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UPDATE OF STANDARDIZED CATCH RATES OF LARGE BLUEFIN TUNA (*THUNNUS THYNNUS*) FROM THE U.S. PELAGIC LONGLINE FISHERY IN THE GULF OF MEXICO 1987-2013 WITH CORRECTION FOR WEAK HOOK EFFECTS

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SUMMARY

An updated index of abundance of bluefin tuna was constructed from logbook reports from the U.S. pelagic longline fishery in the U.S. Gulf of Mexico for the period 1987-2013. The index is an update of the index presented for the 2012 assessment and subsequently updated at the 2013 Species Group meeting.The index was constructed using vessel as a repeated measure to account for the variance in catch rates within vessels, and was standardized using two stage Generalized Linear Mixed Models with separate binomial and a lognormal models. In 2011 vessels were required to use a weak hook that would bend due to pressure from a large fish as a means of reducing bycatch of bluefin tuna. Extensive experiments have determined that these hooks result in a 46% (23-62%CI) reduction in the catch rates of bluefin tuna. Indices for2011, 2012 and 2013 were adjusted upwards by a factor of 1.108,1.85 and 1.85, respectively to account for this expected reduction in CPUE. Adjusted index values for 2012 were among the highest three in the time series and appear to indicate an increasing CPUE trend in recent years, which would not have been estimated to have been as high in the unadjusted index. However, the index has appeared to decline in the 2013. Due to management actions that appear to be impossible to model, we recommend splitting the index between 1991 and 1992.

RÉSUMÉ

Un indice d'abondance actualisé du thon rouge a été créé à partir des registres des carnets de pêche de la pêcherie palangrière pélagique des États-Unis opérant dans le golfe du Mexique au cours de la période 1987-2013. Il s'agit d'une actualisation de l'indice présenté pour l'évaluation de 2012 et ultérieurement actualisé à la réunion de 2013 du Groupe d'espèces. L'indice a été élaboré en utilisant le navire comme une mesure répétée pour tenir compte de la variance dans les taux de capture entre les navires, et il a été standardisé au moyen de modèles linéaires généralisés mixtes en deux étapes avec des modèles séparés binomiaux et lognormaux. En 2011, les navires ont dû utiliser un hameçon "faible" qui se plierait avec la pression exercée par un gros poisson comme moyen de réduire les prises accessoires de thon rouge. Des expériences à grande échelle ont démontré que ces hameçons entraînent une réduction de 46% (CI de 23-62%) des taux de capture du thon rouge. Les indices de 2011, 2012 et 2013 ont été ajustés à la hausse par un facteur de 1,108, 1,85 et 1,85, respectivement afin de tenir compte de cette réduction escomptée dans la CPUE. Les valeurs des indices ajustés pour 2012 étaient parmi les trois plus élevées dans les séries temporelles et elles semblent indiquer une tendance ascendante de la CPUE au cours de ces dernières années, laquelle n'aurait pas été estimée avoir été aussi élevée dans l'indice non ajusté. Toutefois, l'indice semblait avoir chuté en 2013. En raison des mesures de gestion qui semblent impossible à modéliser, nous recommandons de diviser l'indice entre 1991 et 1992.

RESUMEN

Se calculó un índice de abundancia actualizado de atún rojo a partir de los informes de los cuadernos de pesca de la pesquería palangrera pelágica estadounidense en el golfo de México estadounidense para el periodo 1987-2013. El índice es una actualización del índice presentado para la evaluación de 2012 y posteriormente actualizado en la reunión del Grupo de especies de 2013. El índice se obtuvo utilizando los buques como una medida repetida para tener en cuenta la variación en las tasas de capturas entre los buques, y se estandarizó

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mediante modelos lineales mixtos generalizados con modelos separados, binomial y lognormal. En 2011, se requirió a los buques que utilizasen un anzuelo más flojo diseñado para doblarse por la presión de un ejemplar grande, como medio para reducir la captura fortuita de atún rojo. Los amplios experimentos han determinado que estos anzuelos tienen como resultado una reducción del 46% (23-62% CI) en las tasas de captura de atún rojo. Los índices para 2011, 2012 y 2013 se ajustaron al alza con factores de 1,108; 1,85 y 1,85, respectivamente, para tener en cuenta esta reducción prevista en la CPUE. Los valores de los índices ajustados para 2012 se situaron entre los tres índices más elevados de la serie temporal, y parecen indicar un incremento en la CPUE en los últimos años que no se había estimado que fuera tan elevado en el índice sin ajustar. Sin embargo, el índice parece haber descendido en 2013. Debido a las acciones de ordenación que parecen ser imposibles de modelar, recomendamos separar el índice entre 1991 y 1992.

KEYWORDS

Catch/effort, Abundance, Commercial longline, Bluefin tuna

Introduction

This paper is an update of an index constructed from the US pelagic longline fishery in the Gulf of Mexico obtained from vessel logbooks. It is constructed with the same delta-lognormal model as Cass-Calay & Walter (2013) but with data updated through 2013.

The U.S. longline fishery primarily targets swordfish and yellowfin tunas and Bluefin tuna are considered incidental bycatch. Previous studies have used logbook data from this fishery to construct catch rate indices for the western stock of Atlantic bluefin (Cramer and Ortiz 2000; Cramer 2002; Cass-Calay 2007; Diaz and Cass-Calay 2009, Cass-Calay 2011). This indexwas used in the most recent (2014) assessment of Atlantic bluefin tuna.

1. Materials and methods

Data used in this paper come from vessel logbook data from the US Pelagic longline fishery operating in the US Gulf of Mexico. The main features of the U.S. pelagic longline fleet are described by Hoey and Bertolino (1988). Logbook records have beencollected since 1986. Each logbook record contains trip information by fishing day or set, including: vessel ID, date and time, fishing location, catch in numbers and fishing effort (hooks per set). The majority of records describe a unique longline set, other types of records (fishing day) were excluded from the analysis. Because very few sets were reported in 1986, records from 1986 were excluded.

This index is intended to reference the spawning stock biomass of western bluefin tuna. Therefore, to minimize inclusion of effort targeting species unlikely to co-occur with bluefin tuna and/or effort targeting bluefin tuna outside of the spawning period, the analysis dataset was restricted to sets occurring in the Gulf of Mexico (GOM) from January 1 to May 31 of each year.Vessels were included in the analysis if they caught, released or discarded at least one Bluefin tuna during two or more years of the time series (N = 180). Sets from the Desoto closed area were removed prior to and post closure. Data exclusions exactly followed the previous index and data from pre-2010 was exactly the same as this index. An additional data exclusion was to exclude trips for vessels that were fishing as part of an experimental project, which occurred for a few trips from 2008-2012.

In this paper we use the same delta-lognormal model as in Cass-Calay & Walter (2013) and do not update model factors. The model uses a repeated measures approach where the variance in catch rates, by vessel, was modeled using "repeated measures" within the SAS PROC MIXED procedure (Littell *et al*., 1998). The two models used are shown, below:

PROPORTION POSITIVE SETS = YEAR + ZONE + MONTH + ZONE*MONTH + *YEAR*MONTH* + *YEAR*ZONE*

LOG(CPUE) = YEAR + MONTH + ZONE
+ the effect of the repeated measure VESSEL_ID with the covariance structure VESSEL_ID(YEAR)

Where italicized year*factor interaction were modeled as random effects. Parameterization of each model was accomplished using the GLIMMIX procedure for the proportion positive and Proc Mixed for the log(CPUE) (Version 8.02 of the SAS System for Windows © 2000. SAS Institute Inc. Cary, NC, USA). For the lognormal models, the response variable, log(CPUE), was calculated as:

log(CPUE) = log(Number of Bluefin Tuna kept and discarded / 1000 Hooks)

Following exclusions, the dataset contained 38, 576 records from 1987 through 2013. Of these, 4,161 (10.6%) reported catching bluefin tuna (landed, discarded or released).

Correcting for the effects of circle hooks on commercial catch rates

The mandatory use of 'weak' hooks in the Gulf of Mexico beginning on May 5, 2011 was designed to reduce discards of bluefin tuna. The weak hook model and make is Mustad 39988. Prior to and after implementation of this rule, NOAA Fisheries conducted extensive experimental trials to determine the effectiveness of the weak hooks at reducing the incidental capture of Bluefin tuna. The results of these trials indicate a 46% (23-62% 95CI) reduction in the catch rates of bluefin tuna (Foster and Bergmann 2012). Hence it is necessary to adjust the commercial longline CPUE to account for this reduction in catch rate. Converting the estimated decrease in catch rate to a factor to be multiplied by each index gives a factor of 1.85= (1/(1-0.46)). For the year 2011 only 20% of the correction was applied which resulted in a factor of 1/(1-0.46*0.2) = 1.101.
To make this correction it was necessary to make several assumptions:

1. Weak hook effect is knife-edged starting in May 5, 2011. No weak hooks in fishery prior to this time and then 100% compliance after.
2. To account for the implementation in May 5, 2011, 20% of the correction was applied in 2011 as the index is calculated for months January-May.
3. The resulted in the index values being increased by a factor of 1.101, 1.85and 1.85 in 2011, 2012 and 2013, respectively.

To account for the variance of the estimate of the weak hook effect the variance of the corrected index was the calculated from the product of two random variables (eq 5, Goodman 1960):

$$v(xy) = v(x) * x^2 + v(y) * y^2 - v(y) * v(x)$$

Where *x* is the index for a given year, *v(x)* is the estimated variance of the index, *y* is the weak hook effect value and *v(y)* is the estimated variance of the correction.

To estimate *v(y)*, the variance of the correction factor we used the delta method approximation given in Zhou (2002) for the function *y*=1/*k*. We let *k* =(1-*c*) and *c* is the estimated percentage reduction in catch rate which had an estimated variance of 0.01 (Foster and Bergmann 2012). The variable *k* has the same variance as c, 0.01, and an estimated value of 0.54. Then the delta approximation for the $\hat{v}(y)$ is given by (Zhou 2002):

$$\hat{v}(y) = v(k)/\bar{k}^4$$

Hence the variance of the correction factor to be applied for increase of 1.85 is 0.117605. For the increase of 1.101 the variance is 0.00059.

2. Results and Discussion

Overall the index and index diagnostics are almost exactly the same as in previous iterations of this index. Diagnostic plots show almost the same results as Cass-Calay & Walter (2013) for the dependent variables (**Figure 2**), the proportion positive (**Figure 3**) and for the lognormal component (**Figure 4**). The index for the time period 1987-2010 was exactly the same as in Cass-Calay & Walter (2013) (**Table 4, Figure 5**).

As noted in Walter and Calay (2014) there have been numerous management actions (**Figure 6**) that may have altered fisher behavior and hence influenced this index The primary concern with this index as documented in Walter and Cass-Calay (2014) is the precipitous drop between the 1987-1991 time period and 1992-present (**Figure 5**) that was likely induced by the change to one fish per trip regulation. Numerous attempts at data subsetting, such as selecting only vessels that fished after the regulation, only vessels that reported discards during the entire time period, or only reported discards after 1992 were attempted to account for changes that may have occurred during this time period. Also we tried several methods of incorporating environmental or gear charateristics that might have beenindicative of a shift in targeting, yet none of these (water temperature, depth of water, hooks between floats, light sticks or hooks per set as a catergorical variable) could reconcile the magnitude of the CPUE in the two time periods. Given that we could not find any data subsetting, or environmental or targeting factors that could account for the full magnitude of the drop between 1991 and 1992 and hence facilitate modeling this time period, we recommend that the best course of action is to break the index. This will result in two separate indices (**Figure 7**) for the VPA.

Overall, accounting for the effects of the weak hooks increases the index and slightly expands the confidence intervals of the index values. The effect of the weak hooks was estimated to be quite substantial and there were reports of substantial numbers of bent and straightened hooks during the 2012 and 2013 fishing season, presumably due to Bluefin tuna. **Figure 8** shows the nominal CPUE from fishery observers and estimates of the number of bent hooks per thousand hooks set. Overall the index has shown a mostly steady increase during the second time period (1992-present) however, the 2013 data point has decreased from 2012, coinciding also with a drop in the bent hook ratio.

In the 2012 assessment, the year 2011 was removed from the index so the index only was through 2010 as it was unknown how the effects that the Deep Water Horizon oil spill that began in the Gulf of Mexico on April 20, 2010 and subsequent fishery closures and fishery disruptions may have affected fishing effort. In 2011 the U.S. longline fleet operated differently from previous years in that only 16 of the sets that met the filtering criteria (**Table 3**) caught bluefin tuna, and these were limited to vessels targeting swordfish in the southeastern part of the Gulf of Mexico which historically have low CPUE of bluefin tuna. There is substantial divergence from the low nominal values, indicating that the GLM modeling approach that uses zone and month as factors is accounting partially for the absence of full data in that year.

We note also that there are other important management actions that may have affected this index and that these should carefully be considered in future analyses. We note, however that the trend in this index largely reflects the trend in the nominal CPUE from the observer data (**Figure 8**) which provides some confirmation that the logbook reported rates reflect observed catch rates. Currently the observer data has an average of 90 sets for the spawning period in the Gulf of Mexico during 1993-2002; and average 363 sets after this time period. Hence, in future assessments, it may be possible to develop an observer based index as there will be enough years with high sample sizes.

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Table 1. Fixed effects for the binomial submodel.

Solution for Fixed Effects											
Effect	**YR**	**MON**	**ZONE**	**Est**	**SE**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Intercept				-3.155	0.433	51	-7.29	<.0001	0.05	-4.024	-2.286
YEAR	**1987**			1.657	0.532	51	3.12	0.003	0.05	0.5895	2.725
YEAR	**1988**			0.759	0.531	51	1.43	0.1591	0.05	-0.307	1.825
YEAR	**1989**			1.038	0.527	51	1.97	0.0542	0.05	-0.019	2.096
YEAR	**1990**			0.851	0.533	51	1.6	0.1163	0.05	-0.218	1.921
YEAR	**1991**			1.460	0.531	51	2.75	0.0082	0.05	0.3945	2.526
YEAR	**1992**			0.336	0.544	51	0.62	0.5398	0.05	-0.756	1.427
YEAR	**1993**			0.135	0.552	51	0.25	0.8073	0.05	-0.972	1.243
YEAR	**1994**			-0.115	0.568	51	-0.2	0.8399	0.05	-1.255	1.025
YEAR	**1995**			-0.140	0.568	51	-0.25	0.8061	0.05	-1.28	1
YEAR	**1996**			-0.621	0.571	51	-1.09	0.2814	0.05	-1.767	0.524
YEAR	**1997**			-0.169	0.548	51	-0.31	0.7599	0.05	-1.269	0.932
YEAR	**1998**			-0.096	0.554	51	-0.17	0.8636	0.05	-1.208	1.017
YEAR	**1999**			0.471	0.531	51	0.89	0.3791	0.05	-0.595	1.537
YEAR	**2000**			0.773	0.534	51	1.45	0.1539	0.05	-0.299	1.846
YEAR	**2001**			0.225	0.561	51	0.4	0.6896	0.05	-0.901	1.351
YEAR	**2002**			0.193	0.569	51	0.34	0.7353	0.05	-0.949	1.335
YEAR	**2003**			0.749	0.531	51	1.41	0.1645	0.05	-0.317	1.815
YEAR	**2004**			0.784	0.533	51	1.47	0.1472	0.05	-0.285	1.853
YEAR	**2005**			0.475	0.538	51	0.88	0.3817	0.05	-0.606	1.556
YEAR	**2006**			0.159	0.567	51	0.28	0.78	0.05	-0.979	1.297
YEAR	**2007**			0.247	0.562	51	0.44	0.662	0.05	-0.881	1.375
YEAR	**2008**			1.101	0.543	51	2.03	0.048	0.05	0.0101	2.191
YEAR	**2009**			0.949	0.554	51	1.71	0.093	0.05	-0.164	2.062
YEAR	**2010**			0.891	0.543	51	1.64	0.107	0.05	-0.199	1.98
YEAR	**2011**			0.397	0.627	51	0.63	0.5302	0.05	-0.863	1.656
YEAR	**2012**			1.248	0.545	51	2.29	0.0261	0.05	0.1544	2.341
YEAR	**2013**			0.000	.	.	.	.	.	.	.
MONTH		**1**		-1.800	0.337	104	-5.35	<.0001	0.05	-2.467	-1.132
MONTH		**2**		-0.991	0.261	104	-3.8	0.0002	0.05	-1.508	-0.474
MONTH		**3**		-0.934	0.247	104	-3.77	0.0003	0.05	-1.424	-0.443
MONTH		**4**		0.016	0.220	104	0.07	0.9426	0.05	-0.421	0.453
MONTH		**5**		0.000	.	.	.	.	.	.	.
ZONE			**1**	-0.880	0.348	51	-2.53	0.0144	0.05	-1.578	-0.183
ZONE			**2**	0.591	0.161	51	3.66	0.0006	0.05	0.2672	0.915
ZONE			**3**	0.000	.	.	.	.	.	.	.
MONTH*ZONE		**1**	**1**	2.388	0.461	195	5.18	<.0001	0.05	1.478	3.298
MONTH*ZONE		**1**	**2**	0.597	0.313	195	1.91	0.0578	0.05	-0.02	1.214

MONTH*ZONE	**1**	**3**	0.000	.	.	.	.	.	.	.
MONTH*ZONE	**2**	**1**	1.970	0.413	195	4.78	<.0001	0.05	1.1567	2.784
MONTH*ZONE	**2**	**2**	0.582	0.228	195	2.55	0.0114	0.05	0.1325	1.031
MONTH*ZONE	**2**	**3**	0.000	.	.	.	.	.	.	.
MONTH*ZONE	**3**	**1**	2.053	0.403	195	5.09	<.0001	0.05	1.2582	2.849
MONTH*ZONE	**3**	**2**	1.053	0.211	195	5	<.0001	0.05	0.638	1.468
MONTH*ZONE	**3**	**3**	0.000	.	.	.	.	.	.	.
MONTH*ZONE	**4**	**1**	1.130	0.403	195	2.8	0.0056	0.05	0.3351	1.925
MONTH*ZONE	**4**	**2**	0.458	0.178	195	2.58	0.0107	0.05	0.1076	0.809
MONTH*ZONE	**4**	**3**	0.000	.	.	.	.	.	.	.
MONTH*ZONE	**5**	**1**	0.000	.	.	.	.	.	.	.
MONTH*ZONE	**5**	**2**	0.000	.	.	.	.	.	.	.
MONTH*ZONE	**5**	**3**	0.000	.	.	.	.	.	.	

Table 2. Fixed effects for the lognormal submodel.

Solution for Fixed Effects											
Effect	**YEAR**	**ZONE**	**MONTH**	**EST**	**SE**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Intercept				0.704	0.092	967	7.69	<.0001	0.05	0.525	0.884
YEAR	**1987**			0.537	0.102	967	5.25	<.0001	0.05	0.336	0.737
YEAR	**1988**			0.605	0.103	967	5.87	<.0001	0.05	0.403	0.808
YEAR	**1989**			0.787	0.102	967	7.72	<.0001	0.05	0.587	0.987
YEAR	**1990**			0.712	0.105	967	6.78	<.0001	0.05	0.506	0.917
YEAR	**1991**			0.680	0.101	967	6.72	<.0001	0.05	0.481	0.878
YEAR	**1992**			0.293	0.102	967	2.87	0.004	0.05	0.092	0.494
YEAR	**1993**			-0.089	0.112	967	-0.8	0.425	0.05	-0.309	0.130
YEAR	**1994**			-0.157	0.113	967	-1.39	0.166	0.05	-0.378	0.065
YEAR	**1995**			-0.189	0.121	967	-1.56	0.118	0.05	-0.426	0.048
YEAR	**1996**			-0.262	0.116	967	-2.26	0.024	0.05	-0.490	-0.034
YEAR	**1997**			-0.097	0.121	967	-0.8	0.424	0.05	-0.334	0.141
YEAR	**1998**			-0.101	0.120	967	-0.84	0.402	0.05	-0.335	0.135
YEAR	**1999**			-0.112	0.108	967	-1.04	0.3	0.05	-0.324	0.100
YEAR	**2000**			-0.011	0.106	967	-0.11	0.915	0.05	-0.220	0.197
YEAR	**2001**			-0.061	0.112	967	-0.54	0.59	0.05	-0.281	0.160
YEAR	**2002**			-0.095	0.111	967	-0.86	0.389	0.05	-0.313	0.122
YEAR	**2003**			-0.024	0.106	967	-0.23	0.819	0.05	-0.231	0.183
YEAR	**2004**			-0.159	0.105	967	-1.51	0.131	0.05	-0.365	0.047
YEAR	**2005**			-0.149	0.108	967	-1.38	0.168	0.05	-0.360	0.063
YEAR	**2006**			-0.199	0.122	967	-1.64	0.102	0.05	-0.437	0.040
YEAR	**2007**			0.000	0.111	967	0	0.998	0.05	-0.217	0.217
YEAR	**2008**			0.035	0.111	967	0.32	0.751	0.05	-0.183	0.254
YEAR	**2009**			-0.006	0.116	967	-0.05	0.957	0.05	-0.233	0.221
YEAR	**2010**			-0.126	0.114	967	-1.1	0.272	0.05	-0.350	0.099
YEAR	**2011**			0.151	0.191	967	0.79	0.428	0.05	-0.223	0.526
YEAR	**2012**			-0.037	0.109	967	-0.34	0.735	0.05	-0.251	0.177
YEAR	**2013**			0.000	.	.	.	.	.	.	.
MONTH			**1**	-0.215	0.032	1049	-6.68	<.0001	0.05	-0.279	-0.152
MONTH			**2**	-0.164	0.026	1049	-6.19	<.0001	0.05	-0.215	-0.112
MONTH			**3**	-0.069	0.024	1049	-2.94	0.003	0.05	-0.115	-0.023
MONTH			**4**	0.034	0.022	1049	1.55	0.122	0.05	-0.009	0.077
MONTH			**5**	0.000	.	.	.	.	.	.	.
ZONE		**1**		-0.239	0.046	195	-5.18	<.0001	0.05	-0.330	-0.148
ZONE		**2**		-0.180	0.032	195	-5.67	<.0001	0.05	-0.243	-0.117
ZONE		**3**		0.000	.	.	.	.	.	.	.

Table 3. Table of sets, hooks, number of positive sets and number of BFT (sum of kept and discarded) from logbook data in the Gulf of Mexico from sets that met inclusion criteria. Not that these numbers may differ from official U.S. reports.

Year	*Sets*	*Hooks*	*POS*	*BFT (kept + discarded)*	*BFT Discards*
1987	1499	806552	293	491	307
1988	1796	942441	213	298	70
1989	1802	775367	218	400	265
1990	1455	657088	188	262	88
1991	1300	606141	309	471	112
1992	1750	1032910	206	279	114
1993	1162	864111	90	113	30
1994	1081	801206	83	112	34
1995	1214	901175	63	80	9
1996	1472	1077716	68	72	15
1997	1407	1030980	53	65	23
1998	1287	1022432	67	97	57
1999	1825	1430720	160	227	128
2000	1715	1319163	167	400	297
2001	1418	1056371	124	166	93
2002	1557	1211882	142	198	116
2003	1881	1429509	212	313	201
2004	2149	1645196	303	431	228
2005	2127	1672806	196	267	109
2006	1070	816436	81	100	53
2007	1447	1095130	164	233	141
2008	1072	828780	175	324	233
2009	1152	891777	152	246	155
2010	1169	886793	130	180	117
2011	296	160085	16	22	11
2012	1337	1003367	174	217	102
2013	1136	803799	60	79	43

Table 4. Table of number of nominal and standardized index of Bluefin CPUE from US pelagic longline index in the Gulf of Mexico.Shaded values are the index time period 1987-1991 which was split from the time period 1992-2013 Values in italics received adjustment for circle hook implementation. Normalized index values are scaled to a mean of one for each time period.

Year	*Nsets*	*Nominal CPUE*	*% pos*	*std cpue*	*LCI*	*UCI*	*Corrected for circle hook effect (Normalized index)*	*cv, post circle hook*	*std LCI*	*std UCI*	*Adjustment factor*
1987	1499	2.63	20%	3.39	1.90	6.06	1.32	0.30	0.738	2.360	1
1988	1796	1.50	12%	1.63	0.87	3.07	0.64	0.32	0.338	1.196	1
1989	1802	2.06	12%	2.53	1.38	4.64	0.99	0.31	0.538	1.806	1
1990	1455	1.75	13%	1.98	1.05	3.72	0.77	0.32	0.410	1.449	1
1991	1300	3.59	24%	3.31	1.83	5.97	1.29	0.30	0.713	2.325	1
1992	1750	1.27	12%	0.80	0.41	1.59	1.12	0.35	0.568	2.217	1
1993	1162	0.55	8%	0.45	0.22	0.92	0.63	0.37	0.310	1.289	1
1994	1081	0.52	8%	0.33	0.16	0.71	0.46	0.39	0.217	0.992	1
1995	1214	0.31	5%	0.31	0.15	0.67	0.44	0.40	0.204	0.941	1
1996	1472	0.24	5%	0.18	0.08	0.40	0.25	0.40	0.117	0.554	1
1997	1407	0.25	4%	0.33	0.16	0.68	0.47	0.37	0.229	0.952	1
1998	1287	0.34	5%	0.36	0.17	0.74	0.50	0.37	0.242	1.032	1
1999	1825	0.60	9%	0.61	0.32	1.16	0.85	0.33	0.447	1.618	1
2000	1715	1.20	10%	0.89	0.47	1.70	1.25	0.33	0.656	2.376	1
2001	1418	0.72	9%	0.51	0.24	1.06	0.71	0.38	0.339	1.480	1
2002	1557	0.78	9%	0.48	0.22	1.01	0.66	0.39	0.312	1.414	1
2003	1881	0.80	11%	0.86	0.46	1.62	1.21	0.32	0.640	2.270	1
2004	2149	0.92	14%	0.78	0.41	1.47	1.09	0.33	0.575	2.057	1
2005	2127	0.59	9%	0.59	0.30	1.15	0.82	0.34	0.423	1.603	1
2006	1070	0.44	8%	0.41	0.19	0.88	0.58	0.39	0.271	1.234	1
2007	1447	0.80	11%	0.55	0.26	1.15	0.77	0.38	0.368	1.608	1
2008	1072	1.51	16%	1.26	0.66	2.43	1.76	0.34	0.917	3.394	1
2009	1152	1.01	13%	1.05	0.53	2.11	1.47	0.36	0.736	2.952	1
2010	1169	0.80	11%	0.89	0.46	1.73	1.24	0.34	0.638	2.411	1
2011	296	0.53	5%	0.73	0.29	1.82	*1.12*	*0.48*	*0.450*	*2.799*	*1.10*
2012	1337	0.91	13%	1.34	0.70	2.56	*3.47*	*0.38*	*1.674*	*7.178*	*1.85*
2013	1136	0.38	5%	0.43	0.20	0.94	*1.12*	*0.44*	*0.487*	*2.584*	*1.85*

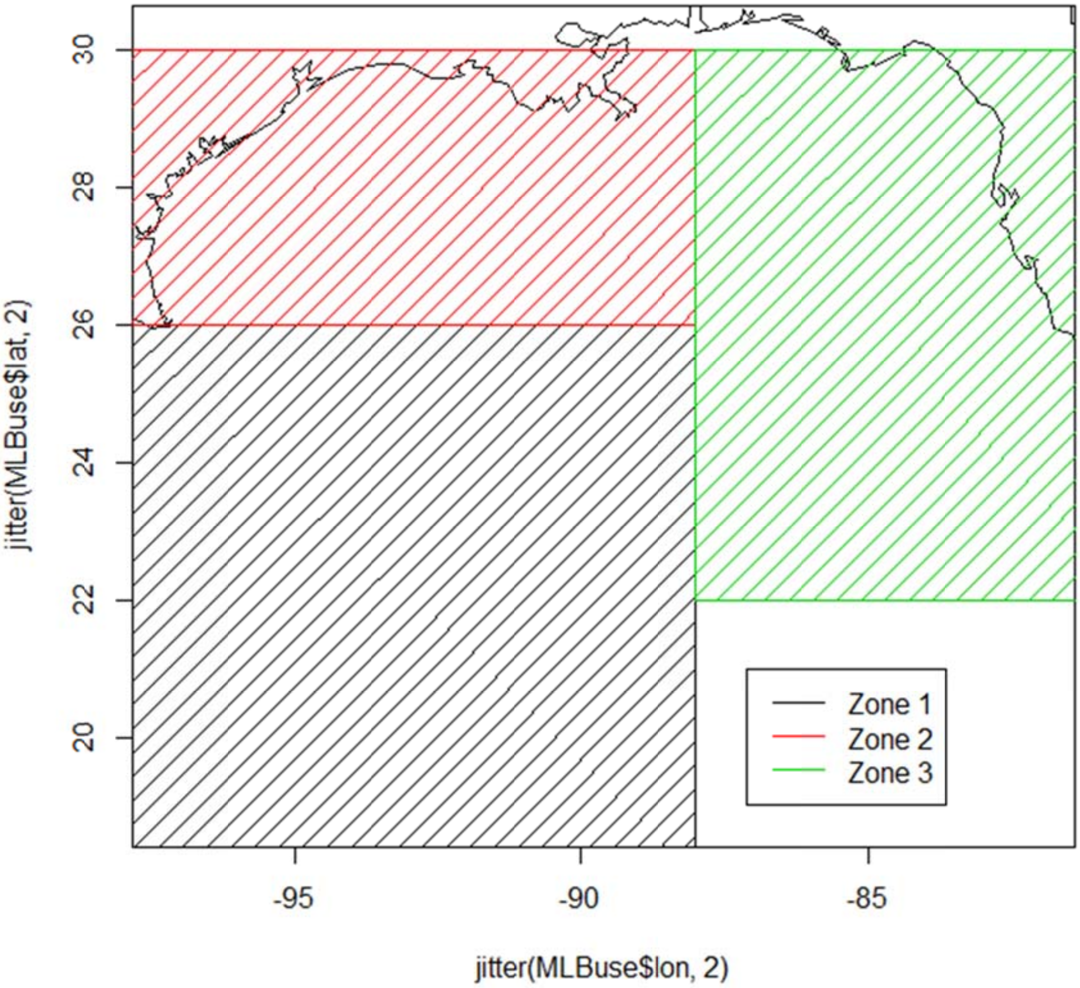

Figure 1. Plot showing spatial areas for modeling of pelagic longline fishing in the Gulf of Mexico.

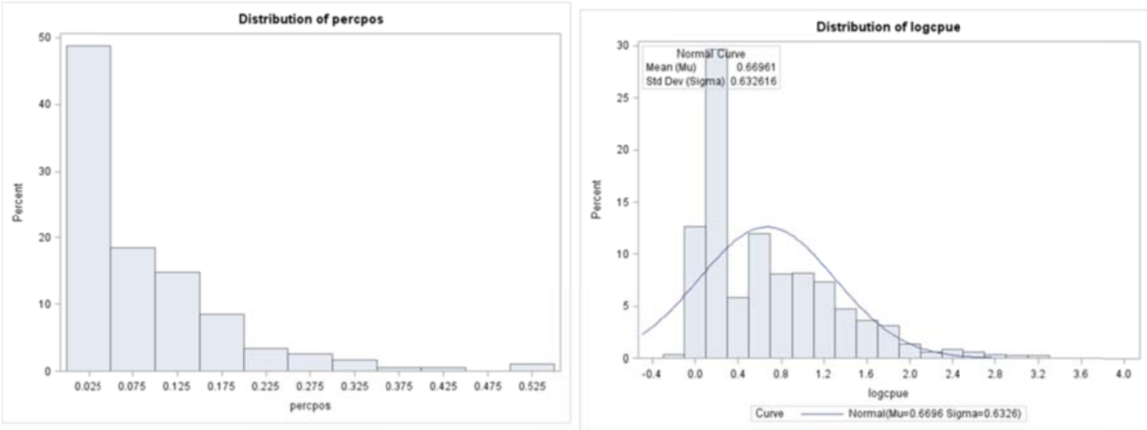

Figure 2. Distribution of proportion positive trips and histogram of log(CPUE).

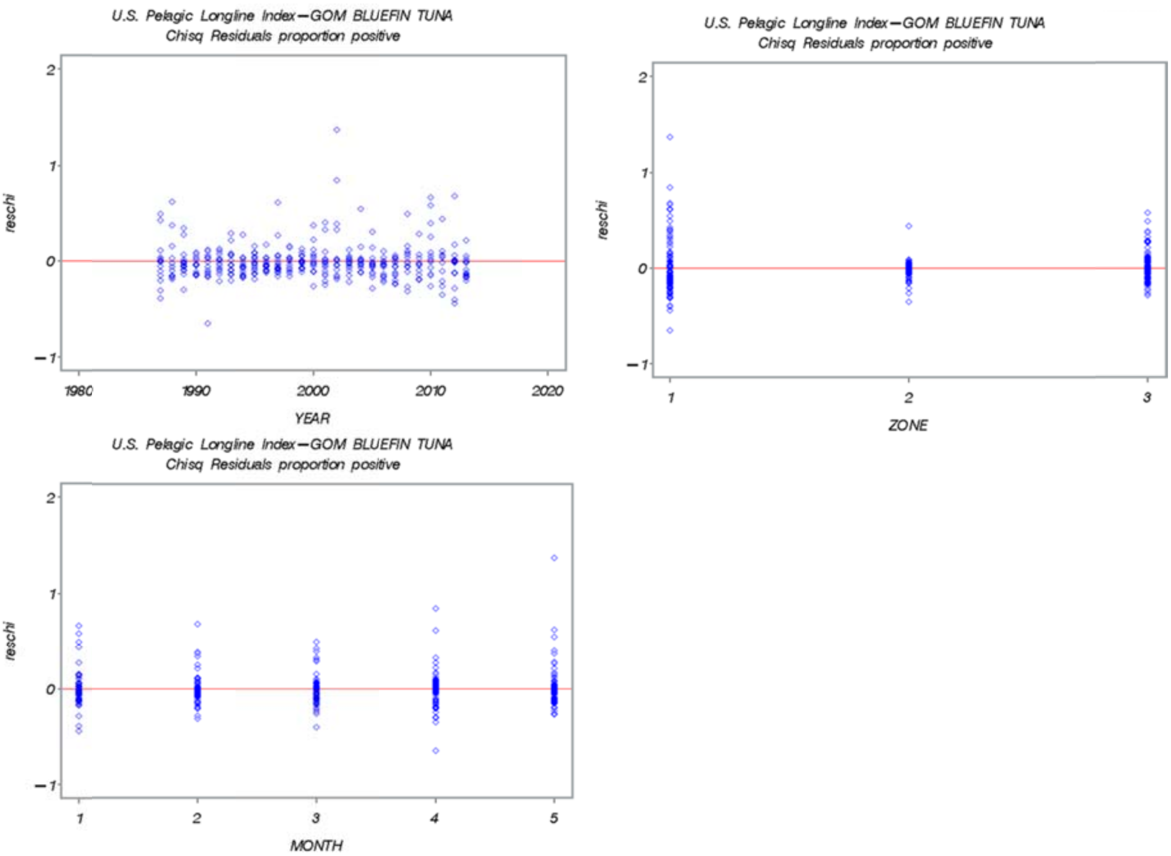

Figure 3. Chi-square residuals by year, zone and month for proportion positive.

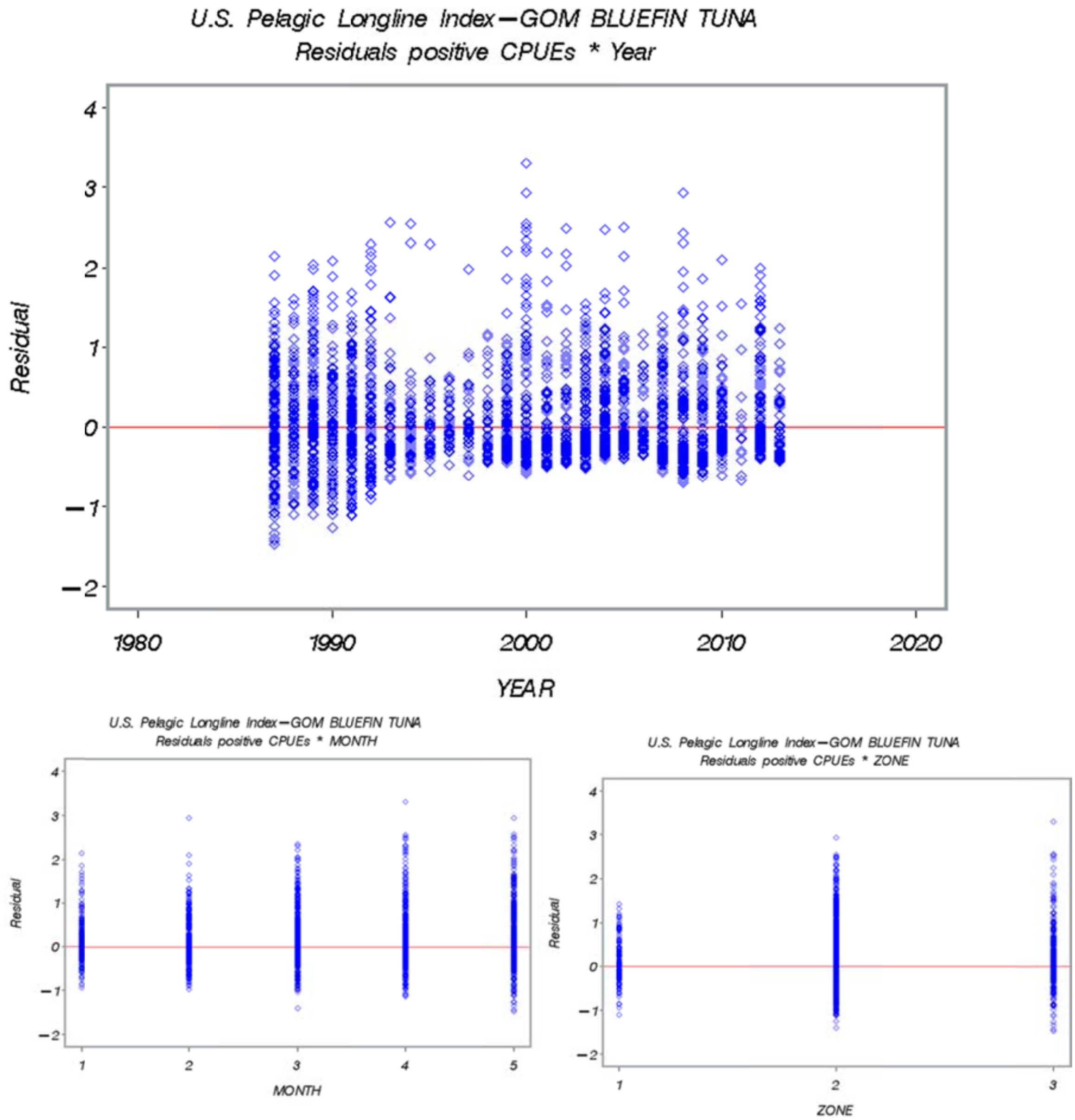

Figure 4. Chi-square residuals by year, zone and month for log(CPUE).

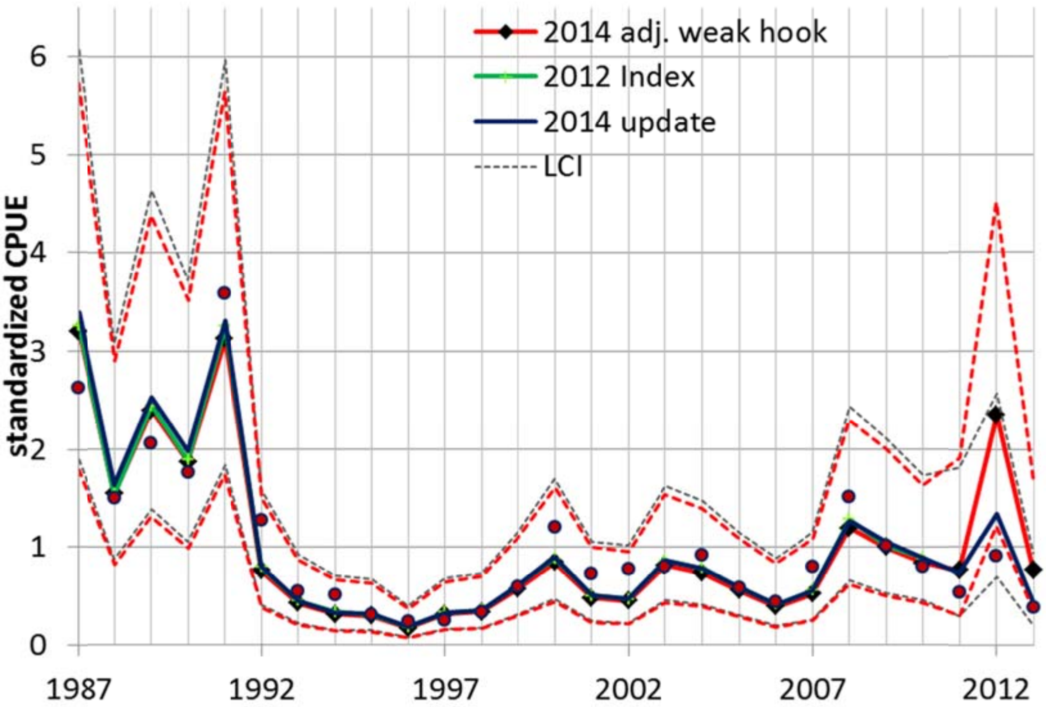

Figure 5. Standardized updated index with 2012 index for reference and index adjusted for weak hook effects in 2011, 2012 and 2013.

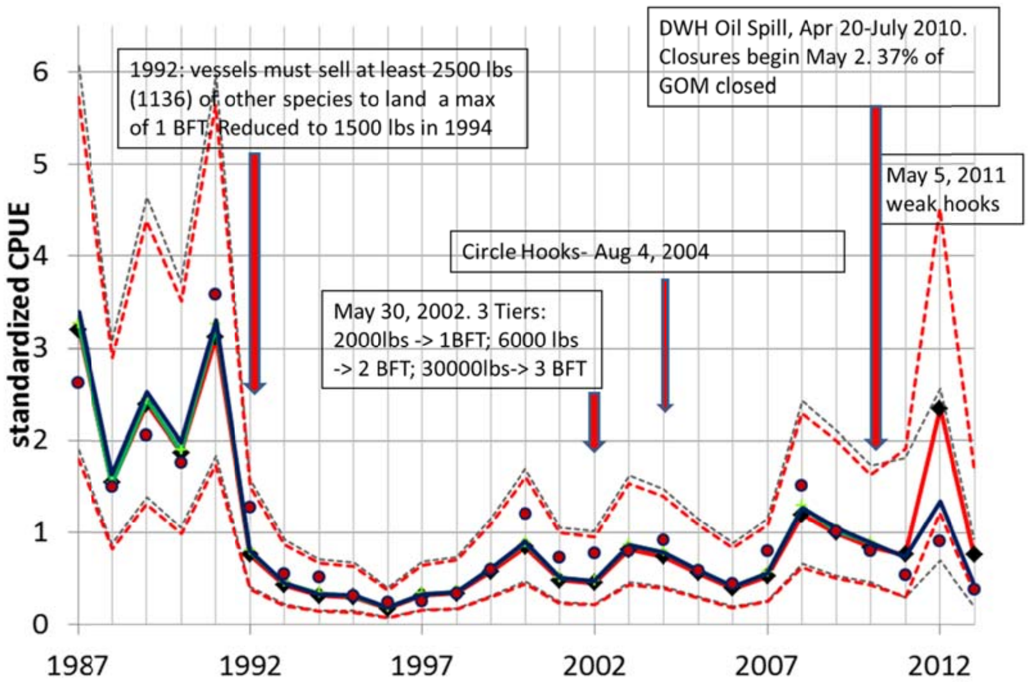

Figure 6. Standardized index and management measures or other factors that may influence catch rates.

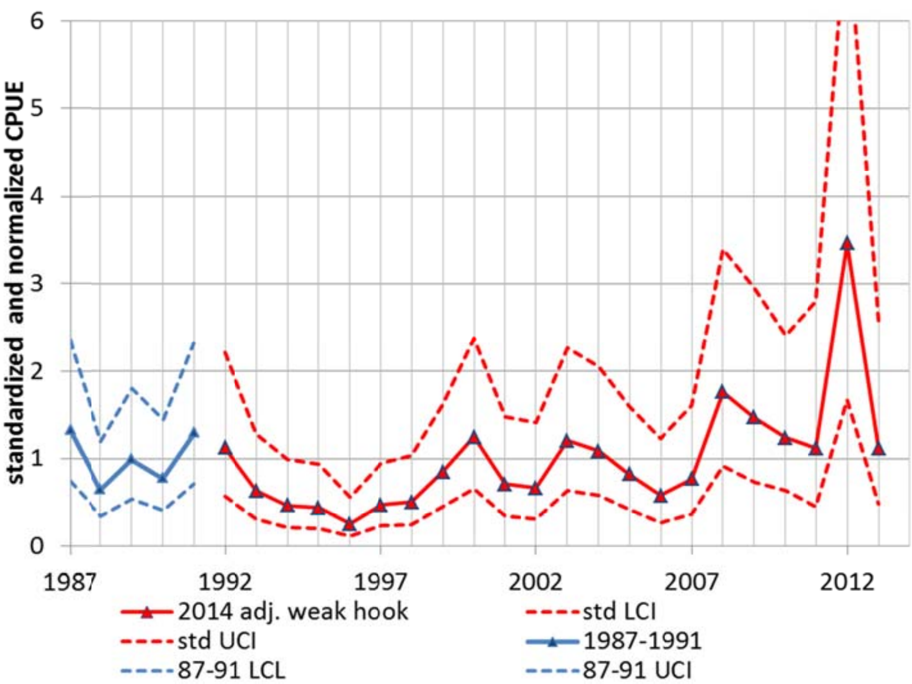

Figure 7. Proposed break in index in 1991. This figure shows the index for the two time periods (1987-1991 and 1992-2013), each normalized to a mean of one.

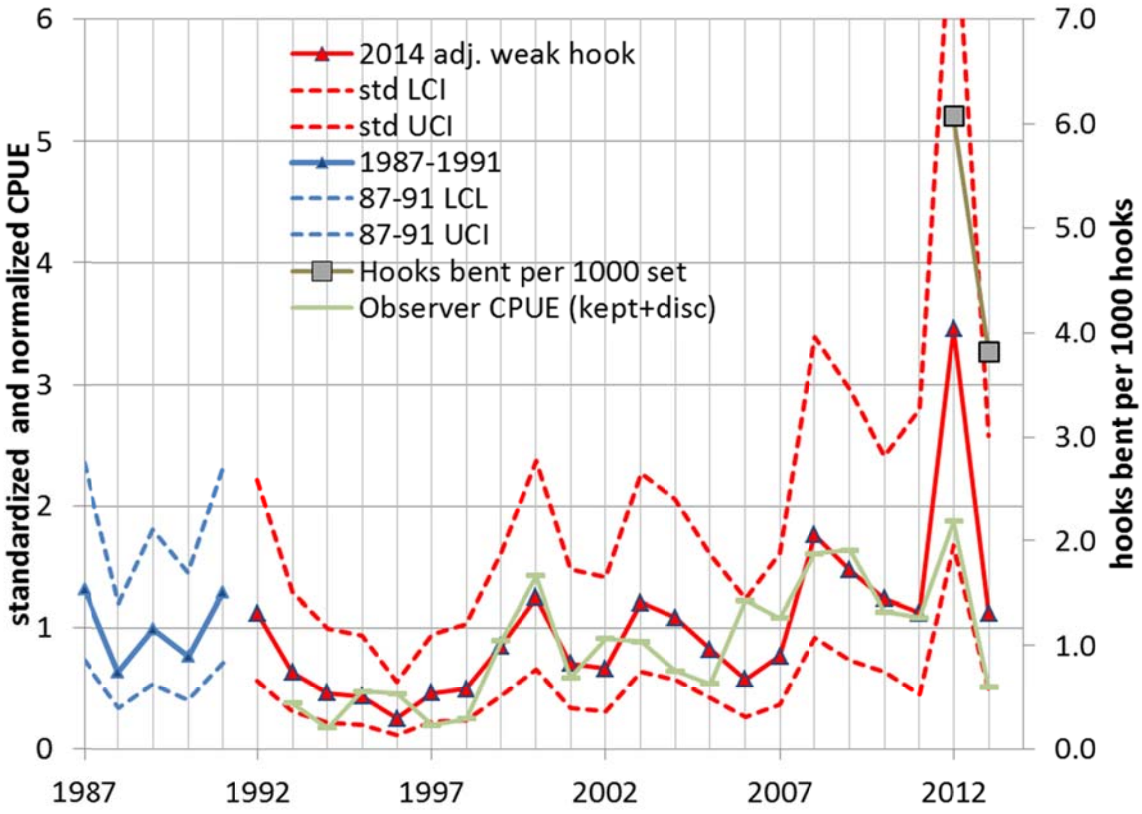

Figure 8. 2014 logbook index with nominal observer CPUE and bent hook ratio (hooks bent per 1000 hooks set) from observer records.

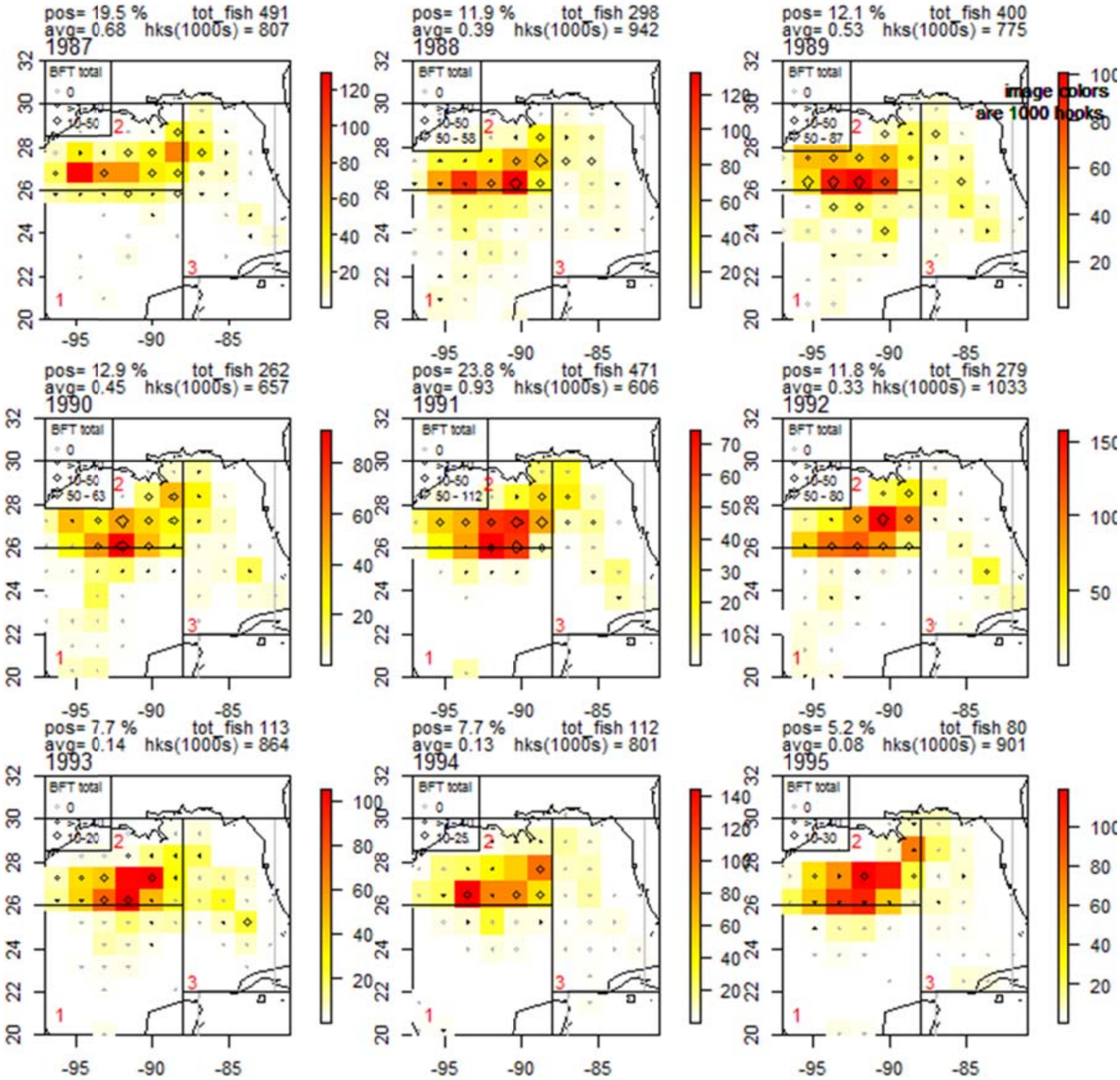

Figure 9. Plots of US pelagic longline catch, CPUE, and effort for the analysis dataset used for the index (Gulf of Mexico records Jan 1-May 31, selected vessels). Summed catch (kept+discards) by cell are shown as diamonds andsummed effort is shaded. All catch and effort are aggregatedto grid cells to preserve data confidentiality.The red numbers on the plots refer to each zone. Notes labeled 'pos' are the nominal % positive and "avg" is the nominal CPUE in BFT/1000 hooks.

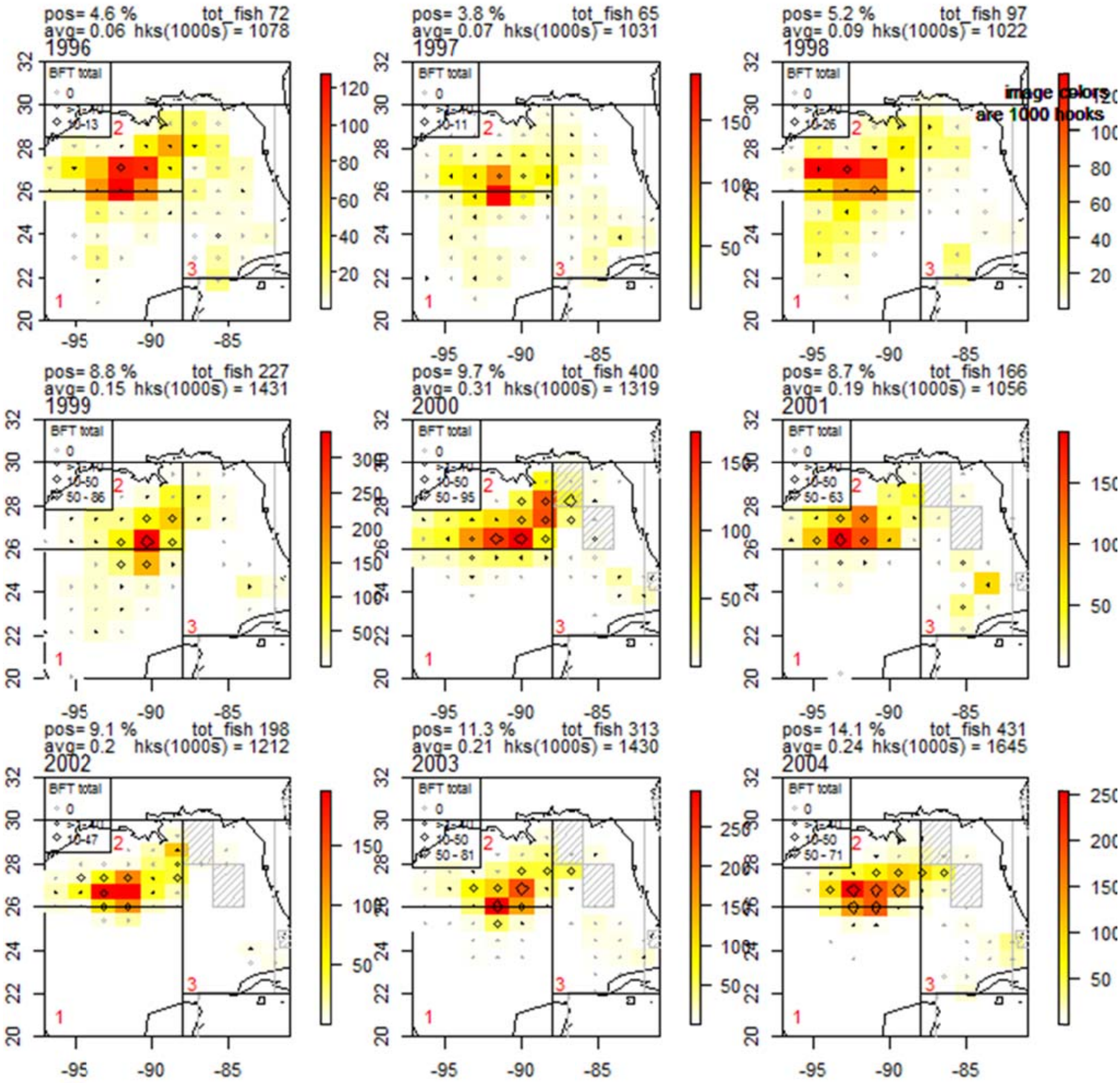

Figure 9. Continued.

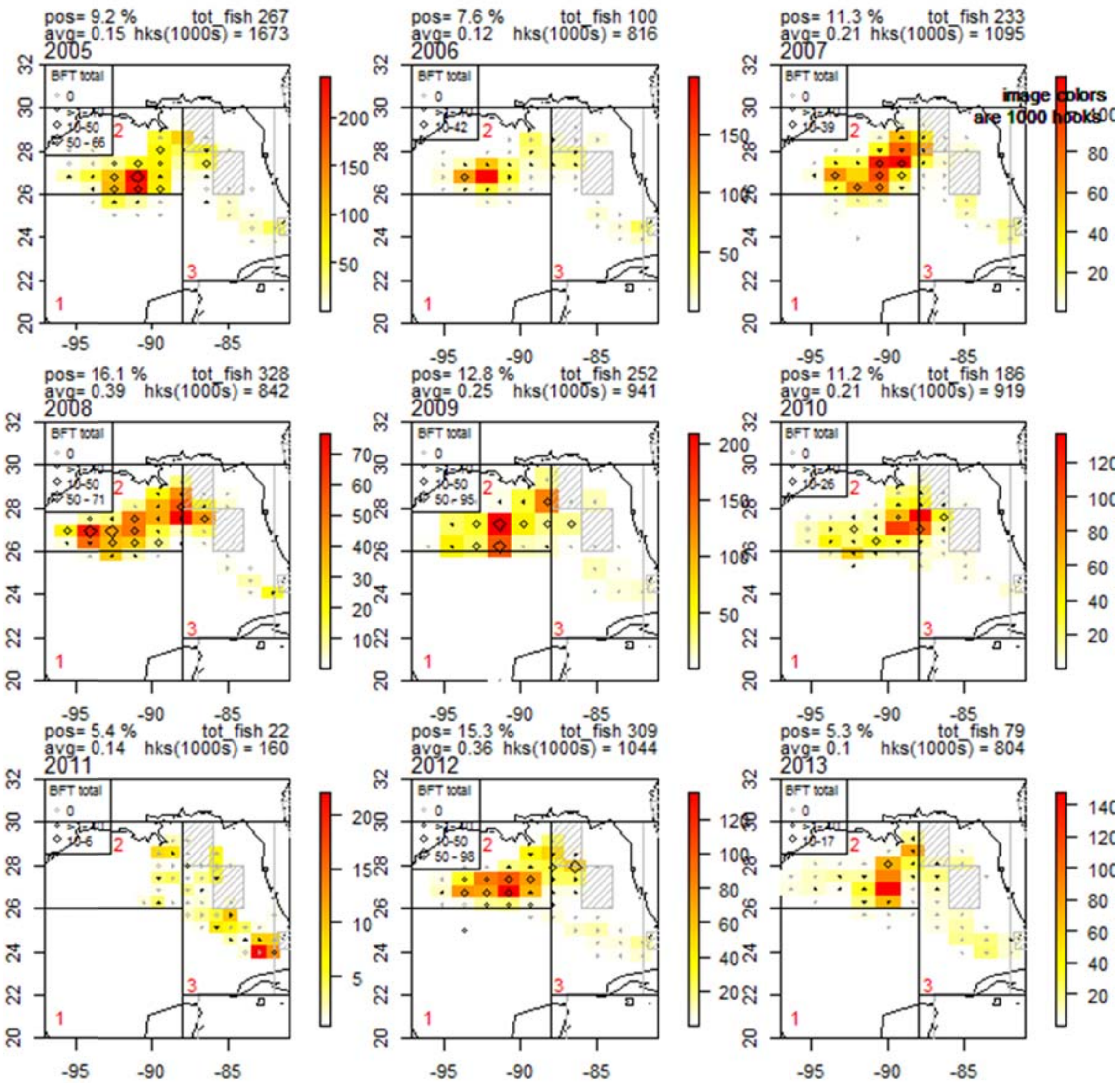

Figure 9. Continued.