

**STANDARDIZED CATCH RATES FOR BIGEYE TUNA (*THUNNUS OBESUS*)
FROM THE PELAGIC LONGLINE FISHERY IN THE
NORTHWEST ATLANTIC AND THE GULF OF MEXICO**

John Walter¹

SUMMARY

Updates of two indices of abundance of bigeye tuna from the United States pelagic longline fishery in the Atlantic are presented; an index of number of fish per thousand hooks estimated from numbers of bigeye tuna caught and reported from pelagic longline logbook data from 1986-2013 and a biomass index (dressed weight) per thousand hooks estimated from dealer weight-out data for the period 1982-2012. The standardization procedure included the following variables; year, area, quarter of the year, gear characteristics (light sticks) and fishing characteristics (operations procedure, and target species calculated as the fraction of swordfish caught to the total catch which is used to identify trips that primarily target and catch swordfish). Standardized indices were estimated using Generalized Linear Mixed Models with a delta binomial-lognormal approach. Both indices indicate an overall decline since the mid-1980s, a second decline in the late 2000s, and stable but low values since 2007.

RÉSUMÉ

Des mises à jour de deux indices d'abondance du thon obèse de la pêcherie palangrière pélagique des États-Unis de l'Atlantique sont présentés ; un indice du nombre de poissons pour mille hameçons estimé à partir du nombre de thons obèses capturés et déclarés dans les données des carnets de pêche palangriers pélagiques de 1986 à 2013 et un indice de biomasse (poids manipulé) pour mille hameçons estimé à partir des données des poids au débarquement des mareyeurs pour la période 1982-2012. La procédure de standardisation incluait les variables suivantes : année, zone, trimestre de l'année, caractéristiques des engins (baguettes lumineuses) et caractéristiques de la pêche (procédure opérationnelle et espèces-cibles calculées comme étant la fraction des espadons capturés par rapport à la prise totale qui est utilisée pour identifier les sorties qui ciblent et capturent essentiellement l'espadon). Les indices standardisés ont été estimés à l'aide de modèles mixtes linéaires généralisés selon une approche delta binomiale-lognormale. Les deux indices font apparaître une chute générale depuis le milieu des années 80, une deuxième chute à la fin des années 2000 et des valeurs stables mais faibles depuis 2007.

RESUMEN

Se presentan las actualizaciones de dos índices de abundancia para el patudo de la pesquería de palangre pelágico de Estados Unidos en el Atlántico; un índice del número de peces por mil anzuelos estimado a partir de los números del patudo capturado y declarados en los datos de los cuadernos de pesca de palangre pelágico de 1986-2013 y un índice de biomasa (peso canal) por mil anzuelos estimado a partir de los datos de peso de los comerciantes para el periodo 1982-2012. El procedimiento de estandarización incluía las siguientes variables: año, área, trimestre del año, características del arte (bastones de luz) y características de la pesca (procedimiento de operaciones y especie objetivo calculadas como la parte de pez espada capturado respecto a la captura total que se utiliza para identificar las mareas que se dirigen y capturan principalmente pez espada). Los índices estandarizados se estimaron utilizando modelos lineales mixtos generalizados con el enfoque del modelo delta binomial-lognormal. Ambos índices indicaron un descenso global desde mediados de los 80, un segundo descenso a finales de los 2000 y valores estables pero bajos desde 2007.

KEYWORDS

*Bigeye tuna, Abundance indices, Catch/effort,
Catch rate standardization, Generalized linear model, Pelagic longline fisheries*

¹ U.S. Department of Commerce National Marine Fisheries Service Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149 USA.

1. Introduction

The report presents updated standardized CPUE estimates in numbers of bigeye tuna obtained from pelagic longline logbook data (PLL) for years 1986 to 2013 and in weight from dealer weigh-out data (DLS) for the years 1982-2013. We use a delta lognormal approach implemented as a generalized linear mixed model in SAS using methodology similar to Ortiz and Diaz (2003) and Ortiz (2004).

2. Materials and methods

Data for this analysis comes from the United States Atlantic and Gulf of Mexico pelagic longline fishery described in detail by Hoey and Bertolino (1988). Swordfish, yellowfin and bigeye tuna (BET) are the predominant target species. The pelagic longline fishing grounds of the US fleet extends from the Grand Banks in the North Atlantic to 5-10° south of the Equator, mainly in the Western Atlantic including the Caribbean Sea and the Gulf of Mexico (**Figure 1**). The fishery has operated under several time-area restrictions since 2000 due to management regulations related to swordfish and other species (U.S. Federal Register 2000, **Figure 1**). These restrictions included two permanent closures to pelagic longline fishing, one in the Gulf of Mexico known as the Desoto Canyon, effective since November 1st 2000, and the second permanent closure on the Florida East Coast effective since March 1st 2001. In addition, three time-area restrictions were also imposed for the pelagic longline gear in the US Atlantic coast: the Charleston Bump, an area off the South Carolina coast closed from February 1st to April 30th starting in 2001 year, The Bluefin Tuna Protection Area off the South New England coast closed from June 1st to June 30th starting in 1999, and the Grand Banks area that was closed from July 17 2001 to January 9, 2002 as a result of an emergency rule implementation (Cramer 2002).

Catch and effort data are available from two sources: pelagic logbooks reported daily by vessel captains (Scott *et al.* 1993, Cramer and Bertolino 1998) and dealer weigh-out data sheets submitted at the completion of each trip. Dealer weigh-out data consists of summarized catch per total effort for an entire trip so that spatial and temporal information on fishing locations and catch rates represent averages for an entire trip. In contrast, logbook daily reports generally have spatially and temporally explicit information on individual longline sets. US pelagic logbook data are available since 1986, however from 1986 to 1991, submission of logbooks was voluntary, and became mandatory in 1992. Weigh-out data collection began in 1981 and observer data collection began in 1992. In this paper we use both vessel logbook reports for the CPUE in number and dealer weigh-out data for the CPUE in weight.

The pelagic longline logbook data (**Figure 2**) comprises a total of 330,699 recorded sets from 1986 through 2014. **Figure 2** presents the geographic distribution of total catch in number of bigeye from the pelagic logbooks for summed by approximately 40x40 nautical mile grid cell for the years 1987 through 2013.

Each record contains information of catch by set, including: date-time, geographical location, catch in numbers of targeted and bycatch species, number of hooks, light stick and various other gear parameters for each set, as well as environmental conditions such as temperature. Various data restrictions were necessary to eliminate incomplete or erroneous records or records that were non-standard, such as very short sets of fewer than 100 hooks, weight of fish incorrectly recorded as number, or sets with zero fish of any species captured. Restricting the logbook data only to sets from 1986 onward, those with greater than 100 hooks per set, and with complete catch, effort, location and date information, resulted in a total of 328,742 sets, of which ~29% were positive for bigeye with the observed proportion positive increasing in recent years.

The pelagic dealer weigh-out data comprises a total of 40,025 records. Similar to the logbook data, we applied a set of data restrictions that eliminated incomplete or clearly erroneous records, resulting in a total of 36,568 reports, of which ~46% reported positive catches of bigeye with the observed proportion positive increasing in recent years.

2.1. Dependent variables

Two dependent variables were used for the analysis, catch per unit effort (1000 hooks) in number (CPUEN) and in weight (CPUEW). CPUEN was obtained from the logbook data as the number of bigeye caught per 1,000 hooks for each longline set. This number included kept as well as live and dead discarded bigeye, however discarded bigeye represented less than 5% of the total number of caught tuna. CPUEW was obtained from the DLS weigh-out database as the total dressed carcass weight of bigeye landed for an entire trip, divided by the total number of hooks set for the trip. For comparison, nominal catch rates of bigeye caught per 1,000 hooks was also obtained from the DLS database. Note that the DLS recorded tuna did not include discarded fish.

2.2. Model factors

Five fixed factors and a random effect of **year** and interactions between the factors were evaluated in the analysis (**Figures 3 and 4**). Eight geographical areas (**area**) of longline fishing have been traditionally used for classification; these include: the Caribbean, Gulf of Mexico, Florida East Coast, South Atlantic Bight, Mid-Atlantic Bight, New England Coastal, Northeast Distant Waters, the Sargasso Sea, and the offshore area (**Figure 1**). Calendar quarters (qtr) 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 the use and number of light-sticks (lightc) expressed as the ratio of light-sticks per hook, and a variable named operations procedures (OP), which is a categorical classification of US longline vessels based on their fishing configuration, type and size of vessel, main target species, and area of operation(s).

Fishing effort is reported as number of hooks per set, and nominal catch rates were calculated as number of bigeye caught per 1,000 hooks for each observation. The US Atlantic longline fleet targets mainly swordfish and yellowfin tuna, but other tuna species are also targeted including bigeye (to a lesser extent, some of the trips target other pelagic species including sharks, dolphin and small tunas). We defined targeting (targ) as a categorical variable with four levels based on the proportion of the number of Swordfish caught to the total number of fish per set, with four discrete target categories corresponding to the ranges 0-25%, 25-50%, 50-75%, and 75-100%. As fishing practices targeting Swordfish generally diverge from those targeting bigeye this provides an empirical means to determine whether vessels are targeting particular species.

Factors related to bigeye-specific fishing strategy such as longer gangions, more hooks between floats and longer floatlines were examined. Due to changes in the units with which gangion length were recorded, this variable proved impossible to use at this time and no clear relationship between floatline length or number of hooks between floats was observed.

Indices of abundance of bigeye were estimated by a generalized linear modeling approach assuming a delta lognormal model (Lo *et al.* 2002). The models used in the standardization were exactly the same as in the most recent iteration of this index (Ortiz and Calay 2011). Model factors were not reevaluated for this paper. Variance estimates of the index were obtained as the product of two uncorrelated random variables (Goodman 1960).

2.3. Time-area restrictions

For the pelagic logbook data, it was possible to assign most of the longline sets to specific latitude-longitude positions to assign the set to a closed area. In contrast, the DLS data represents total catch for a trip with only a general geographic zone that is larger than the time-area closures. Therefore it was not possible to precisely allocate the bigeye catch to closure or non-closure locations. An approximate solution was to assign an average latitude-longitude by linking the weight-out records to the logbook set by set information using the unique trip identifier number. However, prior to 1996 the trip identifier did not exist so it was not possible to assign these trips to closed or open areas.

To get the variance of the index the Goodman (1960) exact formula was used assuming that both lognormal and binomial model estimates are independent.

3. Results and discussion

While the model factors and data treatments are largely the same between the Ortiz and Calay (2011) index there are some slight differences in the CPUE values and sample size, likely due to some different treatments of the data and to different model parameter estimates. Largely, the indices are similar and show similar patterns, described in more detail below. Nominal CPUE and % positive show year*area interactions which were modeled as random effects (**Figures 5 and 6**).

The final models selected for the binomial and lognormal components for the CPUEN and CPUEW were not altered from Ortiz and Calay (2011) and were as follows:

$$\text{Proportion Positive} = \text{Intercept} + \text{Year} + \text{Area} + \text{season} + \text{targ} + \text{OP} + \text{random}(\text{Year} * \text{area}) + \text{random}(\text{Year} * \text{OP}) + \text{random}(\text{Year} * \text{qtr}) + \text{random}(\text{target} * \text{Area})$$

$$\log(\text{CPUEN}) = \text{Intercept} + \text{Year} + \text{Area} + \text{season} + \text{targ} + \text{OP} + \text{random}(\text{Year} * \text{area}) + \text{random}(\text{Year} * \text{OP}) + \text{random}(\text{Year} * \text{qtr}) + \text{random}(\text{target} * \text{Area})$$

The final model selected for the binomial and lognormal components for the CPUEW in biomass were:

$$\text{Proportion Positive} = \text{Intercept} + \text{Year} + \text{Area} + \text{season} + \text{targ} + \text{OP} + \text{random}(\text{Year} * \text{area}) + \text{random}(\text{Year} * \text{OP}) + \text{random}(\text{Year} * \text{qtr}) + \text{random}(\text{target} * \text{Area})$$

$$\log(\text{CPUEW}) = \text{Intercept} + \text{Year} + \text{Area} + \text{season} + \text{targ} + \text{OP} + \text{random}(\text{Year} * \text{area}) + \text{random}(\text{Year} * \text{OP}) + \text{random}(\text{Year} * \text{qtr}) + \text{random}(\text{target} * \text{Area})$$

Since the diagnostic plots are almost exactly similar to Ortiz and Calay (2011), we have not provided updates to them here. Standardized catch rates of bigeye tuna numbers and biomass per 1,000 hooks (**Figures 8,9, Tables 1, 2**) indicate a decline since 1982 to 1986, a stable trend from 1992 to 2002 and then relatively stable but lower values since 2007. Both indices correlate reasonable well ($R^2=0.71$). Noticeably, both show substantial divergence from nominal values beginning in 2007.

In a previous iteration of this index (Walter *et al.* 2008), there was an evaluation of the influence of the closed areas and all observations from closed areas before and after the closures were removed. The resulting indices in number and weight did not differ substantially from the indices with the closed areas included. Ortiz and Calay (2011) took a different approach and tested a ‘closed/open’ factor in the GLM which was not significant. For continuity with Ortiz and Calay (2011) we have not excluded observations that fell in closed areas both before and after the areas were closed. We note, however that there is a strong year*area interaction in the Florida East Coast area (**Figure 10**). The Ortiz and Calay (2011), Walter *et al.* (2008) and this current update model incorporate these (and likely others) as year*area interactions as random effects. Since we can account for this strong interaction as a result of the impact of the area closure, it is recommended that for future index constructions it might be best to remove observations in the part of the Florida East Coast area prior to and after the closure. This may reduce the strength of the year*area interactions. Nonetheless, in either case, the indices when calculated with or without the closed areas included did not show substantial differences, similar to findings in Walter *et al.* (2008).

For the DLS data, it was not possible to assign the DLS data to locations prior to 1996 so the data from subsequently closed areas were not removed. This is due to the inability to assign DLS data to locations prior to 1996, so that the data are unaltered due to the lack of spatial precision in assigning locations after 1996.

It should be noted that the index in number comes from logbook information on individual sets, so the proportion positive is lower than the DLW trip summary information. This accounts for the lower proportion positive in the logbook CPUEN, however on a relative scale the two indices are fairly similar (**Figure 9**).

The defining characteristic of the modeled indices is a strong divergence of the standardized index from the nominal. This is present in both indices. Future research may elucidate the exact factors of the modeling that are creating this divergence between observed and predicted means.

References

- Brown, C. 2007. Standardized catch rates of yellowfin tuna, *Thunnus albacares*, based upon the United States pelagic longline observer program data, 1992-2006. SFD-2007-009.
- Cramer, J. 2002. Large Pelagic Logbook Newsletter 2000. NOAA Tech. Mem. NMFS SEFSC 471, 26 pages.
- Cramer, J. and A. Bertolino. 1998. Standardized catch rates for swordfish (*Xiphias gladius*) from the U.S. longline fleet through 1997. Col. Vol. Sci. Pap. ICCAT 49(1):449-456.
- Cramer, J. and M. Ortiz. 1999. Standardized catch rates for bigeye (*Thunnus obesus*) and yellowfin (*T. albacares*) from the U.S. longline fleet through 1997. Col. Vol. Sci. Pap. ICCAT 49(2):333-356.
- Federal Register. 2000. Atlantic Highly Migratory Species; Pelagic Longline Management; Final rule. 50 CFR part 635. Vol. 65, No. 148 August 1, 2000.
- Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association. 55(292): 708- 713.
- Hoey, J.J. and A. Bertolino. 1988. Review of the U.S. fishery for swordfish, 1978 to 1986. Col. Vol. Sci. Pap. ICCAT 27:256-266.
- Lee, D.W. and C.J. Brown. 1999. Overview of the SEFSC Pelagic Observer Program in the northwest Atlantic from 1992-1996. Col. Vol. Sci. Pap. ICCAT 49(4):398-409.
- Lo, N.C., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49:2515-2526.
- Ortiz, M. 2004. Standardized catch rates for bigeye tuna (*Thunnus obesus*) from the Pelagic longline fishery in the Northwest Atlantic and the Gulf of Mexico. ICCAT SCRS/04/133.
- Ortiz, M and S Calay. 2011. Standardized catch rates for bigeye tuna from the U.S. pelagic longline 1986-2009 Collect. Vol. Sci. Pap. ICCAT, 66(1): 298-307.
- SAS Institute Inc. 1997. SAS/STAT® Software: Changes and Enhancements through release 6.12. Cary NC: SAS Institute Inc., 1997. 1167 pp.
- Scott, G.P., V.R. Restrepo and A. R. Bertolino. 1993. Standardized catch rates for swordfish (*Xiphias gladius*) from the US longline fleet through 1991. Col. Vol. Sci. Pap. ICCAT 40(1):458-467.
- Ortiz, M. A. and G. A. Diaz. 2004. Standardized catch rates for yellowfin tuna (*Thunnus albacares*) from the U.S. pelagic longline fleet. Int. Comm. Conserv. Atl. Tunas, Col. Vol. Sci. Pap. 56(2): 660-675.
- Walter, J., M. Ortiz, and C. Brown. 2008. Standardized catch rates for bigeye tuna from the pelagic longline fishery in the northwest Atlantic and the Gulf of Mexico. Collect. Vol. Sci. Pap. ICCAT, 62(2): 445-468.

Table 1. Nominal and standardized catch rates of bigeye tuna in #/1000 hooks (CPUE) from the pelagic logbook data. Note that the nominal CPUE includes zero catches.

<i>YEAR</i>	<i>NOBS</i>	<i>OBCPUE</i>	<i>OBPPOS</i>	<i>ESTCPUE</i>	<i>STDCPUE</i>	<i>CV_I</i>	<i>LCI</i>	<i>UCI</i>
1986	1988	4.788	0.317	2.229	1.502	0.199	1.502	1.012
1987	14315	3.064	0.292	3.108	2.322	0.147	2.322	1.735
1988	15565	2.445	0.288	2.237	1.640	0.156	1.640	1.203
1989	17384	2.887	0.326	2.327	1.723	0.151	1.723	1.276
1990	16014	2.541	0.302	1.604	1.160	0.163	1.160	0.840
1991	15005	2.548	0.318	1.580	1.146	0.162	1.146	0.831
1992	15021	1.945	0.266	1.357	0.972	0.168	0.972	0.695
1993	14630	2.362	0.304	1.486	1.070	0.165	1.070	0.770
1994	15745	2.150	0.294	1.353	0.972	0.167	0.972	0.698
1995	16842	2.003	0.311	1.208	0.865	0.168	0.865	0.620
1996	16150	1.681	0.252	1.341	0.965	0.165	0.965	0.695
1997	15288	2.156	0.277	1.324	0.956	0.164	0.956	0.689
1998	11915	2.366	0.302	1.321	0.953	0.164	0.953	0.688
1999	12273	2.726	0.291	1.717	1.238	0.165	1.238	0.893
2000	11684	1.768	0.258	1.421	1.023	0.166	1.023	0.736
2001	10445	2.318	0.278	1.747	1.276	0.158	1.276	0.932
2002	9817	1.765	0.275	1.628	1.195	0.156	1.195	0.877
2003	9699	1.090	0.193	0.952	0.665	0.181	0.665	0.464
2004	9865	1.228	0.163	0.684	0.466	0.194	0.466	0.317
2005	8012	1.707	0.233	0.972	0.680	0.180	0.680	0.475
2006	7658	2.622	0.307	1.162	0.818	0.177	0.818	0.576
2007	9145	1.773	0.256	0.927	0.650	0.179	0.650	0.455
2008	8918	2.009	0.289	0.889	0.625	0.177	0.625	0.440
2009	9285	1.723	0.267	0.839	0.585	0.182	0.585	0.408
2010	7602	2.337	0.388	0.831	0.587	0.175	0.587	0.415
2011	8219	2.851	0.391	0.863	0.599	0.184	0.599	0.416
2012	10889	1.881	0.343	0.887	0.627	0.175	0.627	0.442
2013	9369	2.195	0.342	1.011	0.719	0.172	0.719	0.511

Table 2. Nominal and standardized catch rates of bigeye tuna in kg/1000 hooks (CPUEW) from the dealer weigh-out system (DLS).

<i>YEAR</i>	<i>NOBS</i>	<i>OBCPUE</i>	<i>OBPPOS</i>	<i>ESTCPUE</i>	<i>STDCPUE</i>	<i>CV_I</i>	<i>LCI</i>	<i>UCI</i>	<i>EST PER POS</i>
1982	110	279.198	0.245	318.339	1.830	0.406	0.838	3.997	0.360
1983	167	364.029	0.479	407.054	2.340	0.293	1.318	4.158	0.600
1984	178	332.847	0.449	348.681	2.005	0.264	1.192	3.372	0.618
1985	195	227.915	0.390	271.080	1.559	0.257	0.940	2.585	0.527
1986	351	293.185	0.453	327.714	1.884	0.228	1.201	2.957	0.586
1987	844	221.276	0.449	267.106	1.536	0.219	0.997	2.366	0.584
1988	1153	140.993	0.470	274.563	1.579	0.203	1.056	2.361	0.721
1989	897	137.900	0.476	258.271	1.485	0.204	0.992	2.223	0.698
1990	923	140.226	0.433	221.438	1.273	0.203	0.852	1.902	0.681
1991	1372	143.670	0.401	237.400	1.365	0.207	0.906	2.056	0.642
1992	1894	110.047	0.390	144.368	0.830	0.206	0.552	1.247	0.604
1993	2194	137.690	0.420	153.605	0.883	0.202	0.592	1.318	0.650
1994	2316	121.842	0.403	125.608	0.722	0.204	0.482	1.083	0.599
1995	2479	115.405	0.420	118.253	0.680	0.206	0.452	1.022	0.579
1996	1500	86.750	0.425	107.610	0.619	0.203	0.414	0.925	0.611
1997	1635	108.867	0.444	101.121	0.581	0.205	0.388	0.872	0.597
1998	1289	117.664	0.455	124.532	0.716	0.204	0.478	1.073	0.652
1999	1195	202.575	0.539	237.593	1.366	0.199	0.921	2.025	0.761
2000	1277	113.596	0.498	137.112	0.788	0.200	0.530	1.172	0.751
2001	1377	145.586	0.449	113.464	0.652	0.201	0.438	0.971	0.682
2002	1375	89.871	0.470	121.115	0.696	0.201	0.468	1.036	0.700
2003	1330	64.070	0.383	81.473	0.468	0.208	0.310	0.708	0.613
2004	1428	86.958	0.331	56.086	0.322	0.216	0.210	0.495	0.522
2005	1109	127.993	0.469	89.910	0.517	0.208	0.342	0.780	0.648
2006	1069	226.451	0.555	107.393	0.617	0.205	0.412	0.926	0.701
2007	1271	149.597	0.533	91.180	0.524	0.211	0.345	0.796	0.660
2008	1090	138.655	0.525	91.972	0.529	0.207	0.351	0.796	0.663
2009	1172	115.551	0.503	85.970	0.494	0.204	0.330	0.741	0.708
2010	975	130.630	0.619	83.626	0.481	0.207	0.319	0.724	0.695
2011	1042	180.895	0.599	91.213	0.524	0.211	0.346	0.796	0.723

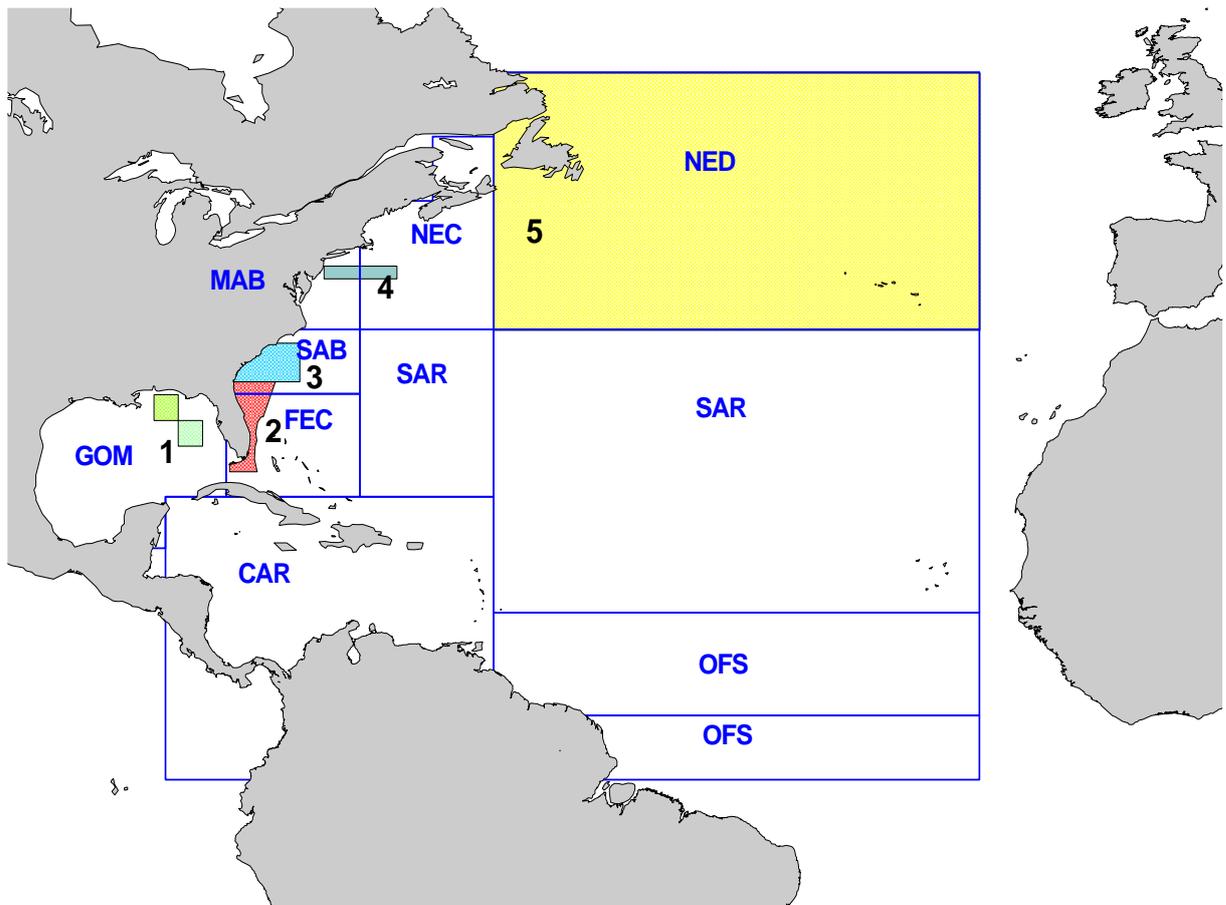


Figure 1. Geographical areas for the US Pelagic Longline fishery: CAR Caribbean, GOM Gulf of Mexico, FEC Florida east coast, SAB South Atlantic bight, MAB mid Atlantic bight, NEC North east coastal Atlantic, NED North east distant waters, SNA Sargasso Sea, and OFS Offshore waters. Shaded areas represent the current time-area closures affecting the pelagic longline fisheries. Permanent closures: (1) the DeSoto Canyon in the Gulf of Mexico and (2) The Florida east coast areas. Non-permanent closures: (3) the Charleston Bump area closed Feb-Apr, (4) the bluefin tuna protection area closed in June, and (5) the Grand Banks closed since Oct-2000.

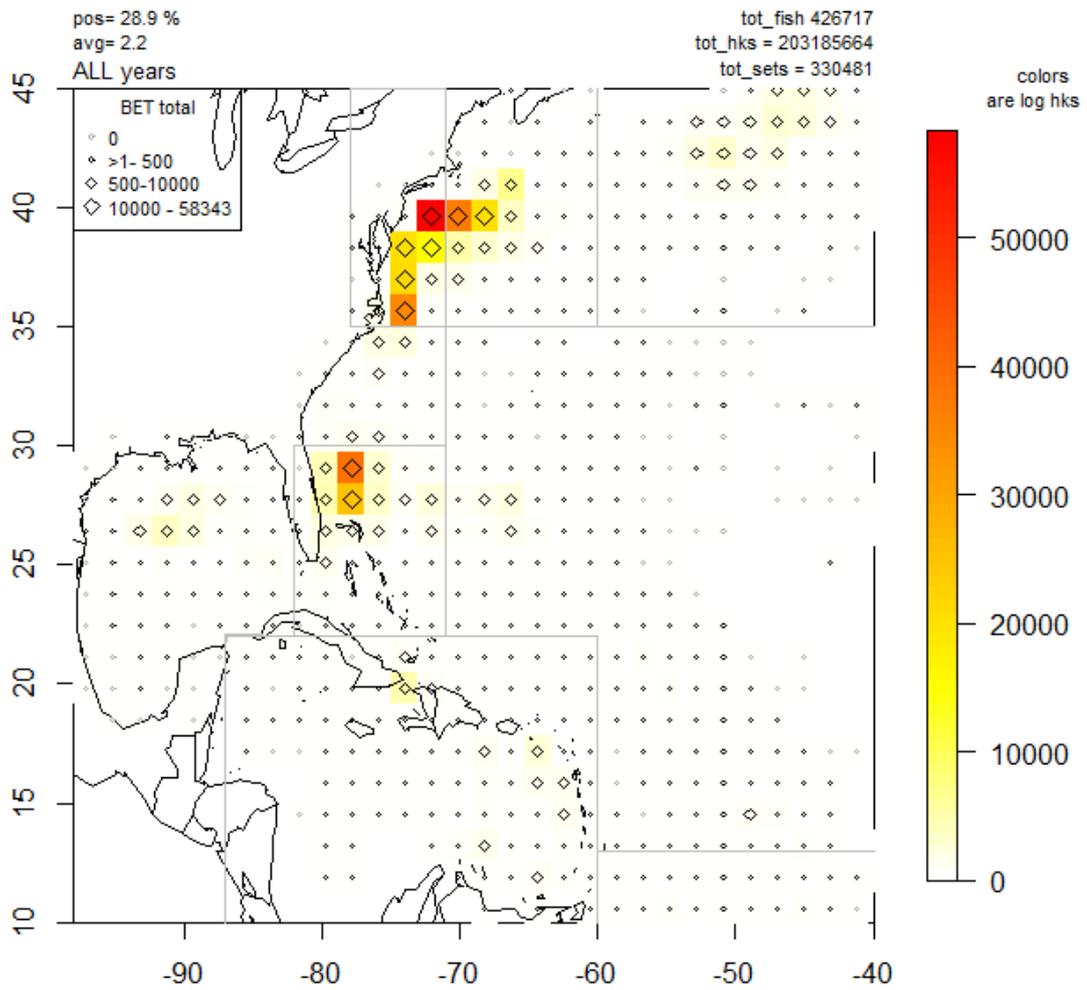


Figure 2. Spatial distribution of catch and effort in the US Pelagic longline fishery for selected years 1987-2013. Scale is log (hooks set) per grid cell. Cell size is approximately 40 x 40 nautical miles.

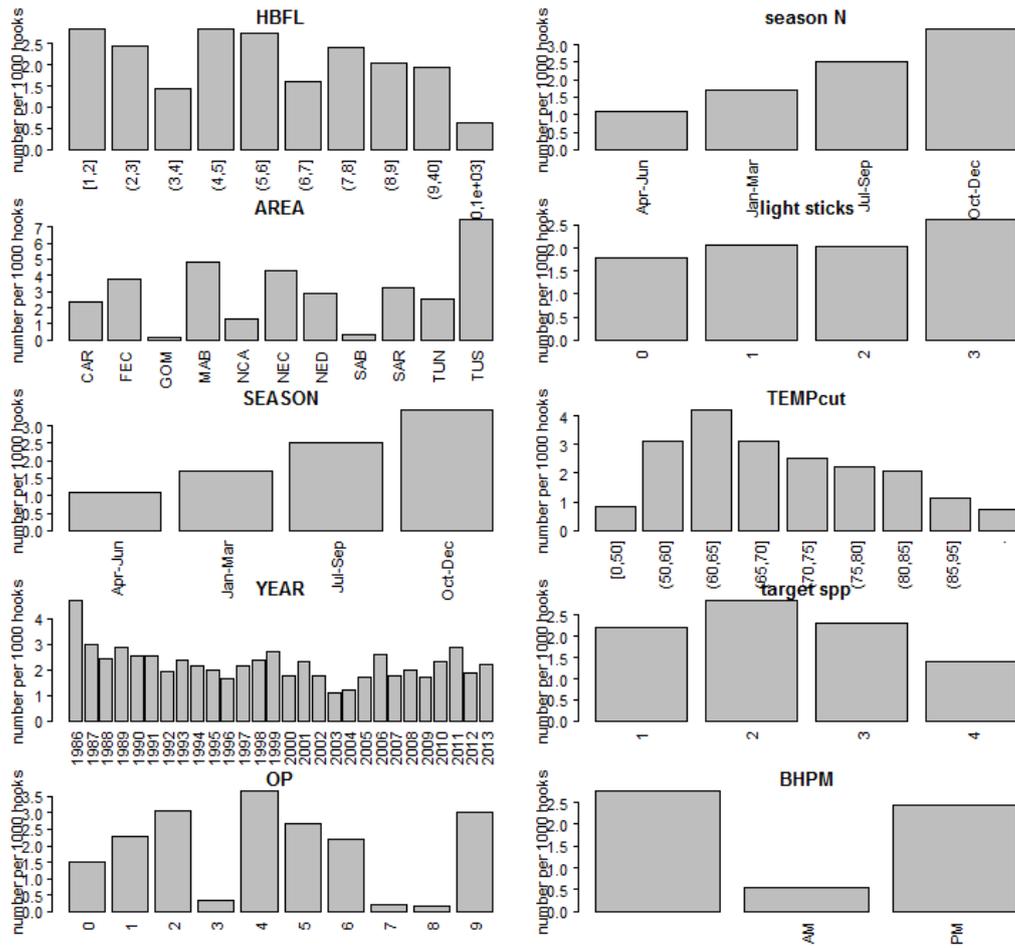


Figure 3. Number of bigeye/1000 hooks by factor levels from pelagic longline logbook data.

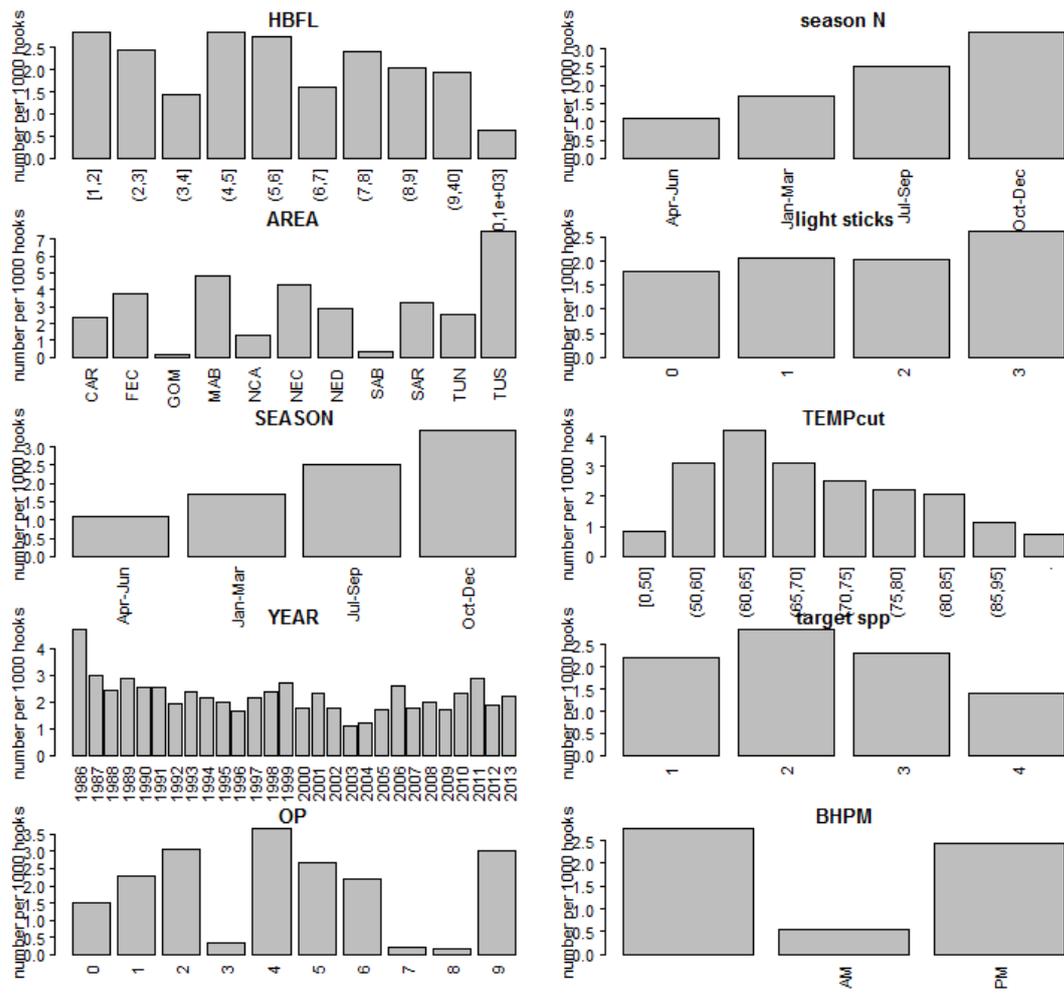


Figure 4. Proportion positive of bigeye hooks by factor levels.

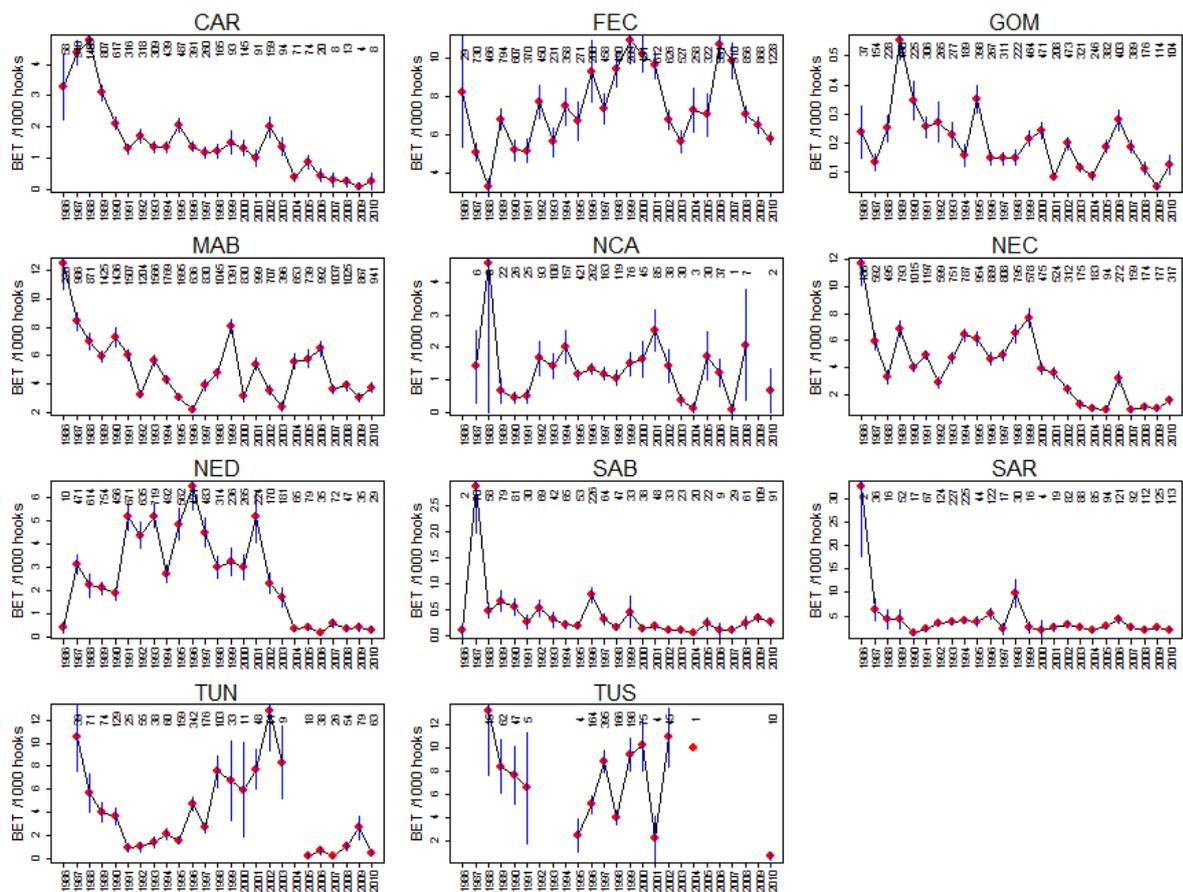


Figure 5. Nominal bigeye tuna catch per 1000 hooks for each area from logbook data. Upper and lower limits are 95% confidence intervals. Numbers are the total number of daily logbook sets reporting positive bigeye catches.

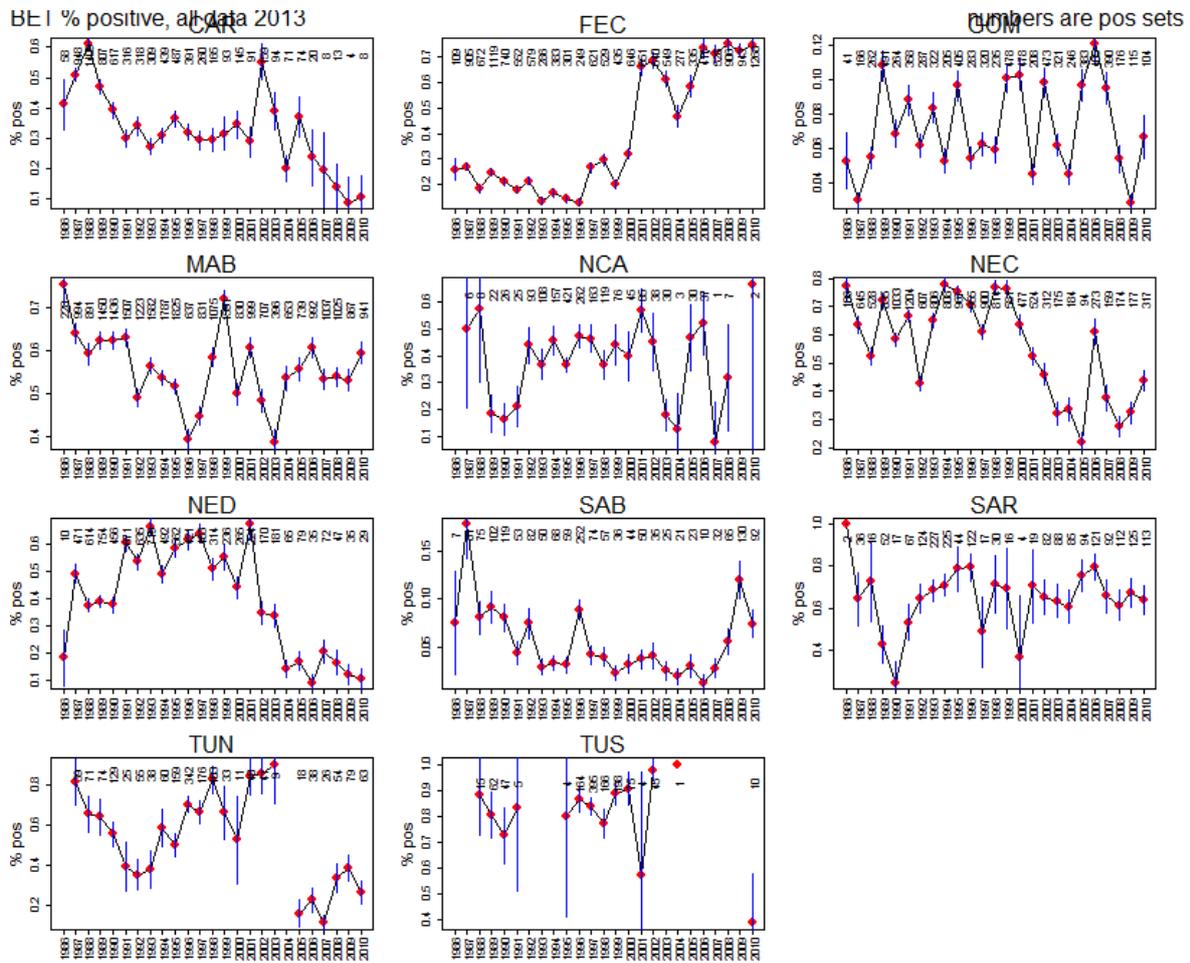


Figure 6. Nominal percentage of positive sets for each area from logbook data. Upper and lower limits are 95% confidence intervals. Numbers are the total number of daily logbook sets reporting positive bigeye catches.

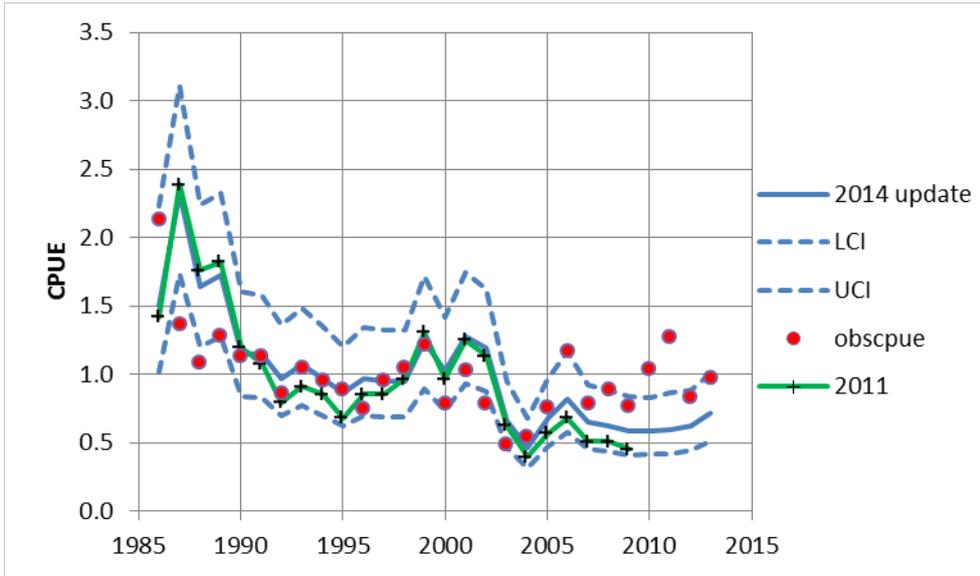


Figure 7. Standardized logbook bigeye tuna CPUE in number per 1000 hooks with comparison with 2011 index values.

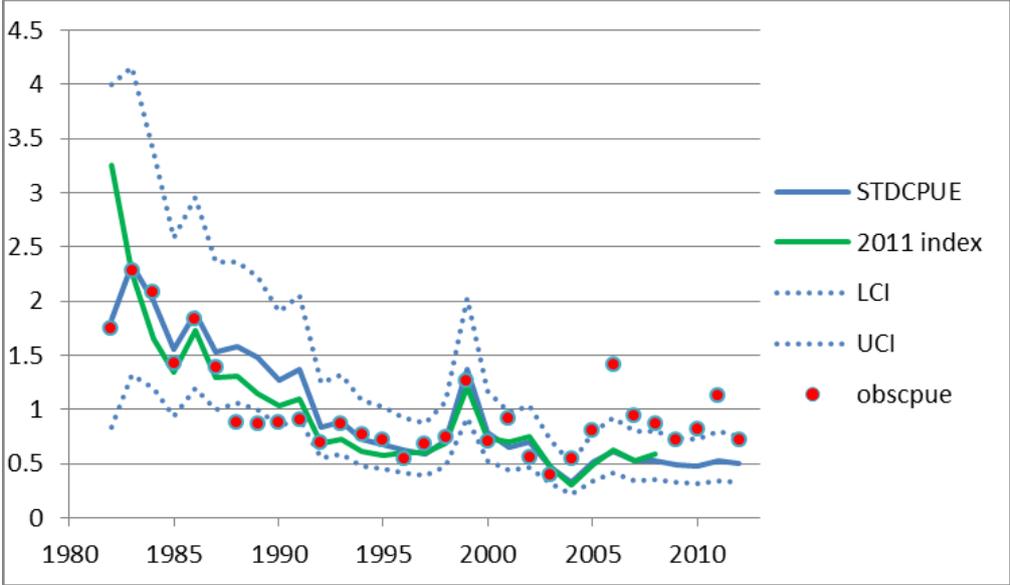


Figure 8. Nominal and standardized catch rates for bigeye from the US Pelagic longline fishery dealer weight out data reported as dress weight (lbs) per thousand hooks. The 2011 index is shown in green.

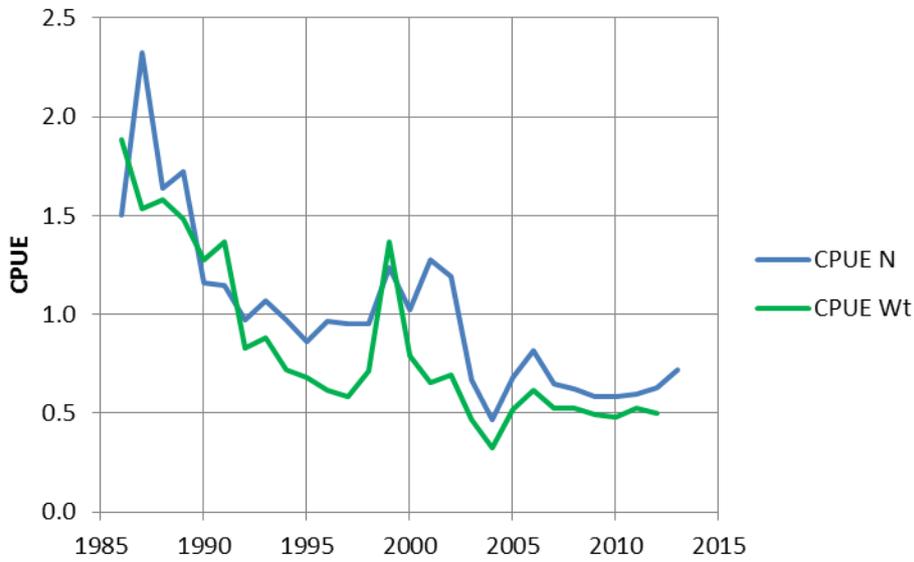


Figure 9. Comparison of CPUE in number (blue) and CPUE in weight standardized indices. Both show relatively similar patterns with an R2 of 0.71.

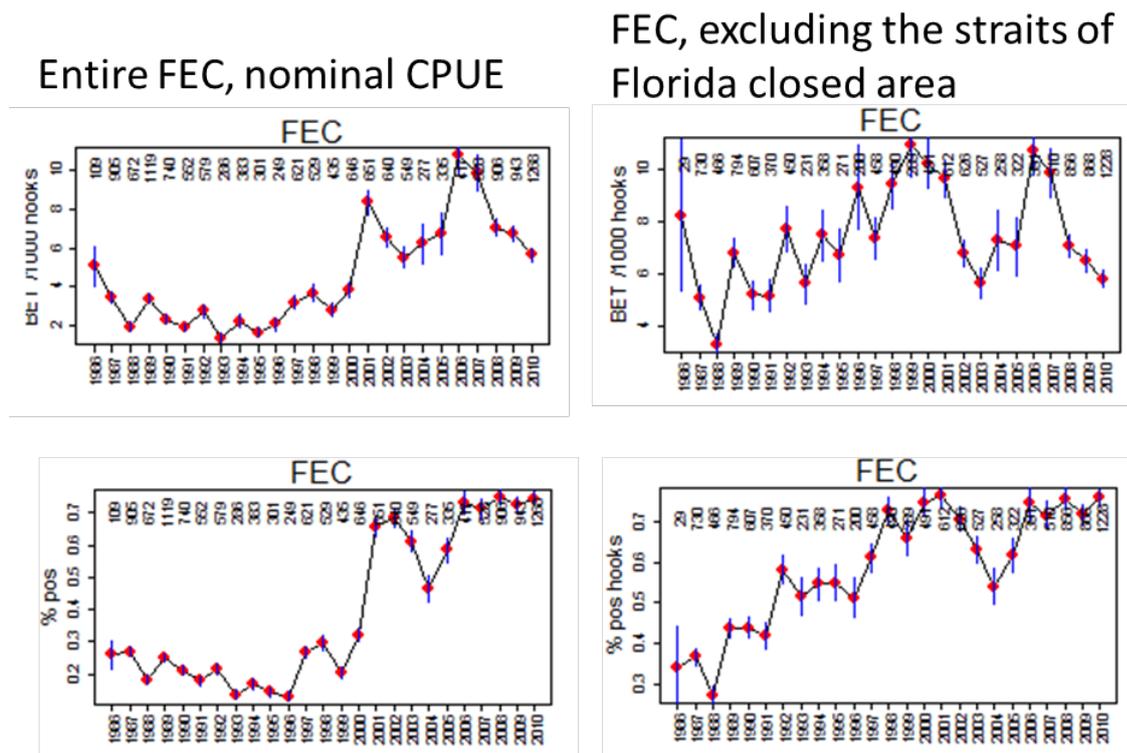


Figure 10. Effects of the closure of the Florida straits on bigeye nominal catch rates in the Florida East Coast (FEC) region. The closure effectively moved effort to bigeye as the only open area of the FEC is north of the Bahamas where bigeye are common.