SCRS/2012/060 Collect. Vol. Sci. Pap. ICCAT, 69(3): 1240-1258 (2013)

WHITE MARLIN (*TETRAPTURUS ALBIDUS*) AND ROUNDSCALE SPEARFISH (*TETRAPTURUS GEORGII*) STANDARDIZED CATCH RATES FROM THE U.S. PELAGIC LONGLINE FISHERY PELAGIC OBSERVER PROGRAM IN THE NORTHWEST ATLANTIC AND GULF OF MEXICO 1992-2011

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SUMMARY

This paper presents a new combined abundance index for white marlin and roundscale spearfish, based on U.S. Pelagic Longline Observer Program observations. Indices of abundance from the northwest Atlantic and U.S. Gulf of Mexico are presented for the period 1992-2011. The index of weight (kg) per thousand hooks was estimated via length-weight conversions, based on direct lengths measured by observers. Standardized indices were estimated using Generalized Linear Mixed Models with the Delta lognormal model approach. The standardization procedure evaluated the variables: year, fishing area, season, number of hooks set between floats, target species, number of light sticks per hook, and temperature, and first order interactions were included as random factors. Final models included significant factors which explained at least 5% of the total model deviance. The combined index prevents the artificial deflation of white marlin abundance caused by the recent separation of roundscale spearfish. In contrast to indices based solely on abundances of white marlin, the combined index shows increases in abundance after 2007, with indices reaching the observed 1992 levels by 2011.

RÉSUMÉ

Ce document présente un nouvel indice d'abondance combiné pour le makaire blanc et le makaire-épée, sur la base des observations recueillies dans le cadre du programme d'observateurs à bord de palangriers pélagiques des États-Unis. Les indices d'abondance provenant de l'Atlantique Nord-Ouest et le Golfe du Mexique des États-Unis sont présentés pour la période 1992-2011. L'indice pondéral (kg) pour mille hameçons a été estimé par le biais des conversions longueur-poids, sur la base des longueurs mesurées directement par les observateurs. Les indices standardisés ont été estimés à l'aide de modèles mixtes linéaires généralisés selon une approche du modèle delta-lognormale. La procédure de standardisation a évalué les variables : année, zone de pêche, saison, nombre de jeux d'hameçons entre les flotteurs, espèce-cible, nombre de baguettes lumineuses par hameçon et température, et des interactions de premier ordre ont été incluses comme facteurs aléatoires. Les modèles finaux incluaient des facteurs significatifs qui expliquaient au moins 5% de la déviance totale du modèle. L'indice combiné empêche la déflation artificielle de l'abondance du makaire blanc causée par la récente séparation du makaire-épée. Contrairement aux indices basés uniquement sur l'abondance du makaire blanc, l'indice combiné fait apparaître des augmentations de l'abondance après 2007, les indices atteignant en 2011 les niveaux observés en 1992.

RESUMEN

En este documento se presenta un nuevo índice de abundancia combinado para la aguja blanca y el marlín peto, basado en las observaciones del Programa de observadores de palangre pelágico de Estados Unidos. Se presentan los índices de abundancia del Atlántico noroccidental y del golfo de México estadounidense para el periodo 1992-2011. Se estimó el índice de peso (kg) por mil anzuelos mediante las conversiones talla-peso, basándose en

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This is Sustainable Fisheries Division Contribution No. SFD-2012-012

mediciones de talla directas realizadas por los observadores. Los índices estandarizados se estimaron utilizando modelos lineales mixtos generalizados con el enfoque del modelo delta lognormal. El procedimiento de estandarización evaluó las variables: año, zona de pesca, temporada, número de anzuelos calados en las flotas, especies objetivo, número de bastones luminosos por anzuelo y temperatura. Se incluyeron interacciones de primer orden como factores aleatorios. Los modelos finales incluían factores importantes que explicaban al menos el 5% de la desviación total del modelo. El índice combinado impide la deflación artificial de la abundancia de aguja blanca generada por la reciente separación del marlín peto. A diferencia de los índices basados únicamente en la abundancia de aguja blanca, el índice combinado muestra incrementos en la abundancia después de 2007. En 2011 los índices alcanzan los niveles observados de 1992.

KEYWORDS

Catch/effort, longlining, white marlin, roundscale spearfish

1. Introduction

This paper presents a new combined index for catch rates of white marlin (*Tetrapturus albidus*), roundscale spearfish *(Tetrapturus georgii*), and an undifferentiated white marlin/roundscale classification, from the United States pelagic longline (PLL) fleet. The U.S. PLL fleet operates across a wide area of the western North Atlantic Ocean, Gulf of Mexico and the Caribbean Sea, targeting swordfish (*Xiphias gladius*) and tunas primarily. Istiophorid billfishes are neither targeted nor landed by the fleet, but are still subject to incidental catch. This bycatch constitutes a component of fishing mortality that can be quantified and used to develop standardized indices of abundance for white marlin. Indices of abundance were prepared using catch and effort information collected through the U.S. Pelagic Observer Program (PLOP). At the program's inception in 1992, the congeners *T. albidus* and *T. georgii* were recognized by observers as a single species (*T. albidus*), and the two species were separated out only after 1995. After 2006, observers were instructed to classify individual *Tetrapturus spp.* that could not be reliably identified with a new combined species code. Thus, indices of *T. albidus* alone based on the PLOP data set would be biased by temporal changes in identification protocols.

2. Materials and Methods

Observers from the U.S. Pelagic Longline Observer Program are assigned to subsample approximately 8% of fishing trips for the U.S. PLL fleet, and record information on catch, fishing gear, environmental conditions, and vessel characteristics for each trip. The longline fishing grounds for the U.S. PLL fleet extend from the Grand Banks in the North Atlantic to latitudes of 5-10°S, off the South America coast, including the Caribbean Sea and the Gulf of Mexico (**Figure 1**). Ten geographical locations of PLL fishing were used for the analysis: the Caribbean (CAR), Gulf of Mexico (GOM), Florida East Coast (FEC), South Atlantic Bight (SAB), Mid-Atlantic Bight (MAB), New England Coastal (NEC), Sargasso Sea (SAR), North Central Atlantic (NCA), Tuna North (TUN; between 5°N and 13°N latitude) and Tuna South (TUS; between 0° and 5°N latitude). Calendar quarters were used to account for seasonal fishery distribution through the year (Jan-Mar, Apr-Jun, Jul-Sep, and Oct-Dec). Other factors included in the analyses of catch rates included: target species (targ), temperature at the beginning of the haul (temp), the number of light-sticks per hook (light), and the number of hooks between floats (HBFL). The number of hooks between floats acts as a proxy for the depth at which the gear is actually fishing, as depth of the hook typically increases with the number of hooks between floats. The number of hooks between floats, number of light sticks per hook, and temperature were treated as categorical variables, and values were binned as specified in **Figure 2**.

The U.S. PLL fleet primarily targets swordfish (SWO) and yellowfin tuna *Thunnus albacares* (YFT), and to a lesser extent bigeye tuna *T. obesus* (BET). A smaller number of trip-sets target other pelagic species such as sharks, dolphin *Coryphaena hippurus*, and small tunas (TUN). Because sample sizes for trips targeting sharks and dolphin were small and both had low average nominal catch rates, these two target species categories were combined with the "mixed" target category, which had a similarly low average nominal catch rate.

The fishery has operated under several time-area restrictions since 2000, due to management regulations related to swordfish and other species (Federal Register 2000, Fig 1). These restrictions include: the Desoto Canyon closure in the Gulf of Mexico (effective in 2000), the Florida East Coast closure (effective in 2001), and the Grand Banks closure (closed from July 17th 2001 – January 9th 2002). Two time-area closures also occurred: the Charleston Bump off the North Carolina coast (closed from February 1st – April 30th starting in 2001), the Bluefin Tuna Protection Area off the New England Coast (closed from June 1st – June 30th starting in 1999). For the present study, any sets located in closed areas prior to or after the closure were removed from the data set. For time-area closures, we removed data for that area and during the closed months from all years.

Because of the various number of hooks per set, catch rates were calculated as the total number of white marlin, roundscale spearfish, or unidentified *Tetrapturus spp.* caught per 1000 hooks. The number of hooks was calculated as the number of hooks set minus the number of hooks lost. Fish length measurements are made directly by PLOP observers, who are directed to record lengths of all species brought on board. For released or discarded animals not brought on board, lengths were estimated by observers. Measurements for billfish species were made from the tip of the lower jaw to the fork of the tail. Observers also recorded the sex when possible. For missing lengths, we used the average length of all other observed individuals from the same year and area. Length to weight conversions for white marlin, roundscale spearfish, and unidentified individuals were all based on equations for white marlin reported by Prager *et al.* (1995). When sex of the fish was known, the conversions for separate sexes were used, and when not known the combined conversion equation was used.

For the PLOP data, indices of combined white marlin and roundscale spearfish relative abundance (number of fish / 1000 hooks and kg / 1000 hooks) were estimated by a GLM approach assuming a delta-lognormal model distribution. The delta model fits separately the: 1) proportion of positive sets, assuming a binomial error distribution, and 2) the mean catch rate of sets where at least one white marlin was caught, assuming a lognormal error distribution. The estimated proportion of successful sets per stratum is assumed to be the result of *r* positive sets of a total *n* number of sets, with each one being an independent Bernoulli-type realization. The estimated proportion is a linear function of fixed effects and interactions. The logit function was used as a link between the linear factor component and the binomial error. For sets that caught at least one white marlin or roundscale spearfish, estimated CPUE were assumed to follow a lognormal error distribution of a linear function of fixed factors and random effect interactions. A step-wise regression process was used to determine the set of systematic factors and interactions that significantly explained the observed variability. Model selection of fixed factors was based on the relative percent of deviance explained by adding the factor in evaluation (using a cutoff of >5%) and the Chi-square test of significance with alpha=0.05.

The final set of explanatory variables in the binomial model for the proportion of positive sets included: year, area, season, temperature, and light-sticks (fixed effects), and year*season, year*light-sticks, season*light-sticks, and area *season (random effects) (**Table 1**). The binomial model failed to converge in cases where at least one of the interaction effect combinations had a proportion equal to exactly one or zero, and thus these interaction effects were excluded. For the log of positive catches in abundance, the variables selected were: year, area, season, and hooks between floats (fixed effects), and area*season, area*target, and area*light sticks (random effects; **Table 1**). For the log of positive catches in weight, the variables selected were: year, area, and hooks between floats (fixed effects), and area*target and area*light sticks (random effects; **Table 2**). Relative indices for the delta model formulation were calculated as the product of the year effect least square means (LSmeans) from the binomial and the lognormal model components. The LSmeans estimates use a weighted factor of the proportional observed margins in the input data to account for the un-balanced characteristics of the data. LSmeans of lognormal positive trips were bias corrected using Lo *et al.* (1992) algorithms. Analyses were done using the GLIMMIX and MIXED procedures from the SAS™ statistical computer software (SAS Institute Inc. 1997).

3. Results and Discussion

The log-transformed frequency distribution for nominal PLL combined white marlin and roundscale spearfish catch rates for positive sets approximates a Gaussian distribution (**Figure 3**). For the lognormal models of positive catch rates, the distributions of the residuals indicate that the lognormal approach is appropriate (**Figure 4**). Standardized CPUE series in number (fish / 1000 hooks) and weight (kg / 1000 hooks) for the combined white marlin/roundscale abundances are shown in **Tables 3 and 4** and **Figures 5 and 6**. For comparative purposes, the CPUE series in numbers and weight were scaled to their overall mean and plotted together (**Figure 7**).

Mean length of white marlin and roundscale spearfish combined remained relatively stable until 2003, increased steadily from 2003 to 2009, and decreased slightly from 2009 – 2011 (**Figure 8**). Coverage from the PLOP ranged from a minimum of 182 sets in 1992 to a maximum of 1,316 sets in 2009 (**Figure 9**). The spatial distribution of observer coverage also varied temporally, with five zones (CAR, NCA, SAR, TUN, and TUS) lacking coverage in some years. In 2007 and 2008, PLOP coverage of the PLL fleet increased dramatically in the Gulf of Mexico, and covered 72% and 80% of all longline fishing sets respectively in those years (Beerkircher *et al*., 2009).

The new white marlin and roundscale spearfish combined index differs notably from the most recently updated index based on only white marlin abundances from the U.S. PLL logbook data (**Figure 10**). The indices diverge in particular after 2007; the logbook index displayed a slight decline from 2007-2010, while the observer index showed an overall increase. This divergence appears to be driven by an increased proportion of white marlin-like individuals identified as roundscale spearfish from 2007 – 2011 (**Figure 11**). Abundances of unidentified *Tetrapturus spp*. (WHX) make up from 36 – 55% of the total observations after 2007, and therefore the exclusion of these individuals would produce dramatically different trends in the abundance index.

In contrast to previous indices of based on PLL logbook observations of *T. albidus* alone (Ortiz and Hoolihan 2011), which indicates an overall decrease in abundance from the period 1985 – 2009, the new combined index suggests that abundance has remained relatively stable since the inception of the PLOP data collection in 1992. Both indices show an anomalous peak in abundance in the year 1999, with the combined weight index reaching its highest value in this year. The combined index also displays peaks in abundance in 1995 and 2005, which are not observed in index based on logbook data. From 2010 – 2011, the combined index shows a dramatic increase, with the 2011 index value surpassing the observed value in 1992.

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Table 1. Deviance analysis table of combined white marlin and roundscale spearfish catch rates in number and proportion of positive sets from the U.S. PLOP data. Percent of total deviance refers to the deviance explained by the full model; p value refers to the Chi-square probability test between two consecutive models.

Model factors for positive catch rates	*d.f.*	*Residual deviance*	*Change in deviance*	*% of total deviance*	*p*
intercept		1266.8			
year	19	1183.4	83.4	24.6%	< 0.001
year area	9	1125.9	57.5	16.9%	< 0.001
year area season	3	1108.3	17.7	5.2%	< 0.001
year area season HBFL	6	1072.1	36.2	10.7%	< 0.001
year area season HBFL temp	8	1057.3	14.8	4.4%	0.063
year area season HBFL temp light	3	1042.9	14.4	4.2%	0.002
year area season HBFL temp light targ	4	1040.3	2.6	0.8%	0.631
year area season HBFL temp light targ season*light	9	1032.3	8.0	2.4%	0.534
year area season HBFL temp light targ area*temp	33	1030.2	10.1	3.0%	1.000
year area season HBFL temp light targ HBFL*light	18	1029.6	10.7	3.2%	0.906
year area season HBFL temp light targ light*targ	12	1029.1	11.2	3.3%	0.511
year area season HBFL temp light targ temp*light	21	1027.4	12.9	3.8%	0.911
year area season HBFL temp light targ season*HBFL	17	1025.0	15.3	4.5%	0.576
year area season HBFL temp light targ HBFL*targ	19	1022.0	18.3	5.4%	0.505
year area season HBFL temp light targ area*season	20	1006.4	33.9	10.0%	0.027
year area season HBFL temp light targ area*targ	20	1004.1	36.2	10.7%	0.015
year area season HBFL temp light targ area*light	22	1002.2	38.0	11.2%	0.018
year area season HBFL temp light targ area*HBFL	39	995.3	45.0	13.3%	0.236
year area season HBFL temp light targ year*light	56	990.0	50.3	14.8%	0.691
year area season HBFL temp light targ year*HBFL	76	987.5	52.7	15.5%	0.981
year area season HBFL temp light targ year*season	56	987.4	52.9	15.6%	0.594
year area season HBFL temp light targ year*targ	59	984.5	55.8	16.4%	0.595
year area season HBFL temp light targ year*temp	89	976.8	63.5	18.7%	0.981
year area season HBFL temp light targ year*area	120	927.5	112.8	33.2%	0.667

Model factors for proportion positives	*d.f.*	*Residual deviance*	*Change in deviance*	*% of total deviance*	*p*
intercept		6613.2			
year	19	6330.8	282.4	12.0%	< 0.001
year area	9	5870.7	460.1	19.6%	< 0.001
year area season	3	5419.6	451.1	19.2%	< 0.001
year area season HBFL	6	5397.5	22.1	0.9%	0.001
year area season HBFL temp	8	4993.7	403.8	17.2%	< 0.001
year area season HBFL temp light	3	4852.4	141.4	6.0%	< 0.001
year area season HBFL temp light targ	4	4810.6	41.8	1.8%	< 0.001
year area season HBFL temp light targ HBFL*light	18	4779.6	30.9	1.3%	0.029
year area season HBFL temp light targ light*targ	12	4777.2	33.4	1.4%	< 0.001
year area season HBFL temp light targ season*HBFL	18	4758.5	52.1	2.2%	< 0.001
year area season HBFL temp light targ area*targ	21	4753.3	57.3	2.4%	< 0.001
year area season HBFL temp light targ year*light	57	4638.1	172.5	7.4%	< 0.001
year area season HBFL temp light targ season*light	9	4598.7	211.9	9.0%	< 0.001
year area season HBFL temp light targ year*season	56	4542.0	268.6	11.5%	< 0.001
year area season HBFL temp light targ area*season	21	4267.3	543.2	23.2%	< 0.001

Table 2. Deviance analysis table of combined white marlin and roundscale spearfish catch rates in weight and proportion of positive sets from the U.S. PLOP data. Percent of total deviance refers to the deviance explained by the full model; p value refers to the Chi-square probability test between two consecutive models.

Model factors for positive catch rates	*d.f.*	*Residual deviance*	*Change in deviance*	*% of total deviance*	*p*
1		1658.9			
year	19	1563.5	95.4	26.4%	< 0.001
year area	9	1501.4	62.1	17.1%	< 0.001
year area season	3	1484.6	16.7	4.6%	< 0.001
year area season HBFL	6	1453.9	30.8	8.5%	< 0.001
year area season HBFL temp	8	1442.3	11.6	3.2%	0.170
year area season HBFL temp light	3	1428.6	13.7	3.8%	0.003
year area season HBFL temp light targ	4	1426.4	2.2	0.6%	0.705
year area season HBFL temp light targ season*light	9	1419.2	7.2	2.0%	0.615
year area season HBFL temp light targ light*targ	12	1417.6	8.8	2.4%	0.719
year area season HBFL temp light targ HBFL*light	18	1415.8	10.6	2.9%	0.911
year area season HBFL temp light targ temp*light	21	1412.2	14.2	3.9%	0.863
year area season HBFL temp light targ area*temp	33	1412.1	14.3	3.9%	0.998
year area season HBFL temp light targ HBFL*targ	19	1407.6	18.8	5.2%	0.471
year area season HBFL temp light targ season*HBFL	17	1407.2	19.2	5.3%	0.316
year area season HBFL temp light targ area*season	20	1397.6	28.8	8.0%	0.092
year area season HBFL temp light targ area*HBFL	39	1388.7	37.7	10.4%	0.527
year area season HBFL temp light targ area*targ	20	1385.2	41.2	11.4%	0.003
year area season HBFL temp light targ area*light	22	1383.5	42.9	11.8%	0.005
year area season HBFL temp light targ year*season	56	1380.8	45.6	12.6%	0.838
year area season HBFL temp light targ year*light	56	1372.6	53.8	14.9%	0.558
year area season HBFL temp light targ year*targ	59	1358.3	68.2	18.8%	0.194
year area season HBFL temp light targ year*HBFL	76	1354.6	71.8	19.8%	0.615
year area season HBFL temp light targ year*temp	89	1347.2	79.2	21.9%	0.761
year area season HBFL temp light targ year*area	120	1296.8	129.6	35.8%	0.260

Model factors for proportion positives	*d.f.*	*Residual deviance*	*Change in deviance*	*% of total deviance*	*p*
intercept		6613.2			
year	19	6330.8	282.4	12.0%	< 0.001
year area	9	5870.7	460.1	19.6%	< 0.001
year area season	3	5419.6	451.1	19.2%	< 0.001
year area season HBFL	6	5397.5	22.1	0.9%	0.001
year area season HBFL temp	8	4993.7	403.8	17.2%	< 0.001
year area season HBFL temp light	3	4852.4	141.4	6.0%	< 0.001
year area season HBFL temp light targ	4	4810.6	41.8	1.8%	< 0.001
year area season HBFL temp light targ HBFL*light	18	4779.6	30.9	1.3%	0.029
year area season HBFL temp light targ light*targ	12	4777.2	33.4	1.4%	< 0.001
year area season HBFL temp light targ season*HBFL	18	4758.5	52.1	2.2%	< 0.001
year area season HBFL temp light targ area*targ	21	4753.3	57.3	2.4%	< 0.001
year area season HBFL temp light targ year*light	57	4638.1	172.5	7.4%	< 0.001
year area season HBFL temp light targ season*light	9	4598.7	211.9	9.0%	< 0.001
year area season HBFL temp light targ year*season	56	4542.0	268.6	11.5%	< 0.001
year area season HBFL temp light targ area*season	21	4267.3	543.2	23.2%	< 0.001

Table 3. Combined white marlin and roundscale spearfish nominal and standardized catch rates (fish / 1000 hooks), coefficient of variation, index, and 95% confidence interval (CI) limits for the standardized index from the U.S. PLOP data (1992-2011).

Year	*Number obs.*	*Prop. positive*	*Nominal CPUE*	*Standardized CPUE*	*Index*	*Lower 95% CI*	*Upper 95% CI*	*CV*	*Std. error*
1992	192	0.286	1.204	0.722	1.442	0.672	3.095	0.396	0.286
1993	633	0.316	1.178	0.688	1.373	0.722	2.611	0.330	0.227
1994	461	0.197	0.613	0.307	0.613	0.287	1.310	0.394	0.121
1995	561	0.317	1.177	0.736	1.469	0.772	2.797	0.330	0.243
1996	290	0.283	0.713	0.403	0.804	0.388	1.669	0.377	0.152
1997	348	0.284	1.112	0.450	0.898	0.437	1.844	0.372	0.167
1998	250	0.236	0.787	0.415	0.828	0.379	1.809	0.406	0.169
1999	306	0.382	1.396	0.836	1.668	0.883	3.153	0.326	0.273
2000	366	0.268	0.854	0.528	1.054	0.518	2.147	0.367	0.194
2001	387	0.181	0.329	0.286	0.571	0.266	1.226	0.396	0.113
2002	349	0.295	0.759	0.530	1.057	0.530	2.111	0.356	0.189
2003	548	0.184	0.354	0.244	0.487	0.231	1.026	0.386	0.094
2004	566	0.316	0.863	0.535	1.067	0.553	2.061	0.338	0.181
2005	536	0.297	0.857	0.658	1.314	0.690	2.504	0.331	0.218
2006	518	0.214	0.481	0.359	0.717	0.351	1.465	0.369	0.133
2007	899	0.159	0.340	0.294	0.586	0.290	1.185	0.363	0.107
2008	1180	0.176	0.362	0.290	0.579	0.289	1.160	0.358	0.104
2009	1338	0.253	0.643	0.526	1.050	0.558	1.975	0.324	0.171
2010	846	0.217	0.481	0.322	0.643	0.321	1.289	0.358	0.115
2011	854	0.391	1.264	0.890	1.777	0.979	3.227	0.305	0.272

Table 4. Combined white marlin and roundscale spearfish nominal and standardized catch rate (kg / 1000 hooks), coefficient of variation, index, and 95% confidence interval (CI) limits for the standardized index from the U.S. PLOP data (1992-2011).

Year	*Number obs.*	*Prop. positive*	*Nominal CPUE*	*Standardized CPUE*	*Index*	*Lower 95% CI*	*Upper 95% CI*	*CV*	*Std. error*
1992	192	0.286	22.823	13.669	1.347	0.648	2.800	0.378	5.171
1993	633	0.316	23.047	11.986	1.182	0.646	2.161	0.309	3.702
1994	461	0.197	13.761	6.811	0.671	0.325	1.386	0.375	2.553
1995	561	0.317	23.949	14.864	1.465	0.800	2.683	0.309	4.600
1996	290	0.283	14.951	8.866	0.874	0.436	1.753	0.359	3.183
1997	348	0.284	22.874	9.452	0.932	0.470	1.848	0.353	3.334
1998	250	0.236	17.114	9.920	0.978	0.462	2.068	0.388	3.849
1999	306	0.382	29.901	18.645	1.838	1.009	3.349	0.307	5.721
2000	366	0.268	16.150	10.141	1.000	0.508	1.966	0.348	3.529
2001	387	0.181	6.553	6.454	0.636	0.306	1.322	0.378	2.442
2002	349	0.295	14.082	10.151	1.001	0.520	1.926	0.336	3.415
2003	548	0.184	5.657	3.787	0.373	0.183	0.760	0.367	1.389
2004	566	0.316	15.059	9.843	0.970	0.523	1.801	0.317	3.118
2005	536	0.297	15.827	12.317	1.214	0.662	2.226	0.310	3.819
2006	518	0.214	9.111	7.285	0.718	0.364	1.415	0.349	2.544
2007	899	0.159	6.753	5.895	0.581	0.298	1.132	0.343	2.021
2008	1180	0.176	7.438	6.410	0.632	0.329	1.215	0.336	2.154
2009	1338	0.253	13.343	11.583	1.142	0.633	2.061	0.302	3.496
2010	846	0.217	9.343	6.926	0.683	0.355	1.314	0.337	2.331
2011	854	0.391	24.181	17.883	1.763	1.013	3.069	0.283	5.054

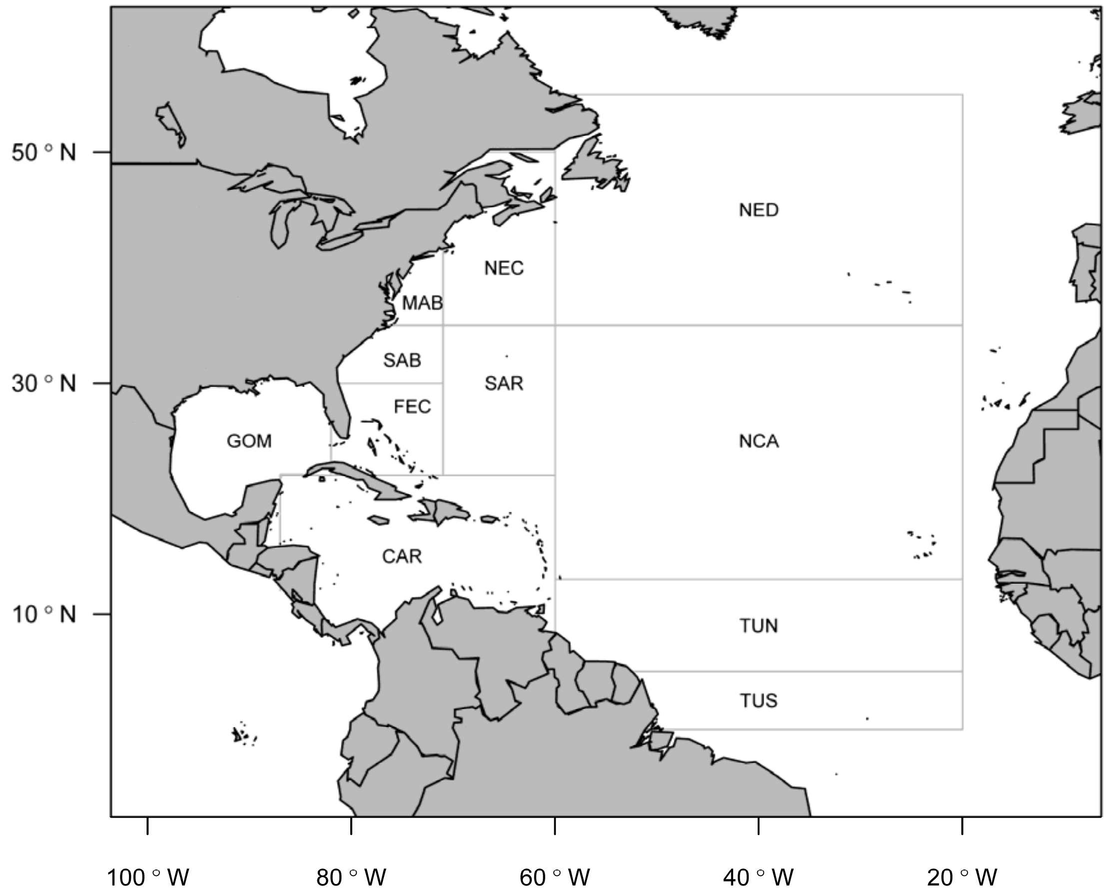

Figure 1. Geographical location classification of U.S. pelagic longline fleet operations used for analyses. *CAR* Caribbean, *GOM* Gulf of Mexico, *FEC* Florida East Coast, *SAB* South Atlantic Bight, *MAB* Mid-Atlantic Bight, *NEC* Northeast Coastal, *SAR* Sargasso, *NCA* North Central Atlantic, *TUN* Tuna North, and *TUS* Tuna South. The *NED* (Northeast Distant) sets are excluded from this analysis due to the Grand Banks closure.

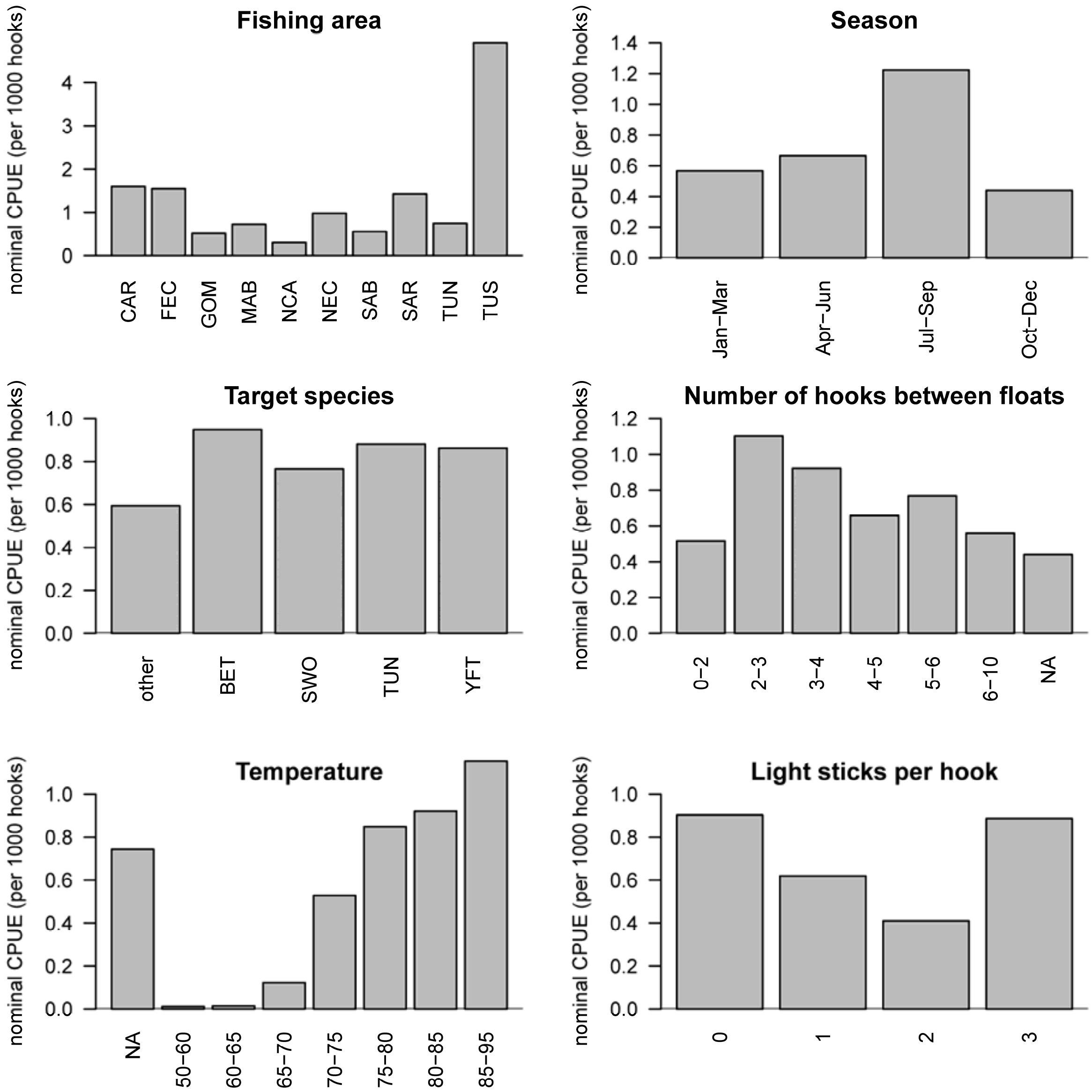

Figure 2. Plots of mean nominal abundance catch rates by model factors.

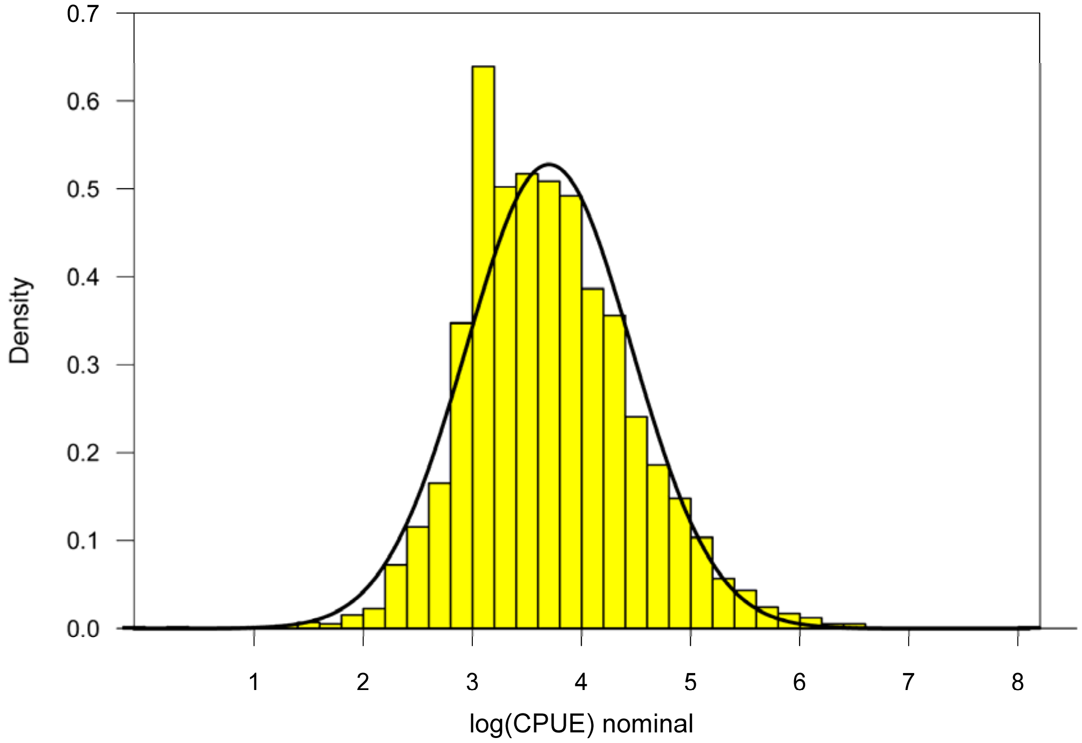

Figure 3. Frequency distribution for log transformed CPUE positive catches (kg /1000 hooks) from the U.S. PLOP data (1992-2011).

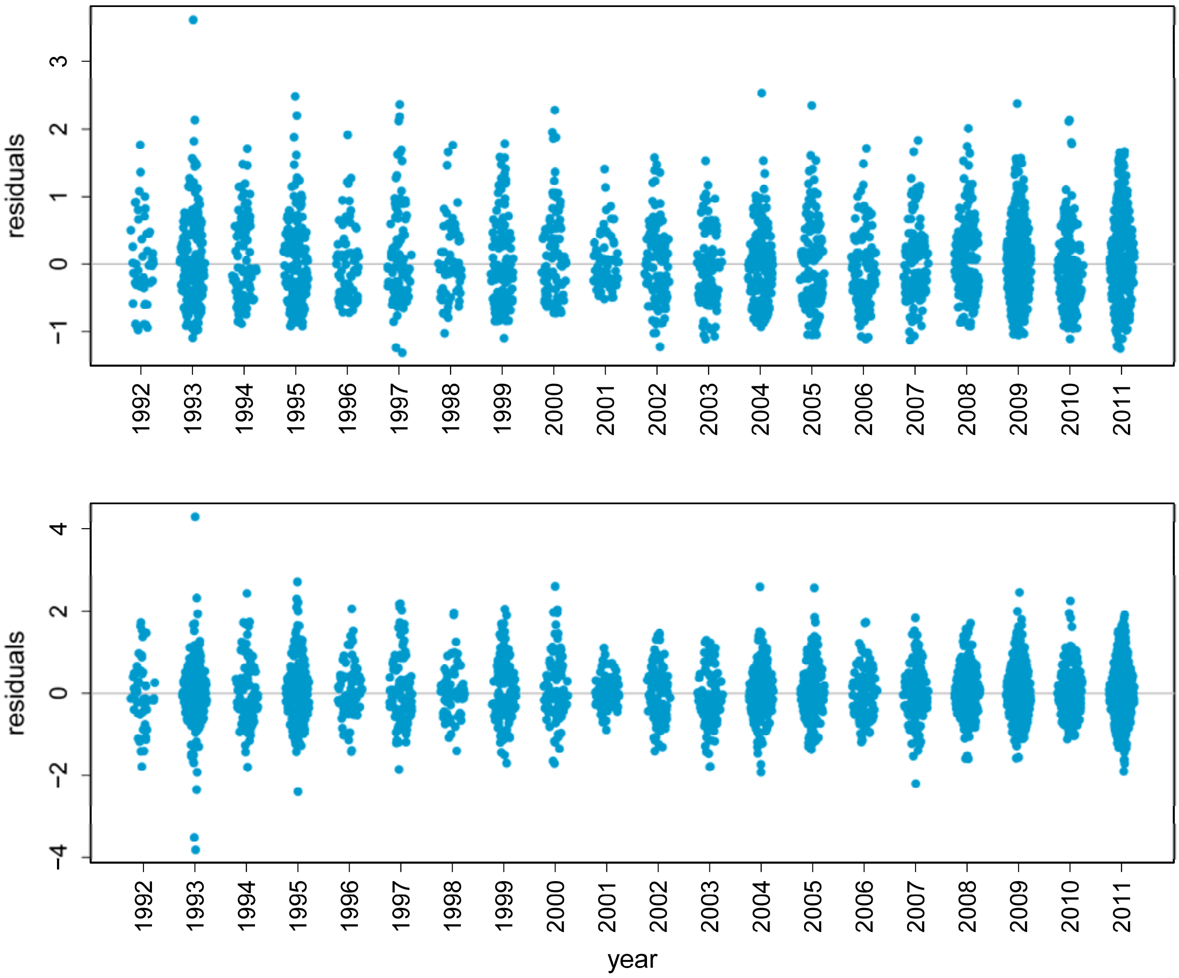

Figure 4. Residuals by year for the GLM model fit of positive observations for abundance (top) and weight (bottom) from the U.S. PLOP data (1992-2011).

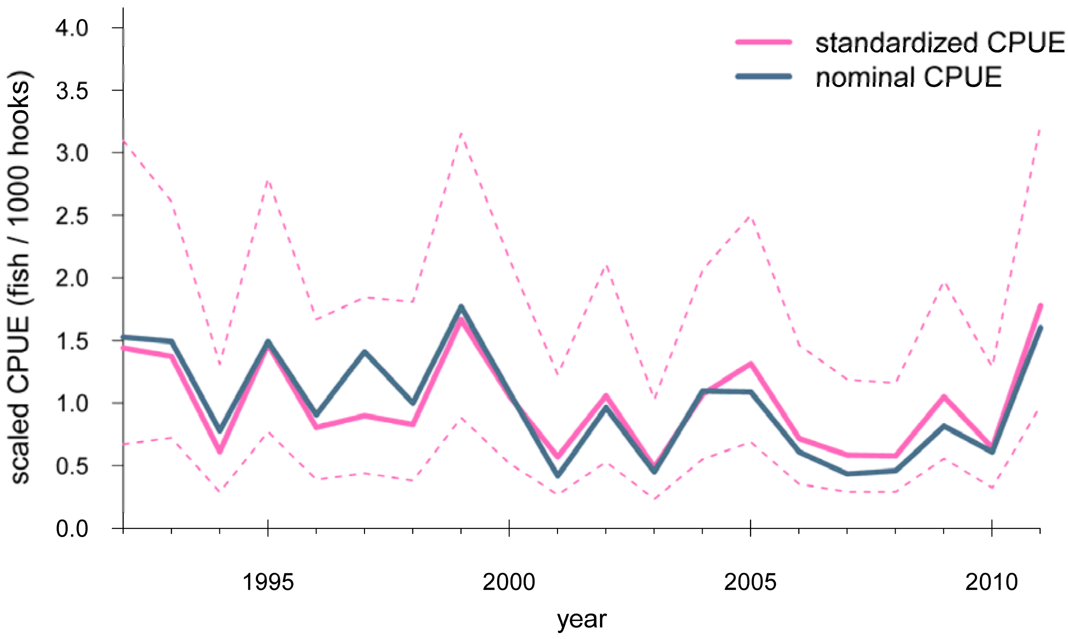

Figure 5. Estimated nominal and standardized CPUE for combined white marlin and roundscale spearfish (fish / 1000 hooks) from the U.S. PLOP data (1992-2011). Dashed lines correspond to upper and lower 95% confidence intervals for the standardized CPUE.

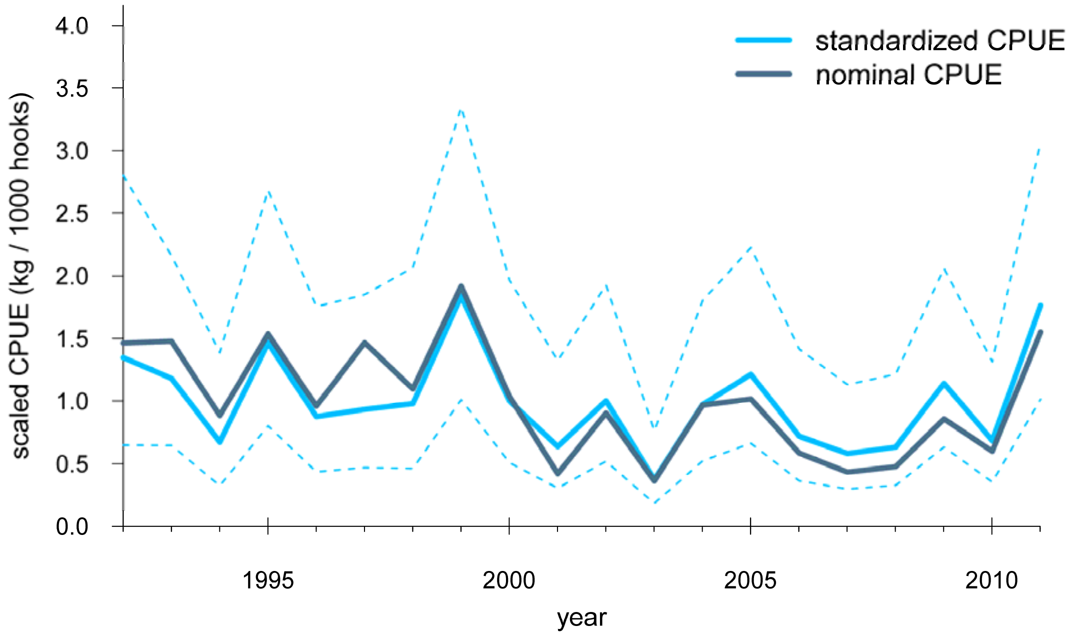

Figure 6. Estimated nominal and standardized CPUE for combined white marlin and roundscale spearfish (kg / 1000 hooks) from the U.S. PLOP data (1992-2011). Dashed lines correspond to upper and lower 95% confidence intervals for the standardized CPUE.

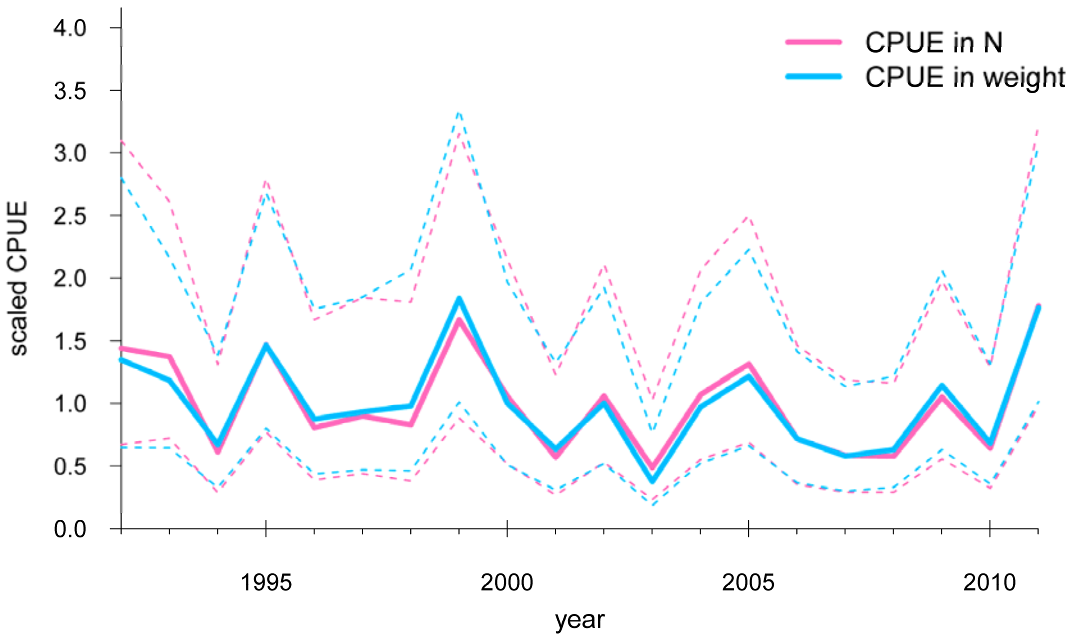

Figure 7. Combined white marlin and roundscale spearfish standardized CPUE series in weight (kg / 1000 hooks) and number of fish (fish / 1000 hooks) estimated from the U.S. PLOP data (1992-2011). Dashed lines correspond to upper and lower 95% confidence intervals of their respective standardized CPUE. For comparative purposes, series are scaled to their overall mean.

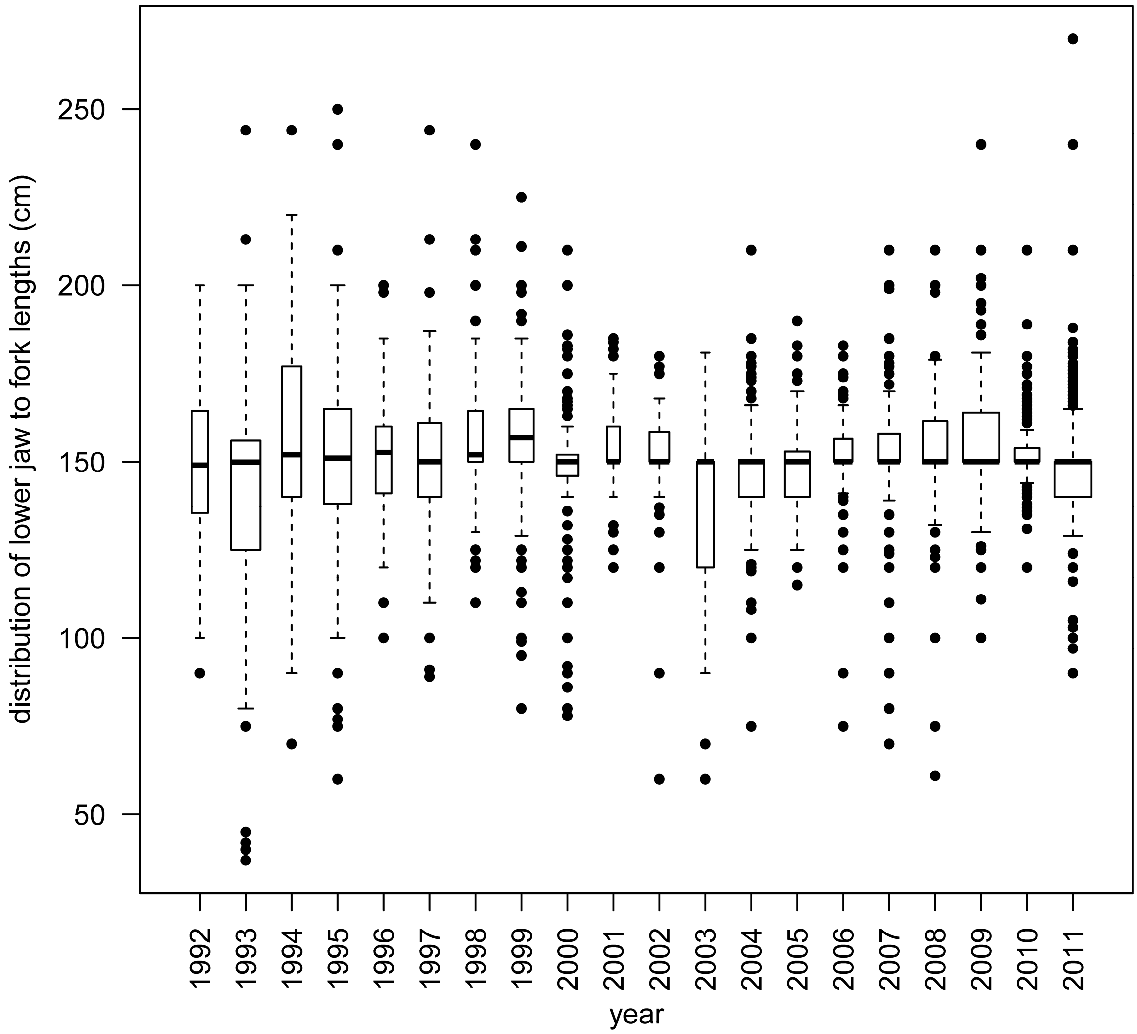

Figure 8. Box and whisker plots (median, 1st, 3rd quartile, minimum and maximum) of white marlin and roundscale spearfish lengths by year in the U.S. PLOP data (1992-2011). Box widths are proportional to sample size.

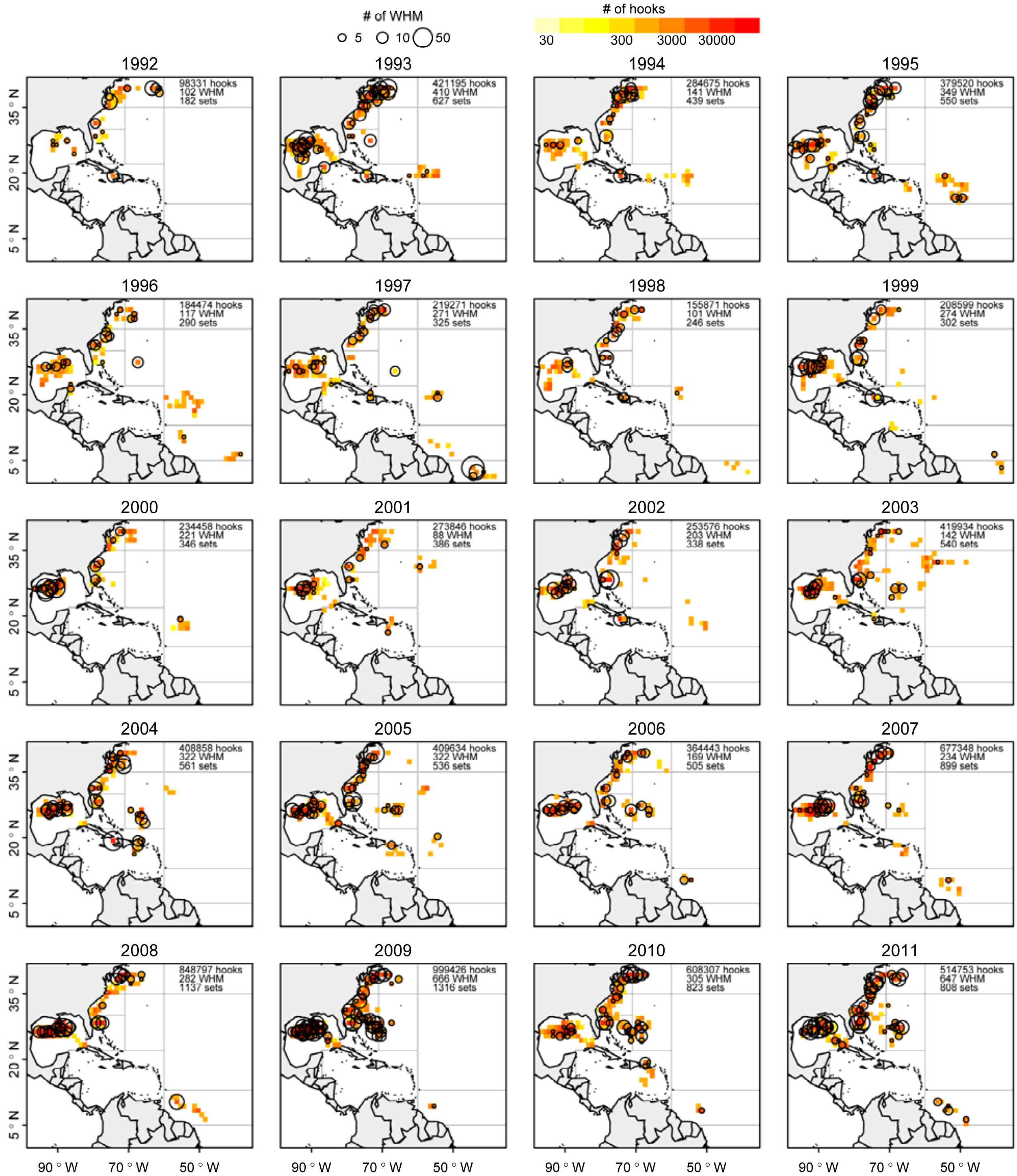

Figure 9. Spatial distribution of catch and effort in the U.S. Pelagic Longline Observer Program for 1992-2011. Cell size is approximately 30 x 30 nautical miles.

Figure 10. Comparison of combined white marlin and roundscale spearfish abundance index based on U.S. Pelagic Longline Observer Program data with previous index based on U.S. pelagic longline fleet logbook data. Dashed lines correspond to upper and lower 95% confidence intervals of the respective standardized CPUE index.

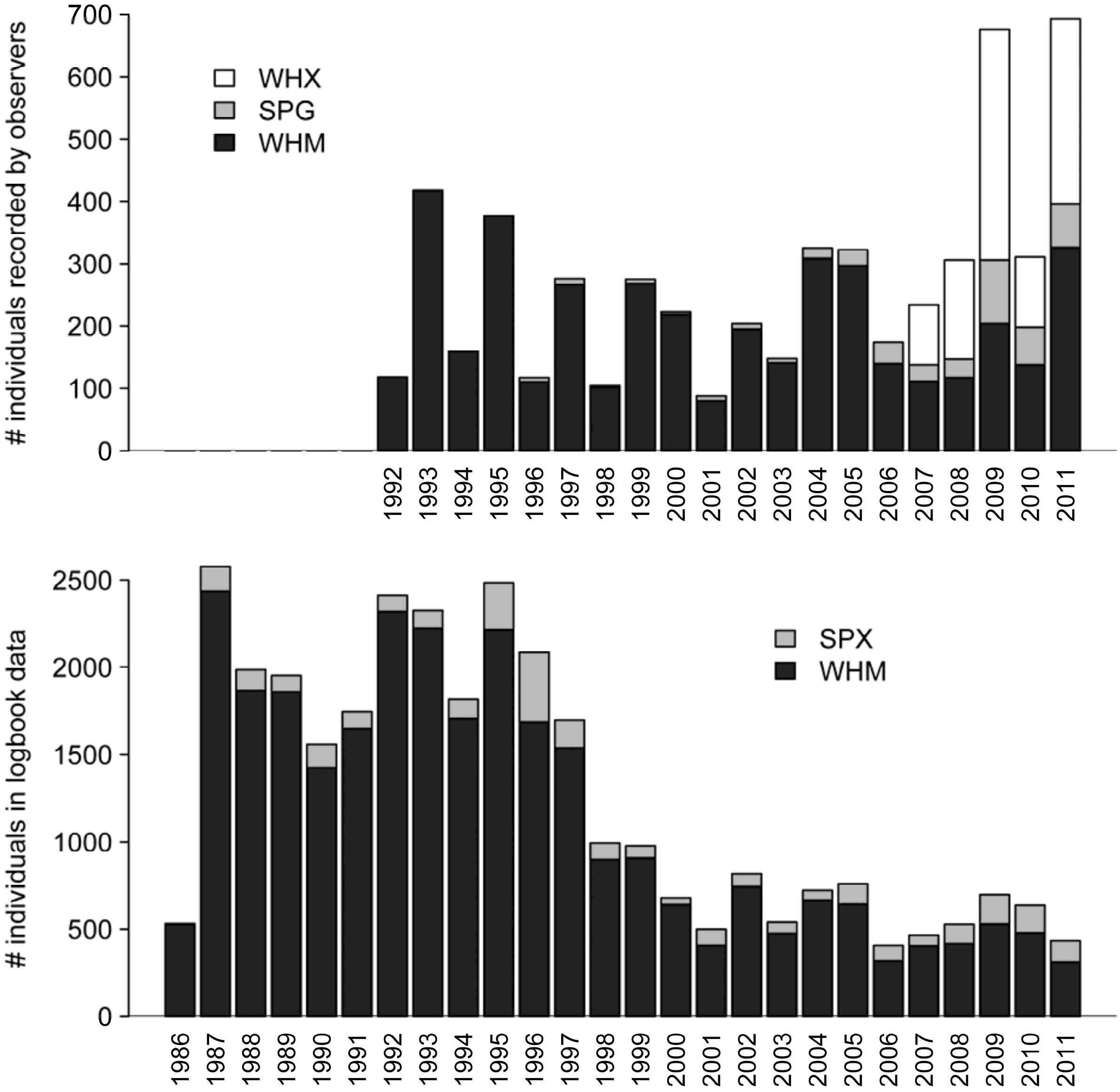

Figure 11. Top: Numbers of observed white marlin (WHM), roundscale spearfish (SPG), and unidentified *Tetrapturus spp*. (WHX) in the U.S. PLOP data by year. Bottom: Numbers of observed white marlin (WHM) and unidentified spearfish (SPX) in the U.S. PLL logbook data by year.