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ANNUAL INDICES OF SWORDFISH (*XIPHIUS GLADIUS*) SPAWNING BIOMASS IN THE GULF OF MEXICO (1982-2015)

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SUMMARY

Fishery independent indices of spawning biomass of swordfish in the Gulf of Mexico are presented utilizing NOAA Fisheries ichthyoplankton survey data collected from 1982 through 2015 in the Gulf of Mexico. Indices were developed using the occurrence of larvae sampled with neuston gear using a zero-inflated binomial model, including the following covariates: time of day, month, area sampled, year, gear and habitat score. The habitat score was based on the presence/absence of other ichthyoplankton taxa and temperature and salinity at the sampling station.

RÉSUMÉ

Des indices, indépendants des pêcheries, de la biomasse reproductrice de l'espadon 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 ont été élaborés en utilisant la survenance des larves échantillonnées au moyen de filets à neuston en utilisant un modèle binomial à inflation de zéros, incluant les covariables suivantes : moment de la journée, mois, zone échantillonnée, année, engin et ponctuation de l'habitat. La ponctuation de l'habitat reposait sur la présence/l'absence d'autres taxons d'ichthyoplancton ainsi que la température et la salinité de la station d'échantillonnage.

RESUMEN

Se presentan los índices independientes de la pesquería de la biomasa reproductora del pez espada 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 se desarrollaron utilizando la presencia de larvas muestreadas con un arte de redes neuston utilizando un modelo binomial de ceros aumentados, incluyendo las siguientes covariables: hora del día, mes, zona muestreada, año, arte y puntuación del hábitat. La puntuación del hábitat se basó en la presencia/ausencia de otros taxones de ictioplancton y en la temperatura y salinidad en la estación de muestreo.

KEYWORDS

Mathematical models, fish larvae

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1. Introduction and methodology

The objective of this paper is to present annual indices of neuston-collected swordfish larvae. These indices are based upon the occurrence of swordfish larvae collected 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, methodologies concerning the use of this survey data to assess other ICCAT species were described or reviewed (Richards 1990; Murphy 1990, Ingram et al. 2010, Ingram 2015).

Govoni *et al*. (2003) report that in the western North Atlantic swordfish spawn year-round. However, spawning peaks in the spring in the north-central and western Gulf of Mexico, in the summer off southern Florida, and in the spring and early summer in the Atlantic off the southeastern United States. The western Gulf Stream frontal zone is the focus of spawning off the southeastern Atlantic coast of the United States, while spawning in the Gulf of Mexico seems to be focused in the east and central areas near the Gulf Loop Current. Govoni *et al*. (2003) propose that larvae may use the Gulf of Mexico and the outer continental shelf off the east coast of the United States as nursery areas. While recent annual surveys off the southeastern Atlantic coast of the United States are lacking, they were conducted from 1973-1985; and this dataset, if obtained, may be the focus of future studies. However, for this study we use data from the SEAMAP Spring Ichthyoplankton Survey, which is conducted annually in the U.S. Gulf of Mexico, to index swordfish spawning biomass.

The evolution of the use of this time series of ichthyoplankton data for other species, such as Atlantic bluefin tuna and skipjack tuna, is detailed in numerous documents (i.e. Ingram *et al*. 2010, Ingram 2015), and the current methodologies, concerning the development of indices based on zero-inflated binomial models (ZIBs), are detailed by Ingram *et al*. (2006, 2008) and Ingram *et al*. (2010).

Ichthyoplankton surveys were conducted from numerous NOAA vessels during mid to late April through May 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. 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. Identifications and measurements of larvae were obtained by the Polish Plankton Sorting and Identification Center in Szczecin, Poland.

Initially, the zero-inflated delta-lognormal model was initially going to be employed in developing the index. However, with, on average, a single individual collected when encountered (detailed below), the ZIB model would be most appropriate.

The ZIB model treats the probability of observing a swordfish larva as a product of the true probability of the site being occupied (o), and the probability of detection (d) when in fact the site is occupied at the time the sample is taken (Tyre *et al*. 2003; Steventon *et al*. 2005; Ingram *et al*. 2010). Multiple samples must be taken at each site in order to estimate d, but the number of samples per site (m) does not have to be equal (Tyre *et al*. 2003). The number of observations of an animal for each site over m samples is denoted as x, and the number of sites sampled as n (Steventon *et al*. 2005).

In the case of this study, a year was treated as a site, since the goal was to develop annual indices of abundance. Therefore, when considering one year after m samples have been taken (i.e., m neuston stations completed), the probability of observing zero swordfish larvae was:

$$(1) \qquad P(x=0) = o(1-d)^m + (1-o)(1)$$

and the probability of observing exactly x swordfish larvae, where x is greater than zero was:

$$(2) \qquad P(x>0) = o\binom{m}{x} d^x (1-d)^{m-x} + (1-o)(0)$$

after Tyre *et al.* (2003), Steventon *et al.* (2005), and Ingram *et al.* (2010). These two probabilities were then combined to form the likelihood function for a single year *y*:

$$(3) \qquad L(o,d \mid x,m) = \begin{cases} o(1-d)^{m} + (1-o), x = 0 \\ o\begin{pmatrix} m \\ x \end{pmatrix} d^{x}(1-d)^{m-x}, x > 0 \end{cases}$$

following the methods of Tyre *et al.* (2003) and Ingram *et al.* (2010).

Steventon *et al.* (2005) expressed the above probability in equation (12) as a generalized Bernoulli distribution, allowing the combination of multiple years into a full likelihood:

$$(4) \qquad L(o,d \mid \{x_y, m_y, u_y\}) = \prod_{y=1}^{n} \left[o(1-d)^{m_y} + (1-o)\right]^{u_y} \times \left[o\begin{pmatrix} m_y \\ x_y \end{pmatrix} d^{x_y}(1-d)^{m_y - y_y}\right]^{1-u_y}$$

where u_y is an indicator variable: $u_y = 1$ when $x_y = 0$ and $u_y = 0$ when $x_y > 0$. The values of *o* and *d* are not required to be constant, and are usually not over time. These values can be influenced by covariates as follows:

$$(5) \qquad \mathbf{o} = \frac{e^{\mathbf{X\beta+\varepsilon}}}{1+e^{\mathbf{X\beta+\varepsilon}}}$$

and

$$(6) \qquad \mathbf{d} = \frac{e^{\mathbf{X\beta+\varepsilon}}}{1+e^{\mathbf{X\beta+\varepsilon}}},$$

where o and d are vectors of probability of occupancy and probability of detection, respectively, 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. Certain covariates may be common between both the above models, while others may be completely different (Steventon *et al.* 2005).

Therefore, in the case of this study, the estimated probability of collecting a swordfish larva during a single ichthyoplankton station was

$$(7) \qquad p_{Z1,y} = o \times d$$

and the probability of collecting at least one swordfish larva after *m* ichthyoplankton stations was

$$(8) \qquad p_{Z,y} = o\left[1-(1-d)^{m}\right],$$

following the methods of Steventon *et al.* (2005) and Ingram *et al.* (2010).

The NLMIXED procedure in SAS (v. 9.4, 2012) was used to develop the ZIB model. The covariates considered were: time of day (two categories: night, 6:00 PM to 6:00 AM, local time; day, 6:00 AM to 6:00 PM, local time), survey date category (four categories: late April, April 20 to April 30; early May, May 1 to May 10; middle May, May 11 to May 20; late May, May 21 to May 31), survey area [original survey area as defined by Scott et al. (1993) divided into three categories plus a category for the far west U.S. Gulf of Mexico: 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)], habitat quality category, gear type (single or double 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.

The habitat quality category, mentioned above, was computed by comparing the occurrence of swordfish larvae with that of 136 other ichthyoplankton taxa and surface temperature and salinity. The 136 taxa were those that occurred in more than 1 % of the stations of the time series. The habitat quality category was derived from the habitat score, which was derived from swordfish larval occurrence at a station, logistically modeled against the occurrence of each of the 136 ichthyoplankton taxa and surface temperature and salinity as continuous variables, which were scaled to a mean of one over the time series. Once modeled, each parameter estimate was multiplied by one minus the *p*-value of that parameter (to weight the value of the parameter estimate on its statistical significance), and then the exponent of this result was taken; and likewise for the parameter estimates of scaled surface salinity and temperature. This resulted in taxon-specific “prescores.” These prescores were then placed in an array that was used to evaluate each station in the dataset, and if certain taxon was present at a station, then the associated prescore was multiplied by one. Else, it was multiplied by zero. Likewise, the scaled surface salinity and temperature values were multiplied by their corresponding prescores. These prescore values were then summed for each station, producing the habitat score for that station. Those parameter estimates which were positive and statistically significant resulted in an increase in the habitat score, while those that were negative and highly significant resulted in a decrease in the habitat score. Once habitat scores were calculated for all stations, the quartiles were calculated and used to categorize the habitat score into the habitat quality category (four categories: poor, fair, good, and best).

Initial SAS code for the NLMIXED procedure was provided by Steventon *et al.* (2005). This code was modified in order to use dummy variables, which were needed to include categorical variables in the model. Variables that were deemed to affect both occurrence and detection of larvae were split between occurrence and detection submodels (see Equations 5 and 6) contained in the ZIB model. Model performance was evaluated using AUC (Area Under Curve) methodology presented by Steventon *et al.* (2005) and residual analyses.

2. Results and Discussion

Table 1 summarizes the number of neuston tows used in these analyses. Also, charts showing neuston effort and number of specimens collected per station for each year in the time series are provided in the **Appendix**. For most survey years, data can be used from late April through the entire month of May. However, there were several years where surveys were started late or ended early due to mechanical, meteorological and/or other logistical factors. For neuston tows, the number of stations sampled during the April 15 through May 31 time period ranged from 59 to 198. The number of specimens collected in neuston tows per year ranged from 0 to 19, and ranged in length from 2.7 to 108.1 mm. **Figure 1** presents the frequency distribution of raw catch numbers, indicating that the majority of occurrences are of a single specimen per tow.

The variables that were used in the model-building process of the ZIB for neuston-collected larvae were: gear type, time of day, survey date category, survey area, habitat category, and year. **Figures 2-8** present the distribution of these variables as compared with larval occurrence. **Figure 9** presents the taxa most significantly associated with the occurrence of swordfish larvae; this information was used in the development of the habitat variable. Also, the **Appendix** provides a summary of habitat (association) scores for all 136 ichthyoplankton taxa. All variables except time of day and gear type were used in the occupancy submodel, while these were used in the detection submodel for the ZIB submodel. The time of day variable was used in the detection submodel as was reasoned that time of day (i.e. day or night) has an effect on the probability of detecting larvae (net avoidance). Likewise, the gear type variable was used, since fishing a single versus a double neuston may have an effect on the probability of detecting larvae, even though only one side (right side) of the gear was sorted. **Table 2** summarizes the parameters used in the ZIB model and their significance. The ZIB submodel had an AUC = 0.726. The AUC statistic provides information on the model’s lack-of-fit, and in this case it means that in 73 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. **Figure 10** provides residual plots by the variables used in the modeling process, and the QQplot of the residuals (**Figure 10e**), which indicates the approximately normal distribution of the residuals of the ZIB submodel.

Table 3 and **Figure 11** summarizes indices of larval swordfish (occurrence per 10-min neuston tow) developed from the ZIB model. Index values were variable throughout the time series. However, when compared to indices developed from the U.S. Pelagic longline fishery (Lauretta *et al.* 2014), some similarities in trends can be observed (**Figure 12**). The highest index value occurred in 1982, while in 1987 and 1988 zero larvae were observed. For most years, differences between nominal and standardized indices are small. Those years with the greatest differences include 1984, 2001, and the terminal year 2015.

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Table 1. Summary of neuston data used in these analyses. Gear "3" is a single neuston, while gear "8" is a double neuston.

Survey Year	*Gear*	*Number of Stations Sampled*	*Start Date*	*End Date*
1982	3	126	4/15/1982	5/25/1982
1983	3	100	4/22/1983	5/23/1983
1984	3	87	4/21/1984	5/16/1984
1986	3	69	4/22/1986	5/21/1986
1987	3	73	4/18/1987	5/20/1987
1988	3	138	4/20/1988	5/26/1988
1989	3, 8	98, 26	4/26/1989	5/19/1989
1990	8	145	4/21/1990	5/31/1990
1991	8	145	4/17/1991	5/22/1991
1992	8	137	4/22/1992	5/23/1992
1993	8	142	4/26/1993	5/31/1993
1994	8	149	4/28/1994	5/31/1994
1995	8	198	4/19/1995	5/31/1995
1996	8	162	4/17/1996	5/24/1996
1997	8	158	4/17/1997	5/31/1997
1998	8	140	4/19/1998	5/30/1998
1999	8	170	4/23/1999	5/30/1999
2000	8	166	4/20/2000	5/26/2000
2001	8	168	4/19/2001	5/29/2001
2002	8	150	4/19/2002	5/28/2002
2003	3	89	5/13/2003	5/30/2003
2004	3	88	5/5/2004	5/30/2004
2005	3	176	4/21/2005	5/29/2005
2006	3	153	4/23/2006	5/29/2006
2007	3	116	4/17/2007	5/28/2007
2008	3	148	4/20/2008	5/30/2008
2009	3	71	5/14/2009	5/31/2009
2010	3	80	4/27/2010	5/22/2010
2011	3	88	5/3/2011	5/27/2011
2012	3	76	4/30/2012	5/24/2012
2013	3	91	5/1/2013	5/29/2013
2014	3	59	5/4/2014	5/30/2014
2015	3	90	4/15/2015	5/30/2015

Table 2. Parameters of the zero-inflated binomial model for neuston tows. The prefix *a* denotes those parameters in the occupancy submodel, while the prefix *b* denotes those parameters in the detection submodel.

Parameter	*Estimate*	*Standard Error*	*Pr > |t|*
a0_est	-3.2045	0.5453	<.0001
amontha_est	-0.7457	0.2265	0.0010
amonthe_est	-0.4785	0.2387	0.0450
amonthm_est	-0.3785	0.2070	0.0676
aareae_est	1.4060	0.4002	0.0004
aareac_est	0.9347	0.3818	0.0144
aareaw_est	-0.08822	0.4276	0.8366
ahabp_est	-1.7350	0.2973	<.0001
ahabf_est	-0.7439	0.2004	0.0002
ahabg_est	-0.1252	0.1658	0.4503
a1982_est	1.3499	0.4916	0.0061
a1983_est	-0.03536	0.6514	0.9567
a1984_est	-0.08373	0.8290	0.9196
a1986_est	-0.2209	0.8279	0.7897
a1989_est	0.6101	0.5332	0.2526
a1990_est	-0.1252	0.5826	0.8298
a1991_est	0.9567	0.5013	0.0564
a1992_est	-0.2571	0.6515	0.6932
a1993_est	-0.5474	0.6505	0.4001
a1994_est	-0.1137	0.5613	0.8394
a1995_est	0.07046	0.5189	0.8920
a1996_est	0.1012	0.5599	0.8565
a1997_est	0.6913	0.5227	0.1860
a1998_est	0.1899	0.5611	0.7350
a1999_est	0.9161	0.4711	0.0519
a2000_est	0.7092	0.4963	0.1530
a2001_est	0.7058	0.5258	0.1796
a2002_est	-0.5945	0.7116	0.4035
a2003_est	0.3349	0.5531	0.5448
a2004_est	-0.1622	0.6549	0.8044
a2005_est	0.2664	0.5286	0.6144
a2006_est	0.4299	0.5092	0.3985
a2007_est	0.6990	0.5146	0.1745
a2008_est	0.3736	0.5213	0.4736
a2009_est	-1.4406	1.0915	0.1870
a2010_est	-0.7404	1.0850	0.4950
a2011_est	-0.4537	0.7151	0.5258
a2012_est	0.7983	0.5735	0.1640
a2013_est	0.06931	0.6141	0.9101
a2014_est	0.08061	0.7206	0.9109
b0_est	-2.5608	0.04603	<.0001
btime_est	-0.09343	0.04872	0.0552
bgear03_est	0.1125	0.04502	0.0125

Table 3. Indices (with 95% confidence limits) and nominal frequency of occurrence of larval swordfish (occurrence per 10-min neuston tow) developed from the zero-inflated binomial model with the total number of samples included in analyses per year.

Survey Year	*Sample Size*	*Nominal Index*	*ZIB Index*	*CV*	*LCL*	*UCL*
1982	126	0.11905	0.15211	0.27686	0.088328	0.26194
1983	100	0.04000	0.04074	0.51962	0.015324	0.10831
1984	87	0.02299	0.03886	0.71198	0.010797	0.13987
1986	69	0.02899	0.03398	0.72349	0.009282	0.12438
1987	73	0.00000				
1988	138	0.00000				
1989	124	0.07258	0.07607	0.35702	0.038050	0.15207
1990	145	0.04138	0.03731	0.43121	0.016337	0.08522
1991	145	0.08966	0.10566	0.30392	0.058312	0.19147
1992	137	0.02920	0.03279	0.51272	0.012478	0.08618
1993	142	0.02817	0.02465	0.52204	0.009234	0.06579
1994	149	0.04698	0.03774	0.40484	0.017314	0.08225
1995	198	0.05051	0.04517	0.34360	0.023157	0.08811
1996	162	0.04321	0.04654	0.39698	0.021657	0.10003
1997	158	0.06329	0.08220	0.33296	0.042975	0.15721
1998	140	0.05000	0.05073	0.39973	0.023490	0.10958
1999	170	0.11176	0.10171	0.25889	0.061111	0.16927
2000	166	0.07831	0.08361	0.30289	0.046233	0.15122
2001	168	0.05357	0.08334	0.34238	0.042822	0.16220
2002	150	0.02000	0.02353	0.59818	0.007784	0.07112
2003	89	0.08989	0.05838	0.39161	0.027429	0.12428
2004	88	0.04545	0.03599	0.52339	0.013451	0.09628
2005	176	0.05114	0.05464	0.35220	0.027572	0.10827
2006	153	0.07190	0.06399	0.32604	0.033886	0.12083
2007	116	0.09483	0.08280	0.33210	0.043361	0.15812
2008	148	0.06757	0.06061	0.34339	0.031084	0.11817
2009	71	0.01408	0.01017	1.01938	0.001881	0.05504
2010	80	0.01250	0.02037	1.00408	0.003835	0.10822
2011	88	0.03409	0.02703	0.59757	0.008951	0.08162
2012	76	0.09211	0.09100	0.40138	0.042008	0.19712
2013	91	0.05495	0.04512	0.46813	0.018523	0.10990
2014	59	0.05085	0.04562	0.59587	0.015148	0.13738
2015	90	0.07778	0.04217	0.39044	0.019854	0.08958

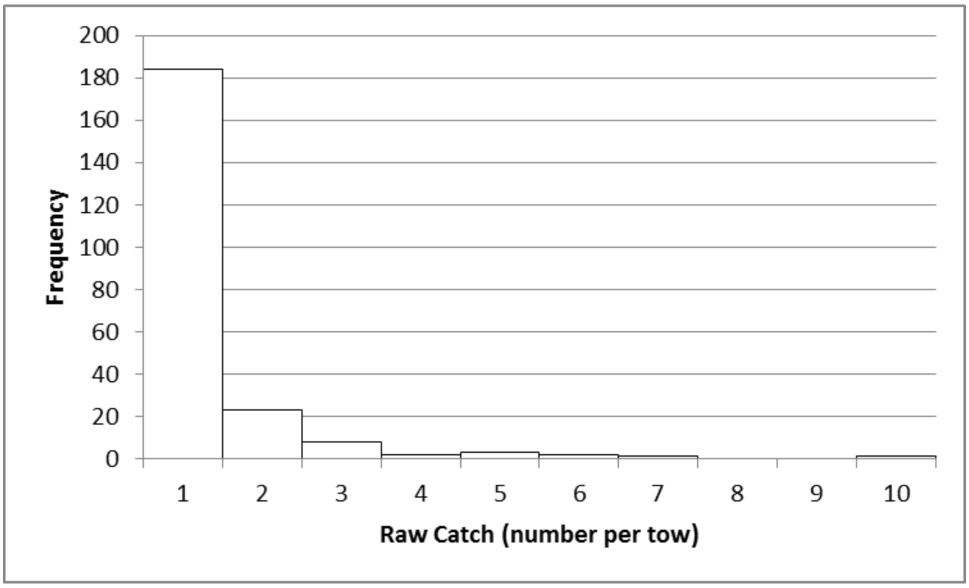


Figure 1. The frequency distribution of raw catch numbers, indicating that the majority of occurrences are of single specimens per tow.

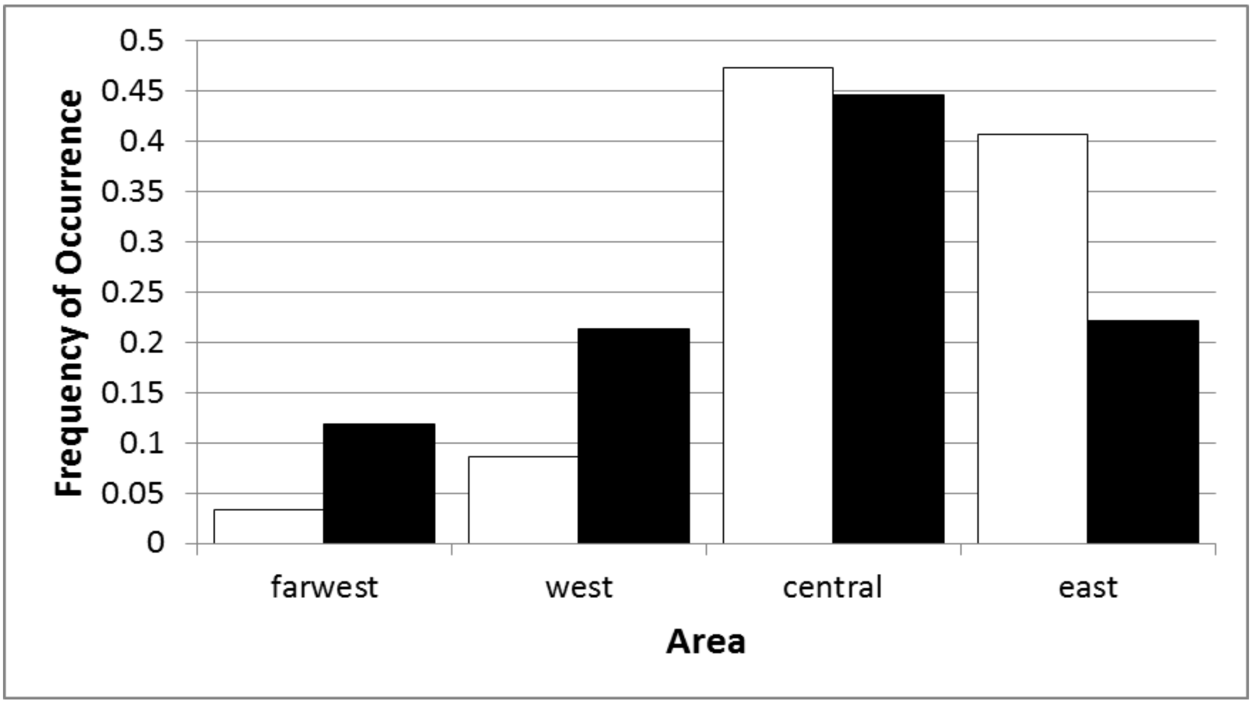


Figure 2. The frequency distribution of samples (black) and larval occurrence (white) by area category.

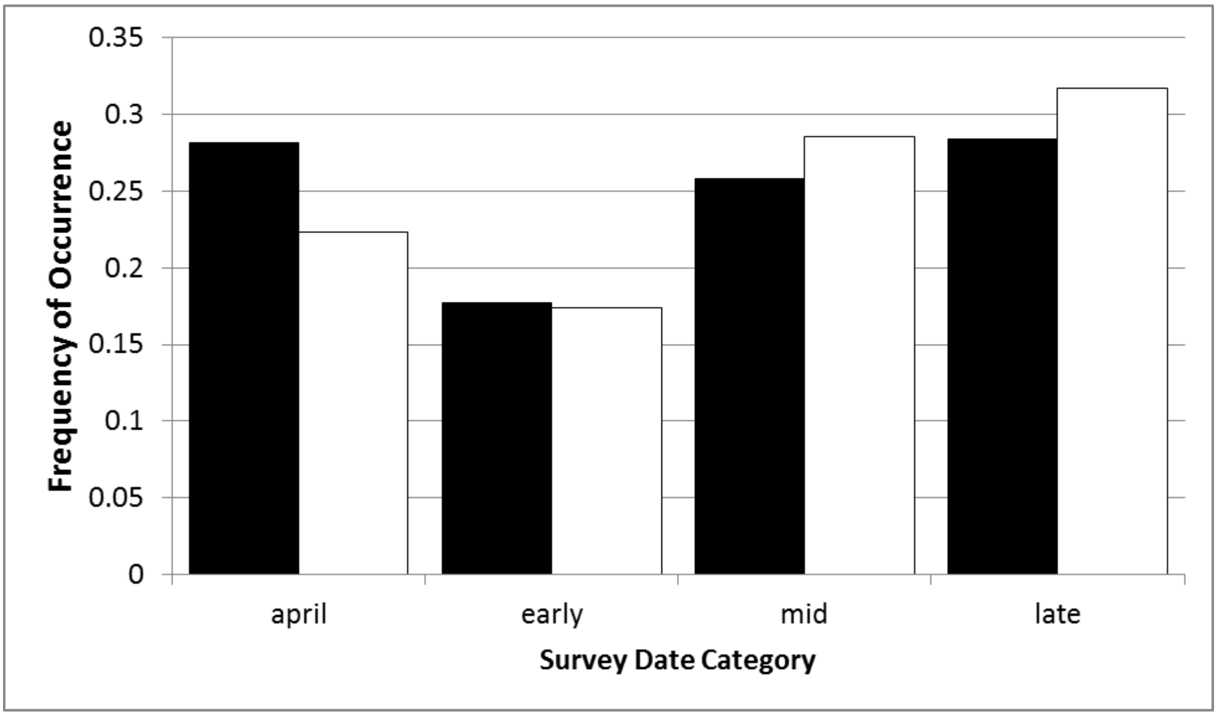


Figure 3. The frequency distribution of samples (black) and larval occurrence (white) by survey data category.

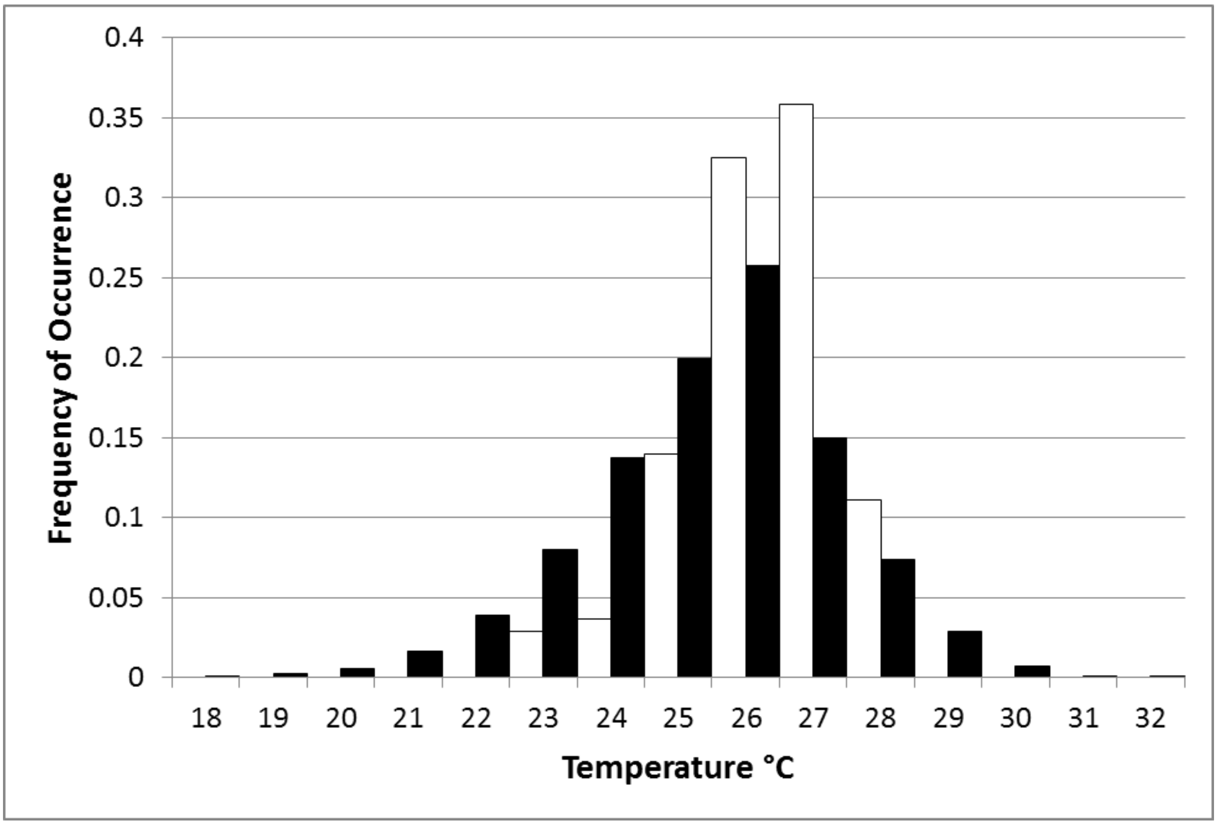


Figure 4. The frequency distribution of samples (black) and larval occurrence (white) by surface temperature.

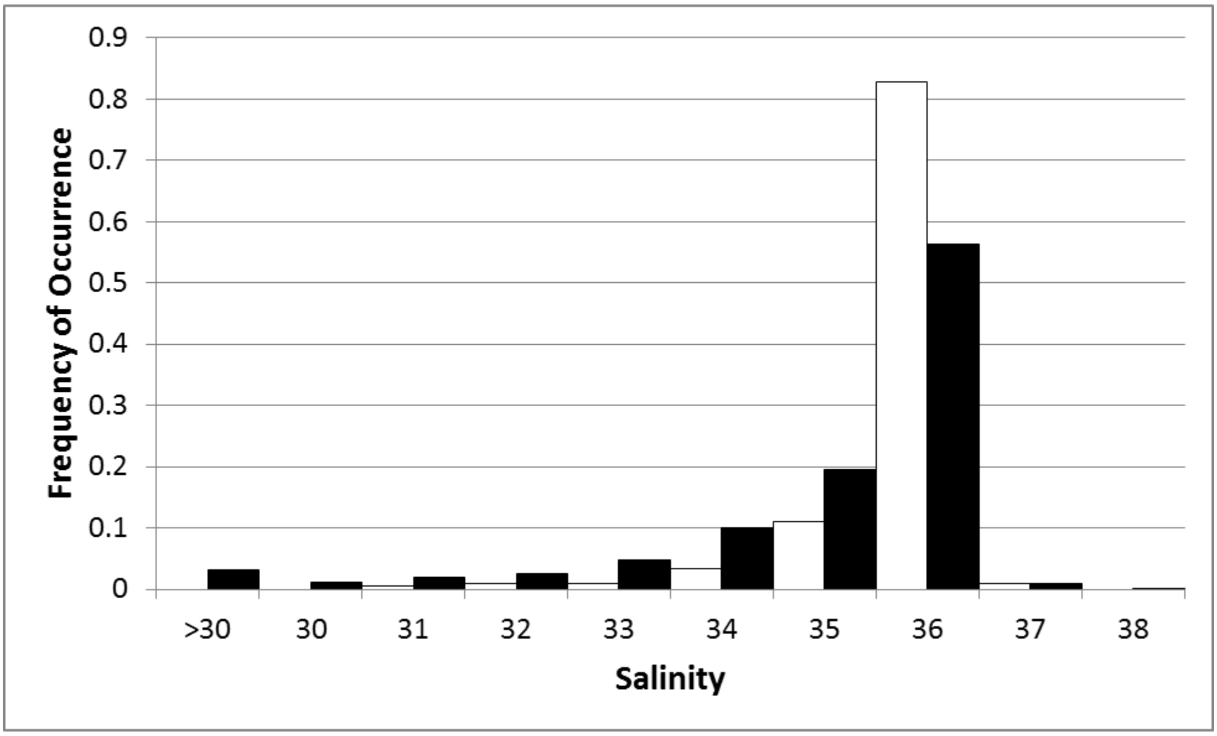


Figure 5. The frequency distribution of samples (black) and larval occurrence (white) by surface salinity.

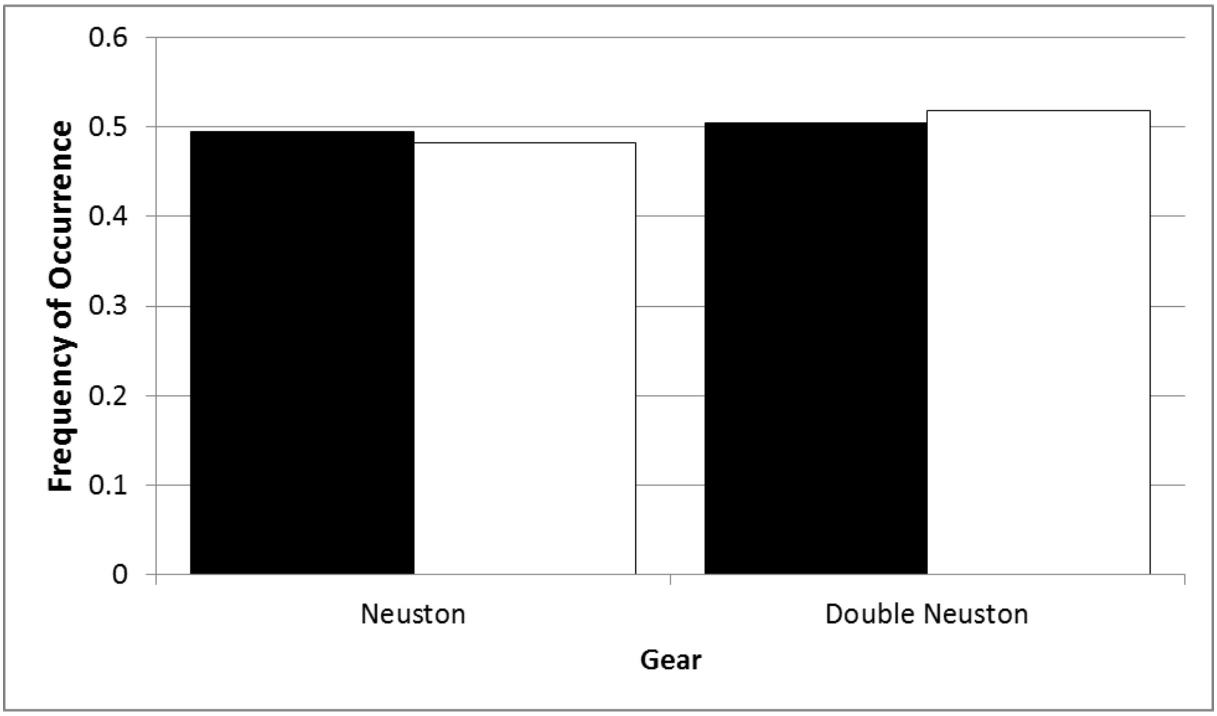


Figure 6. The frequency distribution of samples (black) and larval occurrence (white) by gear.

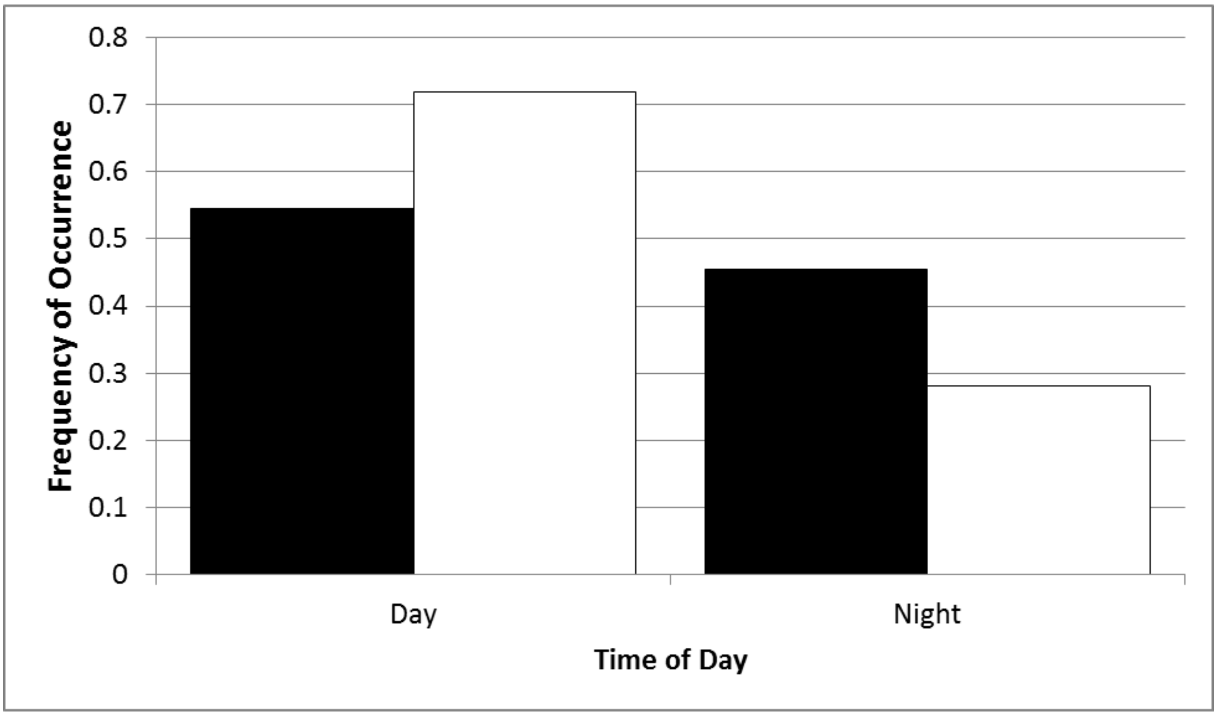


Figure 7. The frequency distribution of samples (black) and larval occurrence (white) by time of day.

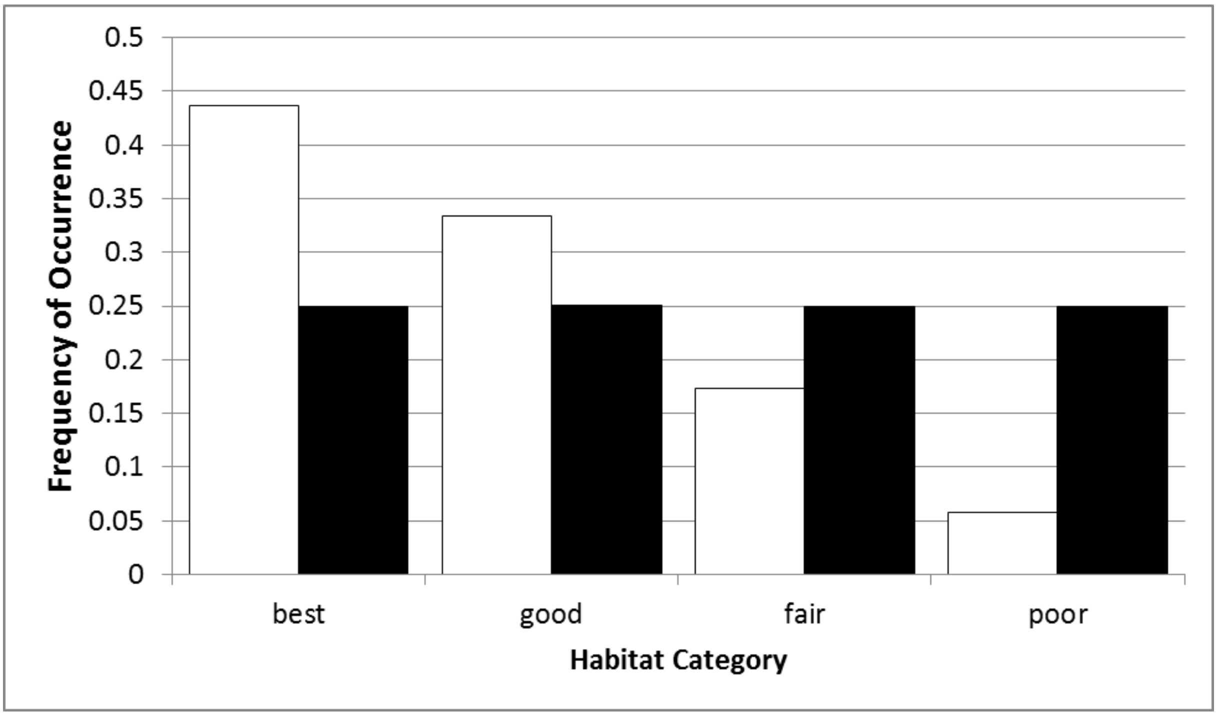


Figure 8. The frequency distribution of samples (black) and larval occurrence (white) by habitat category.

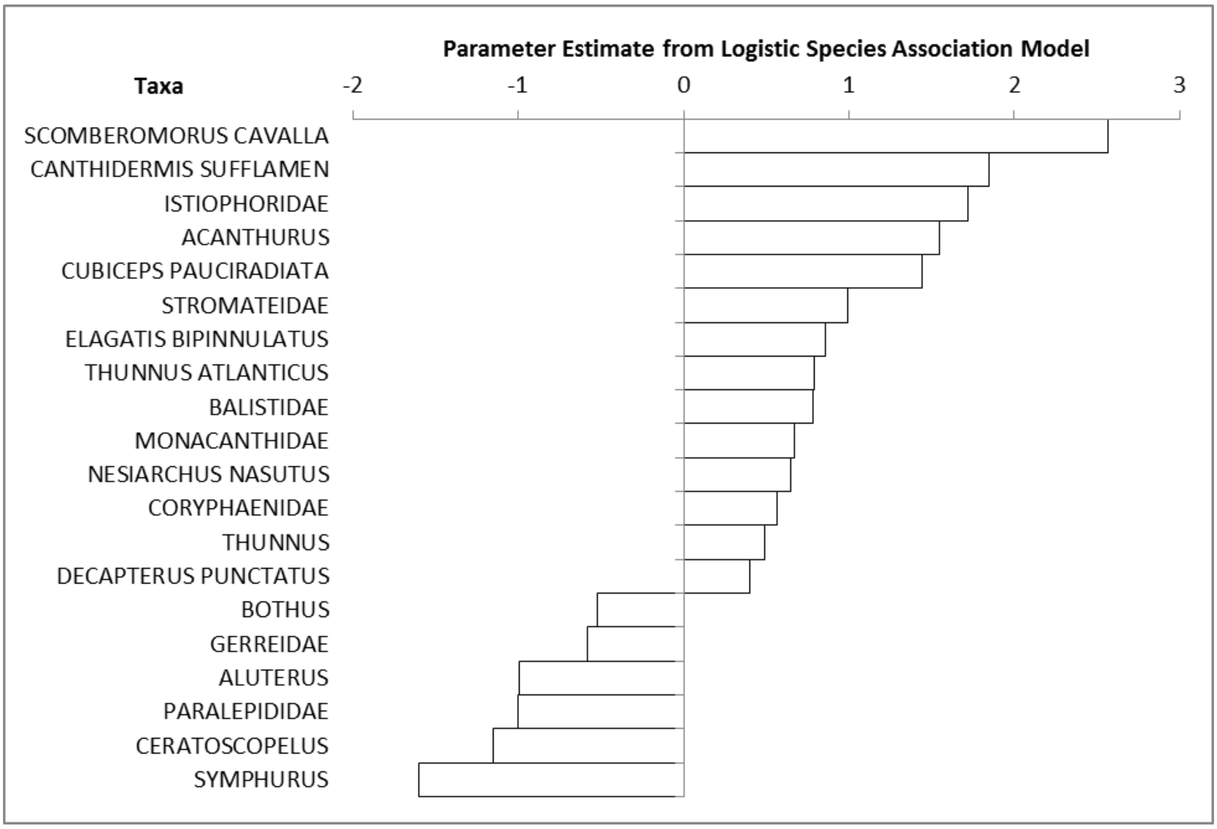


Figure 9. The taxa most significantly associated with the occurrence of swordfish larvae. From the logistic model of the relationship of the occurrence of swordfish larvae with the occurrence of the 136 taxa, only parameter estimates with a *p*-value < 0.1 are presented.

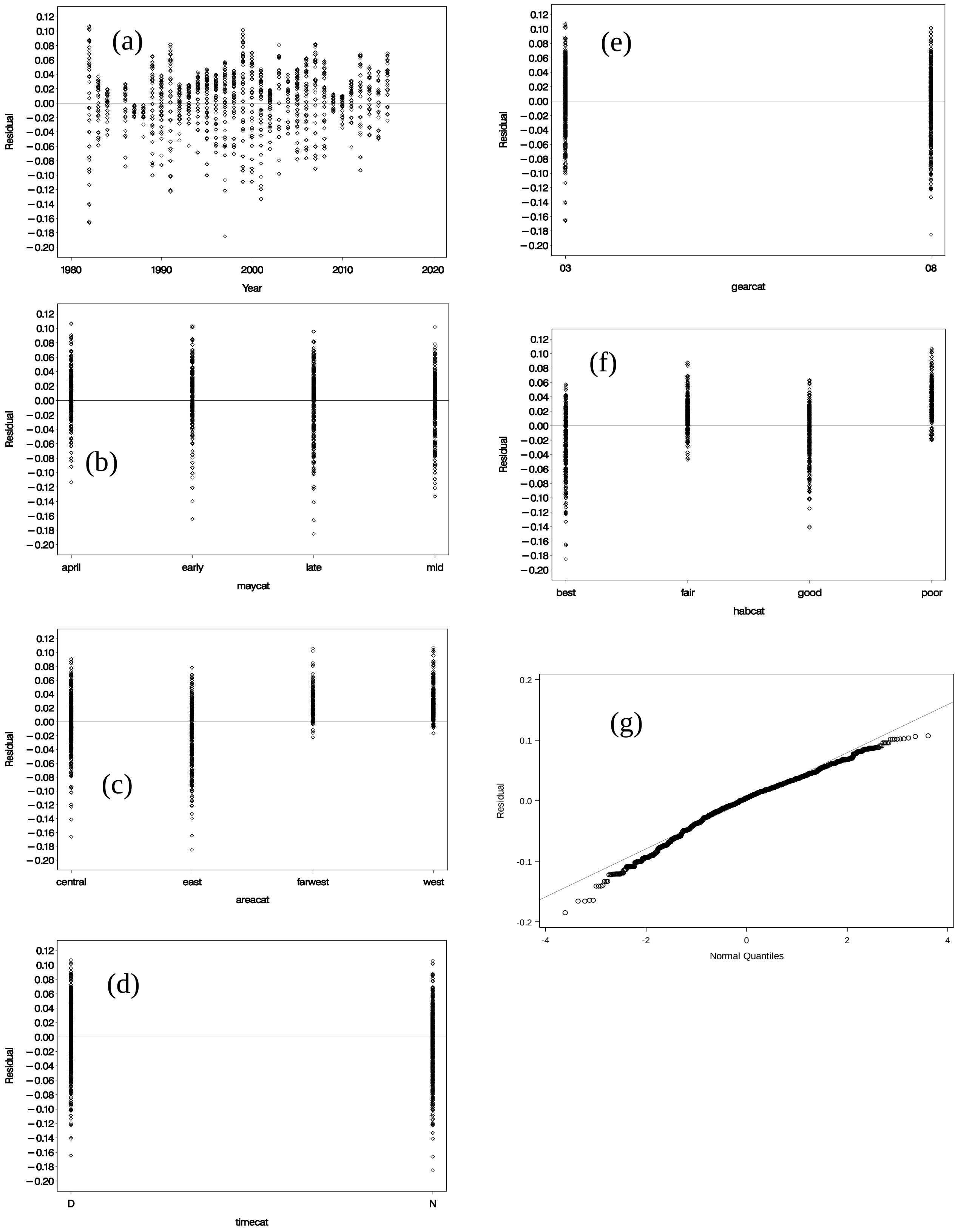


Figure 10. Residual plots of the zero-inflated binomial submodel for larvae collected in neuston tows. Plot **a** is a plot of residuals versus survey year; plot **b** is of residuals versus the survey date variable; plot **c** is a plot of residuals versus the survey area variable; plot **d** is a plot of residuals versus the time of day variable; plot **e** is a plot of residuals versus the gear variable; plot **f** is a plot of residuals versus the habitat category variable; and plot **g** is a QQ plot of the residuals.

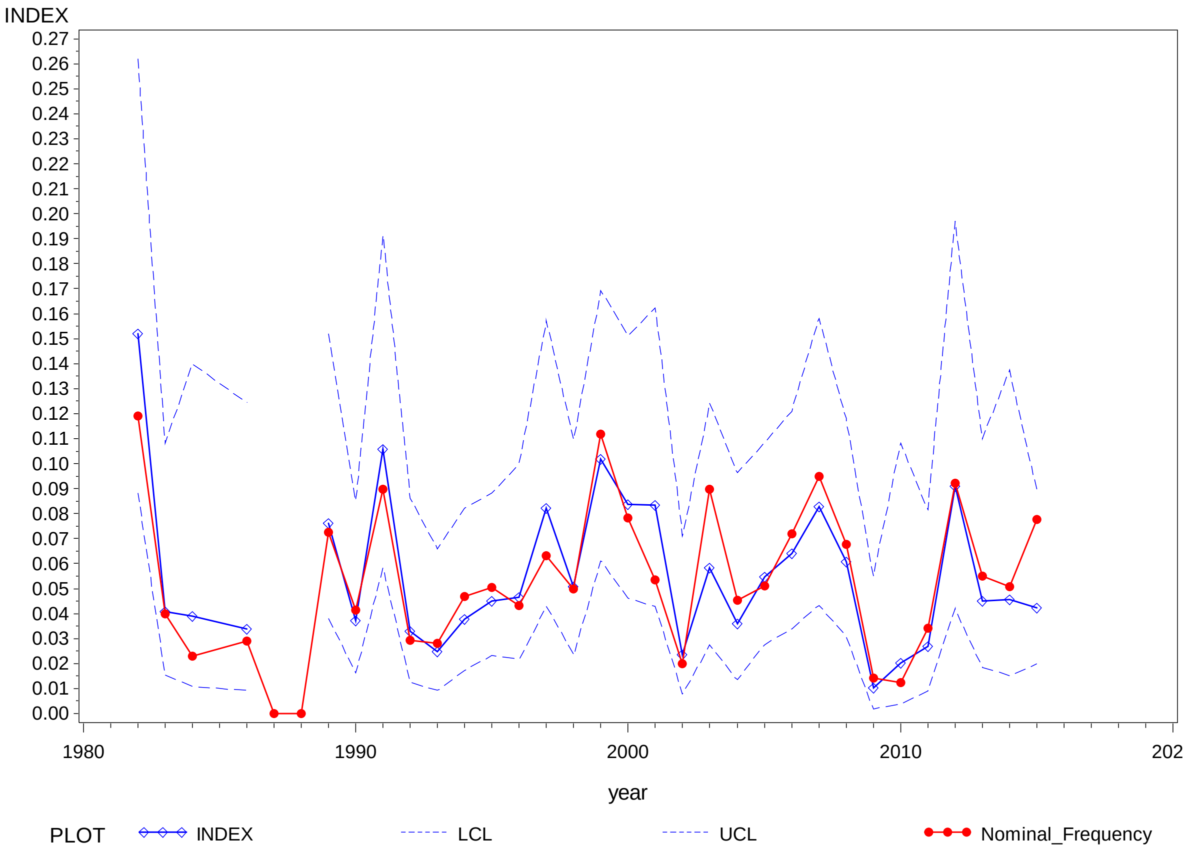


Figure 11. Annual indices (with 95% confidence limits) and nominal frequency of occurrence of larval swordfish (occurrence per 10-min neuston tow) developed from the zero-inflated binomial model.

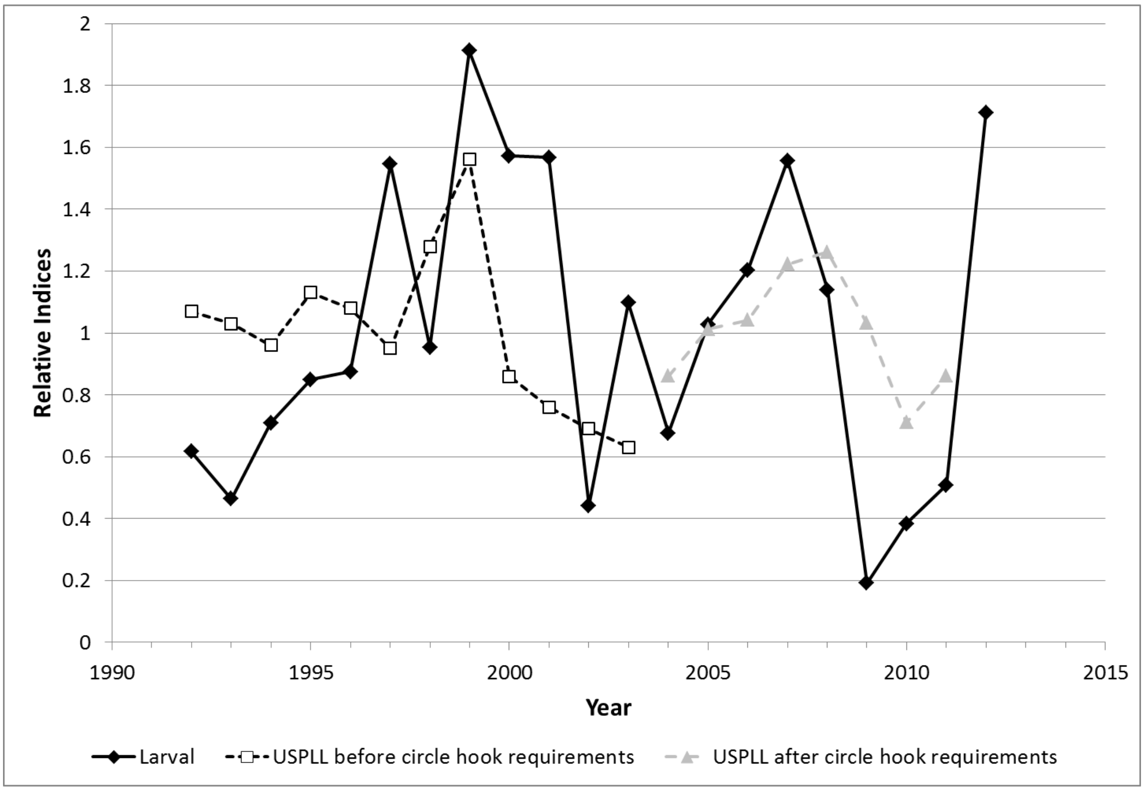
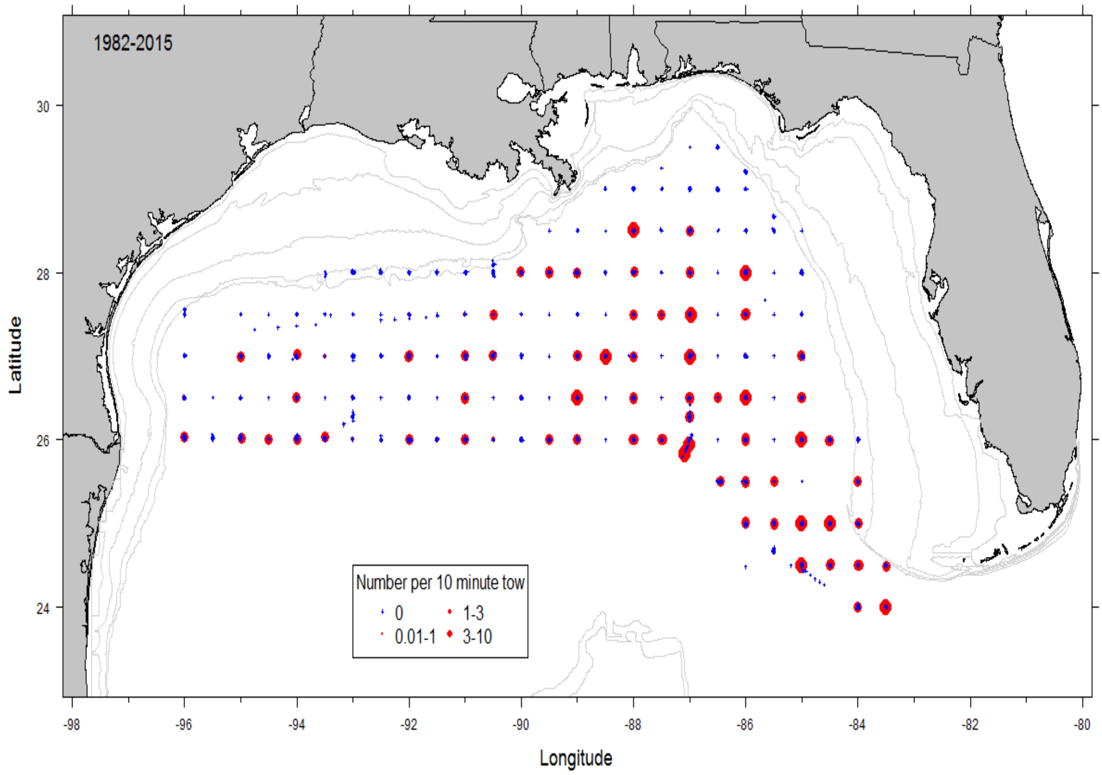
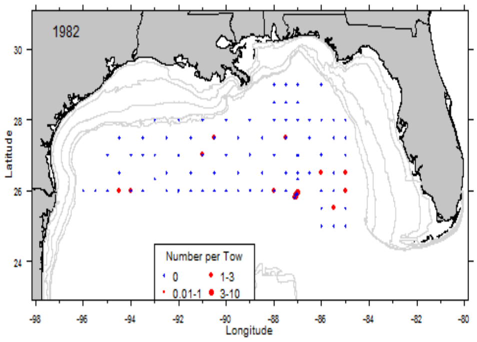


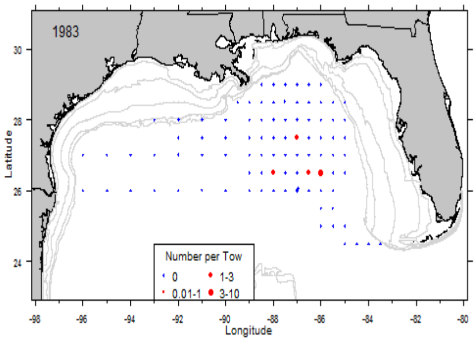
Figure 12. Comparison of larval swordfish indices to those developed from the U.S. pelagic longline fishery.

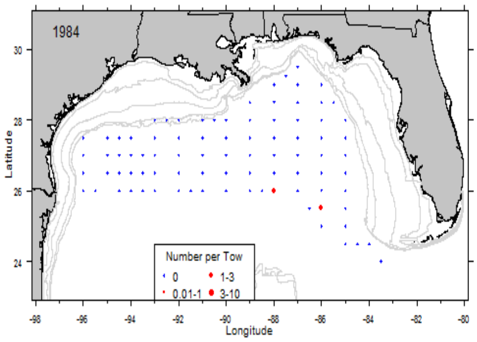
Appendix

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




1982
Number per Tow
0
0.01-1
1-3
3-10
Latitude
30
28
26
24
Longitude
-98
-96
-94
-92
-90
-88
-86
-84
-82
-80


1983
Number per Tow
0
0.01-1
1-3
3-10
Latitude
30
28
26
24
Longitude
-98
-96
-94
-92
-90
-88
-86
-84
-82
-80


1984
Number per Tow
0
0.01-1
1-3
3-10
Latitude
30
28
26
24
Longitude
-98
-96
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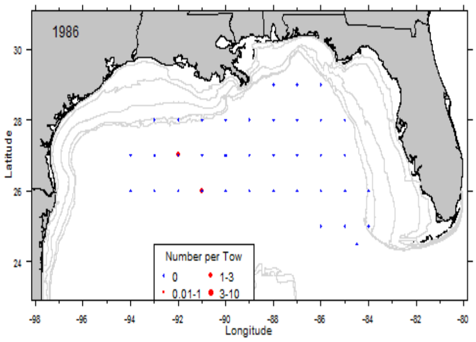
-88
-86
-84
-82
-80


1986
Number per Tow
0
0.01-1
1-3
3-10
Latitude
30
28
26
24
Longitude
-98
-96
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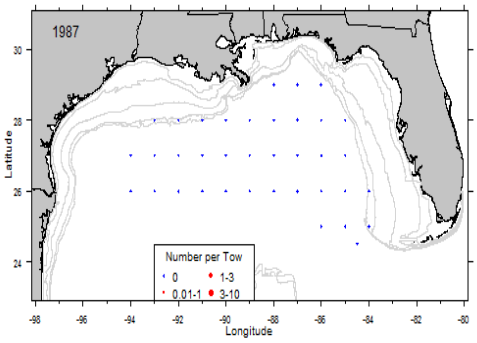
-88
-86
-84
-82
-80


1987
Number per Tow
0
0.01-1
1-3
3-10
Latitude
30
28
26
24
Longitude
-98
-96
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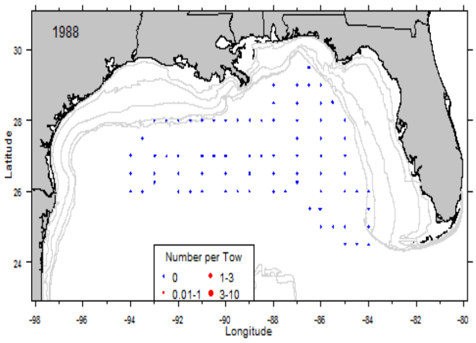
-86
-84
-82
-80


1988
Number per Tow
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0.01-1
1-3
3-10
Latitude
30
28
26
24
Longitude
-98
-96
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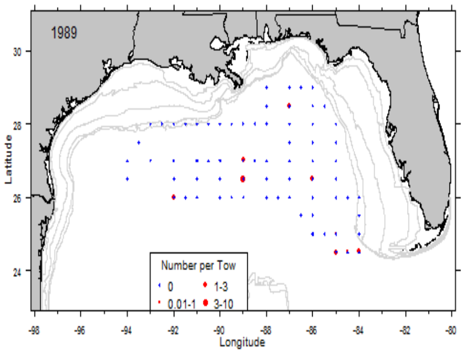
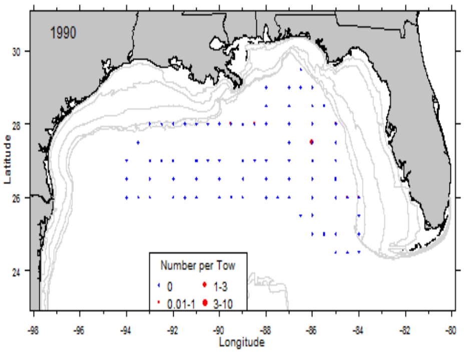
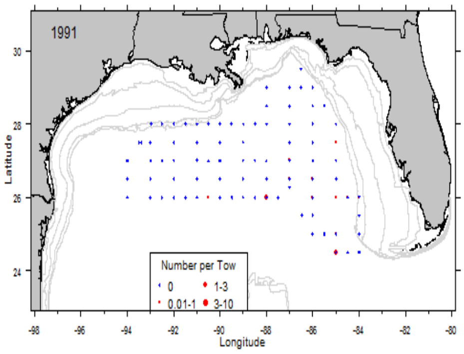
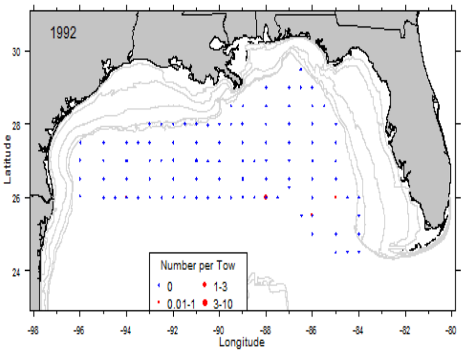
-88
-86
-84
-82
-80


1989
Latitude
30
28
26
24
Longitude
-98
-96
-94
-92
-90
-88
-86
-84
-82
-80
Number per Tow
0
1-3
0.01-1
3-10


1990
Latitude
30
28
26
24
Longitude
-98
-96
-94
-92
-90
-88
-86
-84
-82
-80
Number per Tow
0
1-3
0.01-1
3-10


1991
Latitude
30
28
26
24
Longitude
-98
-96
-94
-92
-90
-88
-86
-84
-82
-80
Number per Tow
0
1-3
0.01-1
3-10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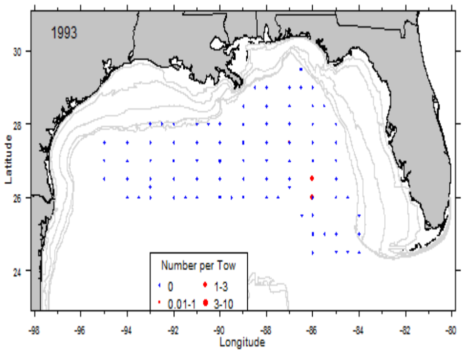
Latitude
30
28
26
24
Longitude
-98
-96
-94
-92
-90
-88
-86
-84
-82
-80
Number per Tow
0
1-3
0.01-1
3-10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Latitude
30
28
26
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Longitude
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-94
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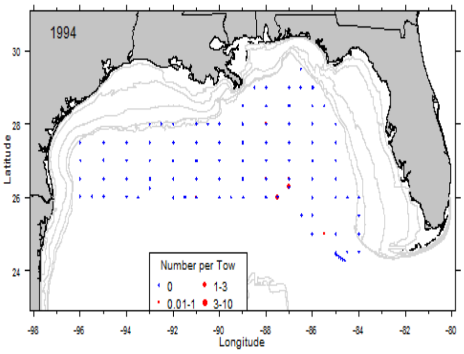
-90
-88
-86
-84
-82
-80
Number per Tow
0
1-3
0.01-1
3-10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Latitude
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Longitude
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-90
-88
-86
-84
-82
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Number per Tow
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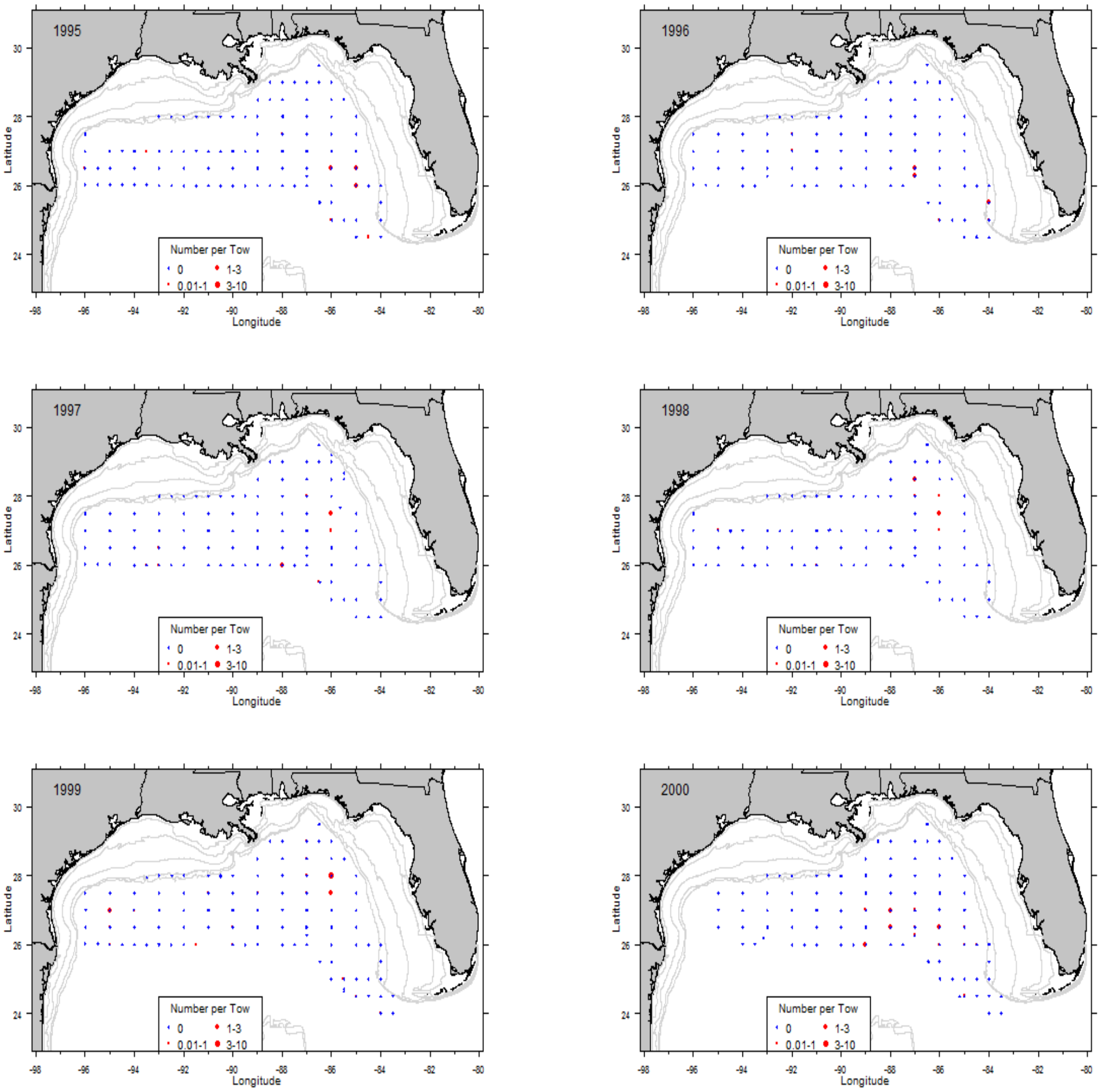
0.01-1
3-10


1995
1996
1997
1998
1999
2000
Number per Tow
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0.01-1
1-3
3-10
Latitude
Longitude
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28
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24
-98
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-94
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-90
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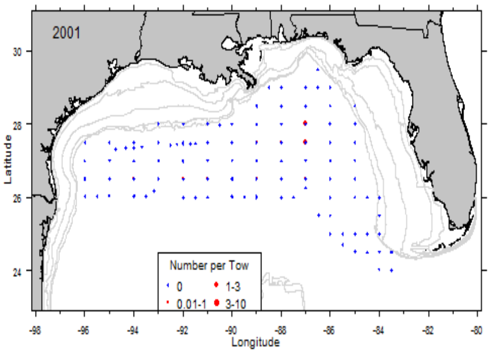
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Latitude
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Longitude
-98
-96
-94
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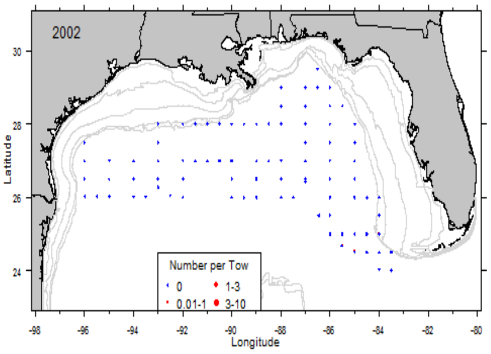
-90
-88
-86
-84
-82
-80
Number per Tow
0
1-3
0.01-1
3-10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Latitude
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Longitude
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-86
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-82
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Number per Tow
0
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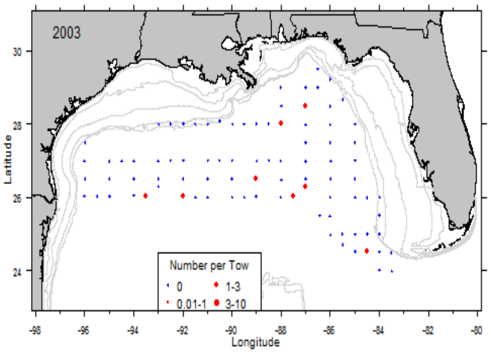
0.01-1
3-10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Latitude
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Longitude
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Number per Tow
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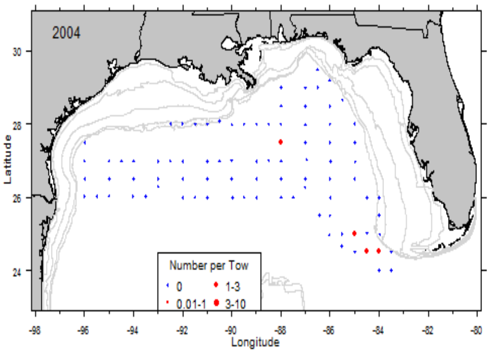
0.01-1
3-10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Longitude
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Number per Tow
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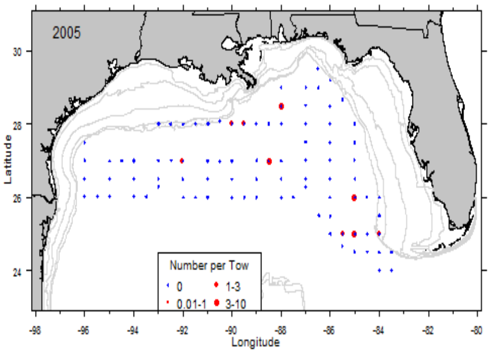
0.01-1
3-10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Latitude
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Longitude
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-94
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-90
-88
-86
-84
-82
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Number per Tow
0
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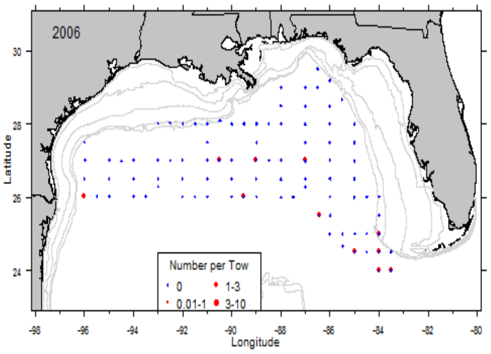
0.01-1
3-10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Latitude
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Longitude
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-94
-92
-90
-88
-86
-84
-82
-80
Number per Tow
0
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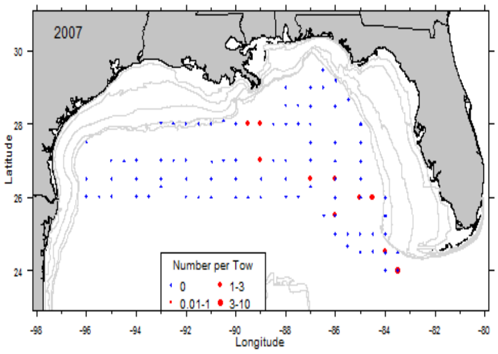
0.01-1
3-10


2007
Number per Tow
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1-3
0.01-1
3-10
Latitude
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Longitude
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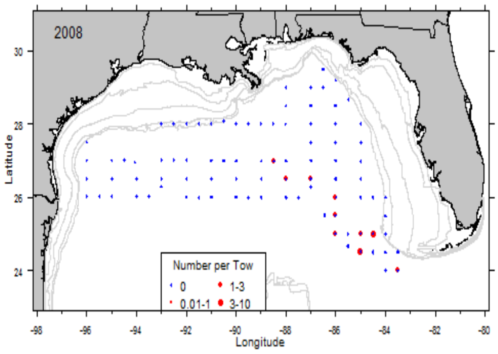
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Number per Tow
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0.01-1
3-10
Latitude
30
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Longitude
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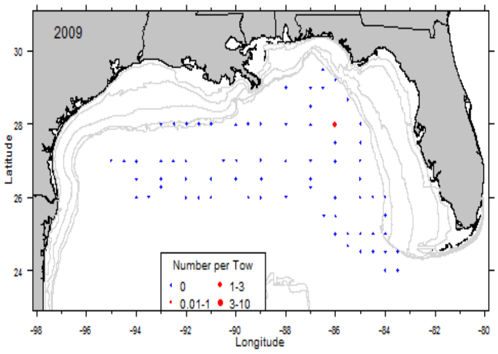
2009
Number per Tow
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0.01-1
3-10
Latitude
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Longitude
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-88
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-84
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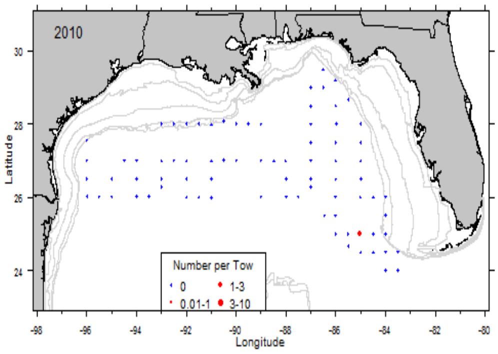
2010
Number per Tow
0
1-3
0.01-1
3-10
Latitude
30
28
26
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Longitude
-98
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-84
-82
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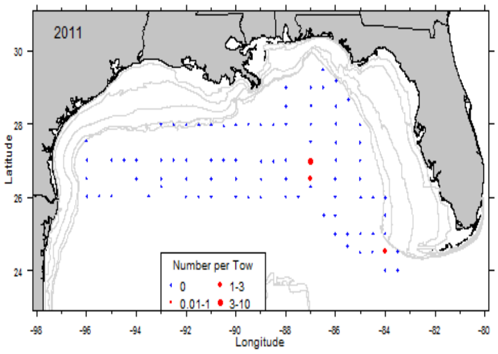
2011
Number per Tow
0
1-3
0.01-1
3-10
Latitude
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Longitude
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-88
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-84
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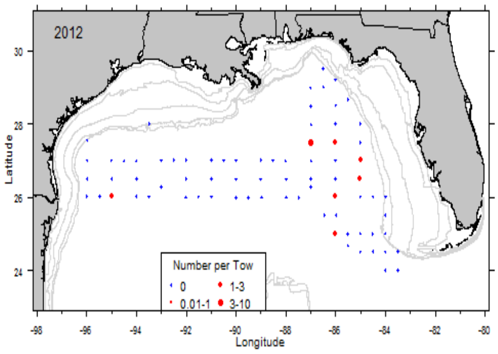
2012
Number per Tow
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1-3
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3-10
Latitude
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Longitude
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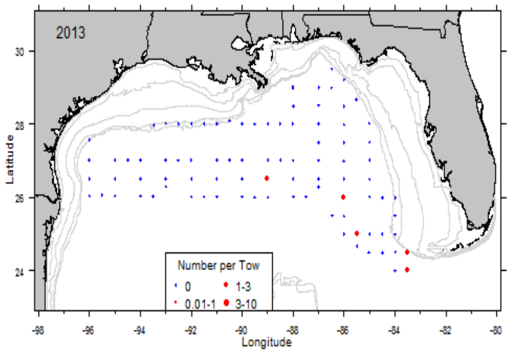
2013
Latitude
30
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26
24
Number per Tow
0
1-3
0.01-1
3-10
-98
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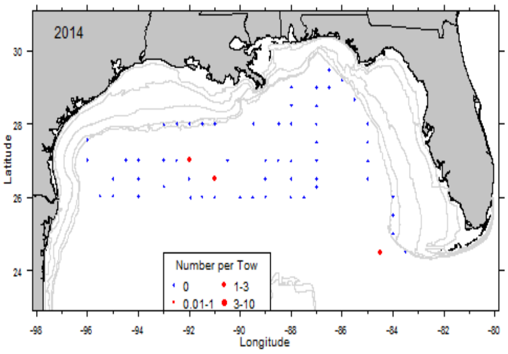
-88
-86
-84
-82
-80
Longitude


2014
Latitude
30
28
26
24
Number per Tow
0
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0.01-1
3-10
-98
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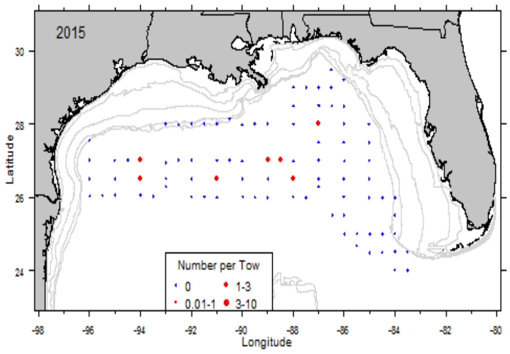
-94
-92
-90
-88
-86
-84
-82
-80
Longitude


2015
Latitude
30
28
26
24
Number per Tow
0
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0.01-1
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-86
-84
-82
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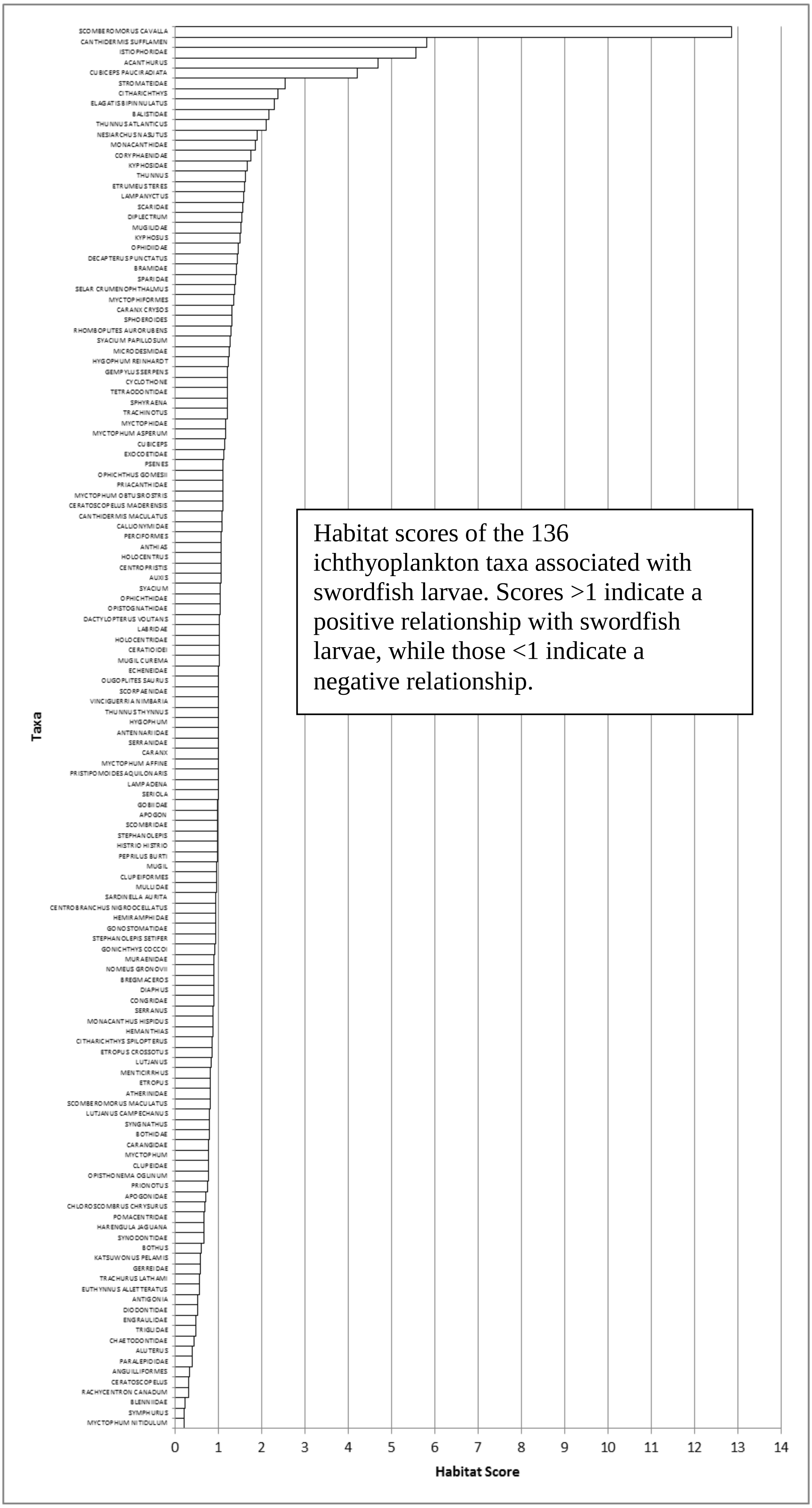
Longitude



Habitat scores of the 136 ichthyoplankton taxa associated with swordfish larvae. Scores >1 indicate a positive relationship with swordfish larvae, while those <1 indicate a negative relationship.