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Relative abundance indices of adult albacore tuna for the US pelagic longline 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 abundance indices of adult albacore tuna for the US pelagic longline fishery in the north Pacific Ocean. Juvenile and adult albacore appear to segregate spatially, with juvenile and sub-adult albacore tuna being caught in the north, and large adults being caught in the southern area. The ALBWG suggested that candidate abundance indices for the southern area be developed for the 2017 assessment. Major regulations have severely affected the fishing operations of US longline vessels in the north Pacific. In particular, there was a ban of shallow-set gear during 2001 – 2004 and other regulations post-2004, in order to reduce turtle interactions. The fishing operations of the US longline fishery changed substantially post-2004 and likely affected the catchability of albacore. Therefore, two abundance indices (1991 – 2000; and 2004 – 2015) were developed by standardizing the catch-per-unit-effort (CPUE) of US longline vessels operating in the southern are to represent the relative abundance trends of adult albacore tuna before and after the shallow-set ban. The main source of data used in this paper is catch-effort information from fishermen logbooks (1991-2015). Delta-lognormal models were used to standardize the CPUE of the longline fishery, with each set as a stratum, because a substantial portion of the sets (>50%) did not capture any albacore. Three explanatory factors (year, quarter, and 10x10° subarea) were used in both the lognormal and binomial submodels. Confidence intervals of the abundance indices were subsequently estimated from 1000 bootstrap runs. During the 1991 – 2000 period, the abundance index peaked in 1997 before declining and the CVs were relatively large (>0.55). The relative abundance in the 2005 – 2015 period was substantially lower than for the 1991 – 2000 period but peaked in 2011 before declining. It is currently unclear if the standardization process has adequately standardized the changes in catchability for the US longline fishery due to the changes in regulations for the fishery. Given the large changes in regulations for this fishery, and the diagnostics of the standardization models, it is recommended that the ALBWG do not use these abundance indices as the primary abundance indices for adult albacore tuna in the 2017 stock assessment. Instead the ALBWG should use the indices in sensitivity runs. In addition, the ALBWG should not assume that both abundance indices share the same catchability.

INTRODUCTION

The objective of this paper is to describe the data sources and methods used to develop abundance indices of adult albacore tuna for the US pelagic longline fishery in the north Pacific Ocean. These abundance indices are candidates for representing the population trends of adult 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).

Size compositions of albacore tuna caught by the US longline fishery suggests that juvenile and adult albacore segregate spatially (Teo, 2016). There appears to be a northern area with primarily juvenile and sub-adult albacore tuna, and a southern area with predominantly large, adult albacore (Figure 1). The ALBWG agreed with these spatial definitions for the US longline fleets and suggested that candidate abundance indices for the southern area (Fleet 2 in Teo 2016) be developed for the 2017 assessment because abundance indices in the southern area would be more representative of the population trends of adult albacore than the northern area.

The vast majority of US longline vessels in the north Pacific operate out of and land fish in Hawaii, and Hawaii-based landings represent >95% of the total north Pacific albacore catch from US longline vessels (McDaniel, Crone, & Dorval, 2006). It is important to note that albacore tuna is not considered a target species of the US longline fishery, with bigeye tuna and swordfish being the preferred species. Vessels in the northern area tend to target swordfish with shallow-set gear while vessels in the southern area tend to target bigeye tuna with deep-set gear.

Major regulations have severely affected the fishing operations of US longline vessels in the north Pacific. In particular, there was a ban of shallow-set gear during 2001 – 2004 in order to reduce turtle interactions. In addition, there were limits on the number of shallow-sets (removed in 2010) and the number of turtle interactions by the shallow-set gear. Although most of the regulations to reduce turtle interactions were targeted at shallow-set gear, there were also regulations affecting deep-set longline gear. The US longline fishery is also currently subject to bigeye tuna catch limits imposed by the Western and Central Pacific Fisheries Commission and the Inter-American Tropical Tuna Commission in their respective regions. It is currently unclear how these regulations may have affected the fishing operations of longline vessels in the southern area but it may be prudent to assume that the catchability of albacore tuna by US longline vessels have been affected to some degree by the regulatory changes.

In this paper, I therefore developed two abundance indices by standardizing the catch-per-unit-effort (CPUE) of US longline vessels operating in the southern area. Index 1 (1991 – 2000) and Index 2 (2005 – 2015) can be considered to represent the relative abundance trends of adult albacore tuna before and after the shallow-set ban, respectively.

MATERIALS AND METHODS

Data sources

The main source of data used in this paper is catch-effort information from fishermen logbooks (1991-2015). A logbook monitoring program for the Hawaii-based longline fishery has been managed by the NOAA since 1990. However, the logbook data from 1990 were not used in this study because data collection only started near the end of the year. Importantly, the logbooks generally recorded set-by-set information on the location (latitude and longitude) of the vessel, the number of albacore caught and discarded, target species, and the number of hooks deployed. Since 1995, logbooks have also recorded the number of hooks per float that were deployed.

Each longline set was assigned to a 10x10° subarea (Figure 1), based on the latitude and longitude. Only sets in the southern area (i.e., subareas 6, 12, 13, 14, 17, 18, 19, 20, 21, 22, 26, 28, 29, 30, and 31 in Figure 1) were used to develop the abundance indices. Sets without location information or had <100 hooks were discarded. In total, 103746 and 159610 longline sets were included in the analysis to develop abundance indices for 1991 – 2000 and 2005 – 2015 respectively.

Model

A preliminary examination of the longline data indicated that a substantial proportion (>50%) of the longline sets did not capture any albacore. Delta-lognormal models (Lo, Jacobson, & Squire, 1992) were therefore used to standardize the CPUE of the longline fishery, with each set as a stratum. First, we identified the strata with at least one albacore caught (positive-catch) or with no albacore catch (zero-catch), and assigned a binomial variable to each stratum based on the presence/absence of albacore catch. Secondly, we calculated the CPUE of positive-catch strata as number of albacore per 1000 hooks and log-transformed the CPUE by ln(CPUE). The year, quarter (3 months = 1 quarter, starting from January), and subarea (Figure 1) were used as explanatory factors. Hooks per float was investigated as an explanatory factor in preliminary models but was eliminated in the final models because including hooks per float resulted in highly similar abundance trends but with substantially shorter time series (starts in 1995). No interaction terms were included in the models because preliminary exploration of the models suggested that adding interactions to the models did not improve model fit substantially. In addition, previous CPUE indices derived from the US longline fishery also did not include any interaction terms (McDaniel et al., 2006).

A binomial GLM with a logit link was used to model the probability of positive-catch while a lognormal GLM was used model the CPUE of the positive-catch strata. The log-transformed CPUE was related to three main factors – year (Y), quarter (Q), and subarea (A) by,

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

where $CPUE_{ijk}$ is the CPUE (fish per 1000 hooks) in year *i*, quarter *j*, and subarea *k*, and *X* is the intercept. The probability of positive albacore catch was related to the same three factors using a binomial GLM with logit link. The standardized CPUE index, I_t, was obtained by calculating population marginal means of the above GLMs for a given year and subsequently back-transforming the result using,

$$I_t = \exp(\hat{\alpha}_t + \frac{\hat{\sigma}_t^2}{2})\frac{\exp(\hat{\beta}_t)}{1 + \exp(\hat{\beta}_t)}$$

where $\hat{\alpha}_t$ is the estimated year factor for the lognormal GLM, $\hat{\beta}_t$ is the estimated year factor for the binomial GLM, and $\hat{\sigma}_t^2$ is the variance of $\hat{\alpha}_t$. Confidence intervals of the abundance indices were subsequently estimated from 1000 bootstrap runs.

RESULTS AND DISCUSSION

Tables 1 – 4 show the summarized results of the binomial and lognormal GLMs for both abundance indices: 1991 – 2000 (Tables 1 and 2), and 2005 – 2015 (Tables 3 and 4). Standard diagnostics for the lognormal GLMs are shown in Figures 2 and 3. Residual plots for both abundance indices indicate that the models may not be fitting the data well at low catch values. These results suggest that other types of models (e.g., zero-inflated negative binomial, random effects) should be considered for standardizing the CPUE of this fishery in the future.

The standardized abundance indices and corresponding coefficients of variation (CVs) are shown in Figures 4 and 5, and Table 5. During the 1991 – 2000 period, the abundance index peaked in 1997 before declining and the CVs were relatively large (>0.55). The relative abundance in the 2005 – 2015 period was substantially lower than for the 1991 – 2000 period but peaked in 2011 before declining.

It is currently unclear if the standardization process has adequately standardized the changes in catchability for the US longline fishery due to the changes in regulations for the fishery. Given the large changes in regulations for this fishery, and the diagnostics of the standardization models, it is recommended that the ALBWG do not use these abundance indices as the primary abundance indices for adult albacore tuna in the 2017 stock assessment. Instead the ALBWG should use the indices in sensitivity runs. In addition, the ALBWG should not assume that both abundance indices share the same catchability.

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Table 1. Summarized results of binomial GLM for 1991 – 2000.

Parameter	**Estimate**	**Standard error**	**z value**	**P(>$\lvert z\rvert$)**
Intercept	-1.311	0.046	-28.798	<2.00E-16
1992	0.178	0.031	5.760	8.42E-09
1993	0.394	0.030	13.031	<2.00E-16
1994	0.490	0.031	15.904	<2.00E-16
1995	0.914	0.030	30.666	<2.00E-16
1996	1.094	0.030	36.785	<2.00E-16
1997	1.065	0.030	35.906	<2.00E-16
1998	1.085	0.030	36.104	<2.00E-16
1999	1.218	0.030	41.065	<2.00E-16
2000	0.330	0.030	10.963	<2.00E-16
Quarter 2	0.169	0.018	9.559	<2.00E-16
Quarter 3	0.259	0.021	12.594	<2.00E-16
Quarter 4	0.213	0.019	11.382	<2.00E-16
Subarea 12	-0.421	0.052	-8.136	4.08E-16
Subarea 13	0.158	0.041	3.860	0.000113
Subarea 14	0.511	0.040	12.851	<2.00E-16
Subarea 17	1.687	0.197	8.572	<2.00E-16
Subarea 18	0.991	0.041	23.938	<2.00E-16
Subarea 19	-0.019	0.041	-0.456	0.648677
Subarea 20	-1.453	0.755	-1.924	0.054392
Subarea 21	-3.014	0.110	-27.477	<2.00E-16
Subarea 22	-4.275	1.006	-4.250	2.14E-05
Subarea 26	-0.537	0.134	-4.006	6.19E-05
Subarea 30	-10.509	53.428	-0.197	0.844064
Subarea 31	-9.754	119.468	-0.082	0.934928

Table 2. Summarized results of lognormal GLM for 1991 – 2000.

Parameter	**Estimate**	**Standard error**	**t value**	**P(>|t|)**
Intercept	1.806	0.035	51.111	<2.00E-16
1992	0.061	0.025	2.461	0.014
1993	0.169	0.024	7.009	0.000
1994	0.334	0.024	13.758	<2.00E-16
1995	0.381	0.022	17.106	<2.00E-16
1996	0.461	0.022	21.083	<2.00E-16
1997	0.718	0.022	32.815	<2.00E-16
1998	0.346	0.022	15.718	<2.00E-16
1999	0.433	0.021	20.184	<2.00E-16
2000	0.051	0.023	2.195	0.028
Quarter 2	0.219	0.013	17.500	<2.00E-16
Quarter 3	0.123	0.014	8.552	<2.00E-16
Quarter 4	-0.019	0.013	-1.409	0.159
Subarea 12	-1.090	0.041	-26.715	<2.00E-16
Subarea 13	-1.195	0.031	-38.115	<2.00E-16
Subarea 14	-1.111	0.031	-36.356	<2.00E-16
Subarea 17	-0.240	0.100	-2.409	0.016
Subarea 18	-1.079	0.031	-34.666	<2.00E-16
Subarea 19	-1.594	0.032	-49.755	<2.00E-16
Subarea 20	-1.341	0.699	-1.917	0.055
Subarea 21	-2.596	0.104	-24.973	<2.00E-16
Subarea 22	0.826	0.988	0.836	0.403
Subarea 26	-1.619	0.113	-14.296	<2.00E-16

Table 3. Summarized results of binomial GLM for 2005 – 2015.

Parameter	**Estimate**	**Standard error**	**z value**	**P(>|z|)**
Intercept	-1.729	0.203	-8.535	<2.00E-16
2006	-0.334	0.028	-11.862	<2.00E-16
2007	-0.594	0.029	-20.598	<2.00E-16
2008	-0.442	0.029	-15.463	<2.00E-16
2009	-0.876	0.031	-28.682	<2.00E-16
2010	-0.231	0.029	-8.056	7.85E-16
2011	0.280	0.027	10.282	<2.00E-16
2012	0.203	0.027	7.560	4.03E-14
2013	-0.498	0.029	-17.299	<2.00E-16
2014	-0.715	0.030	-23.753	<2.00E-16
2015	-0.458	0.029	-15.598	<2.00E-16
Quarter 2	-0.796	0.016	-50.038	<2.00E-16
Quarter 3	-0.552	0.020	-27.438	<2.00E-16
Quarter 4	-1.108	0.017	-64.169	<2.00E-16
Subarea 12	2.268	0.207	10.953	<2.00E-16
Subarea 13	1.712	0.202	8.483	<2.00E-16
Subarea 14	0.767	0.202	3.802	1.43E-04
Subarea 17	3.578	0.220	16.268	<2.00E-16
Subarea 18	2.450	0.202	12.152	<2.00E-16
Subarea 19	1.029	0.202	5.087	3.64E-07
Subarea 20	-1.345	0.317	-4.243	2.20E-05
Subarea 21	-0.335	0.217	-1.548	0.122
Subarea 22	-1.101	0.434	-2.541	0.011
Subarea 28	-1.063	0.546	-1.946	0.052
Subarea 29	-10.078	143.992	-0.070	0.944
Subarea 30	-9.485	86.035	-0.110	0.912
Subarea 31	-9.573	52.404	-0.183	0.855

Table 4. Summarized results of lognormal GLM for 2005 – 2015.

Parameter	Estimate	Standard error	t value	P(>|t|)
Intercept	-0.416	0.162	-2.574	0.010
2006	-0.093	0.019	-4.904	9.41E-07
2007	-0.096	0.020	-4.793	1.65E-06
2008	-0.083	0.019	-4.300	1.71E-05
2009	-0.300	0.021	-14.066	<2.00E-16
2010	0.081	0.019	4.270	1.96E-05
2011	0.120	0.017	6.974	3.13E-12
2012	0.061	0.017	3.537	4.05E-04
2013	-0.157	0.019	-8.079	6.69E-16
2014	-0.370	0.021	-18.036	<2.00E-16
2015	-0.314	0.020	-15.810	<2.00E-16
Quarter 2	-0.067	0.010	-6.532	6.57E-11
Quarter 3	-0.046	0.014	-3.402	6.69E-04
Quarter 4	-0.200	0.012	-16.707	<2.00E-16
Subarea 12	0.976	0.164	5.960	2.55E-09
Subarea 13	0.554	0.161	3.437	5.88E-04
Subarea 14	0.247	0.161	1.530	0.126
Subarea 17	1.186	0.166	7.164	7.96E-13
Subarea 18	0.629	0.161	3.901	9.61E-05
Subarea 19	0.288	0.162	1.784	0.074
Subarea 20	-0.240	0.259	-0.928	0.353
Subarea 21	-0.016	0.174	-0.091	0.928
Subarea 22	-0.123	0.355	-0.347	0.728
Subarea 28	0.006	0.448	0.014	0.989

Table 5. Standardized abundance indices of adult north Pacific albacore tuna for the US pelagic longline fishery for: 1) 1991 – 2000; and 2) 2005 – 2015. Coefficient of variations (CVs) were estimated from 1000 bootstrap runs.

Index 1			**Index 2**		
Year	Value	CV	Year	Value	CV
1991	0.1543	0.6358	2005	0.0247	0.1476
1992	0.1946	0.6273	2006	0.0162	0.1481
1993	0.2659	0.6178	2007	0.0125	0.1490
1994	0.3432	0.6109	2008	0.0147	0.1491
1995	0.5323	0.5898	2009	0.0077	0.1513
1996	0.6776	0.5733	2010	0.0213	0.1479
1997	0.8542	0.5782	2011	0.0365	0.1461
1998	0.5993	0.5772	2012	0.0319	0.1475
1999	0.7352	0.5662	2013	0.0129	0.1515
2000	0.2225	0.6219	2014	0.0084	0.1491
			2015	0.0115	0.1510

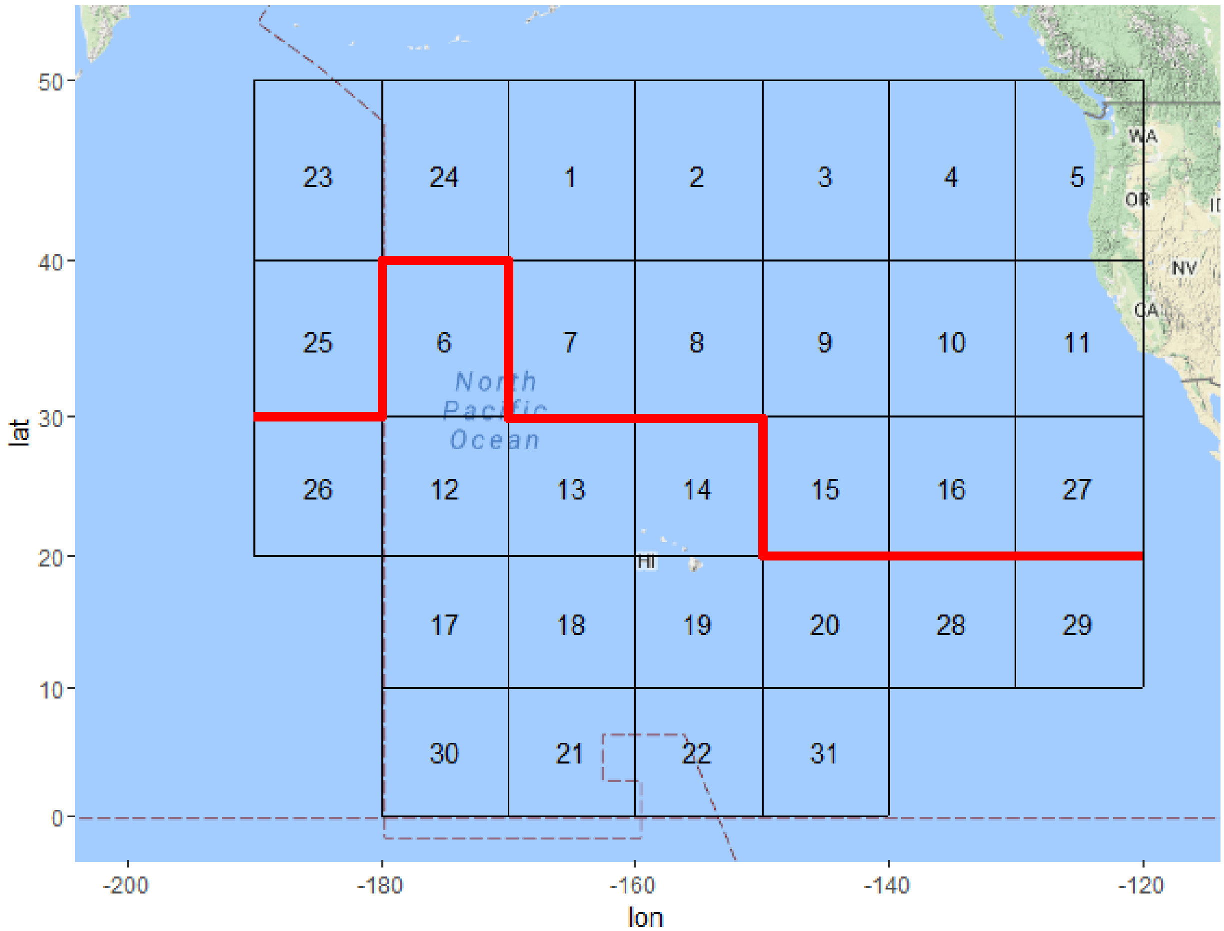


Figure 1. Spatial definition of the 10x10° subareas used to standardize the catch-per-unit-effort (CPUE) of US pelagic longline fishery. Only subareas below the red line were used to develop abundance indices for adult albacore tuna, because Teo (2016) showed that these longline vessels in these subareas consistently caught large, adult albacore tuna. Subareas 1 – 22 had size composition data available and were included in the Teo (2016) analysis, while subareas 23 – 31 only had catch-effort data and were not in the Teo (2016) analysis.

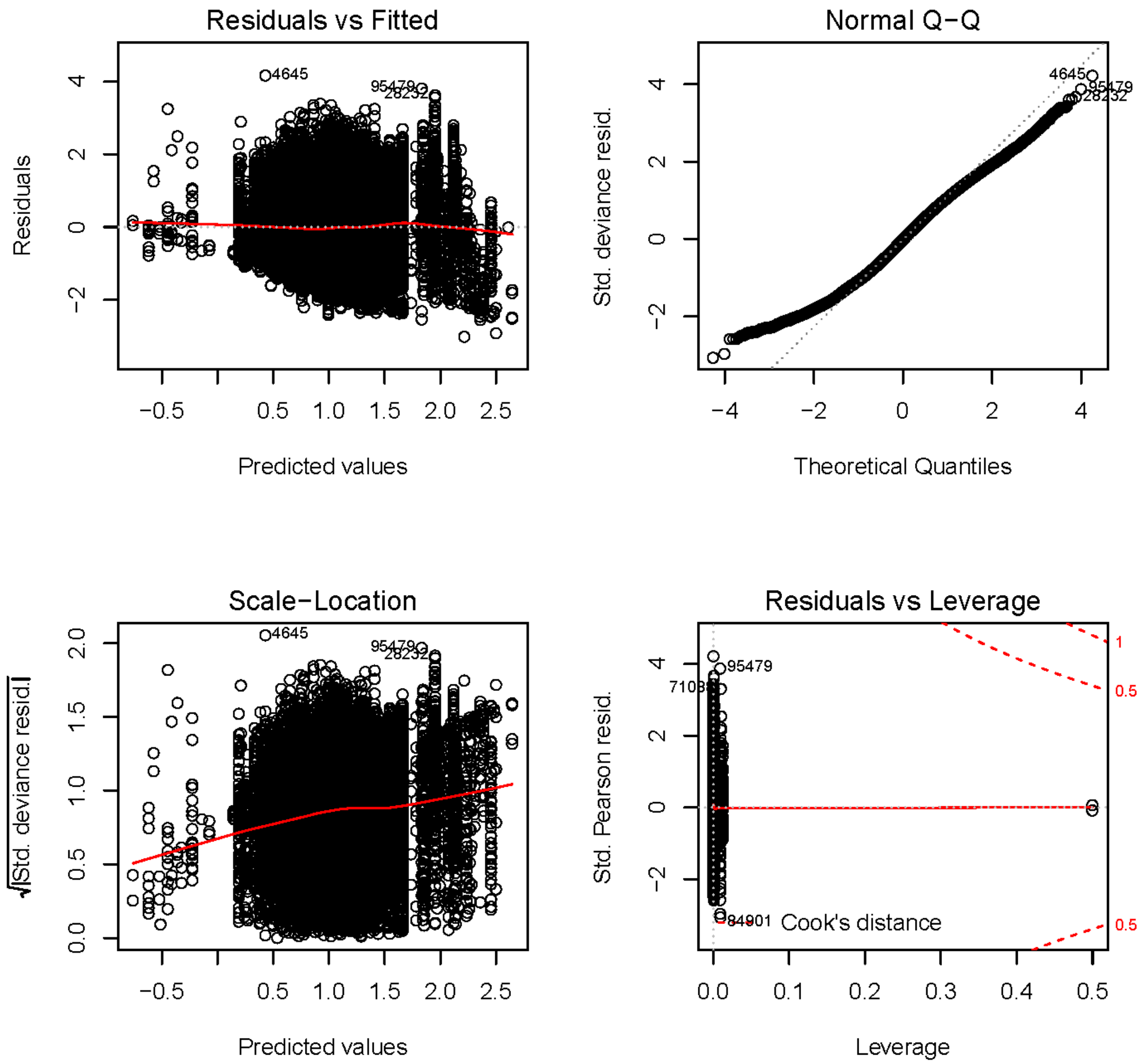


Figure 2. Residuals and Q-Q plots of the lognormal GLM (positive-catch only) for 1991 – 2000.

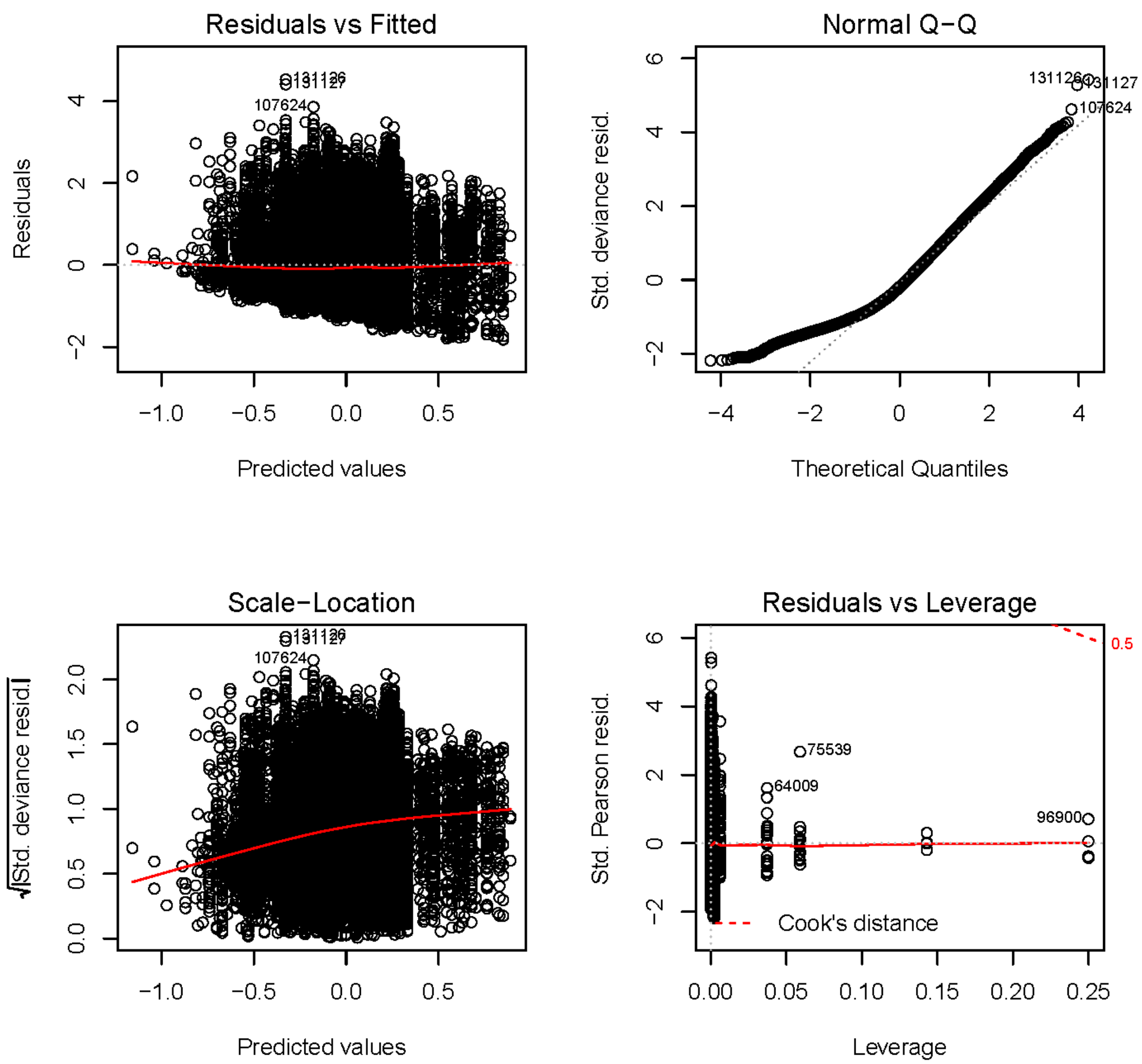


Figure 3. Residuals and Q-Q plots of the lognormal GLM (positive-catch only) for 2005 – 2015.

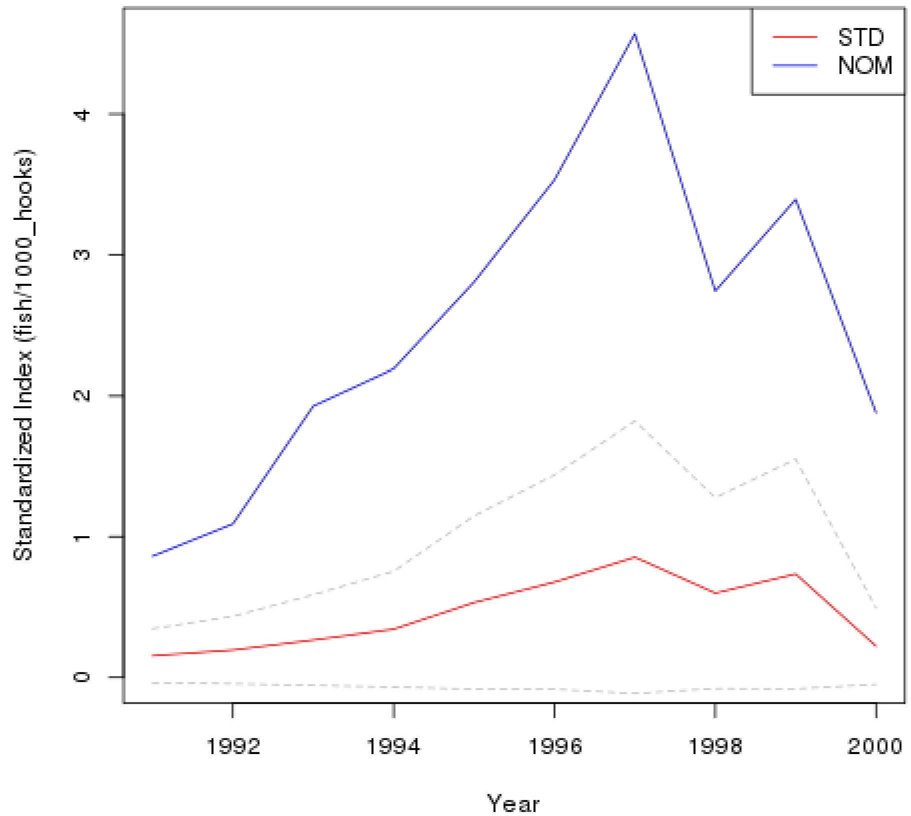
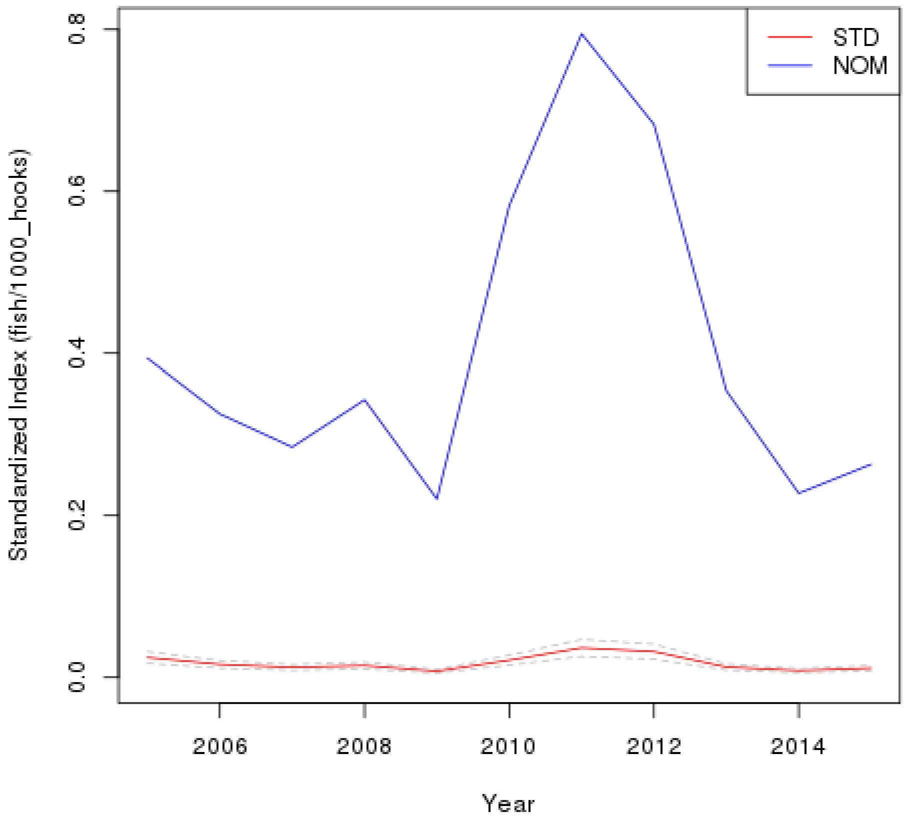


Figure 4. Standardized abundance index (red) and nominal CPUE (blue) of adult north Pacific albacore tuna for the US pelagic longline fishery for 1991 – 2000. Dashed lines indicate 95% confidence intervals from 1000 bootstrap runs.



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