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Relative abundance indices of juvenile albacore tuna for the US surface fishery in the north Pacific Ocean[1]

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ABSTRACT

The objective of this paper is to describe the data sources and methods used to develop relative abundance indices of juvenile albacore tuna for the US surface fishery in the north Pacific Ocean. The US surface fishery for albacore tuna consists of troll and pole-and-line vessels that primarily capture albacore tuna ranging from ages-2 to 4. Unlike assessments in 2011 and 2014, when data from both Canadian and US vessels were used to develop these abundance indices, only data from US vessels were used to develop abundance indices in this study. Similar to the 2014 assessment, relative abundance indices for three periods (1966 – 1978, 1979 – 1998, and 1999 – 2015, excluding 2012), which corresponded to periods of major changes in fishing operations in this fishery, were developed in this study. Data for 2012 was excluded because a lapse in the fishing regime of the US-Canada albacore treaty in 2012 may have changed the fishing operations of the US surface fishery. Data from January to March were also excluded due to very low catches during those months. The main source of data used in this study was a vessel logbook program. Catch and effort data were aggregated into strata of 1 x 1° spatial blocks by month. Only logbook data where locations were recorded at ≤1° resolution and the vessel was actively fishing were included. For each time-area strata, effort was calculated as the number of boat days and catch was calculated as the total number of fish caught (sum of retained and discarded albacore). Strata with <3 boat days of effort were removed from analysis to reduce the influence of peripheral fishing areas with minimal effort. The nominal CPUE (fish per boat day) of each stratum was first calculated and log-transformed by ln(CPUE + 1). Each strata was assigned to a year, quarter, and one of eight areas based on distance from the coast, latitude, and/or longitude bounds. A lognormal generalized linear model (GLM) approach was used to standardize abundance indices for the three periods using year, quarter, and area as main explanatory factors, and interactions between quarter and area. Residual and Q-Q plots for the GLMs indicated that the models were not fitting the data well at low and high CPUE values. The standardization process did not appear to perform well and may not have adequately standardized the changes in catchability for the US surface fishery. Given the poor diagnostics of the standardization models and uncertainty in the representativeness of these indices with respect to abundance trends of the entire north Pacific stock, it is recommended that the ALBWG not use these abundance indices as the primary abundance indices for juvenile albacore tuna in the 2017 stock assessment. Instead the ALBWG should use these indices in sensitivity model runs. In addition, the ALBWG should not assume that abundance indices from all three periods share the same catchability.

INTRODUCTION

The objective of this paper is to describe the data sources and methods used to develop relative abundance indices of juvenile albacore tuna for the US surface fishery in the north Pacific Ocean. These abundance indices are candidates for representing the population trends of juvenile albacore tuna in the 2017 stock assessment of north Pacific albacore tuna, which is conducted by the albacore working group (ALBWG) of the International Scientific Committee on Tuna and Tuna-like Species in the North Pacific (ISC). The US surface fishery for albacore tuna consists of troll and pole-and-line vessels that primarily capture albacore tuna ranging from ages-2 to 4. Although the US albacore surface fishery can be nominally divided into troll and pole-and-line fisheries, it is difficult to consistently separate the fishing effort of these two fisheries based on available logbook data. In addition, the fishing operations of both fisheries are similar enough that the data from both fisheries were combined in previous studies developing abundance indices for these fisheries (Xu, Teo, & Holmes, 2013).

In the 2014 assessment, relative abundance indices for three periods (1966 – 1978, 1979 – 1998, and 1999 – 2011) were developed from the combined catch and effort data of the US surface fishery and the Canada troll fishery. The operational areas of the US and Canada albacore fisheries off the west coast of North America overlap substantially due to the US-Canada albacore treaty. This treaty allows a negotiated number of Canadian vessels to fish for albacore in the US Exclusive Economic Zone (EEZ) and vice versa. Therefore, the catch-effort data from both US and Canadian albacore fisheries were combined to develop abundance indices for the 2011 and 2014 assessment. However, catch-effort data from only the US surface fishery were used to develop standardized abundance indices in this study.

The abovementioned periods were defined based on changes in the fishery operations of these fisheries (Xu et al., 2013). The first (1966 – 1978) period was characterized by fishing effort concentrated along the Pacific coast of North America coast. The fishing effort expanded substantially into the open ocean of the Pacific Ocean during the second period (1979 – 1998). In the most recent period (post-1999), most of the fishing effort has concentrated on the Pacific coast of North America coast (>40 °N). Although data was available for 2012, the ALBWG recommended not to use the 2012 data because the operations of both US and Canadian vessels may have changed during 2012, when there was no agreement between the US and Canada on the number of Canadian vessels allowed to fish for albacore in the US EEZ and vice versa. After 2012 (2013 – 2016), a fishing regime was agreed upon by both countries and albacore fishing in each other's EEZs was allowed albeit at different numbers of vessels. In this study, the analysis of Xu et al (2013) was extended to 2015, although 2012 was excluded from the analysis.

Similar to the 2014 assessment, the ALBWG recommended that the abundance indices be used as alternative abundance indices in the 2017 assessment (i.e., used in sensitivity analyses).

MATERIALS AND METHODS

Data sources

The main source of data used in this study was a vessel logbook program, which was used to obtain time and location specific catch and effort information of the US surface fishery. An annual logbook monitoring program for this fishery has been managed by NOAA's Southwest Fisheries Science Center (SWFSC) since 1961 (Childers & Betcher, 2008). Although logbook data has been collected since 1961, only 1966 – 2015 data were used in order to match the assessment period for the 2017 assessment. The logbook data format has changed over the years but time and location-specific catch-effort information have been consistently recorded throughout the program's existence. Prior to 2005, logbooks were voluntarily submitted to the SWFSC and the logbook coverage varied from 7 – 33% (McDaniel, Crone, & Dorval, 2006). However, logbook submission became mandatory in 2005 for this fishery and logbook coverage has since increased to approximately 75% of total number of boat trips. Importantly, the logbooks included daily (sometimes partial-day) information on the location (latitude and longitude) of the vessel, the number of albacore kept and discarded, and if the vessel was actively fishing.

Catch and effort data were aggregated into strata of 1 x 1° spatial blocks by month. Only logbook data where the location was recorded at ≤1 ° resolution and the vessel was actively fishing were included in this analysis. For each time-area strata, effort was calculated as the number of boat days and catch was calculated as the total number of fish caught (sum of retained and discarded albacore). Strata with <3 boat days of effort were removed from analysis to reduce the influence of peripheral fishing areas with minimal effort. Three data subsets representing the three abovementioned periods were assembled: 1) 1966 – 1978; 2) 1979 – 1998; and 3) 1999 – 2015 (excluding 2012).

Model

A generalized linear model (GLM) approach was used to standardize abundance indices based on data sets defined above. In order to maintain continuity and comparability, we developed the GLMs to be relatively consistent with those developed for previous assessments (McDaniel et al., 2006; Teo, Holmes, & Kohin, 2010; Xu et al., 2013).

The nominal CPUE (fish per boat day) of each stratum was first calculated and log-transformed by ln(CPUE + 1) in order to accommodate strata with zero catch. Less than 1% of the strata had zero catch. Previous studies have found that results of the GLM to be robust to the choice of constant (McDaniel et al., 2006; Teo et al., 2010) and resultant indices using 0.1, 1, or 8.1 (10% of mean CPUE) as the constant were all highly and significantly correlated ($R > 0.99$, $p << 0.0001$) (Teo et al., 2010). Similar to Yi et al. (2013), each strata was assigned to one of eight areas (Figure 1) based on distance from the coast, latitude, and/or longitude bounds: 1) inshore-central (region 1, ≤200 nm from coast, 40 – 48 °N); 2) inshore-north (region 2, ≤200 nm from coast, >48 °N); 3) inshore-south (region 3, ≤200 nm from coast, <40 °N); 4) inshore-offshore transition (region 4, >200 nm, east of 140 °W); 5) offshore-northeast (region 5, ≥40 °N, 140 – 160 °W); 6) offshore-southeast (region 6, <40 °N, 140 – 160 °W); 7) offshore-northwest (region 7, ≥40 °N, 160 °E – 160 °W); and 8) offshore-southwest (region 7, <40 °N, 160 °E – 160 °W). Xu et al. (2015) identified these eight areas as potentially having heterogeneity in catchability of albacore because of different environmental conditions in these areas. The year and quarter (quarter 2: Apr – Jun; quarter 3: Jul – Sep; quarter 4: Oct - Dec) of each stratum were also used as factors in the GLM. Data from January to March were excluded from this analysis due to very low catches during those months.

For each of the three time periods, the log-transformed CPUE was related to three main factors – year (Y), quarter (Q), and area (A) by,

$$\ln\left(CPUE_{ijk} + 1\right) = X + Y_i + Q_j + A_k + Q_j * A_k + \varepsilon_{ijk}$$

where $CPUE_{ijk}$ is the CPUE (fish per boat day) in year *i*, quarter *j*, and area *k*, and X is the intercept representing the reference block. The standardized CPUE indices, I_t, were obtained by back-transforming the above GLM for the reference block and given year using,

$$I_t = \exp(\hat{\alpha}_t + \frac{\hat{\sigma}_t^2}{2})$$

where $\hat{\alpha}_t$ was the estimated year factor and $\hat{\sigma}_t^2$ was the variance of $\hat{\alpha}_t$, to minimize the log-transformation bias. Confidence intervals of the abundance indices were subsequently estimated from 10000 bootstrap runs.

RESULTS AND DISCUSSION

Tables 1 – 3 show the summarized results of the GLM for abundance indices from all three periods: 1) 1966 – 1978 (Table 1); 2) 1979 – 1998 (Table 2); and 3) 1999 – 2015 (excluding 2012; Table 3). Standard diagnostics for the corresponding GLMs are shown in Figures 1 – 3. Residual and Q-Q plots for the GLMs of all three indices (Figures 1 – 3) indicated that the models were not fitting the data well at low and high CPUE values. These results suggest that other models (e.g., negative binomial, random effects) should be considered for standardizing the CPUE of this fishery in the future. In addition, different data stratification (e.g., vessel-specific) should be also considered.

The standardized abundance indices and corresponding coefficients of variation (CVs) are shown in Figures 5, and Table 4. During the 1966 – 1978 period, the abundance index showed a general declining trend. This declining trend continued in the middle period (1979 – 1998), from 1979 until 1989, which was the low point of the index. The relative albacore abundance began to increase after 1989. In the most recent period (1999 – 2015), the abundance index continued on the increasing trend until the mid-2000s before declining. The abundance index have been fluctuating without an obvious trend since 2010. The estimated CVs ranged from ~0.1 in the recent period to ~0.35 in the middle period.

The standardization process did not perform well and may not have adequately standardized the changes in catchability for the US surface fishery. Given the poor diagnostics of the standardization models and the uncertainty in the representativeness of these indices with respect to abundance trends of the entire north Pacific stock, it is recommended that the ALBWG do not use these abundance indices as the primary abundance indices for juvenile albacore tuna in the 2017 stock assessment. Instead the ALBWG should use these indices in sensitivity model runs. In addition, the ALBWG should not assume that abundance indices from all three periods share the same catchability.

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Table 1. Summarized results of GLM for 1966 – 1978.

Parameter	Estimate	Standard error	t value	P(>|t|)
Intercept	4.3758	0.0805	54.361	<2.00E-16
1967	0.3611	0.1100	3.282	0.0010
1968	0.1608	0.1079	1.490	0.1364
1969	0.0028	0.1005	0.028	0.9780
1970	0.3121	0.1016	3.072	0.0022
1971	0.1231	0.1071	1.150	0.2504
1972	0.1379	0.1130	1.220	0.2226
1973	-0.0021	0.1183	-0.018	0.9859
1974	0.0758	0.0965	0.785	0.4324
1975	0.1992	0.0959	2.077	0.0379
1976	-0.1523	0.0932	-1.634	0.1024
1977	-0.4274	0.0919	-4.650	3.54E-06
1978	-0.0556	0.0944	-0.589	0.5559
Quarter 2	-3.9483	0.7868	-5.018	5.70E-07
Quarter 4	-0.4158	0.1317	-3.158	0.0016
Area 2	0.2252	0.0696	3.237	0.0012
Area 3	-0.4868	0.0428	-11.381	<2.00E-16
Area 4	-0.0179	0.1567	-0.114	0.9091
Area 6	4.1534	0.8834	4.701	2.76E-06
Area 8	2.5071	0.8807	2.847	0.0045
Quarter 2:Area 3	3.0909	0.8001	3.863	0.0001
Quarter 4:Area 3	-0.0080	0.1436	-0.056	0.9553
Quarter 2:Area 4	3.5562	0.8173	4.351	1.43E-05

Table 2. Summarized results of GLM for 1979 – 1998.

Parameter	Estimate	Standard error	t value	P(>|t|)
Intercept	3.7067	0.1013	36.582	<2.00E-16
1980	-0.0900	0.1247	-0.721	0.4707
1981	0.0976	0.1205	0.810	0.4182
1982	-0.2035	0.1167	-1.744	0.0813
1983	0.1659	0.1221	1.359	0.1742
1984	0.2403	0.1167	2.059	0.0395
1985	0.4179	0.1256	3.327	0.0009
1986	-0.1105	0.1334	-0.829	0.4073
1987	-0.5318	0.1346	-3.951	0.0001
1988	0.2138	0.1726	1.239	0.2154
1989	-0.7975	0.1553	-5.134	2.96E-07
1990	0.1954	0.1448	1.349	0.1773
1991	-0.2383	0.1391	-1.713	0.0868
1992	0.3806	0.1373	2.772	0.0056
1993	0.0173	0.1345	0.128	0.8980
1994	0.2734	0.1287	2.124	0.0337
1995	0.0984	0.1221	0.806	0.4203
1996	0.5873	0.1208	4.861	1.21E-06
1997	-0.1554	0.1190	-1.306	0.1917
1998	1.1175	0.1291	8.656	<2.00E-16
Quarter 2	-1.5820	0.7236	-2.186	0.0288
Quarter 4	-0.1784	0.1511	-1.180	0.2379
Area 2	0.4765	0.1006	4.736	2.25E-06
Area 3	-0.2983	0.0659	-4.524	6.22E-06
Area 4	-0.2324	0.0662	-3.510	0.0005
Area 5	0.7826	0.0629	12.450	2.00E-16
Area 6	0.0781	0.1400	0.558	0.5768
Area 7	1.1157	0.1554	7.178	8.23E-13
Area 8	0.1415	0.1380	1.026	0.3051
Quarter 4:Area 2	-0.0582	0.4534	-0.128	0.8979
Quarter 2:Area 3	1.6544	0.7425	2.228	0.0259
Quarter 4:Area 3	-0.3530	0.1919	-1.839	0.0659
Quarter 2:Area 4	1.0763	0.7759	1.387	0.1655
Quarter 4:Area 4	0.4623	0.3831	1.207	0.2276
Quarter 2:Area 5	0.5976	0.9160	0.652	0.5142
Quarter 4:Area 5	0.5172	0.2855	1.811	0.0702
Quarter 2:Area 6	1.5832	0.7493	2.113	0.0347
Quarter 4:Area 6	0.9734	0.4279	2.275	0.0230
Quarter 2:Area 7	1.6847	1.4510	1.161	0.2457
Quarter 2:Area 8	1.3901	0.7368	1.887	0.0593

Table 3. Summarized results of GLM for 1999 – 2015 (excluding 2012).

Parameter	Estimate	Standard error	t value	P(>|t|)
Intercept	4.2970	0.0826	52.001	<2.00E-16
2000	0.3006	0.1040	2.891	0.0039
2001	0.3963	0.1033	3.834	0.0001
2002	0.5547	0.1196	4.637	3.68E-06
2003	0.6510	0.1307	4.981	6.67E-07
2004	0.9160	0.1333	6.872	7.61E-12
2005	0.4006	0.1136	3.526	0.0004
2006	1.1502	0.1264	9.099	<2.00E-16
2007	0.5945	0.1256	4.733	2.31E-06
2008	0.6403	0.1259	5.085	3.90E-07
2009	0.6008	0.1184	5.075	4.09E-07
2010	-0.0241	0.1080	-0.223	0.8232
2011	-0.1565	0.1109	-1.411	0.1583
2013	0.1623	0.1171	1.385	0.1660
2014	-0.0474	0.1394	-0.340	0.7339
2015	0.1462	0.1359	1.076	0.2819
Quarter 2	-0.5422	0.1126	-4.817	1.53E-06
Quarter 4	-0.1628	0.0823	-1.979	4.79E-02
Area 2	-0.2489	0.1016	-2.451	0.0143
Area 3	-0.5266	0.0948	-5.555	3.02E-08
Area 4	-0.7086	0.0846	-8.377	<2.00E-16
Area 5	-0.2470	0.0951	-2.598	0.0094
Area 6	-0.5902	0.3646	-1.619	1.06E-01
Area 7	-0.2346	0.1149	-2.041	4.13E-02
Area 8	-0.3302	0.2451	-1.347	0.1781
Quarter 4:Area 2	0.6725	0.5224	1.287	0.1981
Quarter 2:Area 3	0.2520	0.3123	0.807	4.20E-01
Quarter 4:Area 3	-0.5093	0.1792	-2.843	0.0045
Quarter 2:Area 4	0.1881	0.2248	0.837	0.4027
Quarter 4:Area 4	0.4784	0.4545	1.053	0.2925
Quarter 2:Area 5	-0.2819	0.4899	-0.575	0.5651
Quarter 4:Area 5	0.4328	0.3170	1.365	0.1723
Quarter 2:Area 6	0.7472	0.3981	1.877	0.0606
Quarter 4:Area 6	1.3723	0.8091	1.696	0.0900
Quarter 2:Area 7	1.2369	1.2478	0.991	0.3216
Quarter 4:Area 7	0.4366	0.3066	1.424	0.1545
Quarter 2:Area 8	0.2670	0.2776	0.962	0.3361
Quarter 4:Area 8	1.2218	0.5075	2.408	0.0161

Table 5. Standardized abundance indices of juvenile north Pacific albacore tuna for the US troll and pole-and-line fisheries for: 1) 1966 – 1978; 2) 1979 – 1998; and 3) 1999 – 2015 (excluding 2012). Coefficient of variations (CVs) were estimated from 10000 bootstrap runs.

Index 1			**Index 2**			**Index 3**		
Year	Value	CV	Year	Value	CV	Year	Value	CV
1966	73.147	0.199	1979	63.828	0.352	1999	87.1151	0.109
1967	104.961	0.202	1980	58.336	0.357	2000	117.6607	0.121
1968	85.905	0.197	1981	70.368	0.347	2001	129.4743	0.099
1969	73.349	0.199	1982	52.076	0.345	2002	151.7075	0.121
1970	99.937	0.201	1983	75.347	0.347	2003	167.0397	0.133
1971	82.733	0.201	1984	81.164	0.344	2004	217.7254	0.121
1972	83.960	0.199	1985	96.942	0.347	2005	130.0435	0.122
1973	72.994	0.204	1986	57.149	0.358	2006	275.1840	0.131
1974	78.908	0.197	1987	37.501	0.358	2007	157.8613	0.147
1975	89.268	0.191	1988	79.043	0.410	2008	165.2621	0.147
1976	62.811	0.193	1989	28.753	0.373	2009	158.8558	0.117
1977	47.705	0.191	1990	77.605	0.391	2010	85.0389	0.101
1978	69.189	0.198	1991	50.295	0.354	2011	74.4985	0.100
			1992	93.386	0.351	2013	102.4624	0.103
			1993	64.938	0.348	2014	83.0819	0.126
			1994	83.894	0.347	2015	100.8325	0.122
			1995	70.428	0.352			
			1996	114.829	0.349			
			1997	54.640	0.343			
			1998	195.138	0.351			

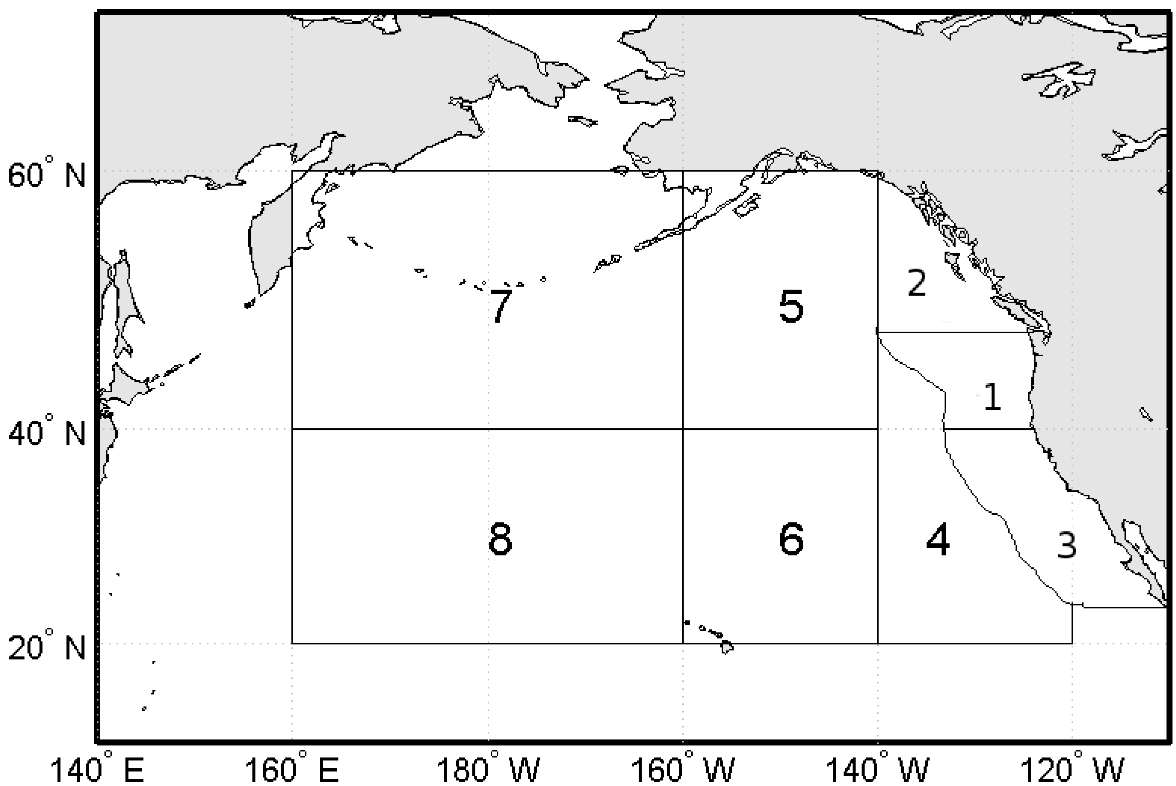

Figure 1. Map of the 8 areas used to standardize the catch-per-unit-effort (CPUE) of US surface fishery. See text for spatial definitions of areas.

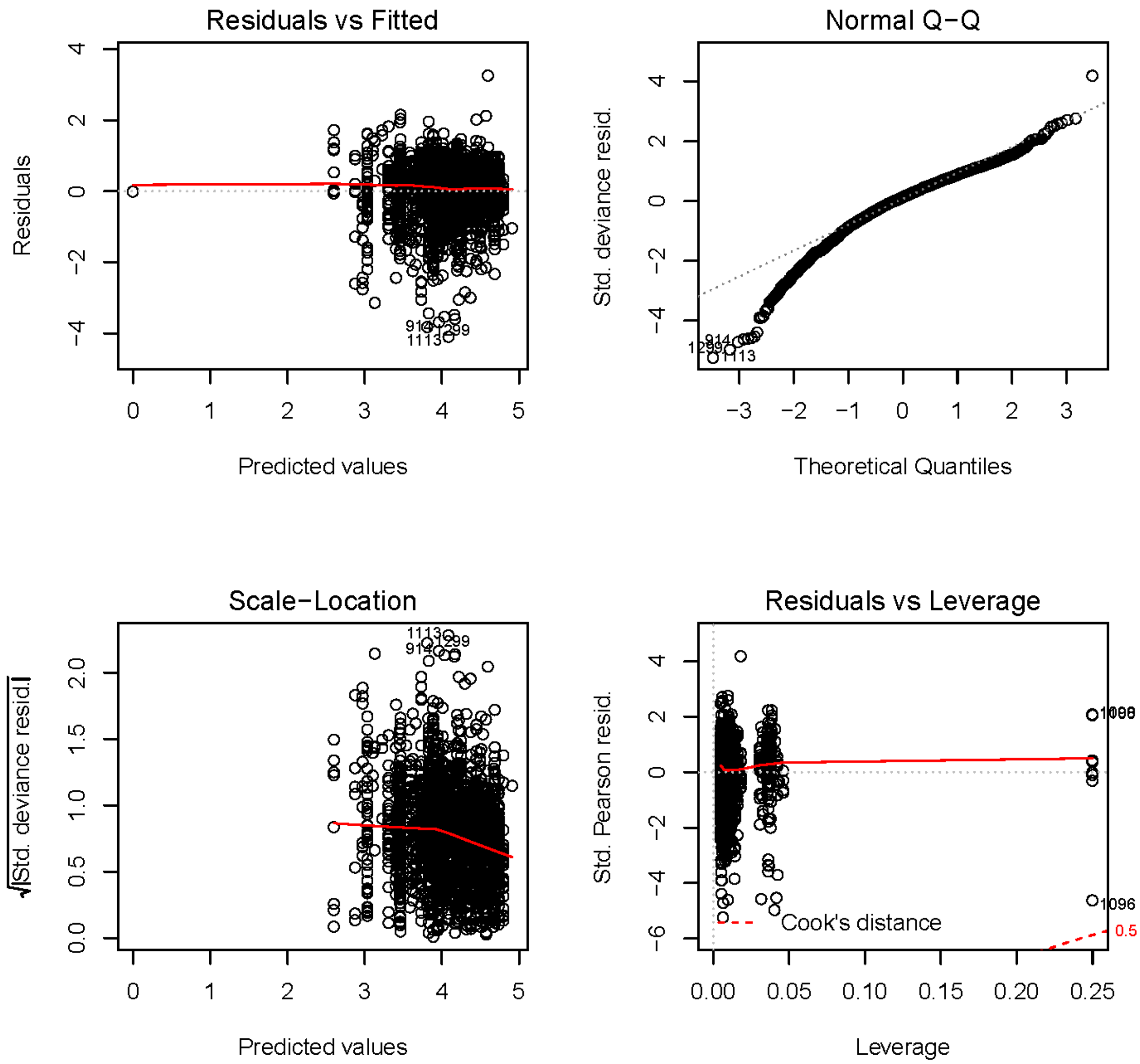

Figure 2. Residuals and Q-Q plots of the GLM for 1966 – 1978.

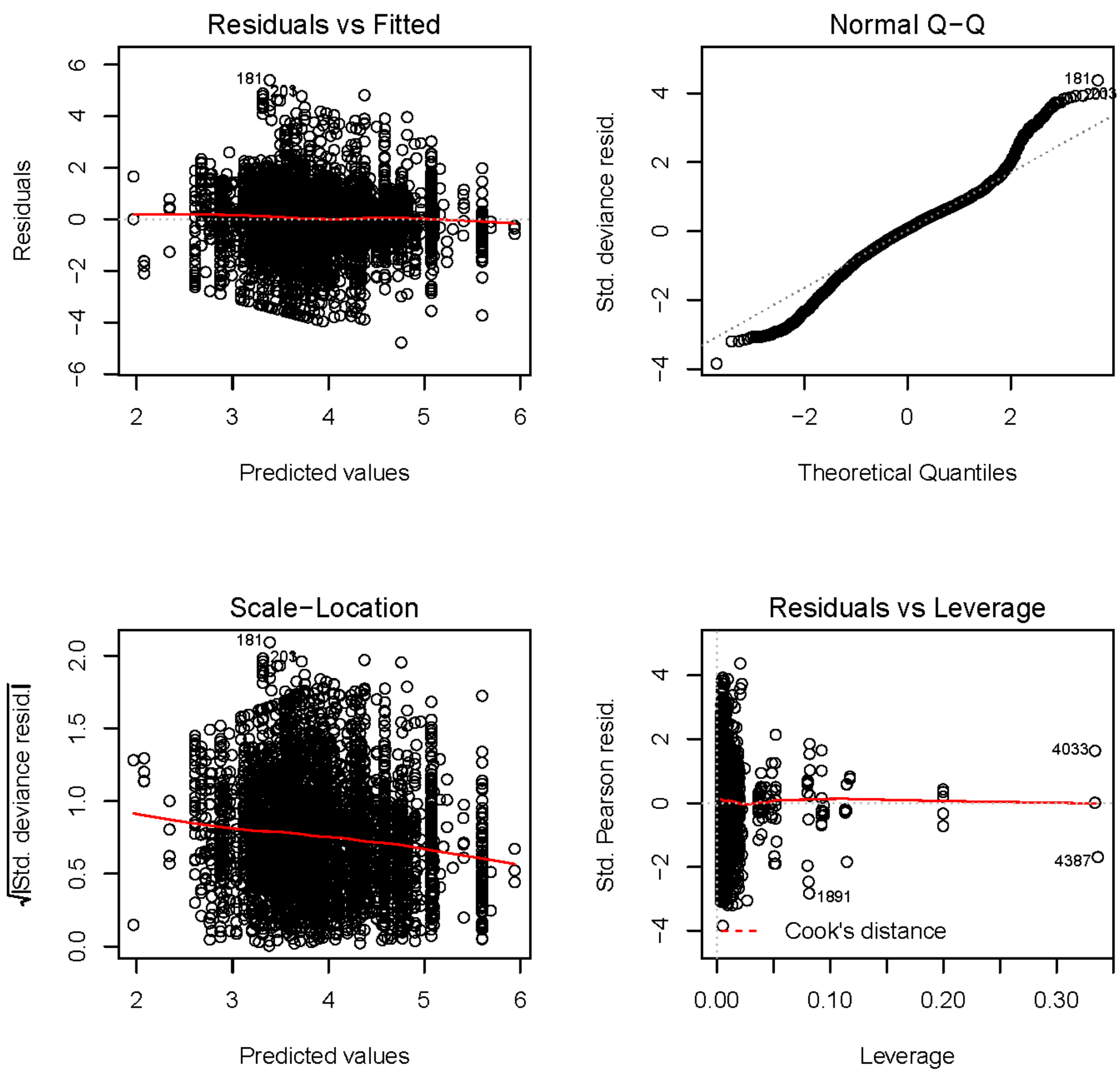

Figure 3. Residuals and Q-Q plots of the GLM for 1979 – 1998.

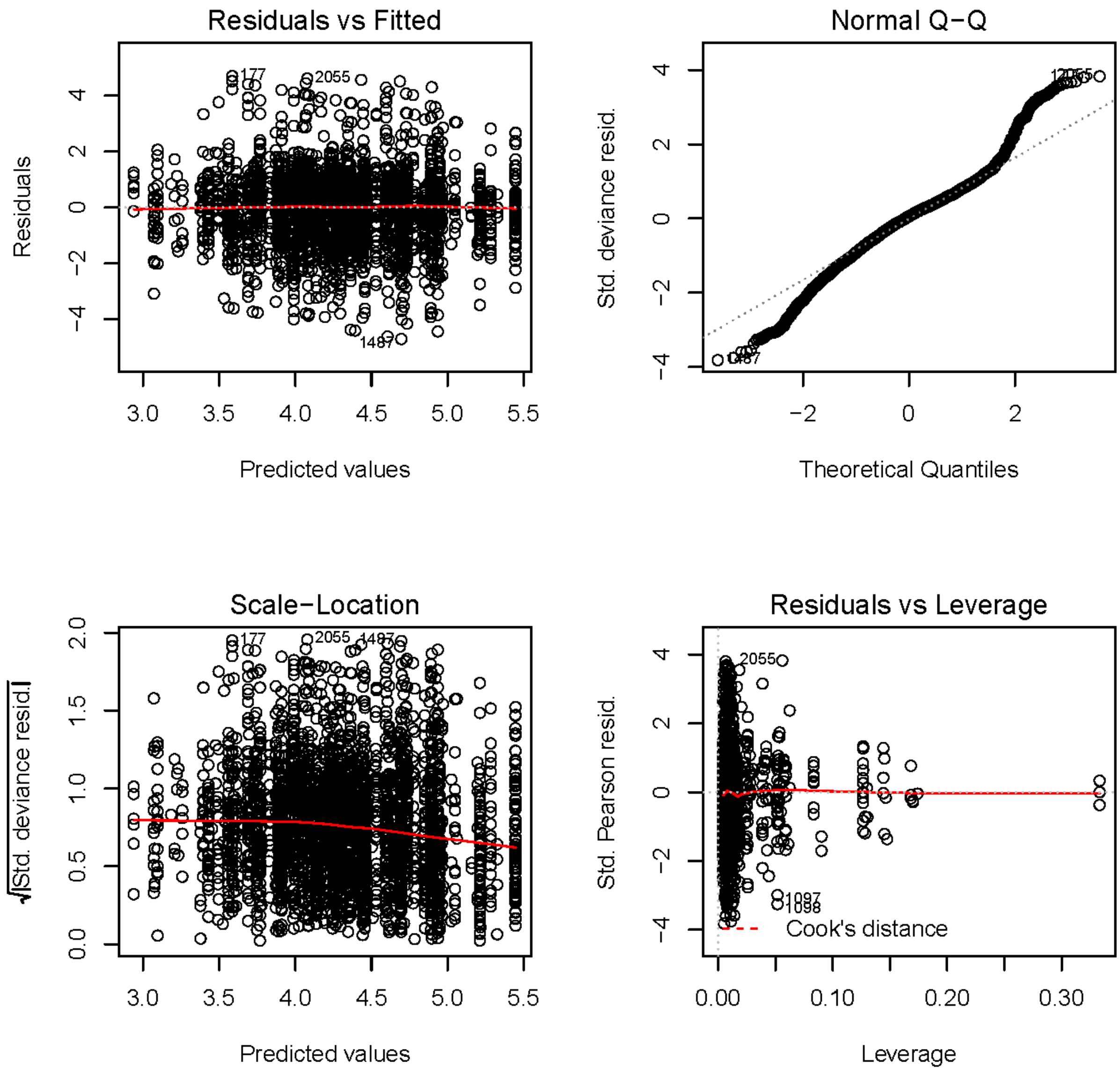

Figure 4. Residuals and Q-Q plots of the GLM for 1999 – 2015 (excluding 2012).

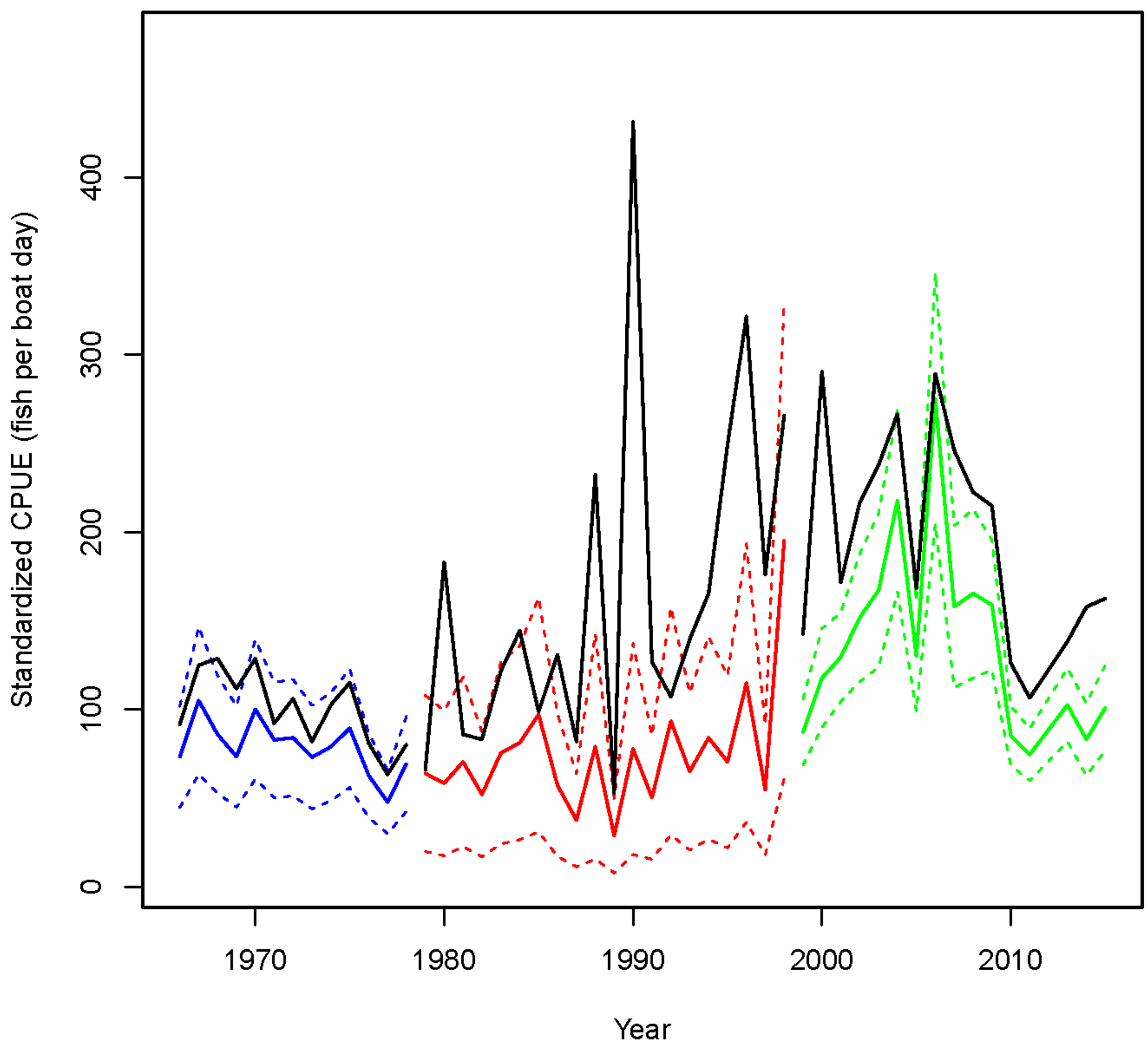

Figure 5. Standardized abundance index of juvenile north Pacific albacore tuna for the US surface fishery for: 1) 1966 – 1978 (blue); 2) 1979 – 1998 (red); and 3) 1999 – 2015 (excluding 2012; green). Black lines indicate nominal CPUE. Dashed lines indicate 95% confidence intervals from 10000 bootstrap runs.