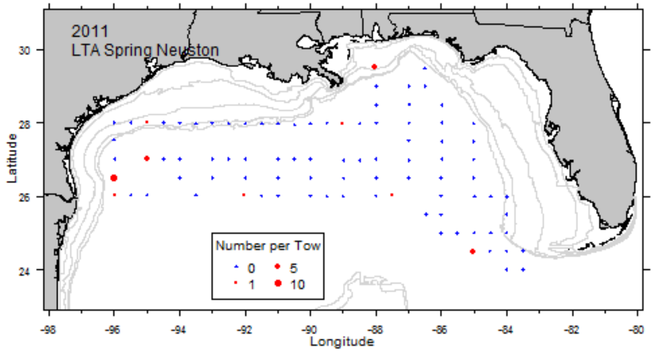
1 10
Latitude
Longitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80


2011
LTA Spring Neuston
Number per Tow
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1 10
Latitude
Longitude
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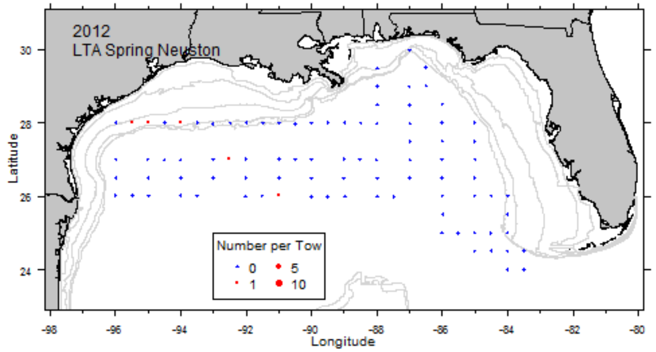
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80


2012
LTA Spring Neuston
Number per Tow
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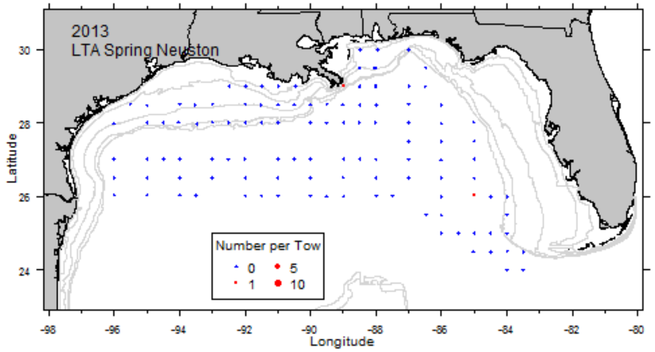
1 10
Latitude
Longitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80


2013
LTA Spring Neuston
Number per Tow
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Latitude
Longitude
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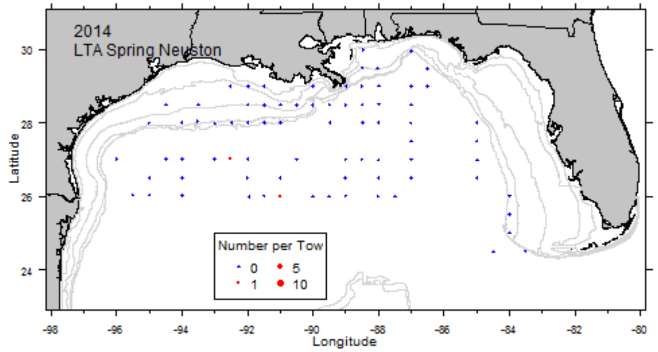
2014
LTA Spring Neuston
Number per Tow
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Latitude
Longitude
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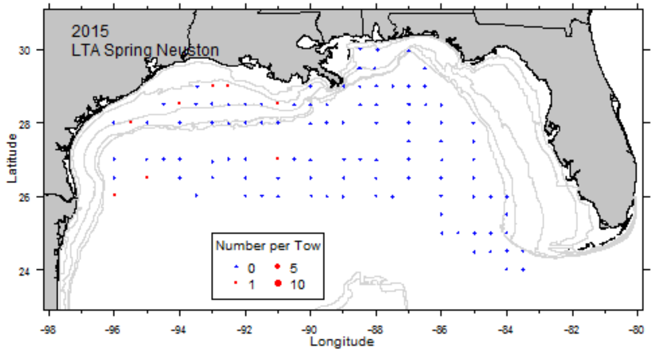
2015
LTA Spring Neuston
Number per Tow
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Latitude
Longitude
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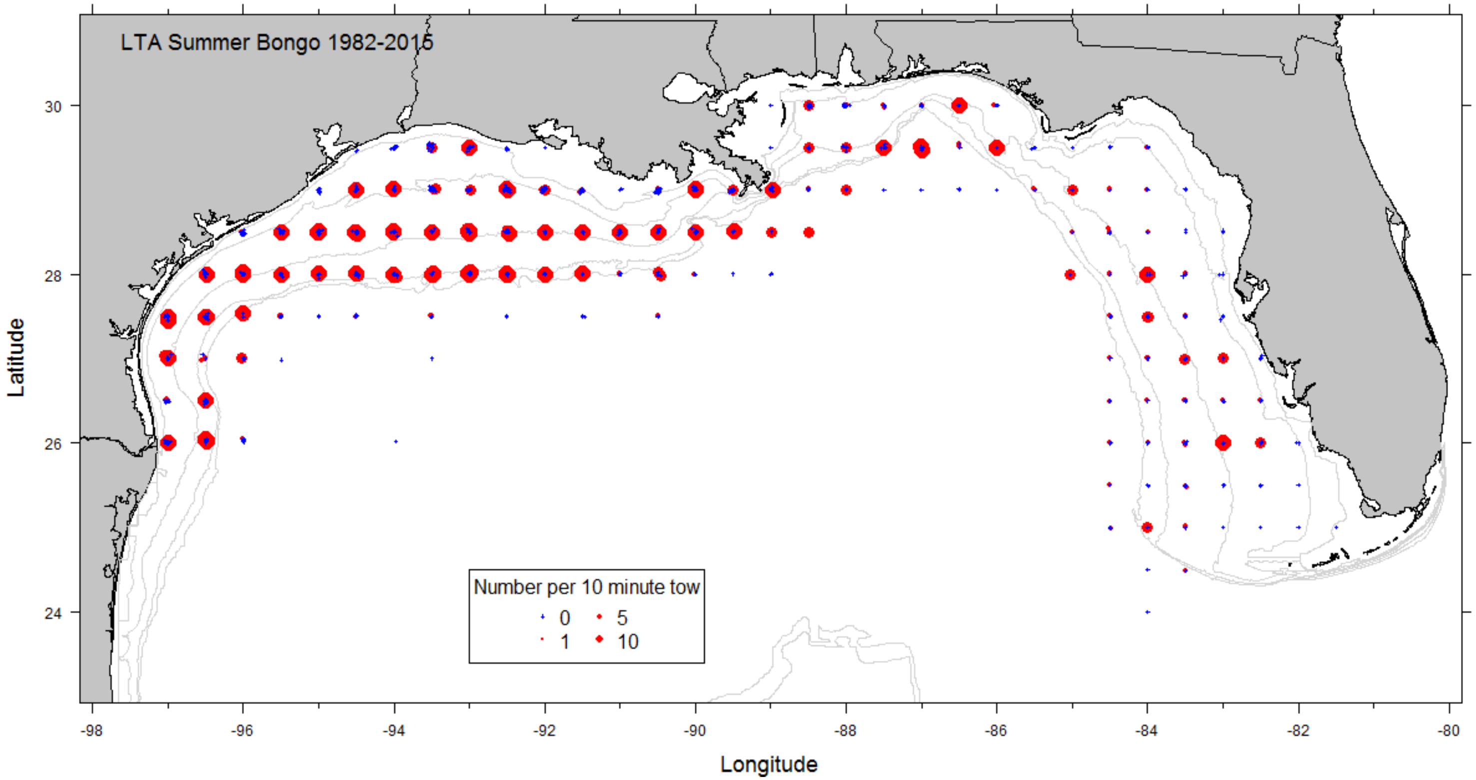
LTA Summer Bongo 1982-2016
Number per 10 minute tow
0
5
1
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Latitude
Longitude
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28
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24
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-94
-92
-90
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-84
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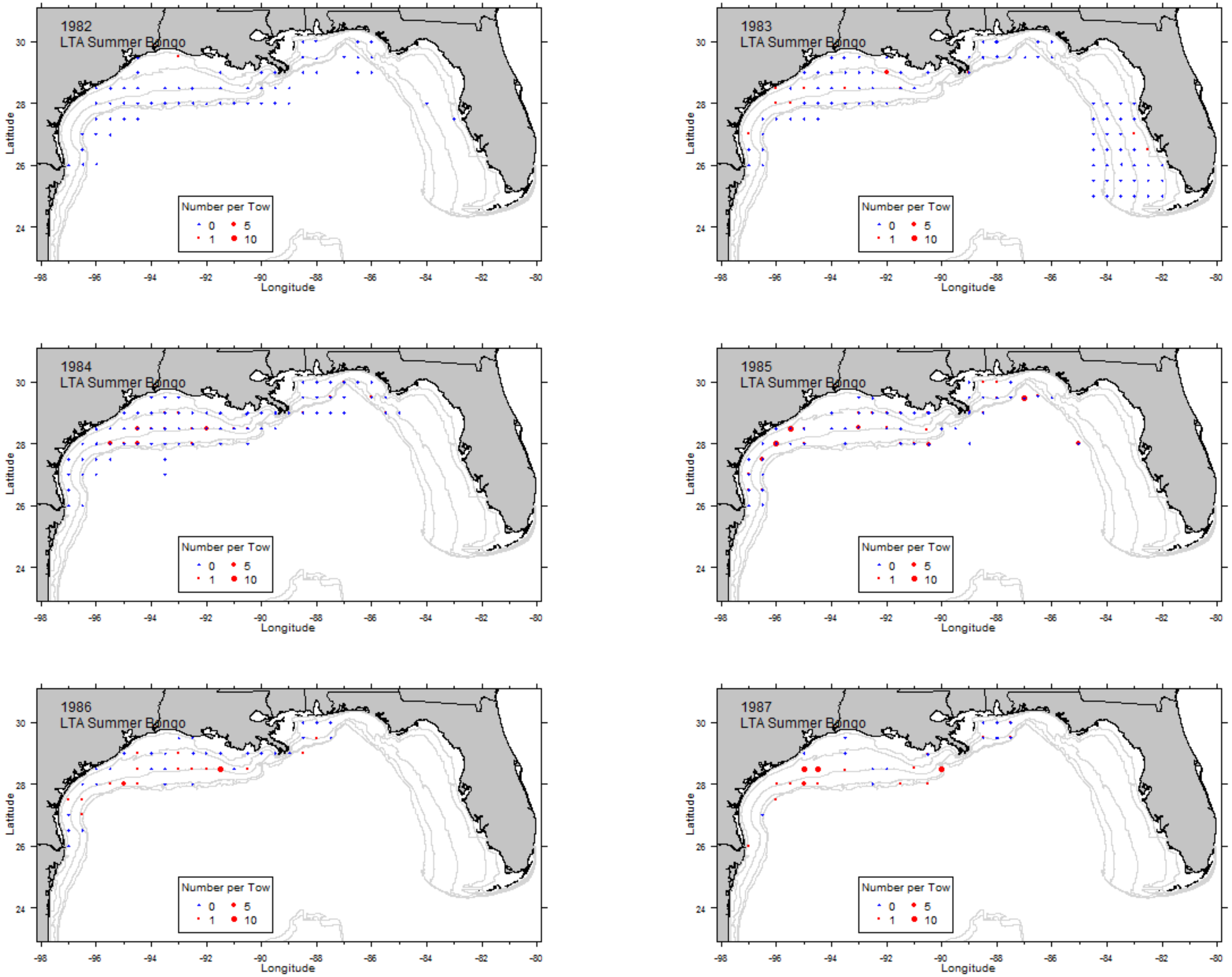
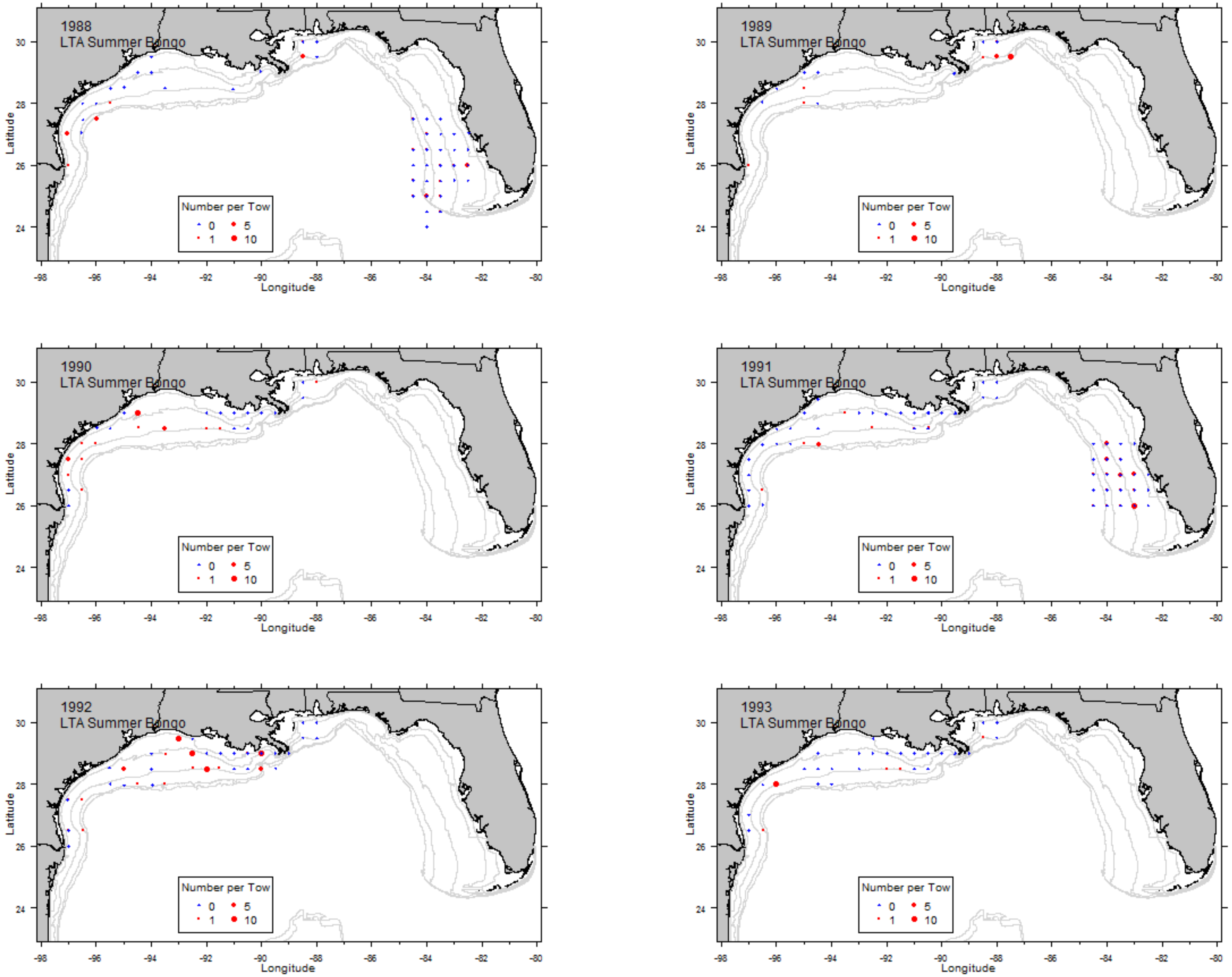

1982
LTA Summer Bongo
Number per Tow
0 5
1 10
Latitude
Longitude
1983
LTA Summer Bongo
Number per Tow
0 5
1 10
Latitude
Longitude
1984
LTA Summer Bongo
Number per Tow
0 5
1 10
Latitude
Longitude
1985
LTA Summer Bongo
Number per Tow
0 5
1 10
Latitude
Longitude
1986
LTA Summer Bongo
Number per Tow
0 5
1 10
Latitude
Longitude
1987
LTA Summer Bongo
Number per Tow
0 5
1 10
Latitude
Longitude


1988
LTA Summer Bongo
1989
LTA Summer Bongo
1990
LTA Summer Bongo
1991
LTA Summer Bongo
1992
LTA Summer Bongo
1993
LTA Summer Bongo
Number per Tow
0
5
1
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Latitude
Longitude
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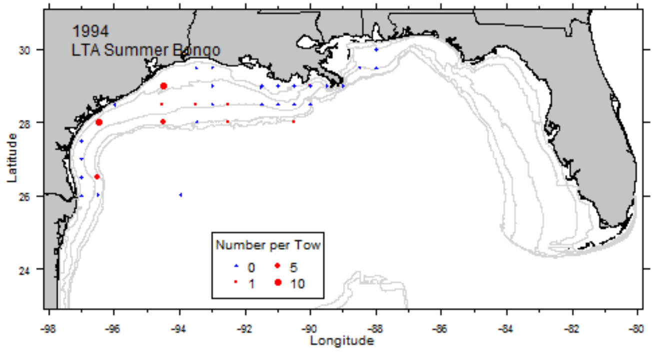
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LTA Summer Bongo
Number per Tow
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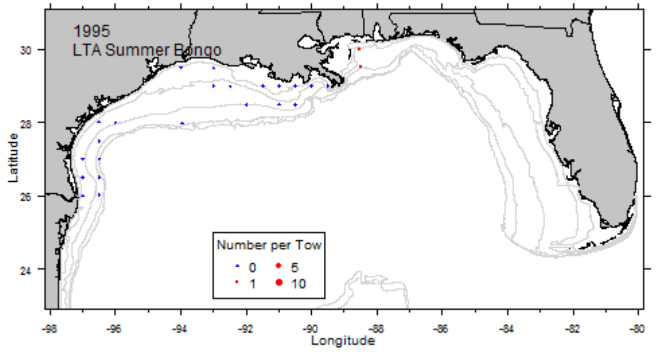
Latitude
Longitude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LTA Summer Bongo
Number per Tow
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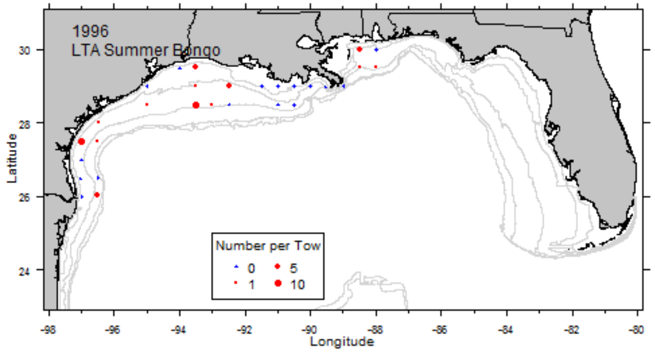
Latitude
Longitude


1996
LTA Summer Bongo
Number per Tow
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Latitude
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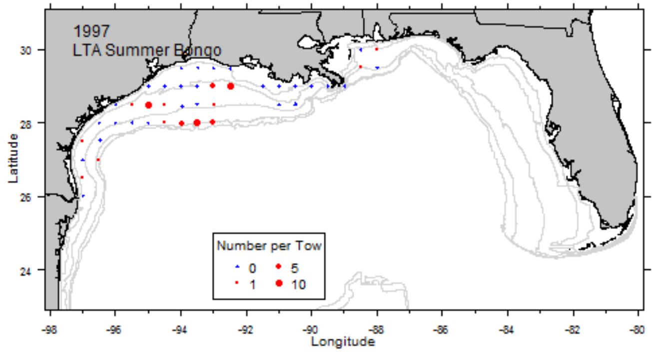
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LTA Summer Bongo
Number per Tow
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Latitude
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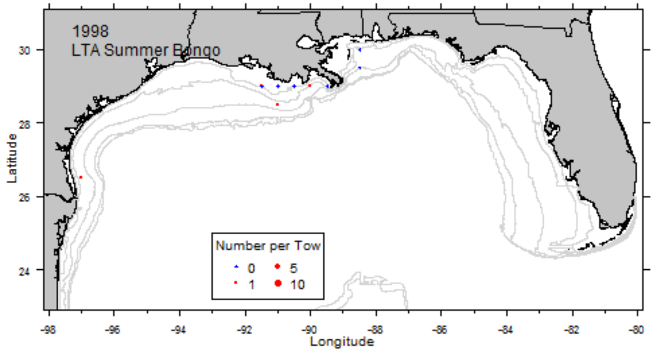
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LTA Summer Bongo
Number per Tow
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Latitude
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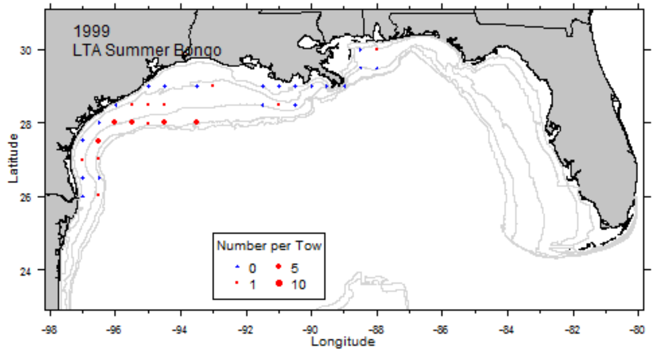
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LTA Summer Bongo
Number per Tow
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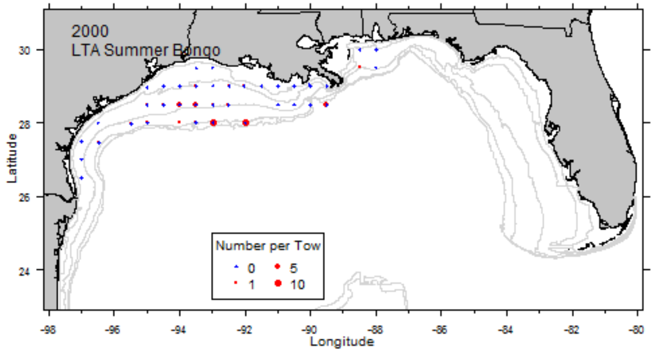
Latitude
Longitude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LTA Summer Bongo
Number per Tow
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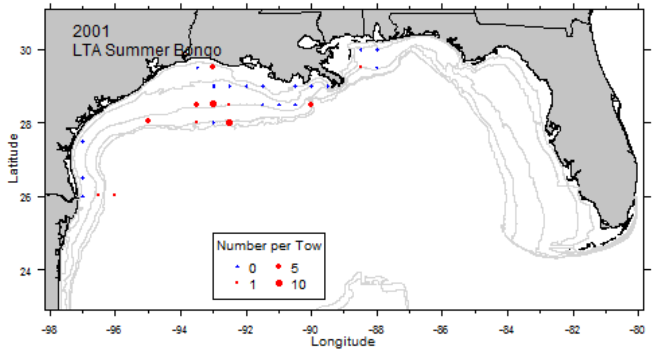
Latitude
Longitude


2001
LTA Summer Bongo
Number per Tow
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Latitude
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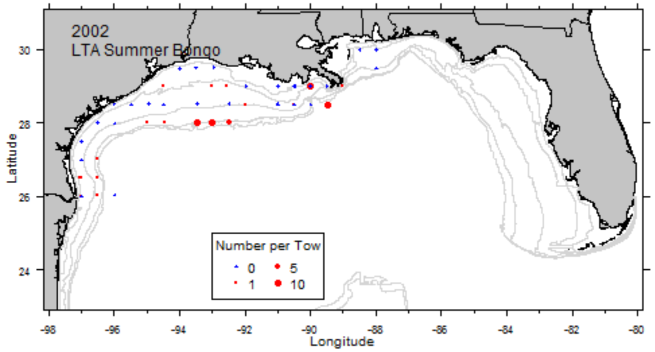
2002
LTA Summer Bongo
Number per Tow
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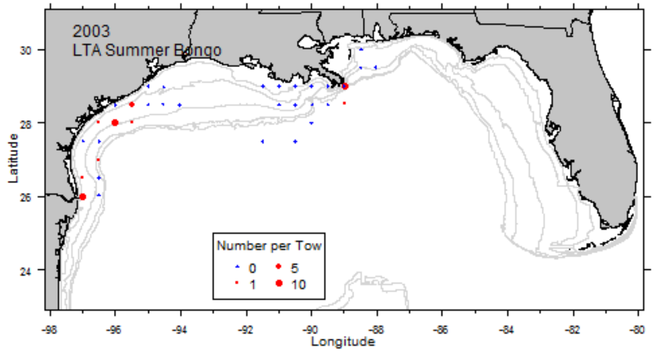
Latitude
Longitude


2003
LTA Summer Bongo
Number per Tow
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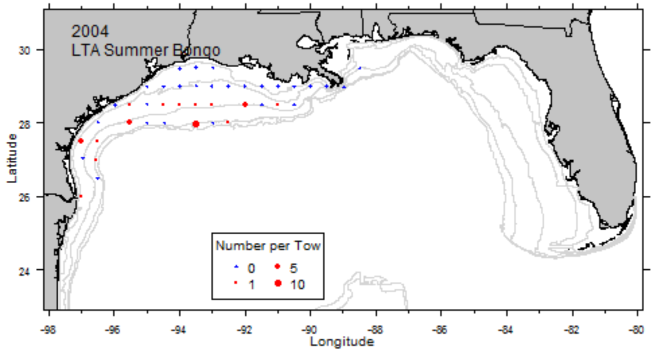
Latitude
Longitude


2004
LTA Summer Bongo
Number per Tow
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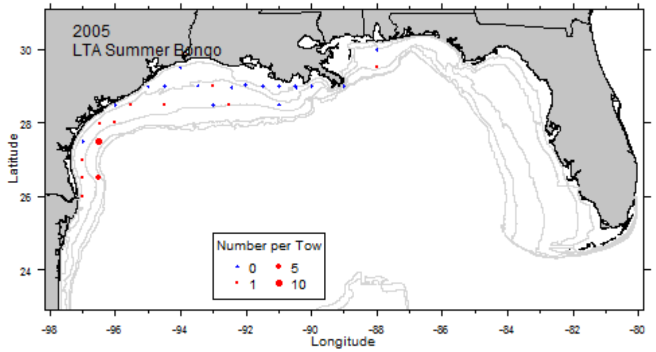
Latitude
Longitude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LTA Summer Bongo
Number per Tow
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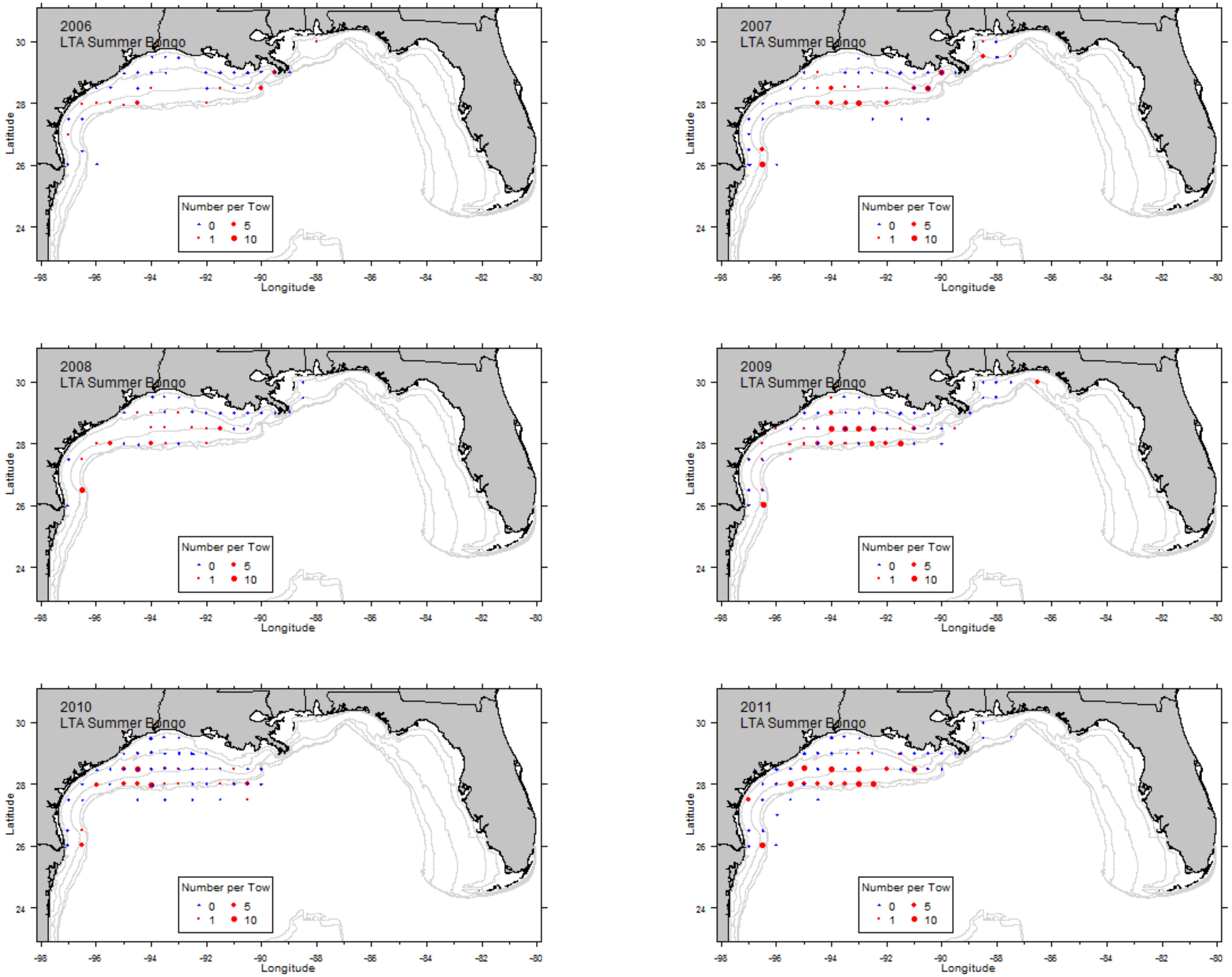
Latitude
Longitude


2006
LTA Summer Bongo
2007
LTA Summer Bongo
2008
LTA Summer Bongo
2009
LTA Summer Bongo
2010
LTA Summer Bongo
2011
LTA Summer Bongo
Number per Tow
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1
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Longitude
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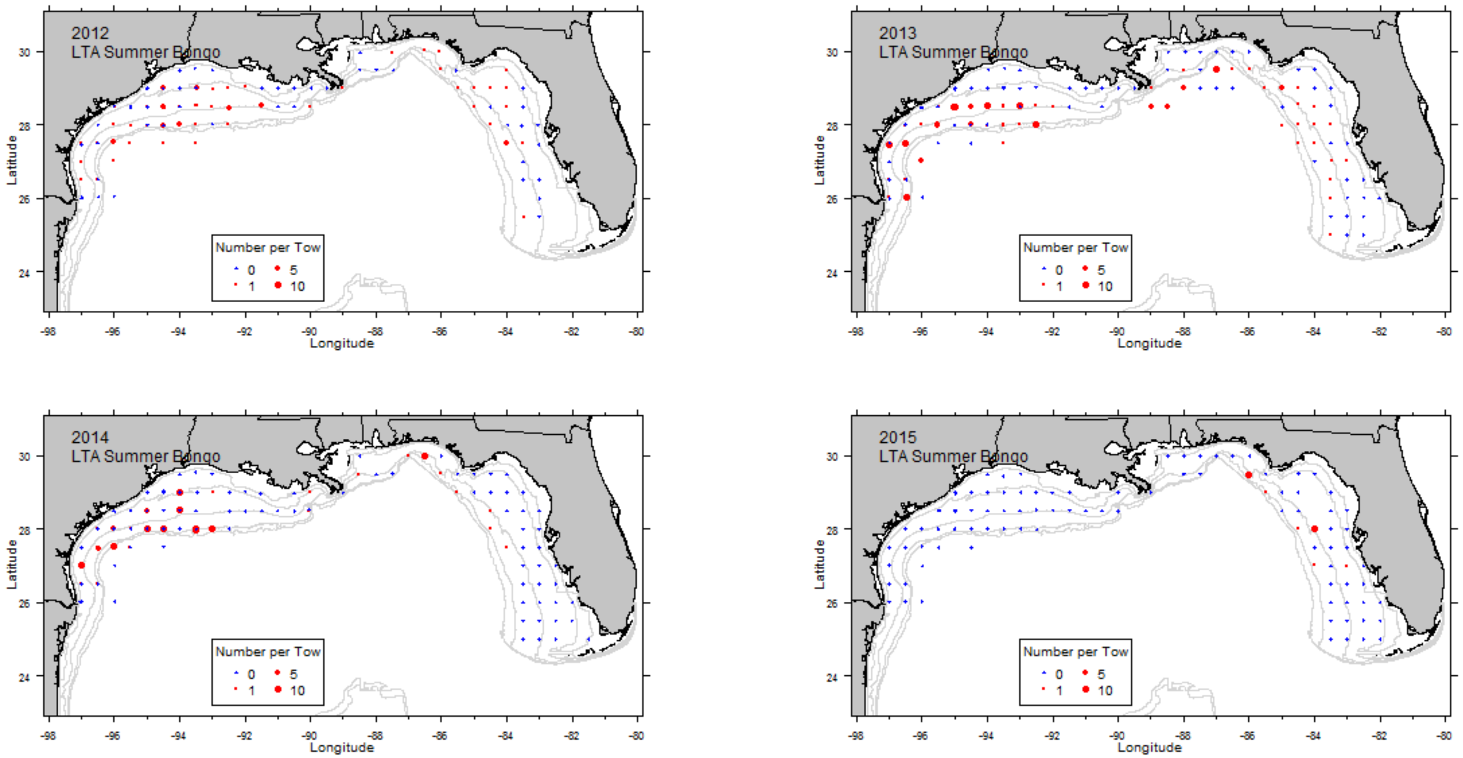
2012
LTA Summer Bongo
Number per Tow
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Latitude
Longitude
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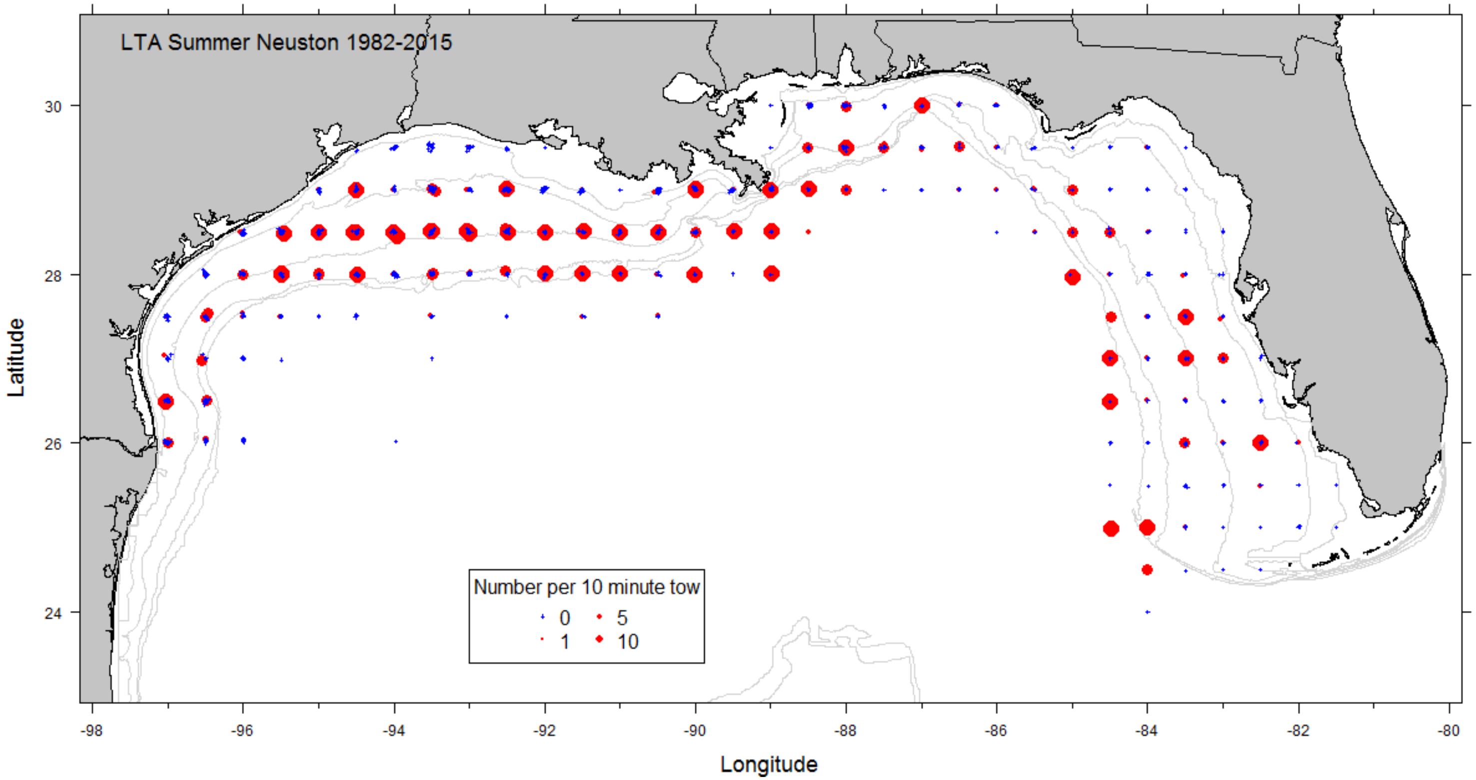
2013
LTA Summer Bongo
2014
LTA Summer Bongo
2015
LTA Summer Bongo


LTA Summer Neuston 1982-2015
Number per 10 minute tow
0
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Latitude
Longitude
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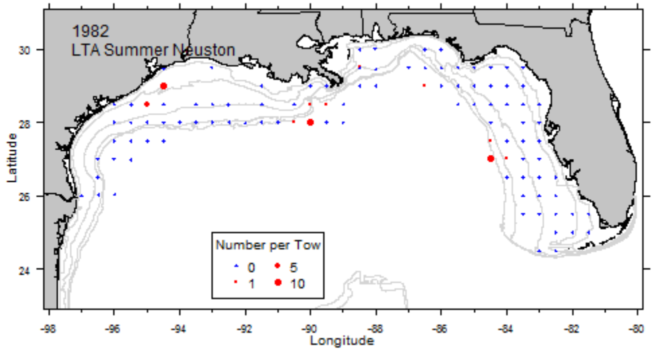
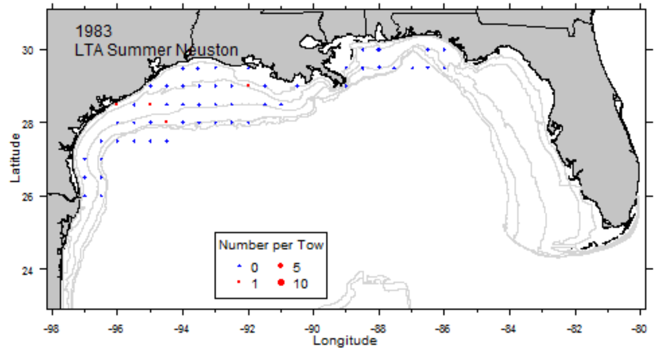
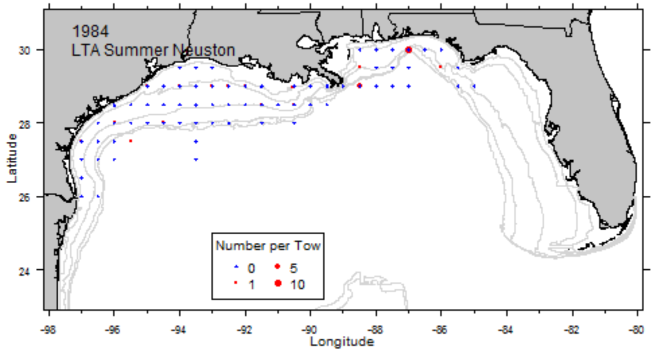

1982
LTA Summer Neuston
Number per Tow
0 5
1 10
Latitude
Longitude


1983
LTA Summer Neuston
Number per Tow
0 5
1 10
Latitude
Longitude


1984
LTA Summer Neuston
Number per Tow
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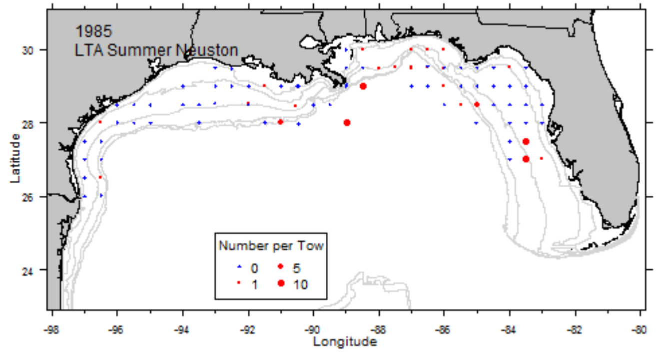
Latitude
Longitude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Number per Tow
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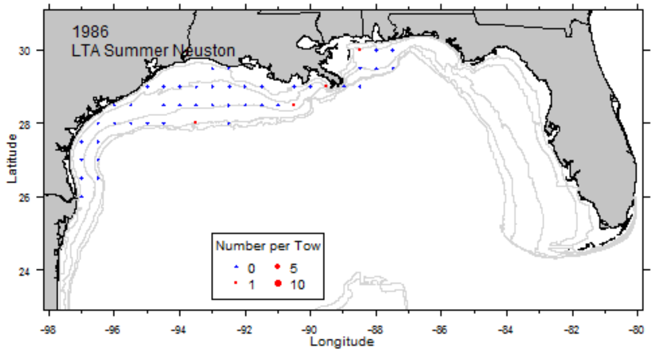
Latitude
Longitude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Number per Tow
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Latitude
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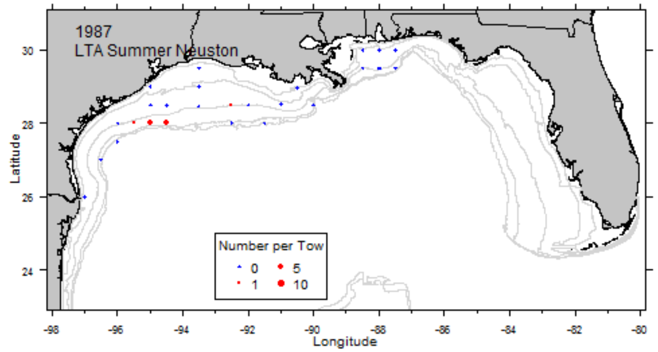
1987
LTA Summer Neuston
Number per Tow
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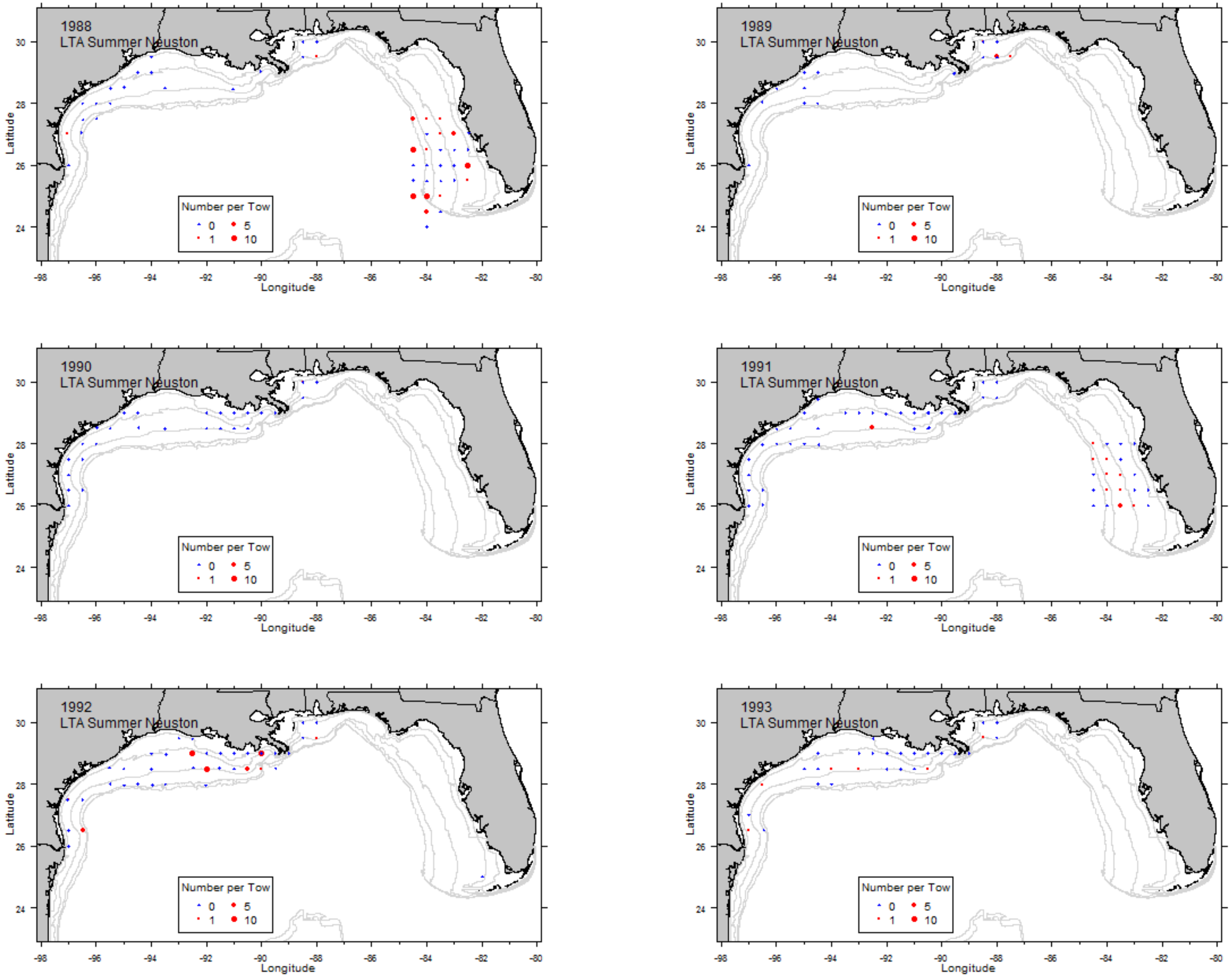
Latitude
Longitude


1988
LTA Summer Neuston
1989
LTA Summer Neuston
1990
LTA Summer Neuston
1991
LTA Summer Neuston
1992
LTA Summer Neuston
1993
LTA Summer Neuston
Number per Tow
0
1
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Latitude
Longitude
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-96
-94
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-88
-86
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24
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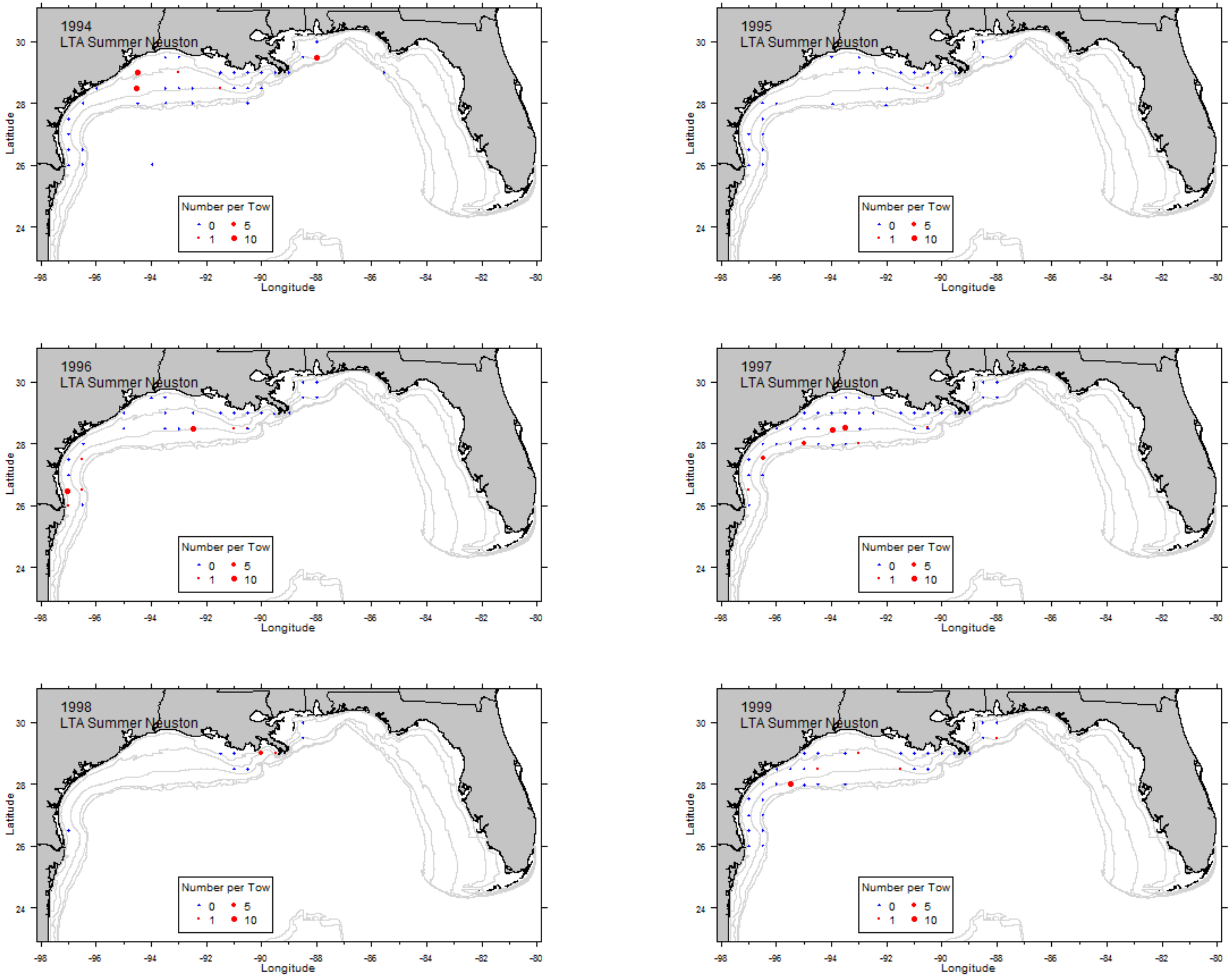
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Number per Tow
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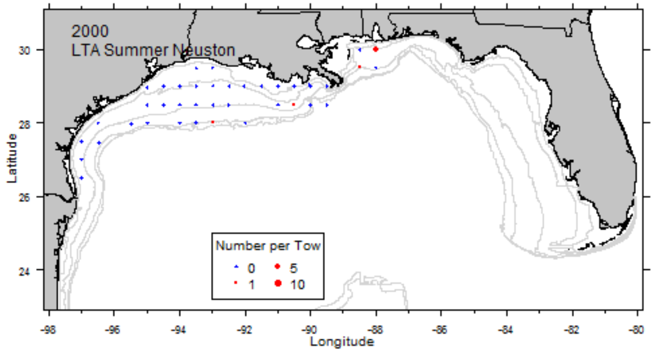
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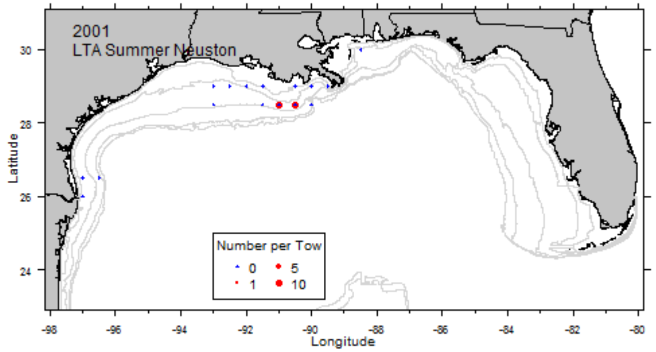
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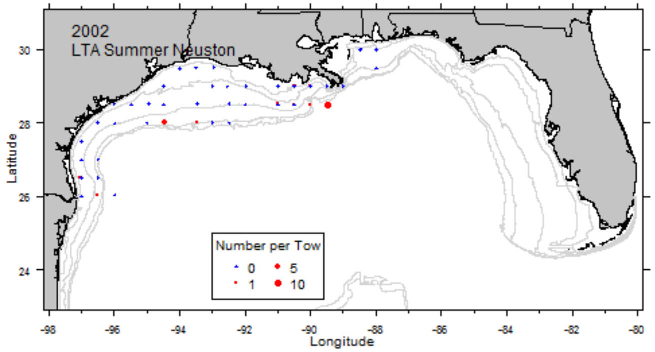
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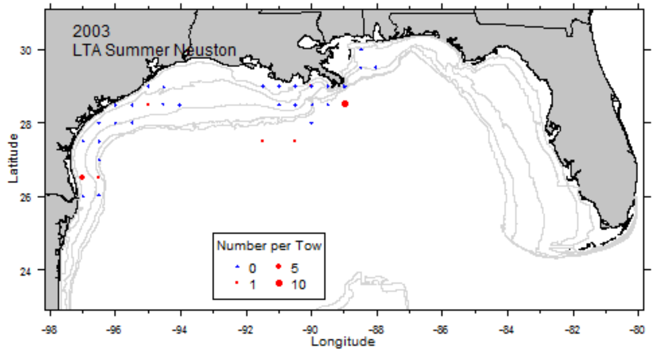
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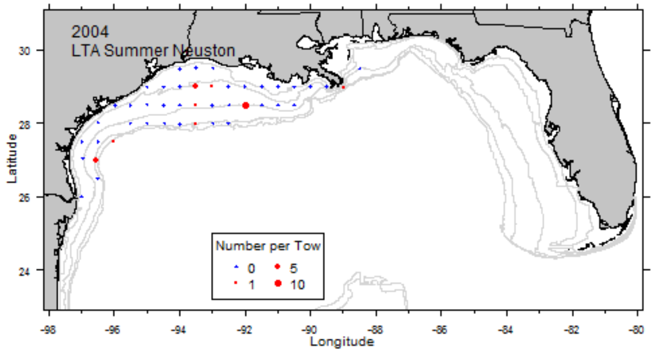
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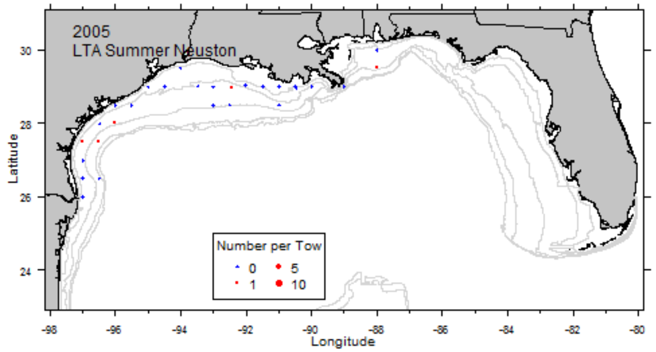
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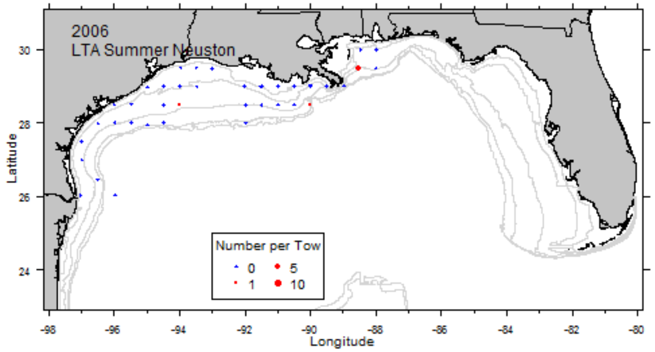
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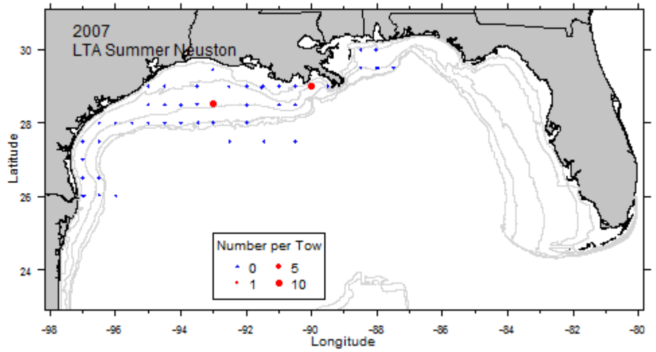
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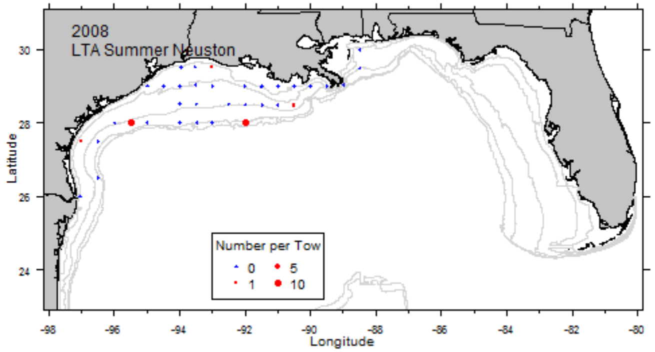
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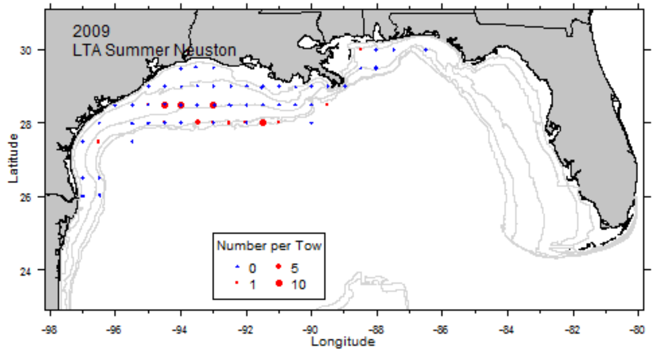
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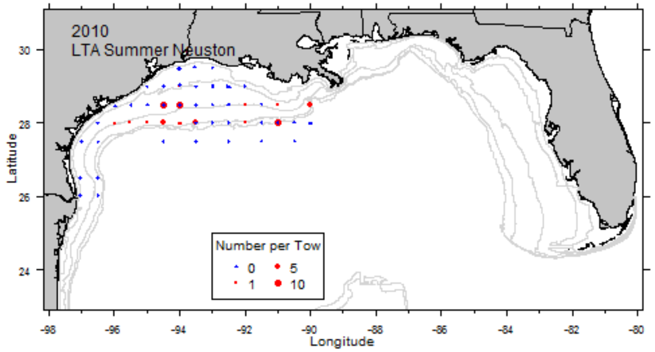
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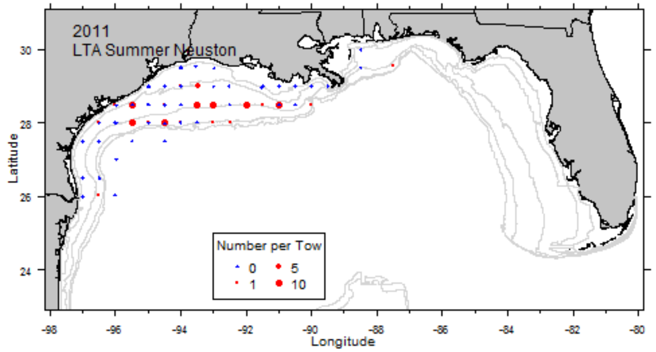
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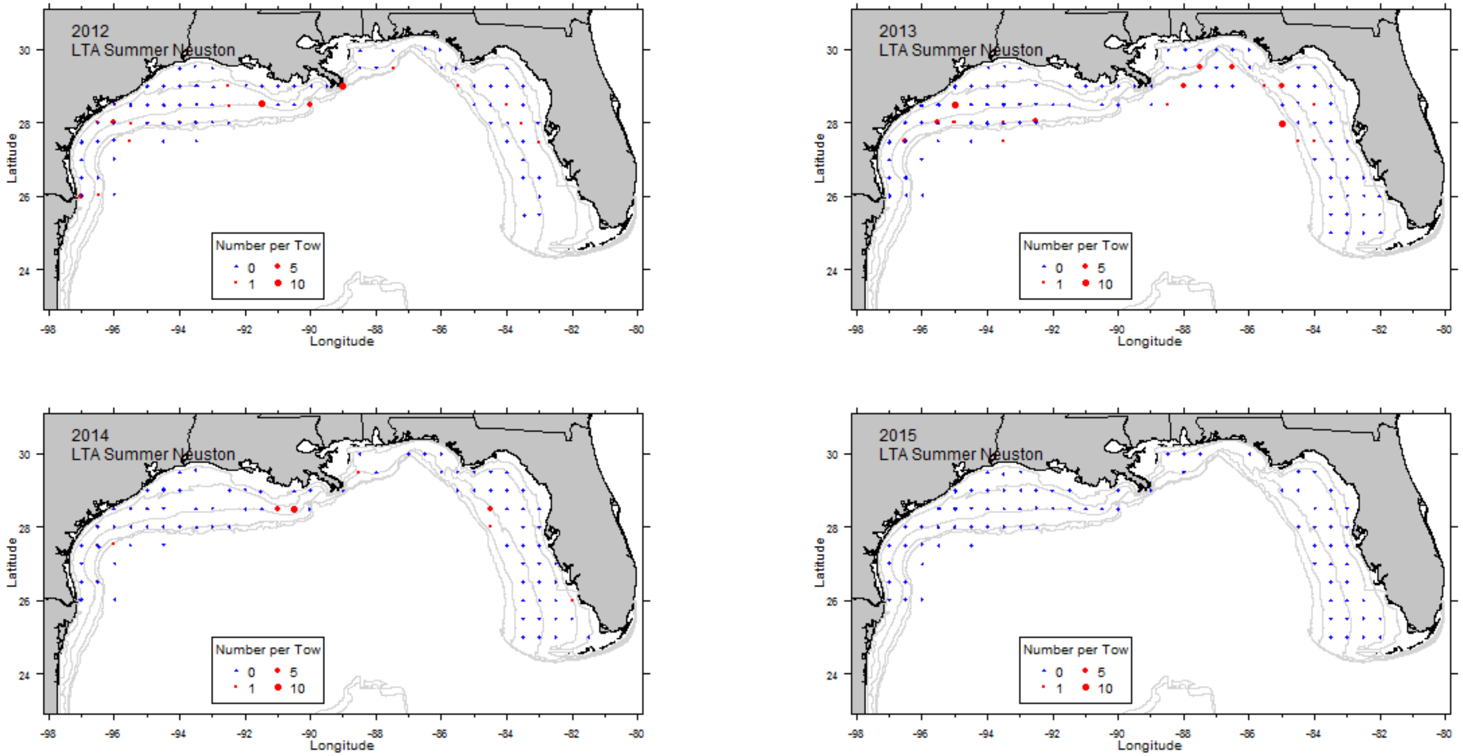
2012
LTA Summer Neuston
2013
LTA Summer Neuston
2014
LTA Summer Neuston
2015
LTA Summer Neuston
Number per Tow
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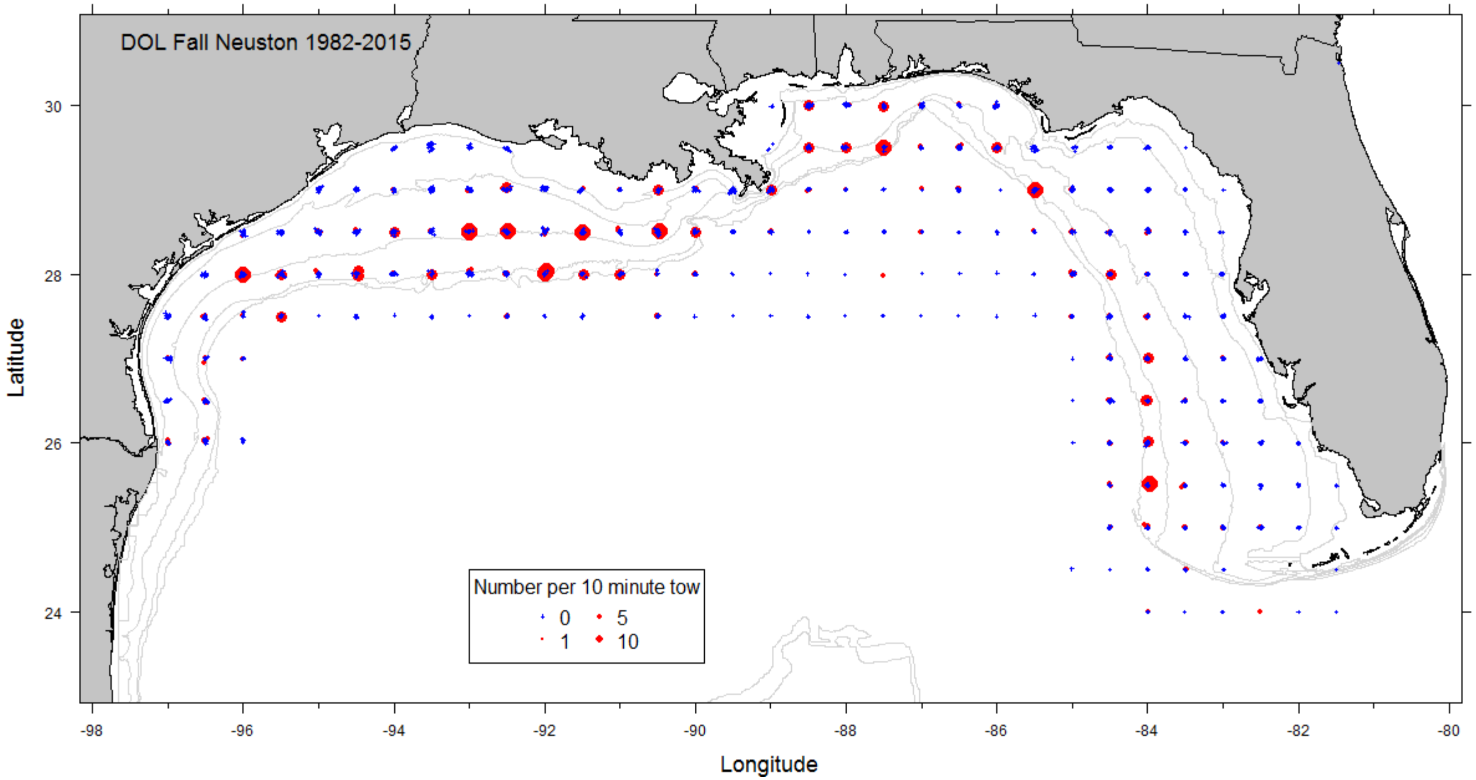
10
Latitude
Longitude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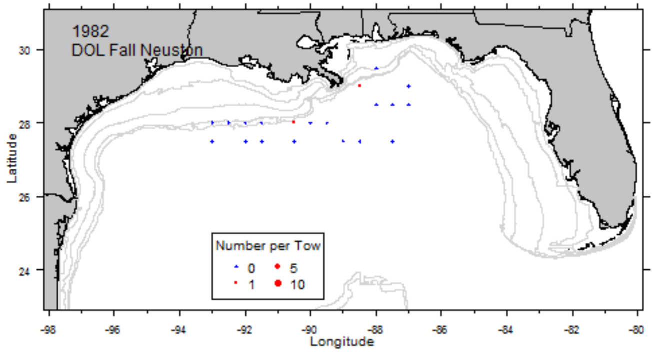
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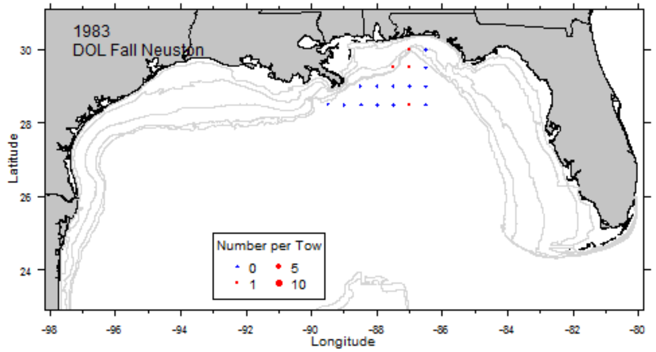
Longitude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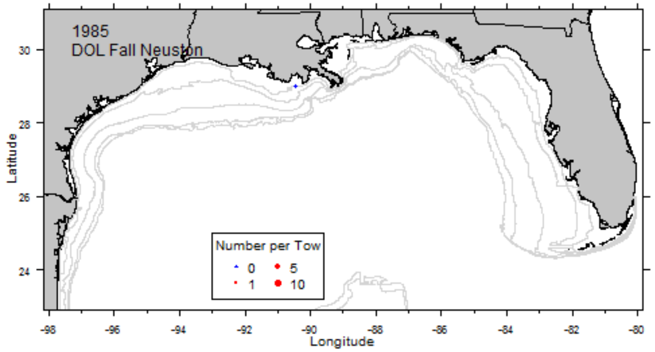
Longitude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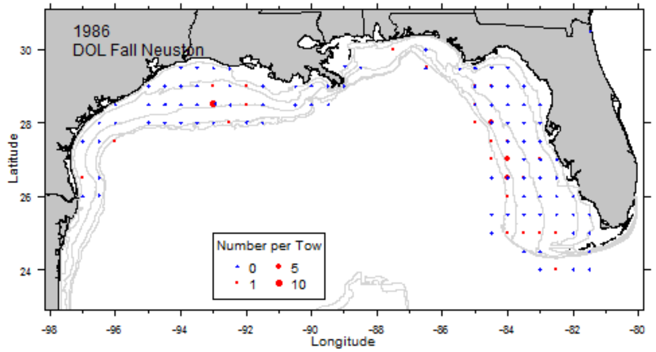
Latitude
Longitude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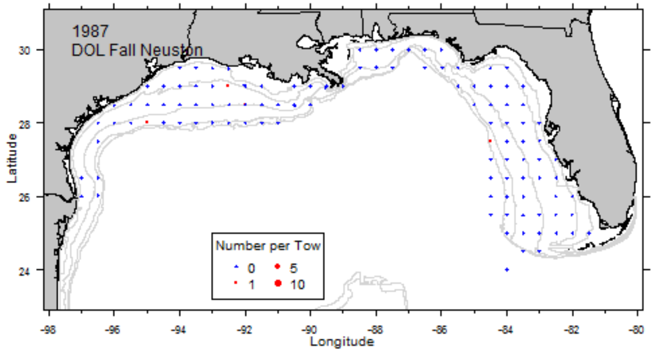
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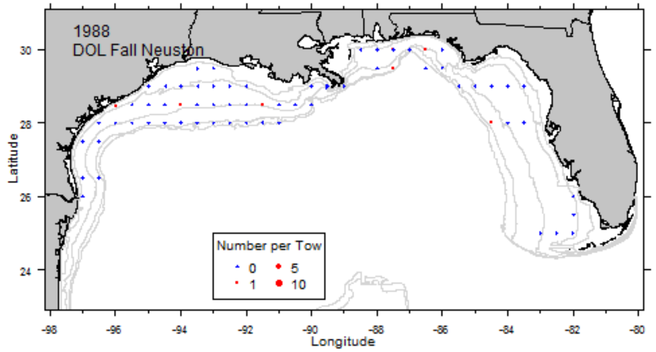
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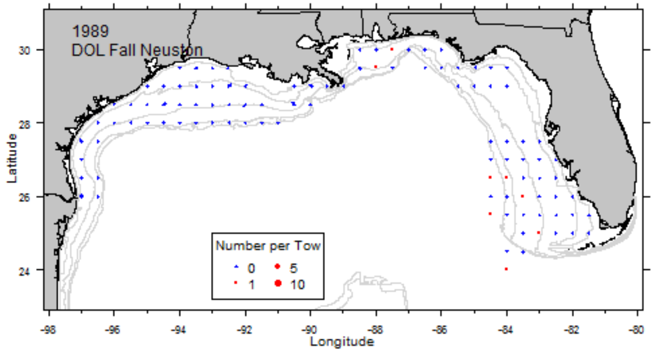
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Number per Tow
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Latitude
Longitude
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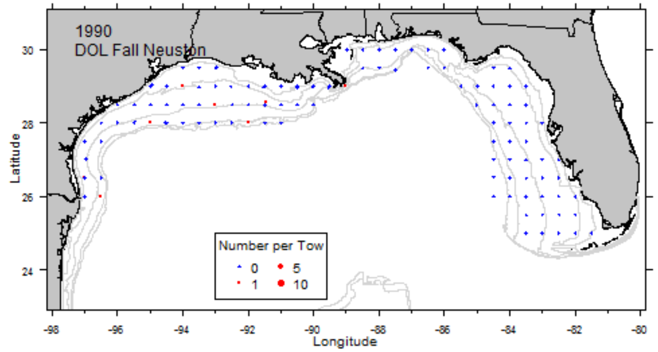
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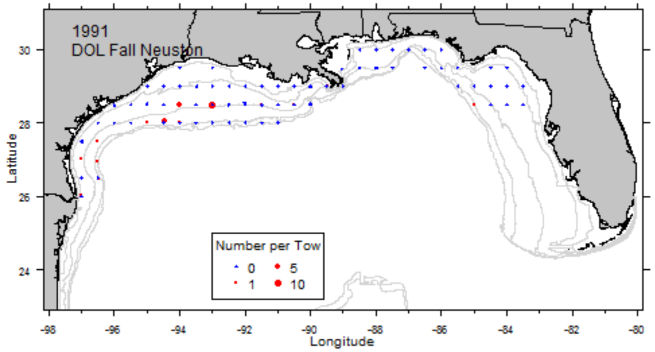
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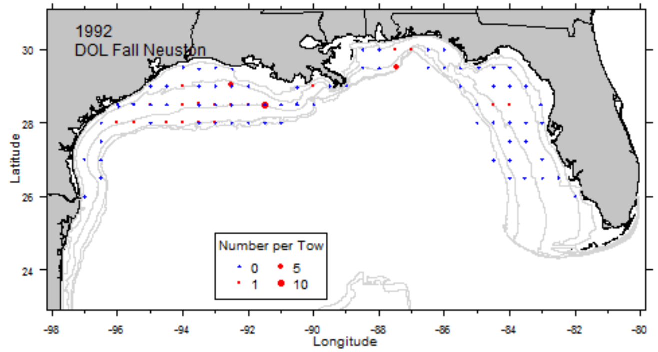
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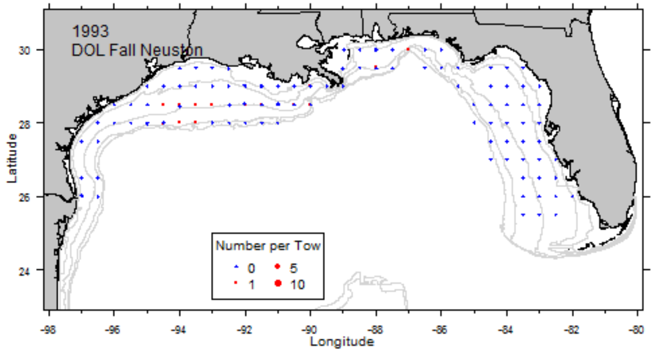
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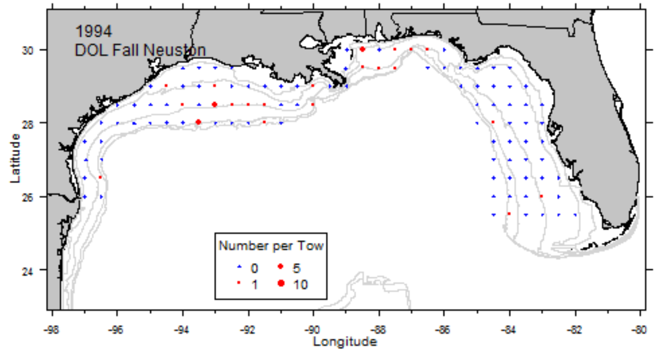
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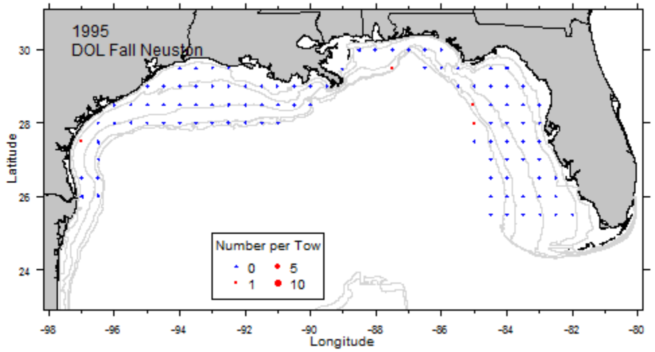
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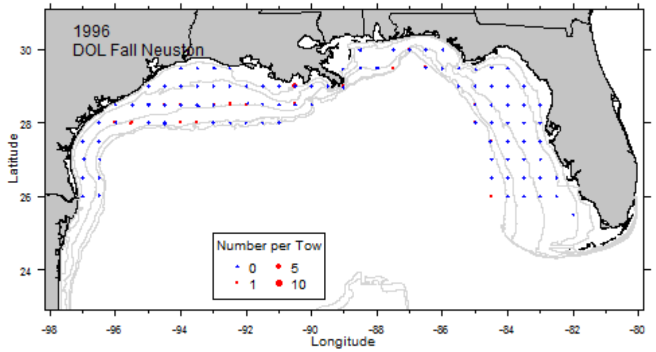
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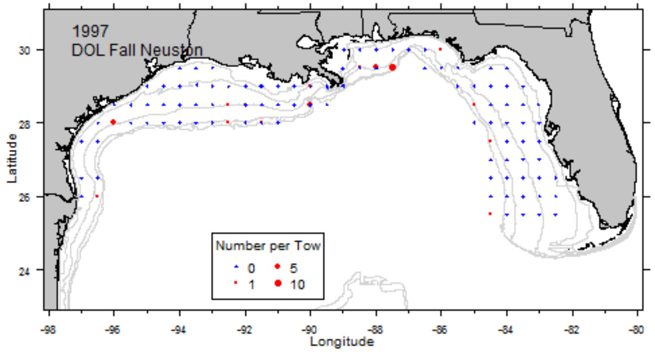
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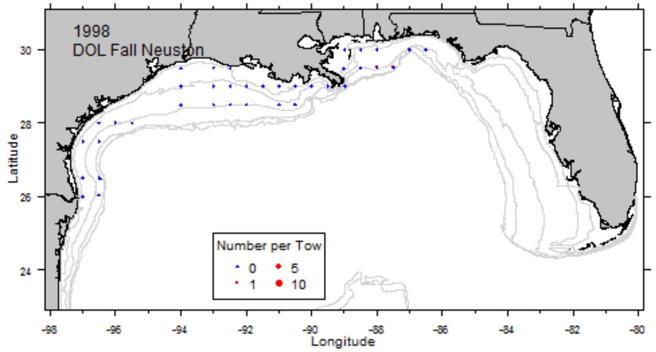
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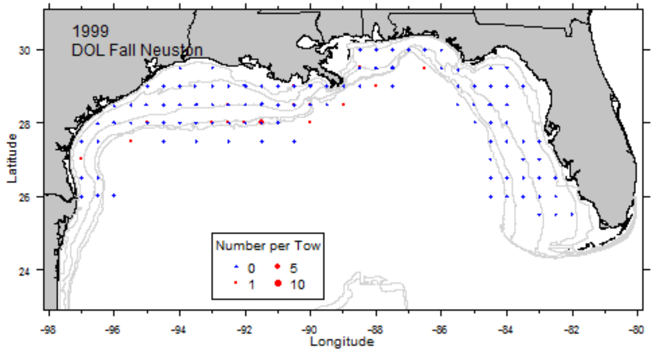
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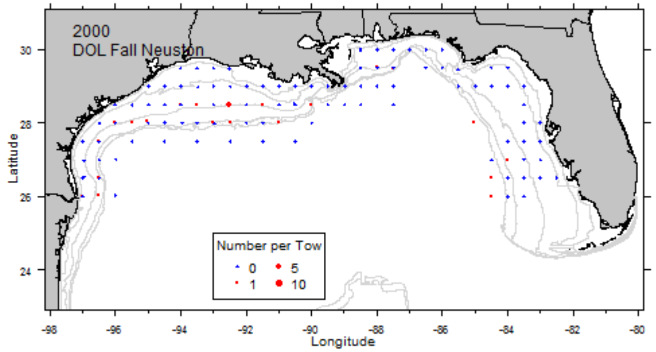
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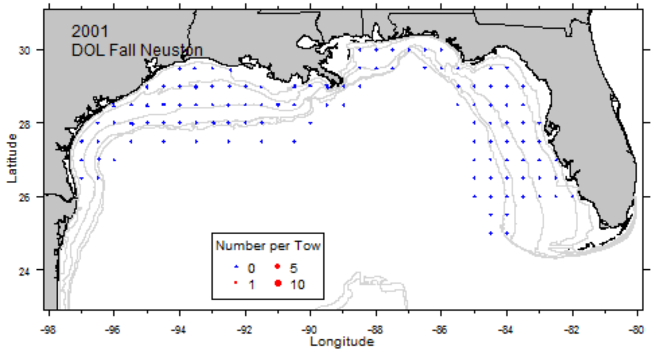
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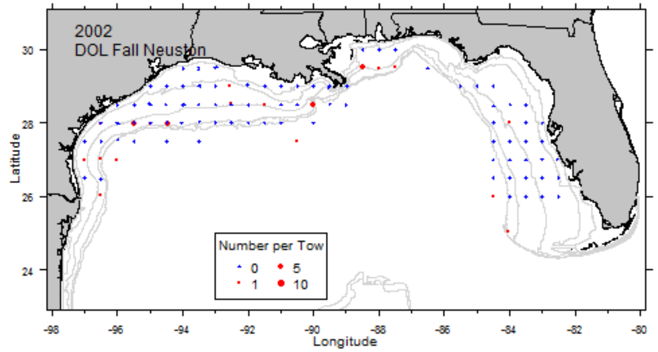
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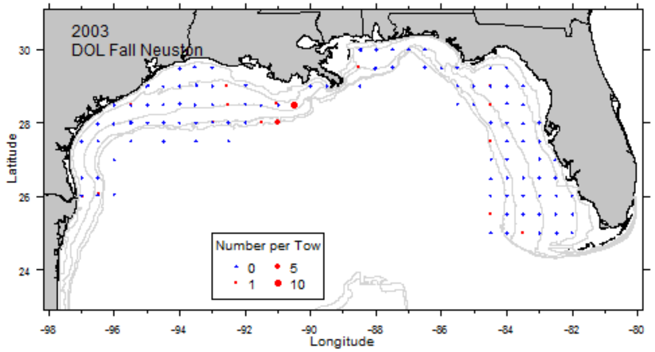
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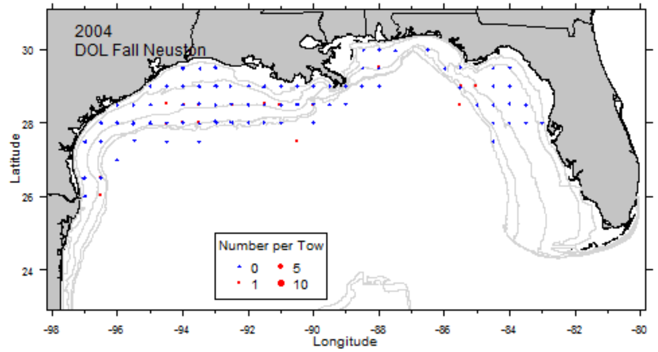
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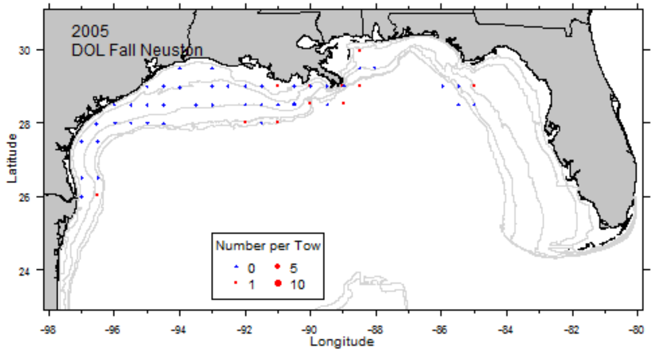
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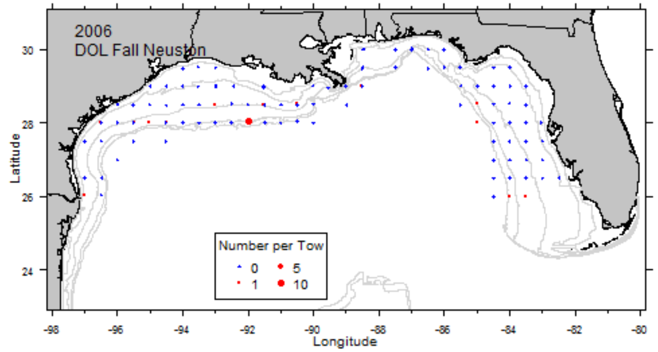
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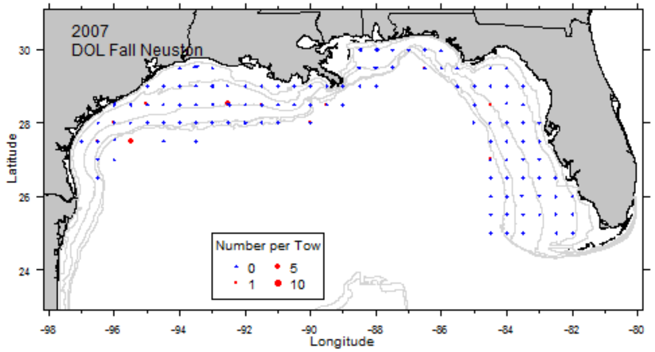
2007
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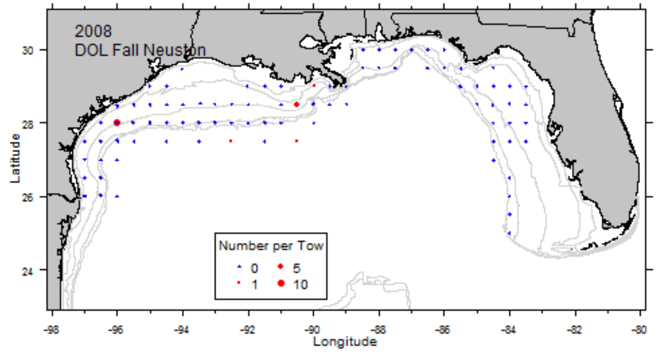
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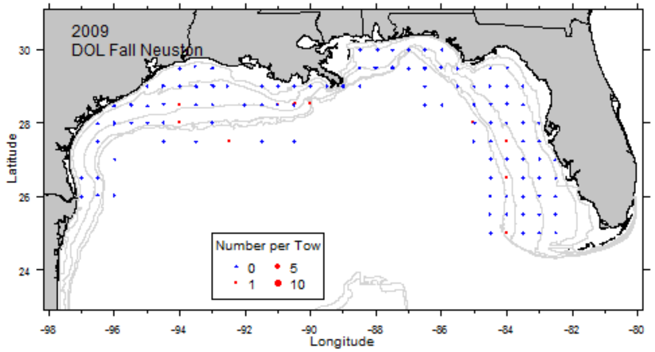
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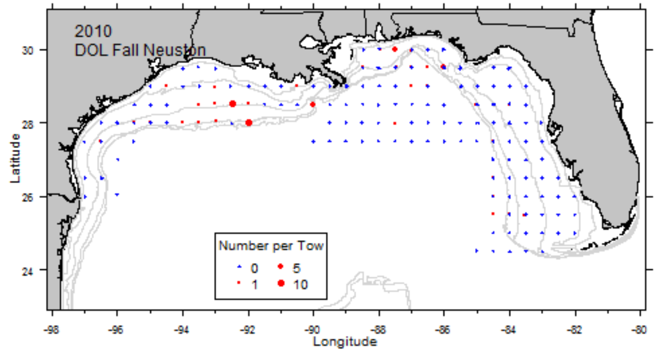
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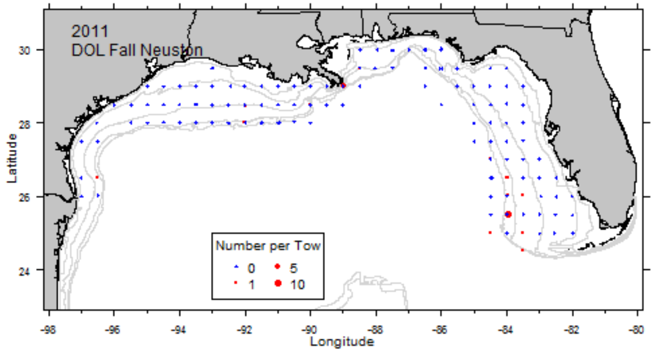
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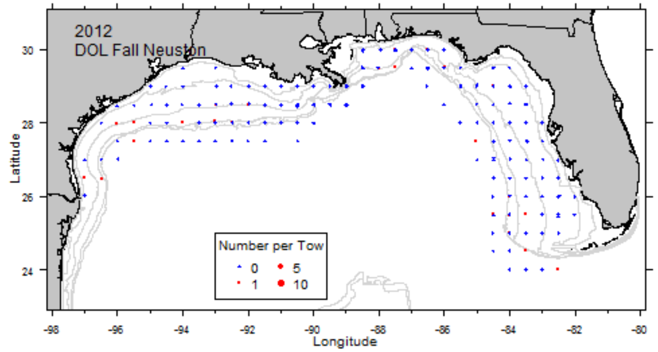
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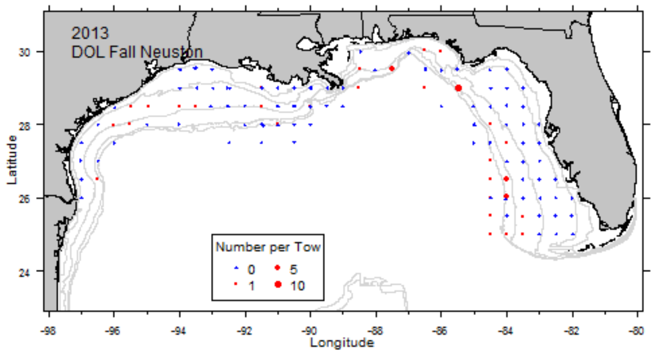
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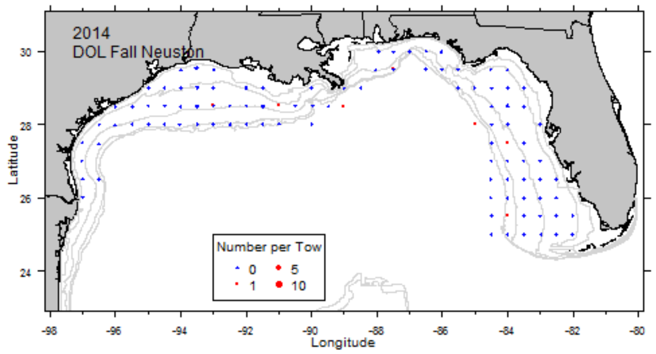
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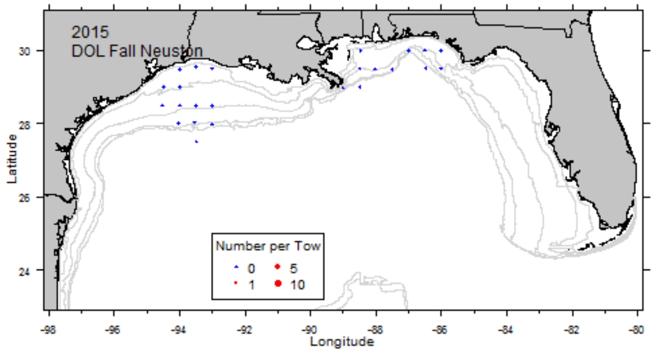
2015
DOL Fall Neuston
Number per Tow
0
1
5
10
Latitude
Longitude
30
28
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-90
-88
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-84
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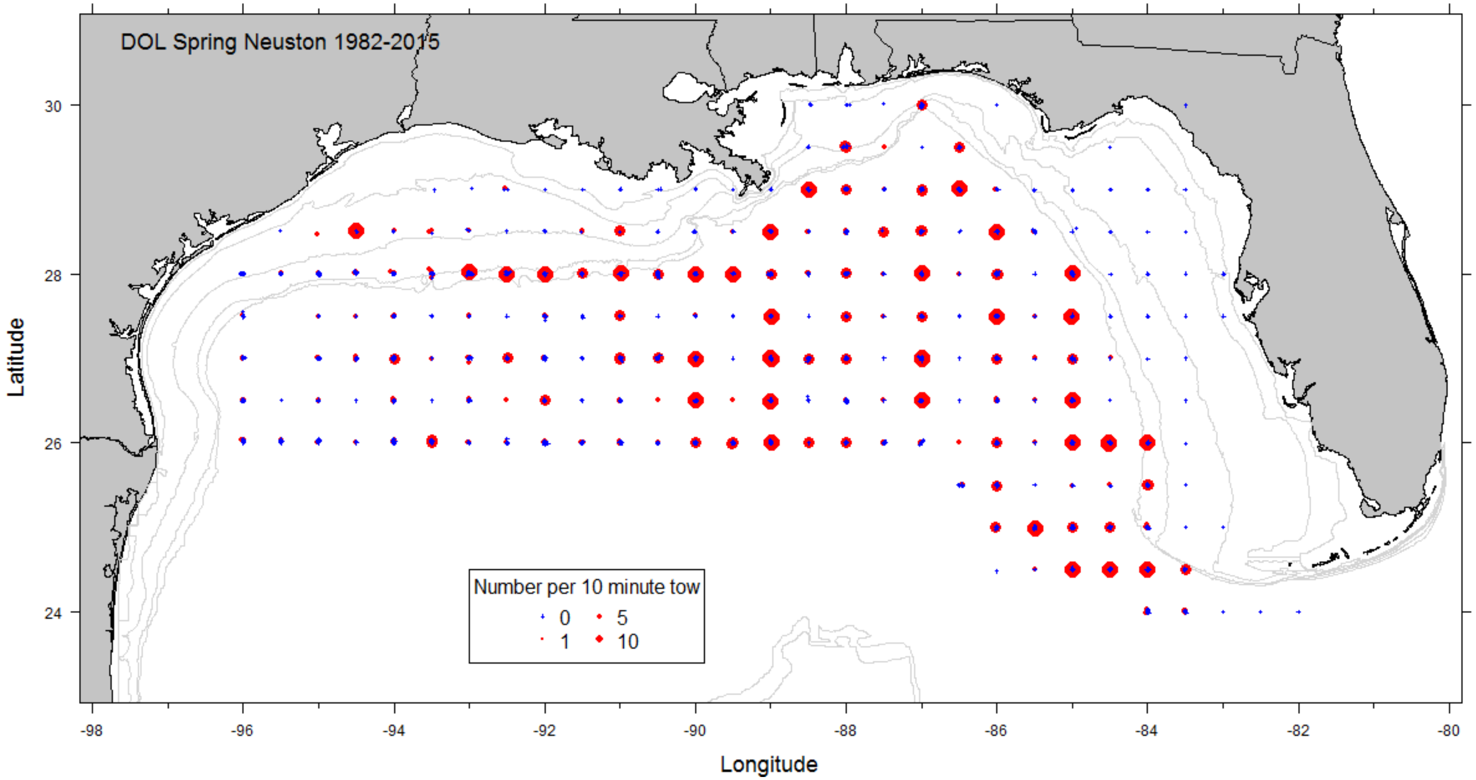
-80


DOL Spring Neuston 1982-2015
Number per 10 minute tow
0
1
5
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Latitude
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-88
-86
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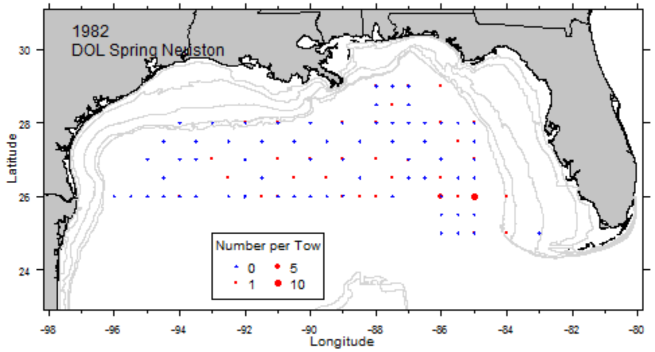
-82
-80
Longitude


1982
DOL Spring Neuston
Number per Tow
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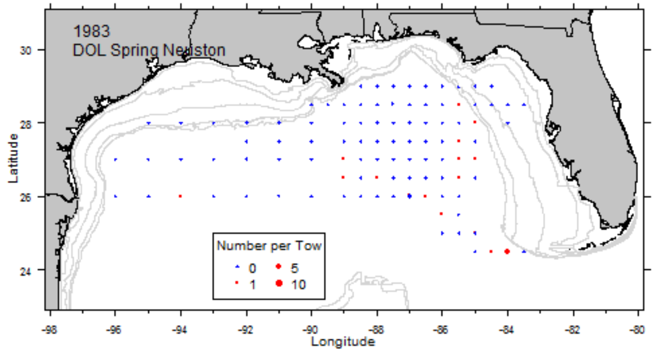
Latitude
Longitude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Number per Tow
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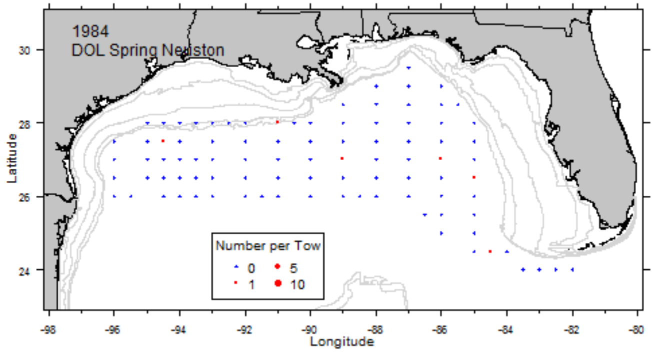
Latitude
Longitude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Number per Tow
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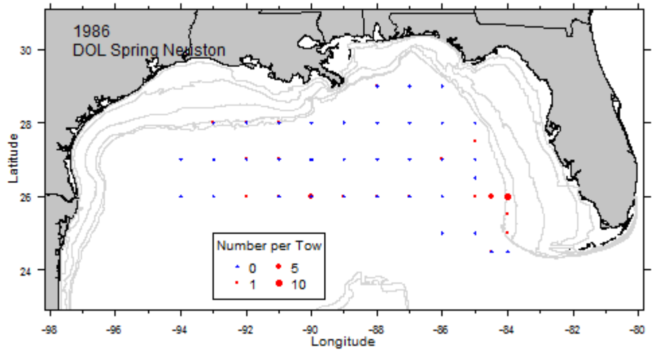
Latitude
Longitude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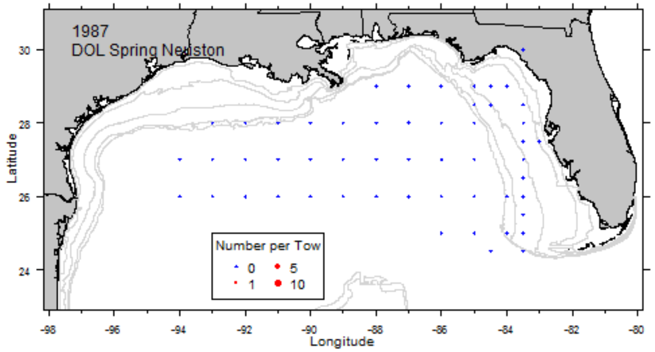
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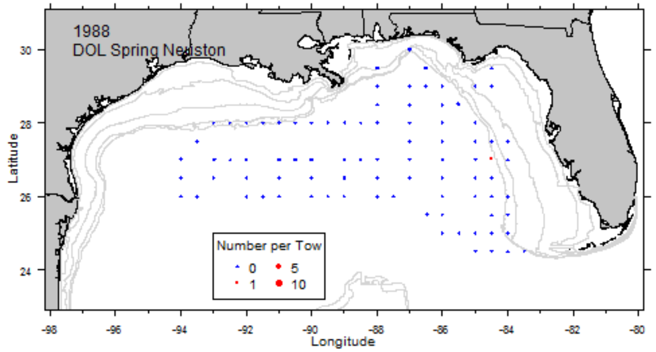
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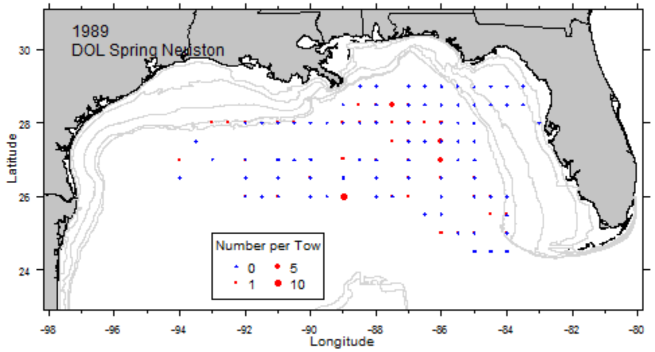
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Number per Tow
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Longitude
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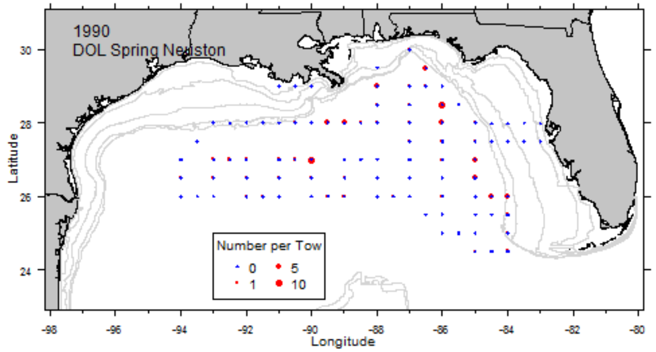
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Number per Tow
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Longitude
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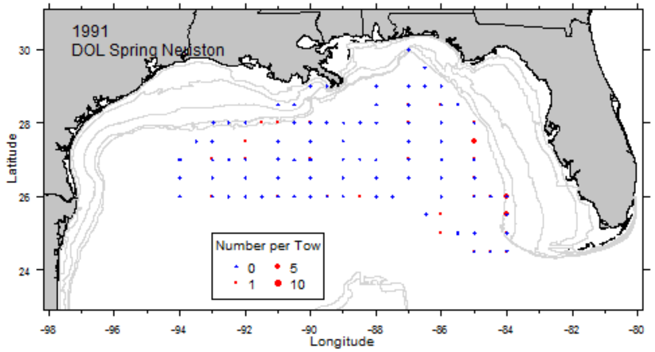
1991
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Number per Tow
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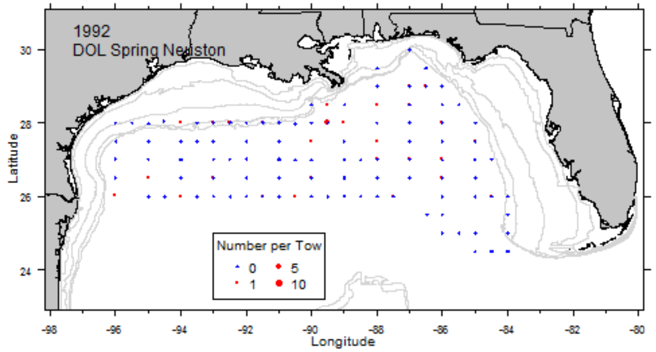
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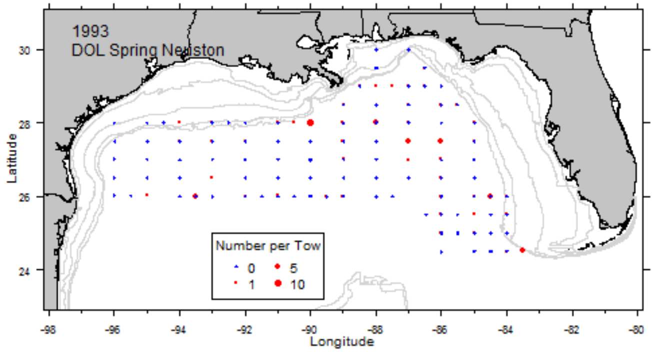
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Number per Tow
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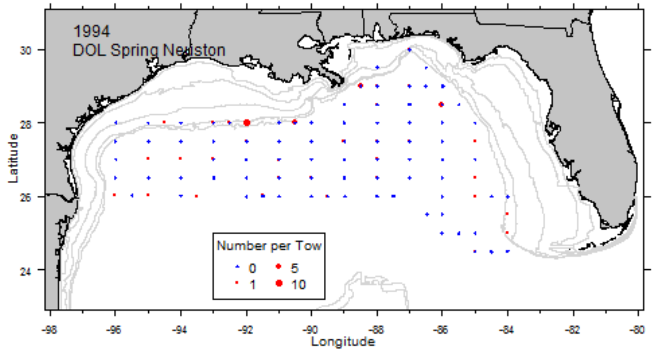
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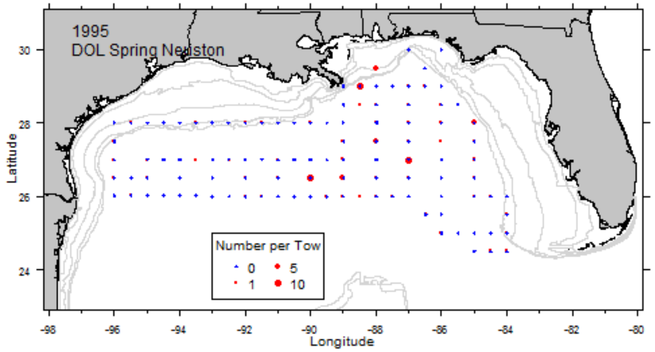
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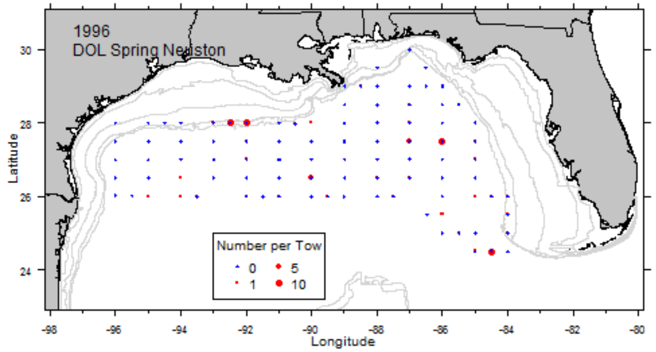
Longitude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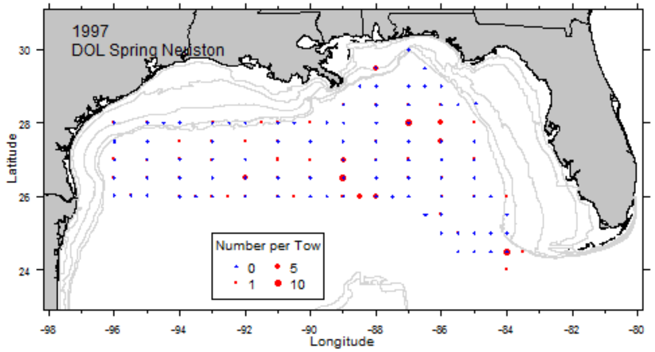
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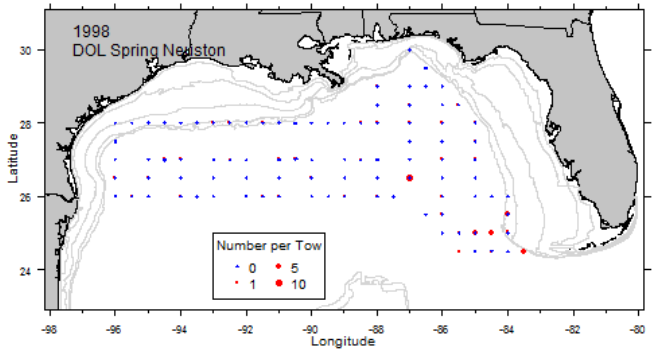
1998
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Number per Tow
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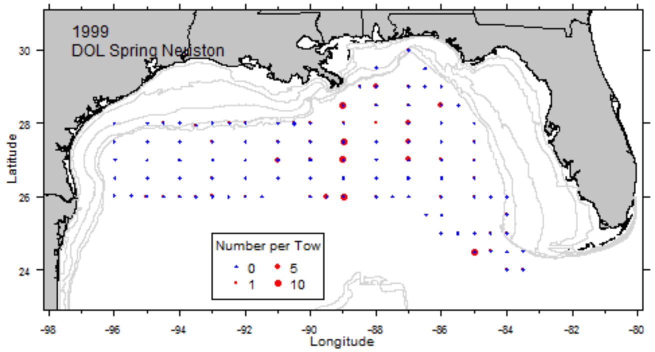
Longitude


1999
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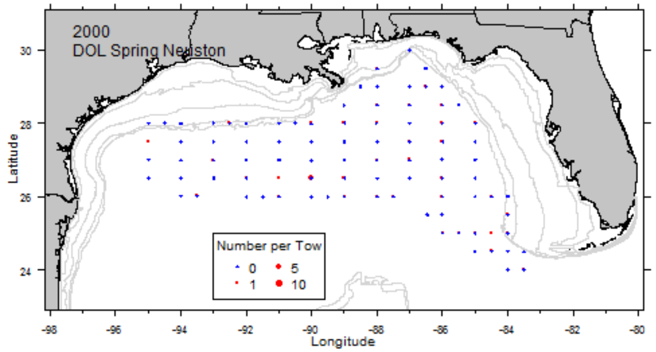
2000
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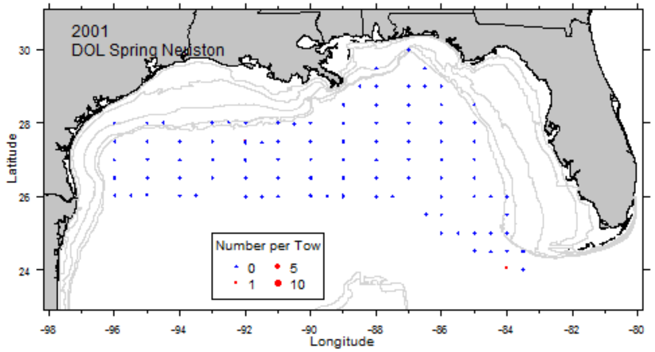
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Number per Tow
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Latitude
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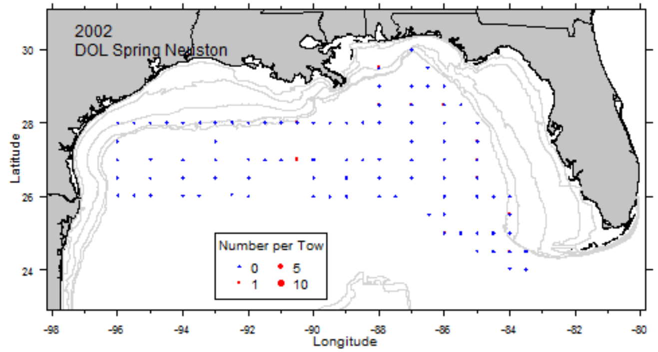
2002
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Number per Tow
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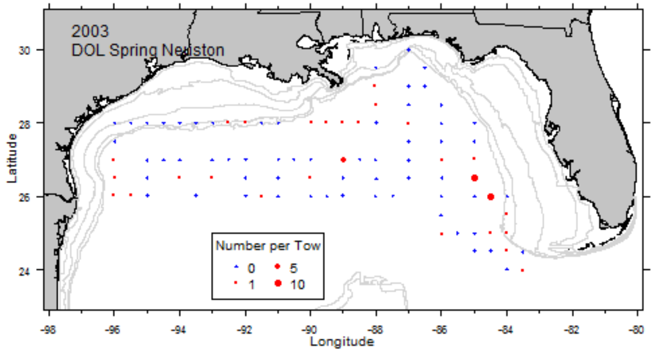
Longitude


2003
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Number per Tow
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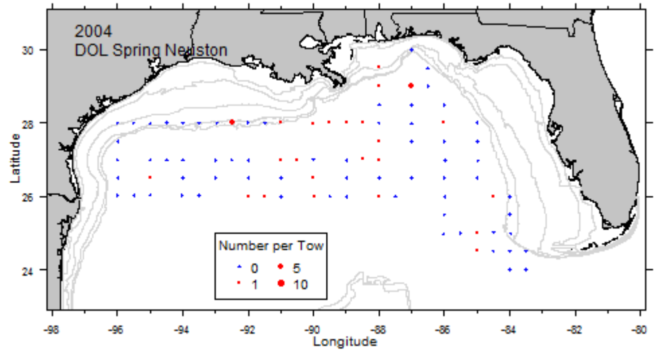
Latitude
Longitude


2004
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Number per Tow
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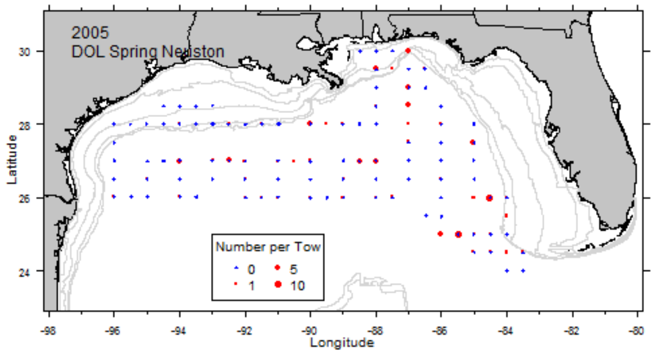
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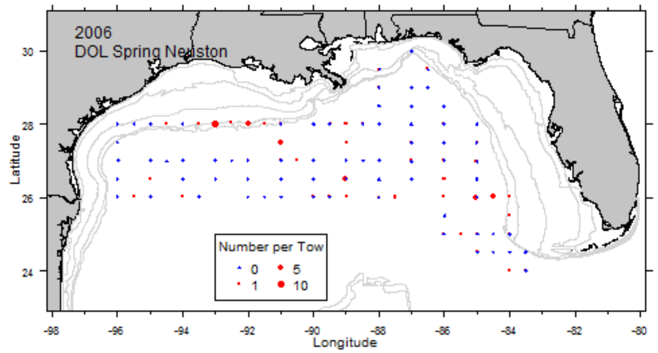
Longitude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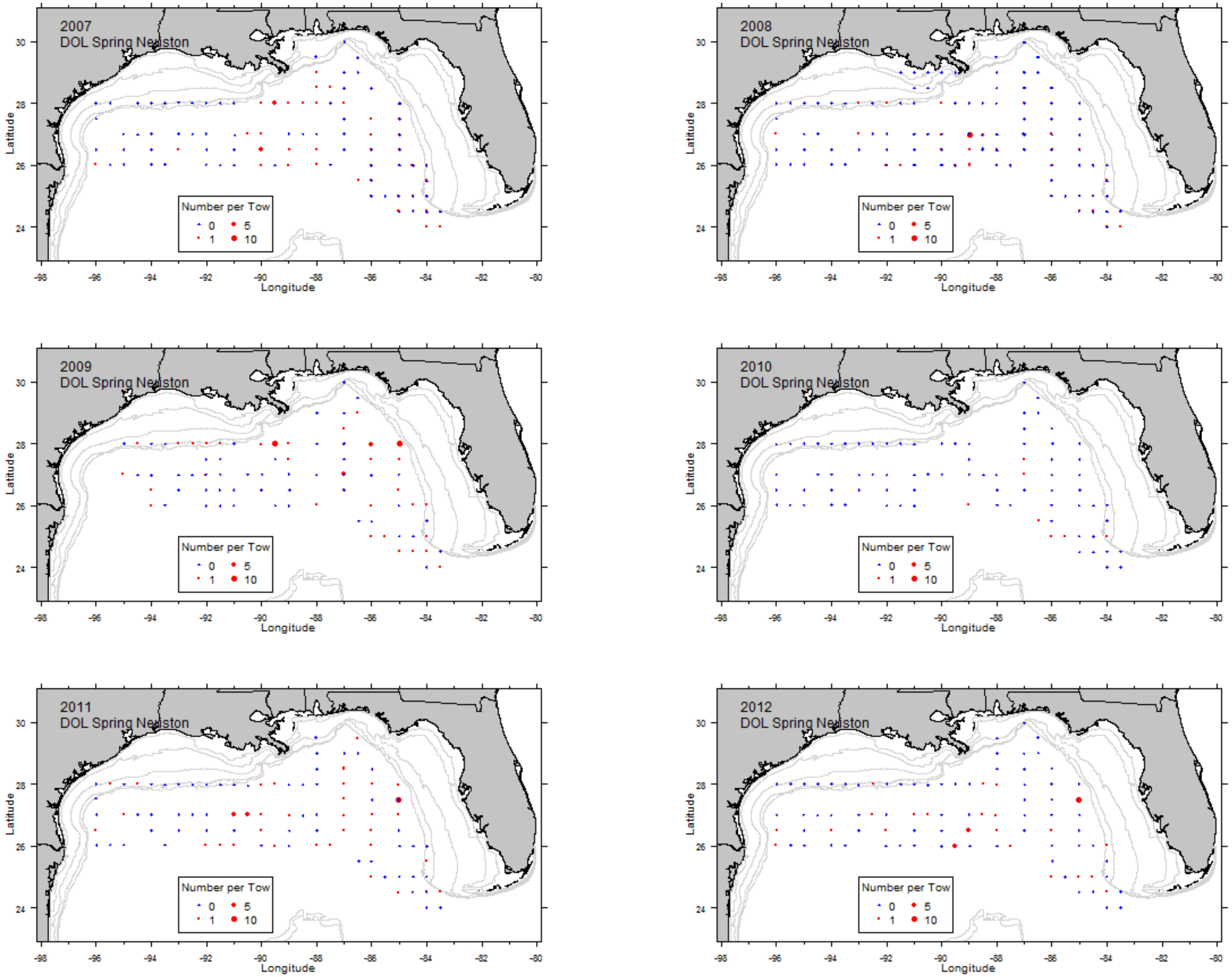
Longitude


2007
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2008
DOL Spring Neuston
2009
DOL Spring Neuston
2010
DOL Spring Neuston
2011
DOL Spring Neuston
2012
DOL Spring Neuston
Number per Tow
0
5
1
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Latitude
Longitude
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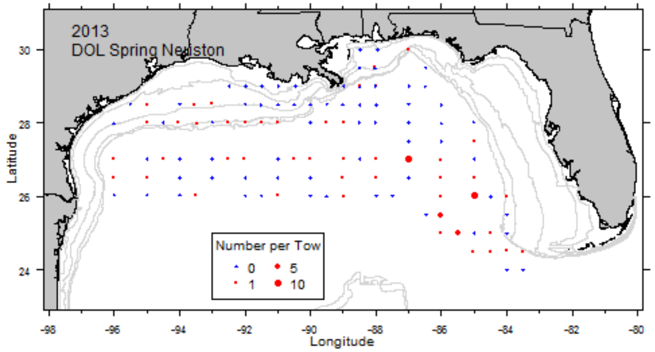
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Number per Tow
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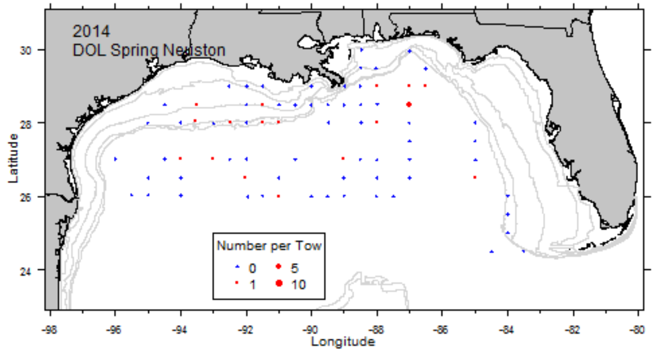
Latitude
Longitude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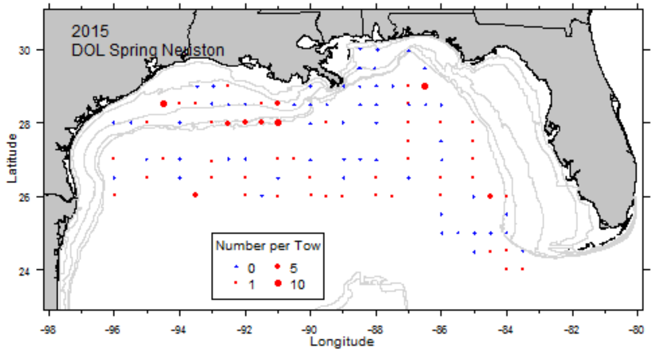
2015
DOL Spring Neuston
Number per Tow
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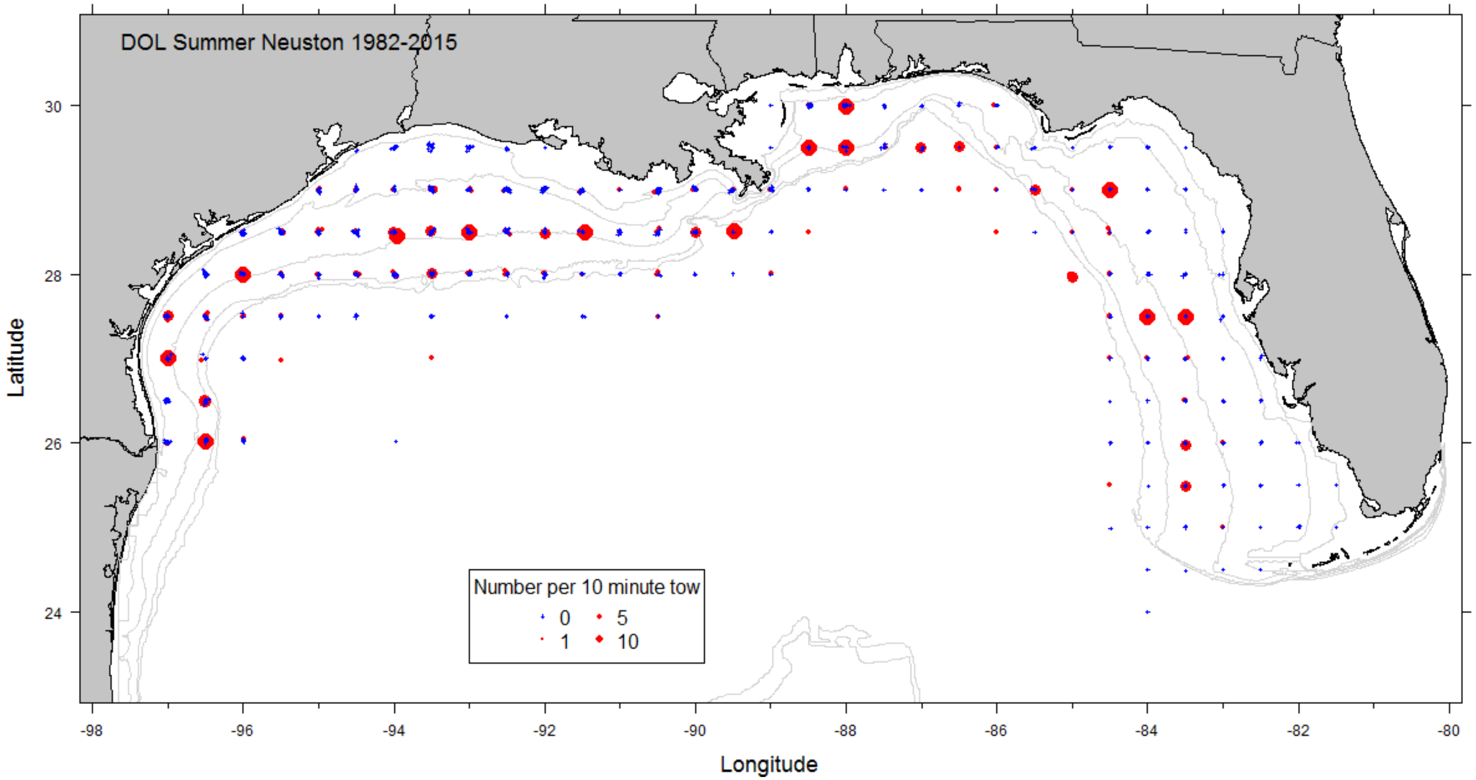
Latitude
Longitude



DOL Summer Neuston 1982-2015
Number per 10 minute tow
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Longitude
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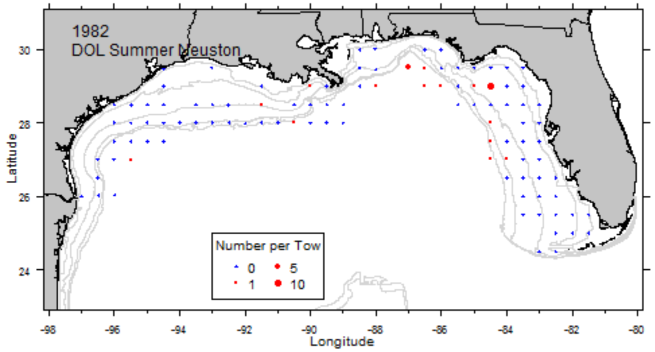
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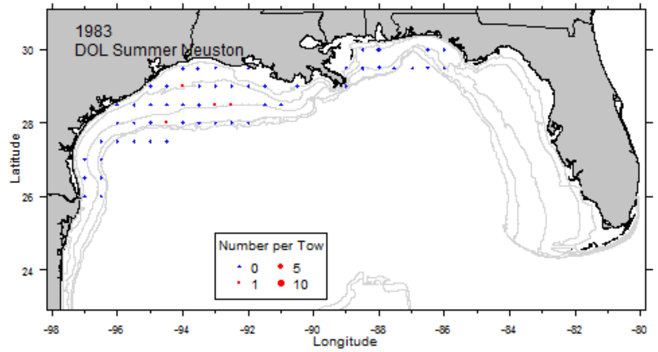
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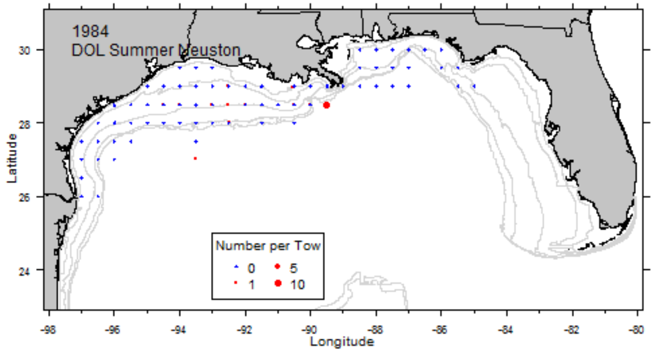
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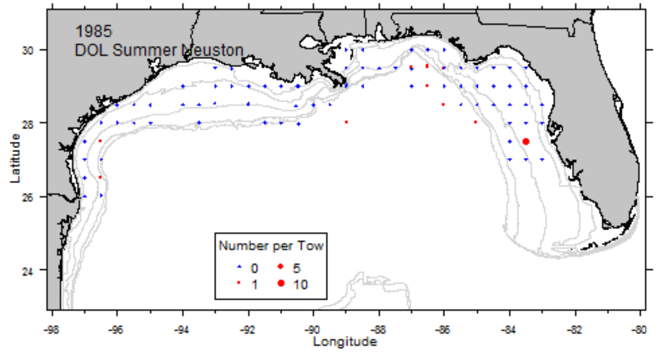
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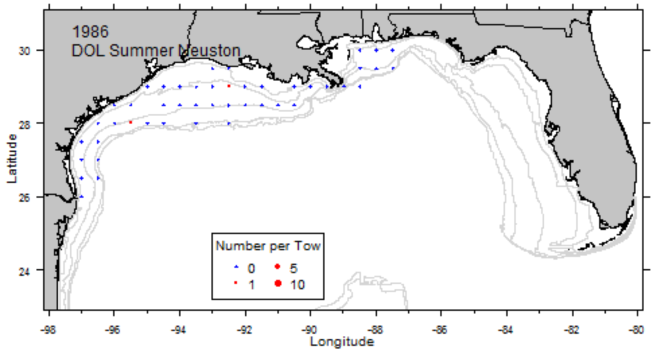
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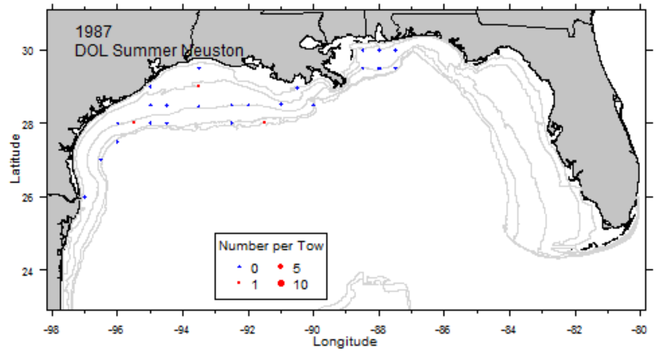
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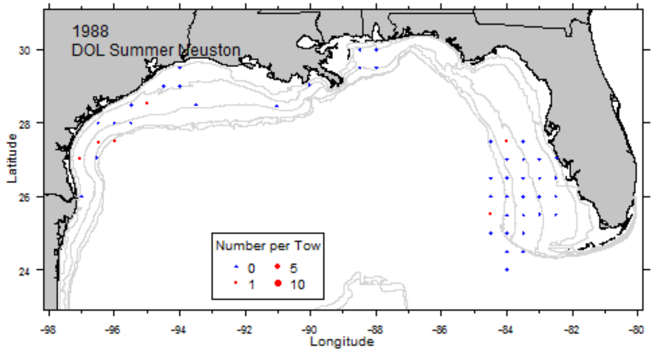
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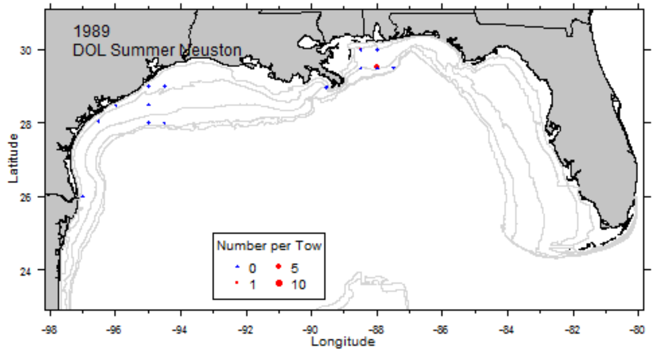
1989
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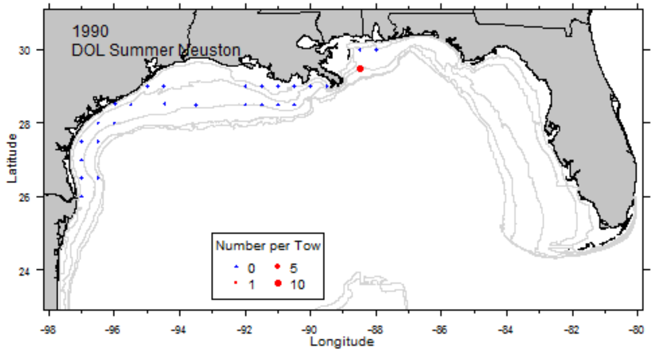
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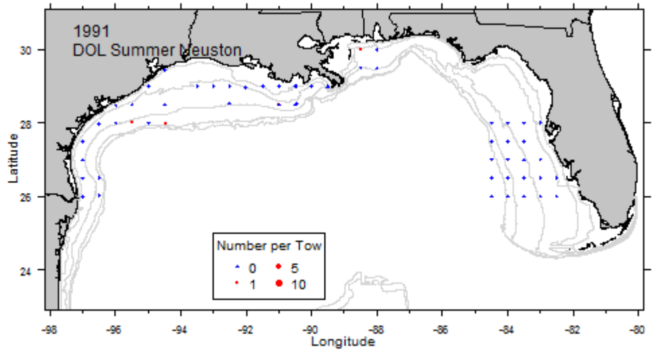
1991
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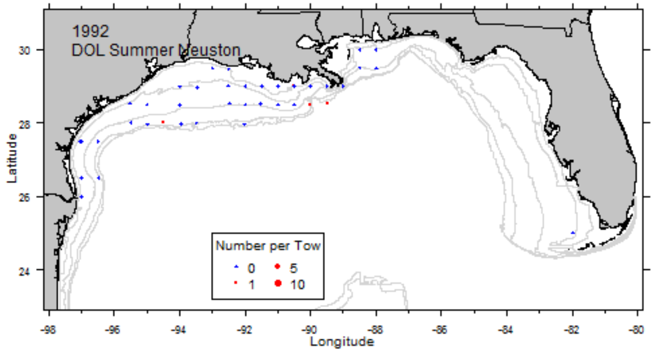
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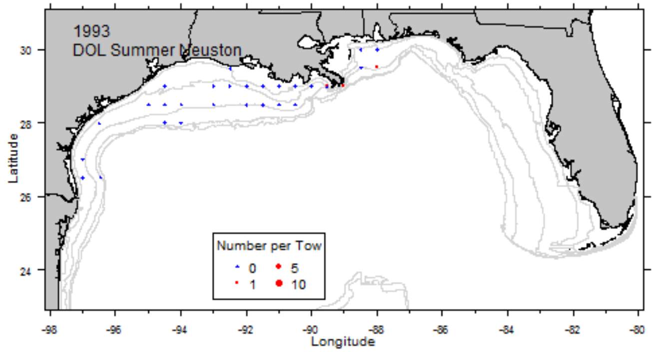
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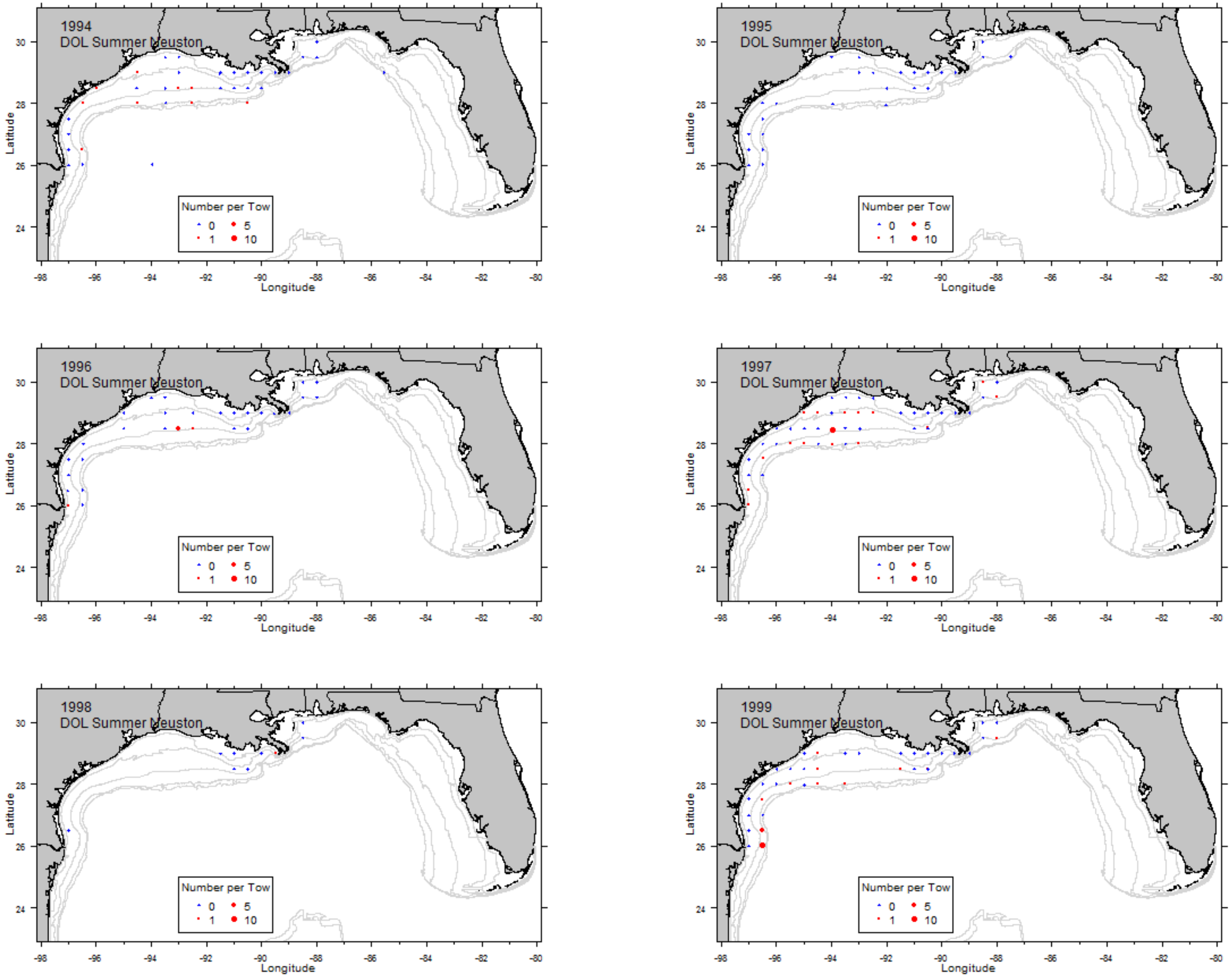
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DOL Summer Neuston
1995
DOL Summer Neuston
1996
DOL Summer Neuston
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1999
DOL Summer Neuston
Number per Tow
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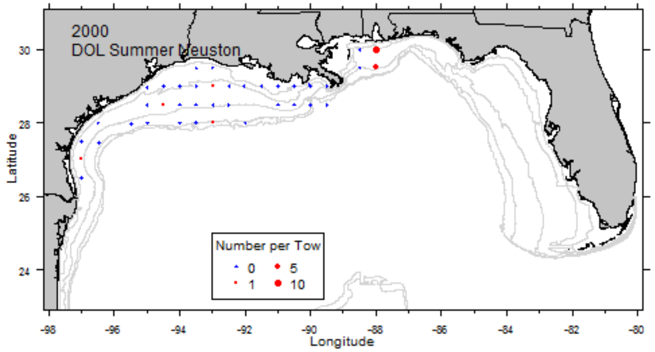
Latitude
Longitude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Longitude
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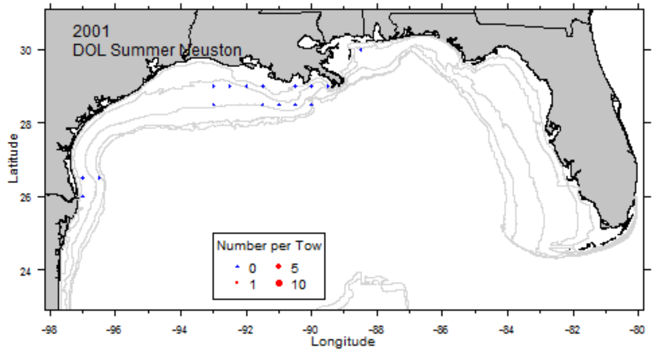
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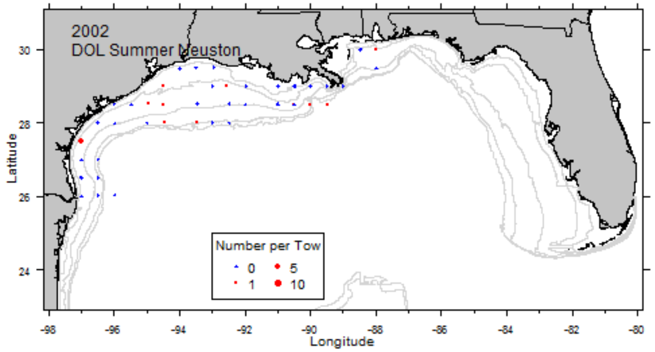
2002
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Longitude
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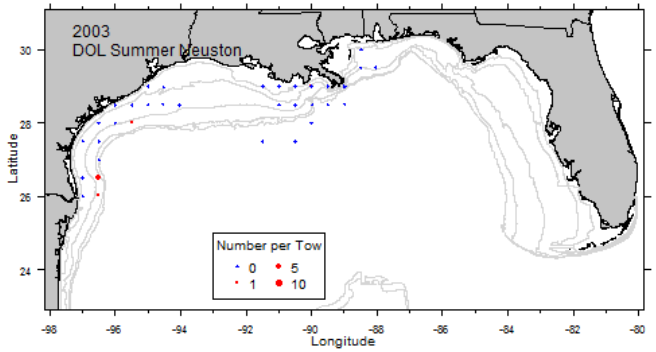
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Longitude
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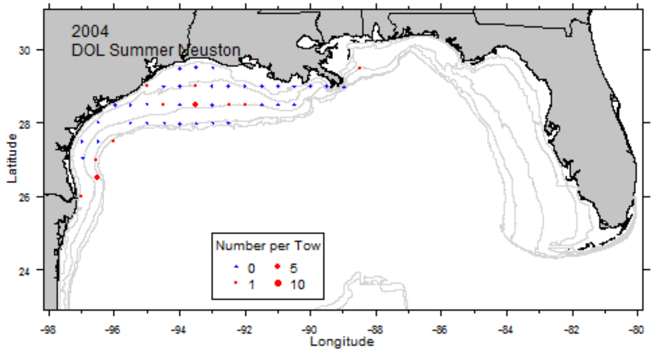
2004
DOL Summer Neuston
Number per Tow
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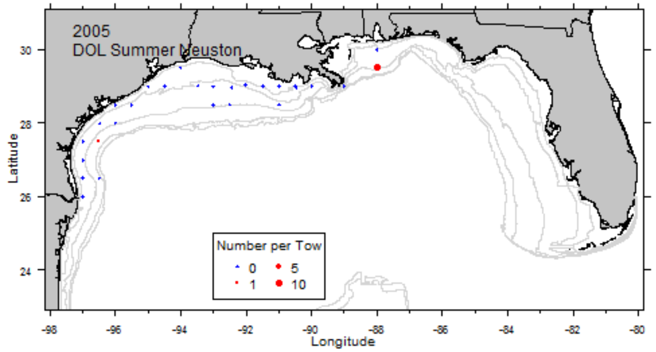
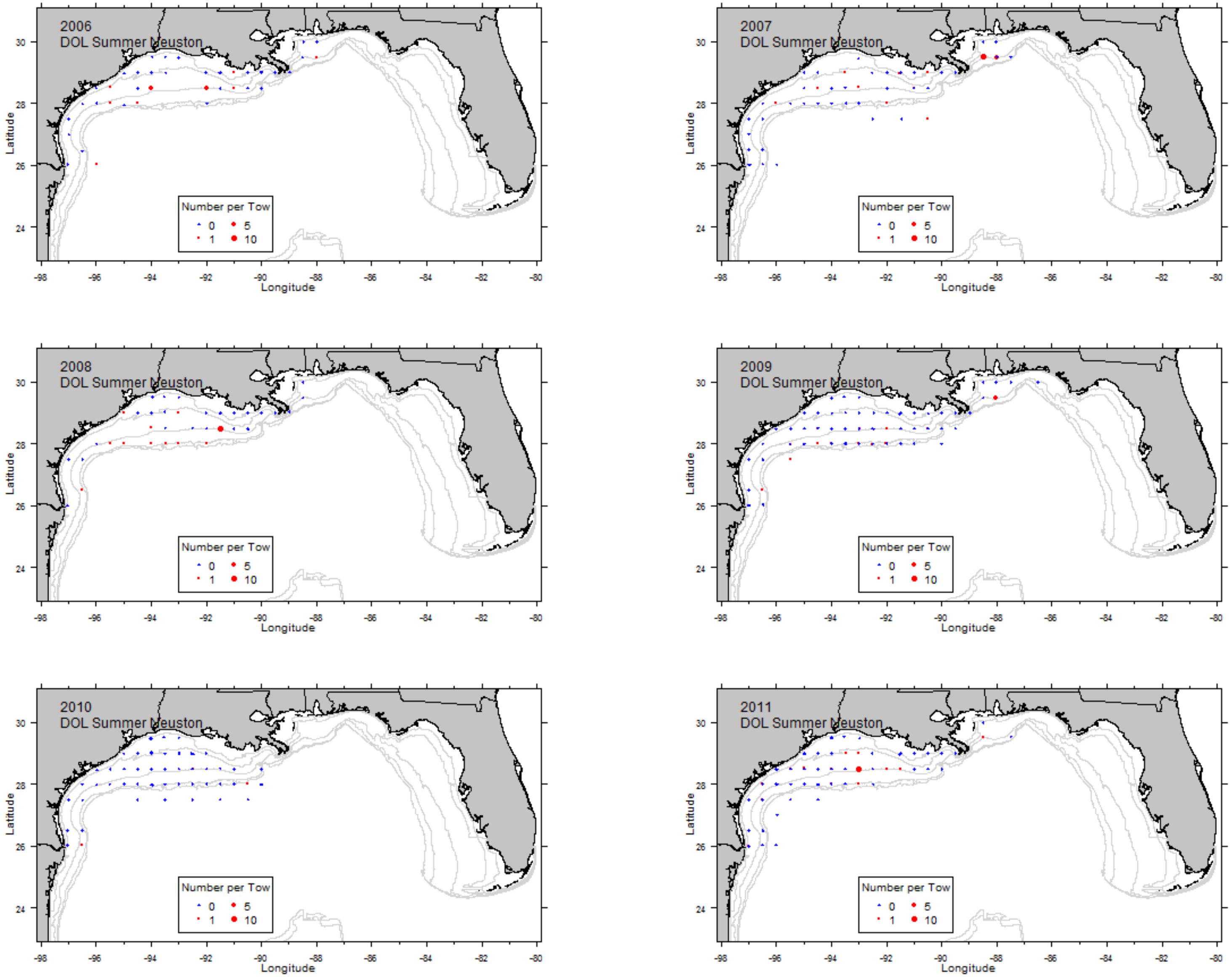
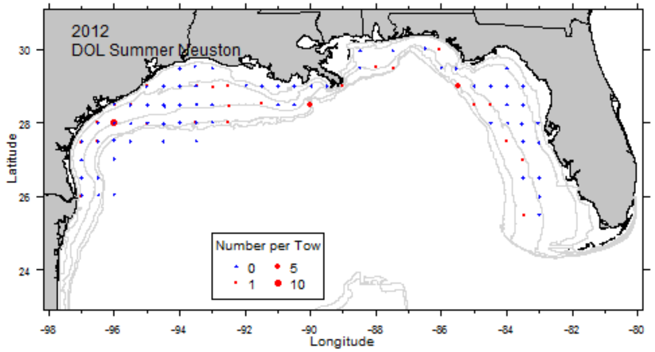
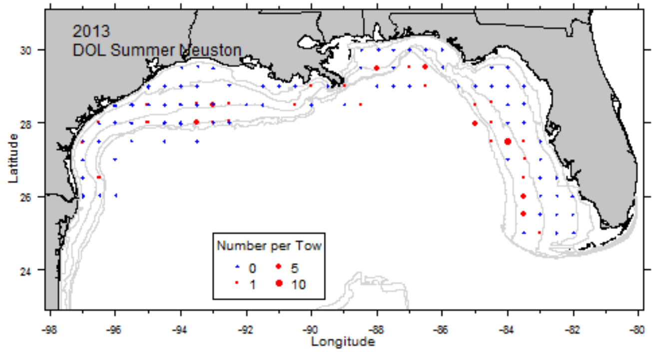
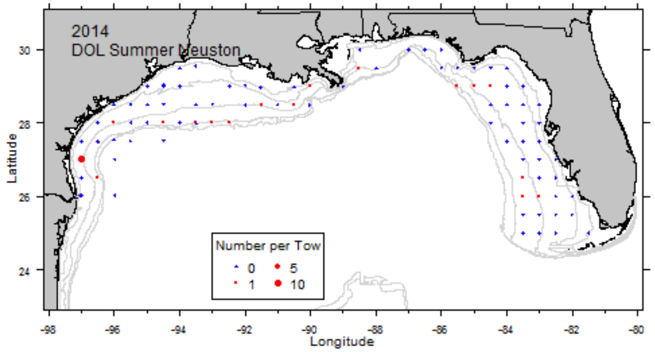
Latitude
Longitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80

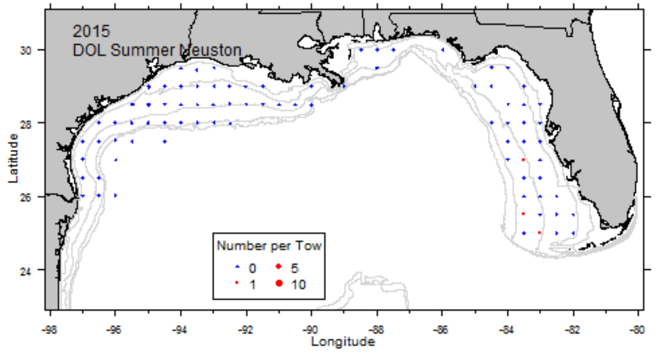

2005
DOL Summer Neuston
Number per Tow
0 5
1 10
Latitude
Longitude
30 28 26 24
-98 -96 -94 -92 -90 -88 -86 -84 -82 -80


2006
DOL Summer Neuston
2007
DOL Summer Neuston
2008
DOL Summer Neuston
2009
DOL Summer Neuston
2010
DOL Summer Neuston
2011
DOL Summer Neuston
Number per Tow
0
1
5
10
Latitude
Longitude
30
28
26
24
-98
-96
-94
-92
-90
-88
-86
-84
-82
-80


2012
DOL Summer Neuston
Number per Tow
0
5
1
10
Latitude
Longitude


2013
DOL Summer Neuston
Number per Tow
0
5
1
10
Latitude
Longitude


2014
DOL Summer Neuston
Number per Tow
0
5
1
10
Latitude
Longitude


2015
DOL Summer Neuston
Number per Tow
0
5
1
10
Latitude
Longitude

Appendix Table 1. Nominal catch and occurrence rates of LTA. Catch rate for bongo is the mean raw number of larvae under 100 m^2 at and for neuston, the mean raw number of larvae per 10-min tow.

gear	*season*	*year*	*occurrence*	*catch*
bongo	fall	1982	0.00000	0.00000
bongo	fall	1983	0.00000	0.00000
bongo	fall	1984	0.00000	0.00000
bongo	fall	1985	0.00000	0.00000
bongo	fall	1986	0.17361	0.23908
bongo	fall	1987	0.30508	0.38850
bongo	fall	1988	0.07447	0.05618
bongo	fall	1989	0.09694	0.07273
bongo	fall	1990	0.08824	0.10865
bongo	fall	1991	0.09333	0.07922
bongo	fall	1992	0.17290	0.13930
bongo	fall	1993	0.15267	0.17256
bongo	fall	1994	0.16667	0.21967
bongo	fall	1995	0.28151	0.44119
bongo	fall	1996	0.19549	0.18653
bongo	fall	1997	0.20940	0.24448
bongo	fall	1998	0.04255	0.01319
bongo	fall	1999	0.25333	0.37312
bongo	fall	2000	0.14667	0.14660
bongo	fall	2001	0.23377	0.44099
bongo	fall	2002	0.29741	0.51718
bongo	fall	2003	0.26829	0.73418
bongo	fall	2004	0.22764	0.66097
bongo	fall	2005	0.05000	0.01103
bongo	fall	2006	0.29060	0.53328
bongo	fall	2007	0.28205	0.58967
bongo	fall	2008	0.09244	0.15502
bongo	fall	2009	0.20979	0.43355
bongo	fall	2010	0.12626	0.23005
bongo	fall	2011	0.18581	0.86429
bongo	fall	2012	0.13369	.
bongo	fall	2013	0.19847	0.00000
bongo	fall	2014	0.22835	0.24068
bongo	fall	2015	0.00000	0.00000
bongo	spring	1982	0.06838	0.32967

gear	*season*	*year*	*occurrence*	*catch*
bongo	spring	1983	0.00000	0.00000
bongo	spring	1984	0.00714	0.00531
bongo	spring	1986	0.05333	0.47644
bongo	spring	1987	0.02747	0.05022
bongo	spring	1988	0.04545	0.03911
bongo	spring	1989	0.02326	0.01980
bongo	spring	1990	0.09177	0.23260
bongo	spring	1991	0.04819	0.07808
bongo	spring	1992	0.07778	0.08924
bongo	spring	1993	0.08621	0.12063
bongo	spring	1994	0.07407	0.14361
bongo	spring	1995	0.11511	0.12999
bongo	spring	1996	0.08421	0.10135
bongo	spring	1997	0.04255	0.14465
bongo	spring	1998	0.06322	0.23730
bongo	spring	1999	0.01744	0.01807
bongo	spring	2000	0.06250	0.07083
bongo	spring	2001	0.04598	0.30986
bongo	spring	2002	0.07059	0.14450
bongo	spring	2003	0.00000	0.00000
bongo	spring	2004	0.02564	0.00000
bongo	spring	2005	0.08081	0.10669
bongo	spring	2006	0.05128	0.05005
bongo	spring	2007	0.07813	0.08516
bongo	spring	2008	0.12500	0.26919
bongo	spring	2009	0.11765	0.11724
bongo	spring	2010	0.08000	0.08267
bongo	spring	2011	0.08889	0.09748
bongo	spring	2012	0.11321	0.20270
bongo	spring	2013	0.00000	.
bongo	spring	2014	0.00971	0.00000
bongo	spring	2015	0.13158	0.14454
bongo	summer	1982	0.01667	0.00575
bongo	summer	1983	0.10938	0.06968
bongo	summer	1984	0.07692	0.10104
bongo	summer	1985	0.28869	0.57173
bongo	summer	1986	0.34783	0.58847

gear	*season*	*year*	*occurrence*	*catch*
bongo	summer	1987	0.48438	1.10980
bongo	summer	1988	0.25000	0.33172
bongo	summer	1989	0.44444	0.58550
bongo	summer	1990	0.40000	0.48694
bongo	summer	1991	0.23333	0.28174
bongo	summer	1992	0.38095	1.00905
bongo	summer	1993	0.16129	0.31351
bongo	summer	1994	0.26316	0.69625
bongo	summer	1995	0.08333	0.02842
bongo	summer	1996	0.43333	0.94273
bongo	summer	1997	0.32609	2.41711
bongo	summer	1998	0.38889	0.34244
bongo	summer	1999	0.40541	0.73438
bongo	summer	2000	0.23810	0.66580
bongo	summer	2001	0.34286	0.43578
bongo	summer	2002	0.39583	1.25743
bongo	summer	2003	0.25000	1.11501
bongo	summer	2004	0.32609	0.61834
bongo	summer	2005	0.41379	0.00000
bongo	summer	2006	0.32500	0.62786
bongo	summer	2007	0.38235	1.16169
bongo	summer	2008	0.40000	1.04957
bongo	summer	2009	0.51948	1.42495
bongo	summer	2010	0.38095	0.90528
bongo	summer	2011	0.36620	2.28855
bongo	summer	2012	0.50962	.
bongo	summer	2013	0.46400	0.27496
bongo	summer	2014	0.26549	0.37244
bongo	summer	2015	0.05607	0.38939
neuston	fall	1982	0.00000	0.00000
neuston	fall	1983	0.00000	0.00000
neuston	fall	1985	0.00000	0.00000
neuston	fall	1986	0.17361	0.53472
neuston	fall	1987	0.13675	0.75214
neuston	fall	1988	0.08333	0.37500
neuston	fall	1989	0.10317	0.30159
neuston	fall	1990	0.06723	0.22689

gear	*season*	*year*	*occurrence*	*catch*
neuston	fall	1991	0.05607	0.14019
neuston	fall	1992	0.18812	0.62376
neuston	fall	1993	0.09924	0.61069
neuston	fall	1994	0.10924	0.47059
neuston	fall	1995	0.17949	1.63248
neuston	fall	1996	0.12030	0.46617
neuston	fall	1997	0.10000	0.69167
neuston	fall	1998	0.01087	0.02174
neuston	fall	1999	0.14189	0.54054
neuston	fall	2000	0.15108	0.56835
neuston	fall	2001	0.15584	0.62987
neuston	fall	2002	0.20690	0.84483
neuston	fall	2003	0.17355	1.95041
neuston	fall	2004	0.14407	1.26271
neuston	fall	2005	0.01887	0.01887
neuston	fall	2006	0.19658	1.80342
neuston	fall	2007	0.11465	0.71019
neuston	fall	2008	0.01667	0.05833
neuston	fall	2009	0.09722	0.99306
neuston	fall	2010	0.07107	0.27919
neuston	fall	2011	0.08446	0.37500
neuston	fall	2012	0.10053	0.46561
neuston	fall	2013	0.04800	0.07200
neuston	fall	2014	0.07438	0.55372
neuston	fall	2015	0.00000	0.00000
neuston	spring	1982	0.04839	0.12097
neuston	spring	1983	0.01869	0.04673
neuston	spring	1984	0.08602	0.16129
neuston	spring	1986	0.01351	0.32432
neuston	spring	1987	0.01136	0.01136
neuston	spring	1988	0.00671	0.00671
neuston	spring	1989	0.03371	0.20787
neuston	spring	1990	0.03987	0.06645
neuston	spring	1991	0.02312	0.03468
neuston	spring	1992	0.00617	0.00926
neuston	spring	1993	0.07042	0.20657
neuston	spring	1994	0.06954	0.22185

gear	*season*	*year*	*occurrence*	*catch*
neuston	spring	1995	0.04301	0.18280
neuston	spring	1996	0.02381	0.11310
neuston	spring	1997	0.01622	0.04324
neuston	spring	1998	0.02976	0.03869
neuston	spring	1999	0.02571	0.04857
neuston	spring	2000	0.01765	0.07059
neuston	spring	2001	0.05988	0.12575
neuston	spring	2002	0.05732	0.13376
neuston	spring	2003	0.04494	0.04494
neuston	spring	2004	0.03371	0.03371
neuston	spring	2005	0.04762	0.11640
neuston	spring	2006	0.06000	0.18667
neuston	spring	2007	0.05217	0.26087
neuston	spring	2008	0.06918	0.72327
neuston	spring	2009	0.04762	0.15476
neuston	spring	2010	0.06173	0.58025
neuston	spring	2011	0.10000	0.51111
neuston	spring	2012	0.05556	0.10000
neuston	spring	2013	0.01739	0.01739
neuston	spring	2014	0.02597	0.05195
neuston	spring	2015	0.07273	0.16364
neuston	summer	1982	0.10784	0.85294
neuston	summer	1983	0.06557	0.11475
neuston	summer	1984	0.13675	0.54701
neuston	summer	1985	0.29070	4.29070
neuston	summer	1986	0.08696	0.15217
neuston	summer	1987	0.12903	0.54839
neuston	summer	1988	0.30612	4.12245
neuston	summer	1989	0.16667	0.61111
neuston	summer	1990	0.03448	0.06897
neuston	summer	1991	0.17241	0.50000
neuston	summer	1992	0.18182	2.20455
neuston	summer	1993	0.20000	0.33333
neuston	summer	1994	0.12821	2.07692
neuston	summer	1995	0.03846	0.11538
neuston	summer	1996	0.23333	1.63333
neuston	summer	1997	0.15217	1.32609

gear	*season*	*year*	*occurrence*	*catch*
neuston	summer	1998	0.22222	1.11111
neuston	summer	1999	0.13514	0.56757
neuston	summer	2000	0.09524	0.30952
neuston	summer	2001	0.10000	4.95000
neuston	summer	2002	0.22449	1.00000
neuston	summer	2003	0.19444	1.47222
neuston	summer	2004	0.16327	0.59184
neuston	summer	2005	0.17857	0.39286
neuston	summer	2006	0.07317	0.24390
neuston	summer	2007	0.04000	2.01000
neuston	summer	2008	0.15789	1.26316
neuston	summer	2009	0.21250	1.10000
neuston	summer	2010	0.24590	2.31148
neuston	summer	2011	0.28767	6.82192
neuston	summer	2012	0.21154	0.94231
neuston	summer	2013	0.17460	0.78571
neuston	summer	2014	0.11000	0.49000
neuston	summer	2015	0.00000	0.00000

Appendix Table 2. Numbers of sampling stations and numbers of specimens of LTA for each gear, season, year.

gear	*season*	*year*	*stations*	*specimens*
bongo	fall	1982	21	0
bongo	fall	1983	18	0
bongo	fall	1984	2	0
bongo	fall	1985	3	0
bongo	fall	1986	188	69
bongo	fall	1987	118	100
bongo	fall	1988	53	7
bongo	fall	1989	166	37
bongo	fall	1990	125	26
bongo	fall	1991	78	19
bongo	fall	1992	108	35
bongo	fall	1993	132	69
bongo	fall	1994	120	58
bongo	fall	1995	126	110
bongo	fall	1996	134	57
bongo	fall	1997	118	80
bongo	fall	1998	64	4
bongo	fall	1999	195	141
bongo	fall	2000	162	55
bongo	fall	2001	154	136
bongo	fall	2002	120	146
bongo	fall	2003	123	173
bongo	fall	2004	123	141
bongo	fall	2005	47	2
bongo	fall	2006	124	166
bongo	fall	2007	169	247
bongo	fall	2008	119	36
bongo	fall	2009	143	94
bongo	fall	2010	199	69
bongo	fall	2011	149	157
bongo	fall	2012	187	187
bongo	fall	2013	131	79
bongo	fall	2014	139	218
bongo	fall	2015	24	0
bongo	spring	1982	117	81
bongo	spring	1983	108	0

gear	*season*	*year*	*stations*	*specimens*
bongo	spring	1984	233	1
bongo	spring	1986	75	13
bongo	spring	1987	109	8
bongo	spring	1988	89	6
bongo	spring	1989	86	3
bongo	spring	1990	185	66
bongo	spring	1991	96	13
bongo	spring	1992	93	19
bongo	spring	1993	136	26
bongo	spring	1994	81	28
bongo	spring	1995	139	35
bongo	spring	1996	95	18
bongo	spring	1997	94	25
bongo	spring	1998	172	81
bongo	spring	1999	171	5
bongo	spring	2000	80	8
bongo	spring	2001	88	38
bongo	spring	2002	85	25
bongo	spring	2003	43	0
bongo	spring	2004	39	3
bongo	spring	2005	99	23
bongo	spring	2006	86	5
bongo	spring	2007	64	8
bongo	spring	2008	80	30
bongo	spring	2009	51	11
bongo	spring	2010	50	8
bongo	spring	2011	45	6
bongo	spring	2012	53	13
bongo	spring	2013	116	0
bongo	spring	2014	103	1
bongo	spring	2015	114	43
bongo	summer	1982	60	3
bongo	summer	1983	100	23
bongo	summer	1984	178	49
bongo	summer	1985	99	111
bongo	summer	1986	47	50
bongo	summer	1987	40	90

gear	*season*	*year*	*stations*	*specimens*
bongo	summer	1988	77	55
bongo	summer	1989	19	32
bongo	summer	1990	38	40
bongo	summer	1991	84	63
bongo	summer	1992	44	136
bongo	summer	1993	31	16
bongo	summer	1994	38	55
bongo	summer	1995	24	2
bongo	summer	1996	31	68
bongo	summer	1997	46	198
bongo	summer	1998	10	6
bongo	summer	1999	38	55
bongo	summer	2000	73	100
bongo	summer	2001	35	72
bongo	summer	2002	50	126
bongo	summer	2003	36	78
bongo	summer	2004	46	49
bongo	summer	2005	29	43
bongo	summer	2006	40	43
bongo	summer	2007	58	155
bongo	summer	2008	41	55
bongo	summer	2009	77	201
bongo	summer	2010	74	118
bongo	summer	2011	71	268
bongo	summer	2012	104	135
bongo	summer	2013	126	344
bongo	summer	2014	121	395
bongo	summer	2015	107	60
neuston	fall	1982	20	0
neuston	fall	1983	17	0
neuston	fall	1985	2	0
neuston	fall	1986	144	77
neuston	fall	1987	117	88
neuston	fall	1988	72	27
neuston	fall	1989	126	38
neuston	fall	1990	119	27
neuston	fall	1991	107	15

gear	*season*	*year*	*stations*	*specimens*
neuston	fall	1992	101	63
neuston	fall	1993	131	80
neuston	fall	1994	119	56
neuston	fall	1995	117	191
neuston	fall	1996	133	62
neuston	fall	1997	120	83
neuston	fall	1998	62	2
neuston	fall	1999	148	80
neuston	fall	2000	139	79
neuston	fall	2001	154	97
neuston	fall	2002	116	98
neuston	fall	2003	121	236
neuston	fall	2004	118	149
neuston	fall	2005	53	1
neuston	fall	2006	117	211
neuston	fall	2007	166	156
neuston	fall	2008	120	7
neuston	fall	2009	144	143
neuston	fall	2010	197	55
neuston	fall	2011	149	65
neuston	fall	2012	189	88
neuston	fall	2013	125	9
neuston	fall	2014	121	67
neuston	fall	2015	24	0
neuston	spring	1982	128	16
neuston	spring	1983	107	5
neuston	spring	1984	93	15
neuston	spring	1986	74	24
neuston	spring	1987	88	1
neuston	spring	1988	149	1
neuston	spring	1989	180	37
neuston	spring	1990	301	20
neuston	spring	1991	173	6
neuston	spring	1992	203	3
neuston	spring	1993	214	44
neuston	spring	1994	184	42
neuston	spring	1995	280	51

gear	*season*	*year*	*stations*	*specimens*
neuston	spring	1996	172	19
neuston	spring	1997	185	8
neuston	spring	1998	318	11
neuston	spring	1999	350	17
neuston	spring	2000	170	12
neuston	spring	2001	167	21
neuston	spring	2002	157	21
neuston	spring	2003	89	4
neuston	spring	2004	89	3
neuston	spring	2005	189	22
neuston	spring	2006	150	28
neuston	spring	2007	115	30
neuston	spring	2008	159	115
neuston	spring	2009	84	13
neuston	spring	2010	81	47
neuston	spring	2011	92	46
neuston	spring	2012	90	9
neuston	spring	2013	115	2
neuston	spring	2014	77	4
neuston	spring	2015	110	18
neuston	summer	1982	102	87
neuston	summer	1983	61	7
neuston	summer	1984	117	64
neuston	summer	1985	86	369
neuston	summer	1986	46	7
neuston	summer	1987	31	17
neuston	summer	1988	49	202
neuston	summer	1989	18	11
neuston	summer	1990	29	2
neuston	summer	1991	58	29
neuston	summer	1992	44	97
neuston	summer	1993	30	10
neuston	summer	1994	39	81
neuston	summer	1995	26	3
neuston	summer	1996	30	49
neuston	summer	1997	46	61
neuston	summer	1998	9	10

gear	*season*	*year*	*stations*	*specimens*
neuston	summer	1999	37	21
neuston	summer	2000	42	13
neuston	summer	2001	20	99
neuston	summer	2002	49	49
neuston	summer	2003	36	53
neuston	summer	2004	49	29
neuston	summer	2005	28	11
neuston	summer	2006	41	10
neuston	summer	2007	51	106
neuston	summer	2008	38	48
neuston	summer	2009	80	88
neuston	summer	2010	61	141
neuston	summer	2011	73	498
neuston	summer	2012	104	98
neuston	summer	2013	126	99
neuston	summer	2014	100	49
neuston	summer	2015	93	0

Appendix Table 3. Nominal catch and occurrence rates of DOL. Catch rate for neuston is the mean raw number of larvae per 10-min tow.

gear	*season*	*year*	*occurrence*	*catch*
neuston	fall	1982	0.10000	0.40000
neuston	fall	1983	0.23529	0.29412
neuston	fall	1985	0.00000	0.00000
neuston	fall	1986	0.21528	0.62500
neuston	fall	1987	0.03419	0.03419
neuston	fall	1988	0.09722	0.11111
neuston	fall	1989	0.06349	0.10317
neuston	fall	1990	0.06723	0.08403
neuston	fall	1991	0.14019	0.39252
neuston	fall	1992	0.22772	0.53465
neuston	fall	1993	0.10687	0.14504
neuston	fall	1994	0.18487	0.40336
neuston	fall	1995	0.03419	0.04274
neuston	fall	1996	0.15789	0.33083
neuston	fall	1997	0.12500	0.38333
neuston	fall	1998	0.05435	0.10870
neuston	fall	1999	0.11486	0.20946
neuston	fall	2000	0.16547	0.28058
neuston	fall	2001	0.00000	0.00000
neuston	fall	2002	0.17241	0.39655
neuston	fall	2003	0.13223	0.30165
neuston	fall	2004	0.15254	0.27119
neuston	fall	2005	0.20755	0.30189
neuston	fall	2006	0.12821	0.23077
neuston	fall	2007	0.06051	0.11146
neuston	fall	2008	0.14167	0.33333
neuston	fall	2009	0.07639	0.11806
neuston	fall	2010	0.18782	0.53807
neuston	fall	2011	0.10135	0.26351
neuston	fall	2012	0.13228	0.21693
neuston	fall	2013	0.24800	0.85600
neuston	fall	2014	0.05785	0.06612
neuston	fall	2015	0.00000	0.00000
neuston	spring	1982	0.32258	0.64919
neuston	spring	1983	0.15888	0.24299
neuston	spring	1984	0.06452	0.07527

gear	*season*	*year*	*occurrence*	*catch*
neuston	spring	1986	0.28378	0.72973
neuston	spring	1987	0.00000	0.00000
neuston	spring	1988	0.00671	0.00671
neuston	spring	1989	0.29213	0.63483
neuston	spring	1990	0.25914	0.65449
neuston	spring	1991	0.21965	0.38728
neuston	spring	1992	0.14815	0.20988
neuston	spring	1993	0.30986	0.62128
neuston	spring	1994	0.22517	0.50000
neuston	spring	1995	0.27061	0.70430
neuston	spring	1996	0.22024	0.71429
neuston	spring	1997	0.34595	0.94595
neuston	spring	1998	0.17262	0.40476
neuston	spring	1999	0.20000	0.68571
neuston	spring	2000	0.22941	0.40588
neuston	spring	2001	0.01198	0.01198
neuston	spring	2002	0.08280	0.10191
neuston	spring	2003	0.31461	1.08989
neuston	spring	2004	0.26966	0.58427
neuston	spring	2005	0.31746	0.83598
neuston	spring	2006	0.37333	0.99333
neuston	spring	2007	0.37391	0.82609
neuston	spring	2008	0.25157	0.51572
neuston	spring	2009	0.40476	1.11905
neuston	spring	2010	0.08642	0.11111
neuston	spring	2011	0.38889	0.94444
neuston	spring	2012	0.25556	0.60000
neuston	spring	2013	0.40870	0.86087
neuston	spring	2014	0.22078	0.38961
neuston	spring	2015	0.46364	1.46364
neuston	summer	1982	0.14706	0.41176
neuston	summer	1983	0.06557	0.09836
neuston	summer	1984	0.11111	0.23932
neuston	summer	1985	0.12791	0.43023
neuston	summer	1986	0.04348	0.06522
neuston	summer	1987	0.09677	0.12903
neuston	summer	1988	0.12245	0.16327

gear	*season*	*year*	*occurrence*	*catch*
neuston	summer	1989	0.11111	0.55556
neuston	summer	1990	0.03448	0.34483
neuston	summer	1991	0.06897	0.10345
neuston	summer	1992	0.09091	0.13636
neuston	summer	1993	0.10000	0.23333
neuston	summer	1994	0.23077	0.30769
neuston	summer	1995	0.00000	0.00000
neuston	summer	1996	0.10000	0.23333
neuston	summer	1997	0.34783	1.00000
neuston	summer	1998	0.11111	0.11111
neuston	summer	1999	0.29730	0.81081
neuston	summer	2000	0.14286	1.00000
neuston	summer	2001	0.00000	0.00000
neuston	summer	2002	0.22449	0.38776
neuston	summer	2003	0.11111	0.36111
neuston	summer	2004	0.22449	0.53061
neuston	summer	2005	0.07143	0.53571
neuston	summer	2006	0.21951	0.56098
neuston	summer	2007	0.22000	0.58000
neuston	summer	2008	0.28947	0.73684
neuston	summer	2009	0.20000	0.48750
neuston	summer	2010	0.04918	0.11475
neuston	summer	2011	0.19178	0.45205
neuston	summer	2012	0.25962	0.57692
neuston	summer	2013	0.26984	0.76190
neuston	summer	2014	0.20000	0.38000
neuston	summer	2015	0.03226	0.05376

Appendix Table 2. Numbers of sampling stations and numbers of specimens of LTA for each gear, season, year.

season	*year*	*stations*	*specimens*
fall	1982	20	8
fall	1983	17	5
fall	1985	2	0
fall	1986	144	90
fall	1987	117	4
fall	1988	72	8
fall	1989	126	13
fall	1990	119	10
fall	1991	107	42
fall	1992	101	54
fall	1993	131	19
fall	1994	119	48
fall	1995	117	5
fall	1996	133	44
fall	1997	120	46
fall	1998	62	8
fall	1999	148	31
fall	2000	139	39
fall	2001	154	0
fall	2002	116	46
fall	2003	122	43
fall	2004	118	32
fall	2005	53	16
fall	2006	117	27
fall	2007	166	21
fall	2008	120	40
fall	2009	144	17
fall	2010	197	106
fall	2011	149	39
fall	2012	189	41
fall	2013	125	107
fall	2014	121	8
fall	2015	24	0
spring	1982	128	83
spring	1983	107	26
spring	1984	93	7
spring	1986	74	54
spring	1987	88	0

season	*year*	*stations*	*specimens*
spring	1988	149	1
spring	1989	180	114
spring	1990	301	197
spring	1991	173	67
spring	1992	203	42
spring	1993	216	135
spring	1994	184	97
spring	1995	280	197
spring	1996	172	120
spring	1997	185	175
spring	1998	318	105
spring	1999	350	240
spring	2000	170	69
spring	2001	167	2
spring	2002	157	16
spring	2003	89	97
spring	2004	89	52
spring	2005	189	158
spring	2006	150	149
spring	2007	115	95
spring	2008	159	82
spring	2009	84	94
spring	2010	81	9
spring	2011	92	97
spring	2012	90	54
spring	2013	115	99
spring	2014	77	30
spring	2015	110	161
summer	1982	102	42
summer	1983	61	6
summer	1984	117	28
summer	1985	86	37
summer	1986	46	3
summer	1987	31	4
summer	1988	49	8
summer	1989	18	10
summer	1990	29	10
summer	1991	58	6

season	*year*	*stations*	*specimens*
summer	1992	44	6
summer	1993	30	7
summer	1994	39	12
summer	1995	26	0
summer	1996	30	7
summer	1997	46	46
summer	1998	9	1
summer	1999	37	30
summer	2000	42	42
summer	2001	20	0
summer	2002	49	19
summer	2003	36	13
summer	2004	49	26
summer	2005	28	15
summer	2006	41	23
summer	2007	50	29
summer	2008	38	28
summer	2009	80	39
summer	2010	61	7
summer	2011	73	33
summer	2012	104	60
summer	2013	126	96
summer	2014	100	38
summer	2015	93	5