Time series associated with albacore fisheries based in the Northeast Pacific Ocean[1]

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[1]Working document submitted to the ISC Albacore Working Group Meeting, 12-19 October 2010, Southwest Fisheries Science Center, NOAA, La Jolla, California, USA. Document not to be cited without author's permission.

ABSTRACT

Time series of catch, size composition, and relative abundance are important inputs into the stock assessments of North Pacific albacore. In this paper, we describe in detail the data sources and methods used to develop these time series from albacore fisheries based in the Northeast Pacific. Time series were developed for both SS3 and VPA models. For the SS3 model, we developed time series of: 1) catch in numbers of fish for the US/Canada troll, US longline, and EPO miscellaneous fisheries; 2) size compositions for the US troll, and longline fisheries; and 3) standardized abundance indices for the US/Canada troll and US longline fisheries. For the VPA, we developed time series of: 1) catch-at-age in numbers of fish for the EPO surface and US longline fisheries; and 2) standardized abundance indices for the US/Canada troll and US longline fisheries. Three main sources of data were used to develop the time series: 1) albacore landings in metric tons from fisheries based in the Northeast Pacific (1966-2008); 2) logbook data from the U.S. troll (1966-2008) and longline (1991-2008) fisheries; and 3) albacore size data (fork length in cm) from the U.S. troll (1966-2008) and longline (1994-2008) fisheries.

INTRODUCTION

The objective of this document is to describe the data sources and methods used to develop time series from albacore fisheries based in the Northeast Pacific Ocean that are important for the stock assessment of North Pacific albacore conducted by the albacore working group (ALBWG) of the International Scientific Committee on Tuna and Tuna-like species (ISC) in 2011. For the 2011 assessment, the ALBWG is transitioning from a Virtual Population Analysis (VPA) model to a Stock Synthesis 3 (SS3) model. Due to this transition, the ALBWG decided in previous meetings to develop both a VPA and a SS3 model for this assessment, although most of the effort and analysis will be concentrated on the SS3 model.

As such, we developed time series for both SS3 and VPA models. Our analyses primarily focused on the US-based albacore troll and longline fisheries but other fisheries were also incorporated into particular analyses (primarily other surface fisheries operating out of the US, Canada, and Mexico). Finally, over the years, pole-and-line and longline fleets of Japan and longline vessels of Taiwan (i.e., fisheries based in the Northwest Pacific Ocean) have fished at varying levels of intensity in the Eastern Pacific Ocean (EPO), catching North Pacific albacore. However, data from these fisheries were not used in analyses presented here.

For the SS3 model, we developed time series of: 1) catch in numbers of fish for the US/Canada troll, US longline, and EPO miscellaneous fisheries; 2) size compositions for the US troll, and longline fisheries; and 3) standardized abundance indices for the US/Canada troll and US longline fisheries. For the VPA, we developed time series of: 1) catch-at-age in numbers of fish for the EPO surface and US longline fisheries; and 2) standardized abundance indices for the US/Canada troll and US longline fisheries. Although previous VPA-based assessments used age-specific abundance indices, the ALBWG agreed at previous meetings to use age-aggregated abundance indices in the VPA model so as to ease comparison with the SS3 model (Anonymous, 2010).

MATERIALS AND METHODS

Data Sources

Three main sources of data were used to develop the time series: 1) albacore landings in metric tons from various fisheries based in the Northeast Pacific (primarily US, Canada, and Mexico), including troll, pole-and-line, gillnet, purse seine, recreational, and unspecified gears (1966-

2008); 2) logbook data from the U.S. troll (1966-2008) and longline (1991-2008) fisheries; and 3) albacore size data from the U.S. troll (1966-05) and longline (1994-05) fisheries.

Estimated annual landings of North Pacific albacore in metric tons by fishery were submitted by member countries to the ISC (Anonymous, 2010) (see Table 1 for EPO-based fisheries). As some Northeast Pacific-based fisheries catch albacore west of 180°W, estimated annual landings of each fishery include all North Pacific albacore landings irrespective of capture location.

For US fisheries, commercial landings of North Pacific albacore are estimated from several databases. Landings data for California, Oregon, and Washington states are maintained in the Pacific Fisheries Information Network (PacFIN) database, while landings in Hawaii and US territories in the Pacific are maintained in the Western Pacific Fishery Information Network (WPacFIN) database. Additionally, the Western Fishboat Owners' Association (WFOA), which represents the US commercial surface fleet, monitors all landings of albacore and maintains an independent database. The National Marine Fisheries Service Southwest Fisheries Science Center (SWFSC) incorporates data from these databases to estimate the annual US albacore landings by fishery, which are then submitted to the ISC. Landing statistics for US-caught albacore dates back to 1952 but only data from 1966-2008 data were used for this analysis (see below). During 1966-2008, the troll fishery has been the largest US fishery for albacore but other fishing gears have also been employed, including pole-and-line, gill net, longline, purse seine, recreational, and 'other' (e.g., hand-line, gear unknown; Table 1). Albacore landings from US longline vessels are primarily made at fish auction sites in Hawaii. Although a few vessels also operate out of California each year, Hawaii-based landings constitute over 95% of the total albacore catch from US longline vessels. It is important to note that albacore is not considered a target species of the US longline fleet, with bigeye tuna and swordfish the preferred stocks. Landing statistics reflect both Hawaii and California longline operations. A small amount of albacore is likely unaccounted for each year because some fishermen sell directly to the public and may not document those sales. Discard rates of albacore from the US troll fishery are not known definitively, but limited observer data from the 1990s indicated that these rates are likely low and if accounted for, would not substantially change the estimated catch. Cursory examinations of longline discard rates collected from mandatory logbook data indicate total discards of albacore from US longlines are relatively low; however, results from a longline observer sampling program do reveal that in some years, some small fish were discarded prior to landing. The catch data were not adjusted to account for discards because discards were inconsistent and infrequent, and accounting for discards would not substantially change the estimated catch.

Logbook data were used to obtain time and location-specific catch and effort of the US troll and longline fisheries. An annual logbook monitoring program for the US albacore troll fishery has been managed by the SWFSC since 1961 (Childers and Betcher, 2008). Although logbook data for the US troll fishery has been collected since 1961, only 1966-2008 data were used for this analysis (see below). The logbook 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 sampling coverage varied from 7-33% (McDaniel, et al., 2006). However, in 2005, logbook submission became mandatory for this fishery and sampling coverage has increased to approximately 75% of the total number of boat trips. Importantly, the logbooks generally include 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. For the US longline fishery, a mandatory logbook program has been in place since 1991 and has collected similar catch and effort data on a set-by-set basis, including the number of hooks and number of hooks between floats for each longline set. For both troll and longline fisheries, the number of albacore caught was the sum of the number of albacore kept and discarded.

Size information (fork length to the nearest cm) from the US troll and longline fisheries were collected through port-sampling and longline observer programs, respectively. A port sampling program for the US albacore surface fisheries has been conducted for approximately six decades (Childers and Betcher, 2008). Size composition time series (1966-2008) presented here were based only on troll fishery samples although small numbers of samples from other fisheries (e.g., pole-and-line, recreational, and gill net fisheries) are also present in the port-sampling database. Although information on albacore size composition was collected prior to 1961, these older data were not associated with accurate location information and were primarily from the pole-and-line fishery. For most boat trips after 1961, a sample of usually 50 to 100 fish per trip was measured to the nearest cm. If the albacore from a boat trip were sorted by size class prior to measurement, approximately 25 fish from each size class were measured. The number of measured fish used in the analysis for each year ranged from 208 in 1993 to 49425 in 1996, with >15000 fish measured for most years (Coan, 2006). For the US longline fishery, the size composition time series (1994-2008) was developed from a longline observer sampling program rather than from a port-side sampling program conducted at fish auction sites in Hawaii. This was because previous analysis showed that the mean estimated length distributions from the longline port-side census program (converted from originally-collected weight data) did not include smaller fish that were present in size compositions developed from the observer sampling program. Due to the relatively small numbers of albacore caught by the US longline fishery, most of the individuals caught during an observed longline set were measured and included in the size composition time series.

Finally, it is important to note that some data sources for the US troll and longline fisheries extend back to the early 1950s. However, the time series in this analysis begin in 1966 because current assessment models start in 1966 due to concerns regarding the accuracy associated with some of the sample data collected prior to 1966 for both eastern and western Pacific Ocean fisheries.

Time Series for SS3 Model

<u>Catch</u>

Based on previous work, the ALBWG defined three main EPO-based fisheries for the SS3 model: 1) US/Canada troll, 2) US longline, and 3) EPO miscellaneous fisheries (Anonymous, 2010). We therefore developed catch time series (catch in numbers of fish by quarter) for these fisheries (1966-2008). In general, annual landings in metric tons for each fishery were first converted into catch in numbers of fish by dividing the annual landings with the average weight of the fish for that year. Subsequently, the annual catch in numbers of fish was converted into quarterly catch by multiplying the annual catch with the estimated proportion of fish caught in each quarter and year.

Annual landings for the US/Canada troll fishery was calculated as the sum of US troll, Canada troll, US pole-and-line, and US sport fisheries' landings because the operations and size selectivity of these fisheries are highly similar. Annual landings for the US longline fishery consisted of only US longline landings. Annual landings for the EPO miscellaneous fishery was calculated as the sum of US purse seine, US gillnet, US tropical troll, US others, Mexico purse seine, Mexico pole-and-line, and Others troll fisheries' landings because these are relatively minor fisheries and only landings data are available (Table 1).

The average weights of albacore from the US troll and longline fisheries for each year were estimated from the size samples of these fisheries (see Data Sources above) and the appropriate length-weight relationships. Watanabe et al (2006) had previously estimated the length-weight relationships for various regions of the Pacific during specific quarters. For each year, the sizes of sampled albacore were first converted to weights using the following length (L)-weight (W) relationships: $W = 2.3E\text{-}5*L^{2.98}$ (troll fishery), and $W = 7.0E\text{-}5*L^{2.71}$ (longline fishery), which were the length-weight relationships found for Area 3/Quarter 3 and Area 4/Quarter 1 respectively by Watanabe et al (2006), and then averaged to estimate the annual average weight of albacore in each fishery. Due to poor or missing size information, several substitutions were required for the annual average weights. The average weight of albacore in 1993 for the troll fishery was considered unreliable because only 2 trips were sampled and were replaced by the average of the weights from 1992 and 1994. Since observers only began to measure albacore from the longline fishery in 1994, we used the average of the weights in 1994-1996 to substitute for the average weights during the years 1966-1993, when there were no observer samples.

The proportions of catch in each quarter for the US troll and longline fisheries were estimated from the logbook data of the respective fisheries. The logbooks for these fisheries record the number of fish caught for each day or longline set, respectively (see Data Sources above). The number of albacore caught in each year and quarter block was calculated for each fishery and converted into proportions. For the troll fishery, negligible amounts of catch occurred in the first quarter (January-March), therefore the catch was assumed to be distributed only from quarter two to four. Since logbook records from the longline fishery began in 1991, we used the average proportions of catch for each quarter in 1991-1993 to substitute for the years 1966-1990, when there were no logbook data.

To calculate the catch time series in numbers of fish, we assumed that the annual average weights and proportions of catch of the US troll fishery were representative of the US/Canada troll and EPO miscellaneous fisheries. The US longline catch time series simply used the information from the US longline fishery. The quarterly catch time series was derived by multiplying the annual catch with the estimated proportion of fish caught in each quarter and year. The quarterly catches of all three fisheries are shown in Fig. 1.

Size Compositions

Size composition (fork length in cm) time series for the US troll (1966-2008) and longline (1994-2008) fisheries were developed from data collected through a port sampling program and a Hawaii-based longline observer sampling program, respectively.

The size distributions were developed as follows: 1) 1 cm bins that ranged from $\leq$26 to 89 cm, 2) 2 cm bins whose lower edges ranged from 90 to 98 cm, 3) 4 cm bins whose lower edges ranged from 100 to 140 cm. All nominal bins reflect the lower edge of the intervals (e.g., a 4 cm bin at 100 cm consists of fish from 100 to 103 cm).

For both US troll and longline fisheries, size compositions were developed for each quarter and year block. If a quarter and year block had less than 50 fish measured or less than 3 trips sampled, that block was removed from the time series.

Standardized Abundance Indices

A standardized abundance index was developed from the logbook data of the US and Canada troll fisheries. Previous stock assessments used an index derived from only US troll fishery logbook data but the ALBWG suggested incorporating data from the Canadian troll fishery due to similarity in operations and fishing areas. Teo et al. (2010a) provides a detailed description of the joint US/Canada index. In general, catch and effort (number of boat-days) data were extracted from US and Canada troll fisheries' logbooks and compiled into monthly 1x1° strata. The log-transformed CPUE was then standardized by relating it to year, season, and area using a generalized linear model (GLM)

A standardized abundance index was also developed from catch and effort information obtained from the US longline fishery. A preliminary examination of the data found a large proportion of sets (63%) and trips (24%) without any albacore catch. We therefore used a delta-lognormal model to standardize the catch-per-unit-effort (CPUE) of the longline fishery, with each trip as a stratum. A previous study showed that the majority of albacore caught by the US longline fishery are caught by longline vessels targeting bigeye tuna (>80%), while a smaller portion was caught by vessels targeting swordfish (Teo, et al., 2010c). Longline vessels targeting bigeye tuna tend to fish during daylight hours in areas south of 30°N and use substantially more hooks per float in order to reach the deeper depths, where bigeye tuna are more abundant. In contrast, the vessels targeting swordfish tend to operate north of 30°N and fish at night with shallower gear. 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). Each stratum was assigned to one of two areas (north: ≥30°N; south: <30°N), which was used as a factor in the models. The year and quarter (3 months = 1 quarter, starting in January) of each stratum were also used as factors. 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 area (A) by,

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

where $CPUE_{ijk}$ is the CPUE (fish per boat day) in year *i*, quarter *j*, and area *k*, and *X* is the intercept. The probability of positive-catch was related to the same three factors using a binomial GLM with a logit link. The standardized CPUE index, I_t, was obtained by calculating the population marginal means (Searle, et al., 1980) of the above GLMs for each given year and subsequently back-transforming the result using,

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

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 $\hat{\sigma}_t$, is the standard error of $\hat{\alpha}_t$. Confidence intervals of the abundance index were subsequently estimated from 1000 bootstrap runs.

Time Series for VPA Model

Catch-at-Age

We developed two catch-at-age matrices (1966-2008): 1) EPO surface, and 2) US longline fisheries. With the exception of the US longline fishery, all fisheries listed in Table 1 were considered EPO surface fisheries, for the purpose of constructing the catch-at-age matrix.

First, two catch time series in numbers of fish were developed using the same methods as described for the SS3 model, by dividing the total landings (in metric tons) with the estimated average annual weights of sampled albacore. The annual average weights were estimated from the size compositions (fork length) and appropriate length-weight relationships for each respective fishery. We assumed that the size compositions for the US troll fishery were representative of all EPO surface fisheries.

The same size compositions were used to derive age compositions of the fisheries for each year. Similar to previous work, the age compositions for the US troll fishery were derived using a length-at-age relationship and visual evaluations of modal progressions to determine limits of size distributions within respective age classes (McDaniel, et al., 2006). First, upper limits of size distributions within age classes were determined by visually examining estimated annual size. Second, the original size data from the sample data sets (by year) were converted to ages based on the results from the age-slicing evaluation. The same upper limits as in previous studies (McDaniel et al. 2006) were used in this document. This visual method of age slicing works well for the EPO surface fisheries because a very limited range of sizes of young fish with very distinct modes and cohorts are caught (Fig. 2).

The age distributions for the US longline fishery were developed using MULTIFAN software (Otter Research Ltd 1990). MULTIFAN is an integrated data analysis system (based on robust maximum likelihood methods) for simultaneously analyzing multiple sets of fishery-related length compositions for purposes of estimating age compositions and the parameters of the von Bertalanffy growth function. Size data (fork length) from the Hawaii-based longline observer sampling program were used in this analysis. Parameterization for this analysis was based on previous recommendations of the ALBWG, which recommended standardizing various options in MULTIFAN for purposes of determining age distribution statistics from length distribution data (McDaniel, et al., 2006). Annual age compositions were estimated for 1994-2008 but due to the lack of reliable size data for the periods prior to 1994, we assumed that the size compositions during 1966-1993 were equal to the mean age compositions during 1994-1996, as was done for previous assessments. This substitution is unlikely to have a significant effect on the assessment because landings from the US longline fishing prior to 1994 represent less than 1% of the total North Pacific albacore landings.

Finally, the catch time series was combined with the resulting age compositions to obtain the catch-at-age matrices for the EPO surface and US longline fisheries. The age bins for catch-at-age matrices are as follows: 1) 8, 1-yr bins that ranged from 1 to 8 yr; and (2) a single bin reflects all fish ≥9 yr.

Standardized Abundance Indices

As stated above, the standardized abundance indices for the VPA model are identical to the indices for the SS3 model. Although previous VPA-based assessments used age-specific abundance indices, the ALBWG agreed at previous meetings to use age-aggregated abundance indices in the VPA model so as to ease comparison with the SS3 model (Anonymous, 2010). Standardized abundance indices were developed from the logbook data of the US and Canada troll, and the US longline fisheries.

RESULTS AND DISCUSSION

Catch

Catch in thousands of albacore for the Northeast Pacific-based fisheries are shown in Figure 1. The catches of the US/Canada troll (including pole-and-line, and sport) fishery occur primarily between July and September and have increased substantially from historical lows in 1989-1991. The catches from these surface fisheries are several-fold larger than the other Northeast Pacific-based fisheries.

Size Compositions

The size compositions for the US troll fishery were relatively consistent with a strong mode at ~65 cm and a secondary mode at ~75 cm (Fig. 2). The data coverage was relatively high but seasonal (Fig. 2). Size compositions of the US longline fishery were also relatively consistent with the majority of fish ranging from 100-120 cm (Fig. 3).

Standardized Abundance Indices

The standardized abundance index derived from the US/Canada troll fishery showed a decline in CPUE from 1966 to 1990 and a subsequent increase with relatively high levels observed in the recent decade (Fig. 4). Model fit and diagnostics for the index were reasonable with an R^2 of 0.149 (Teo, et al., 2010a). Relatively high inter-annual variability in the abundance index is apparent after 1996 but the causes for this are unclear at this moment.

The standardized abundance index for the US longline fishery was relatively high in the 1990s but since 2002, the index has been relatively low (Fig. 5). The residuals and Q-Q plots of the lognormal GLM (positive-catch only) did not show any obvious problems with the model (Fig. 6). We also investigated the use of set-by-set data to derive a standardized abundance index and found the indices to be highly correlated and with negligible differences ($r = 0.995$, $p < 0.0001$). It should be noted that previous studies have shown that the majority of the albacore catch from the US longline comes from a relatively small area around Hawaii (Teo, et al., 2010c). Therefore, caution is advised in interpreting the results for this index because changes in this index could be the result of local changes and/or stock-wide changes in population dynamics and conditions.

Catch-at-Age

The catch-at-age matrix of the EPO surface fisheries show that most the catch is on age-3 fish (Fig. 7). In contrast, the catch-at-age matrix of the US longline fishery shows that most of the albacore catch from that fishery is from fish >5 years of age. These matrices are similar to those used in previous assessments (McDaniel, et al., 2006).

General Considerations

For the upcoming assessment, landings in metric tons will be converted into catch in numbers outside of the SS3 stock assessment model. In future assessments using SS3, the ALBWG should investigate the use of catch in biomass rather than catch in numbers of fish. This would allow the model to better incorporate the uncertainties inherent in the relationships between weight, length, and age into the assessment. One of the potential improvements would be to include age-at-length data and updated age/length/weight relationships into the model. The SWFSC is currently obtaining biological samples of albacore in the Northeast Pacific so as to obtain age-at-length data and update the age/length/weight relationships for future assessments.

Previous studies have shown small differences in the surface fishery size compositions between areas north and south of 40°N in the Northeast Pacific (Teo, et al., 2010b). Together with other results (e.g., Laurs and Lynn, 1977), this suggests that age/size-specific movements are an important component of the biology of albacore tuna and that including explicit spatial and movement components into future models should be considered to improve the assessment.

Finally, it should be noted that although the landings and catch-at-age data are similar to those used in the 2006 assessment, the results from the VPA model of the 2011 assessment may be substantially different from past assessments because of the large differences in the abundance indices used (age-aggregated vs age-specific). Future assessments are likely to be conducted using the SS3 model, and future comparisons between model runs and retrospective analyses will help demonstrate model performance rather than comparisons with VPA runs.

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Table 1. North Pacific albacore landings (mt) by country and gear for fisheries based primarily in the Northeastern Pacific Ocean (1966-2008)[a].

	US								Canada	Mexico		Others
Year	Purse Seine	Gill Net	Pole & Line	Troll	Tropical Troll & handline	Sport	Longline	Other gears	Troll	Purse Seine	Pole & Line	Troll
1966	0	0	1600	15333	0	588	8	0	44	0	0	0
1967	0	0	4113	17814	0	707	12	0	161	0	0	0
1968	0	0	4906	20434	0	951	11	0	1028	0	0	0
1969	0	0	2996	18827	0	358	14	0	1365	0	0	0
1970	0	0	4416	21032	0	822	9	0	390	0	0	0
1971	0	0	2071	20526	0	1175	11	0	1746	0	0	0
1972	0	0	3750	23600	0	637	8	0	3921	100	0	0
1973	0	0	2236	15653	0	84	14	0	1400	0	0	0
1974	0	0	4777	20178	0	94	9	0	1331	1	0	0
1975	0	0	3243	18932	0	640	33	10	111	1	0	0
1976	0	0	2700	15905	0	713	23	4	278	36	5	0
1977	0	0	1497	9969	0	537	37	0	53	3	0	0
1978	0	0	950	16613	0	810	54	15	23	1	0	0
1979	0	0	303	6781	0	74	0	0	521	1	0	0
1980	0	0	382	7556	0	168	0	0	212	31	0	0
1981	0	0	748	12637	0	195	25	0	200	8	0	0
1982	0	0	425	6609	0	257	105	21	104	0	0	0
1983	0	0	607	9359	0	87	6	0	225	0	0	0
1984	3728	0	1030	9304	0	1427	2	0	50	107	6	0
1985	26	2	1498	6415	7	1176	0	0	56	14	35	0
1986	47	3	432	4708	5	196	0	0	30	3	0	0
1987	1	5	158	2766	6	74	150	0	104	7	0	0
1988	17	15	598	4212	9	64	307	10	155	15	0	0
1989	1	4	54	1860	36	160	248	23	140	2	0	0
1990	71	29	115	2603	15	24	177	4	302	2	0	0
1991	0	17	0	1845	72	6	312	71	139	2	0	0
1992	0	0	0	4572	54	2	334	72	363	10	0	0
1993	0	0	0	6254	71	25	438	0	494	11	0	0
1994	0	38	0	10978	90	106	544	213	1998	6	0	158
1995	0	52	80	8045	177	102	882	1	1763	5	0	94
1996	11	83	24	16938	188	88	1185	0	3316	21	0	469
1997	2	60	73	14252	133	1018	1653	1	2168	53	0	336
1998	33	80	79	14410	88	1208	1120	2	4177	8	0	341
1999	48	149	60	10060	331	3621	1542	1	2734	0	57	228
2000	4	55	69	9645	120	1798	940	3	4531	70	33	386
2001	51	94	139	11210	194	1635	1295	0	5248	5	18	230
2002	4	30	381	10387	235	2357	525	0	5379	28	0	466
2003	44	16	59	14102	85	2214	524	0	6861	28	0	378
2004	1	12	127	13346	157	1506	361	0	7856	104	0	0
2005	0	20	66	8413	175	1719	296	0	4845	0	0	0
2006	0	3	23	12524	95	385	270	0	5832	109	0	0
2007	0	4	21	11887	98	1225	250	0	6075	40	0	0
2008	0	1	1050	10672	29	257	353	0	5478	10	0	0

[a] The Northeastern Pacific Ocean-based fisheries are represented here by the countries U.S., Canada, Mexico, and 'Others'(Belize, Cook Islands, Tonga, and Ecuador). Asian countries (e.g., Japan, Taiwan, and Korea) that have also harvested albacore from these waters are not accounted for in this tabulation.

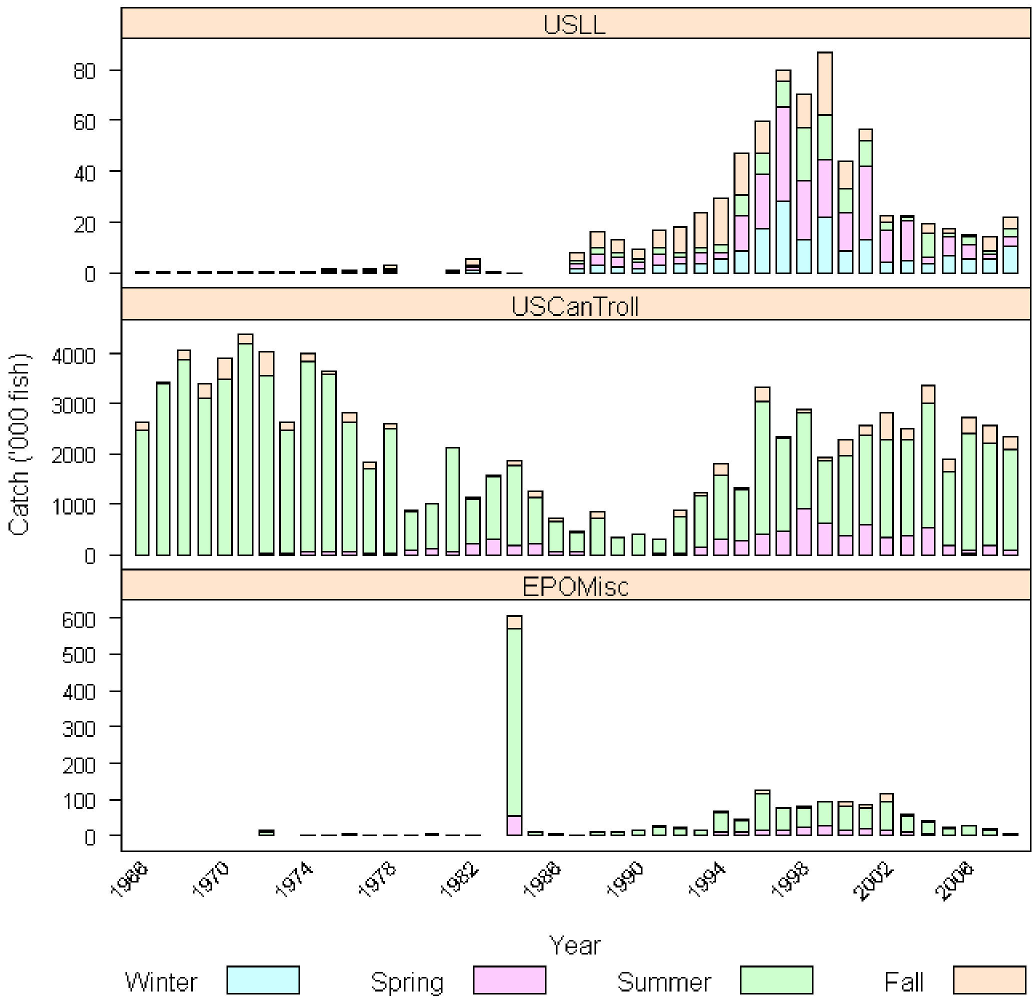

Figure 1. Albacore catch in thousands of fish of US longline (USLL), US/Canada Troll (USCanTroll), and EPO miscellaneous (EPOMisc) fisheries (see fisheries definitions in text) by year and season.

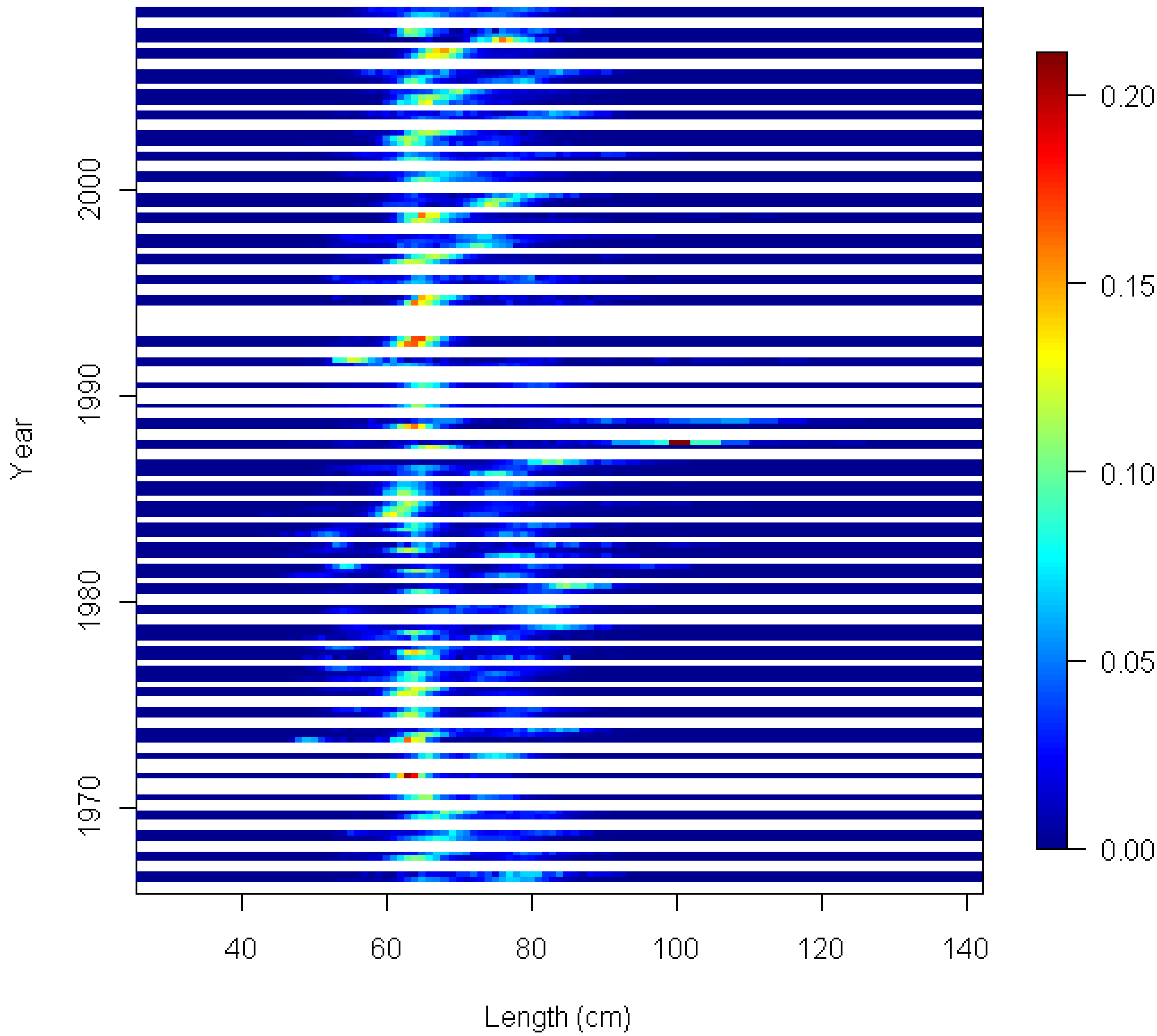

Figure 2. Quarterly size compositions (fork length, cm) of albacore for US troll (1966-2008) fishery. White bars indicate missing data.

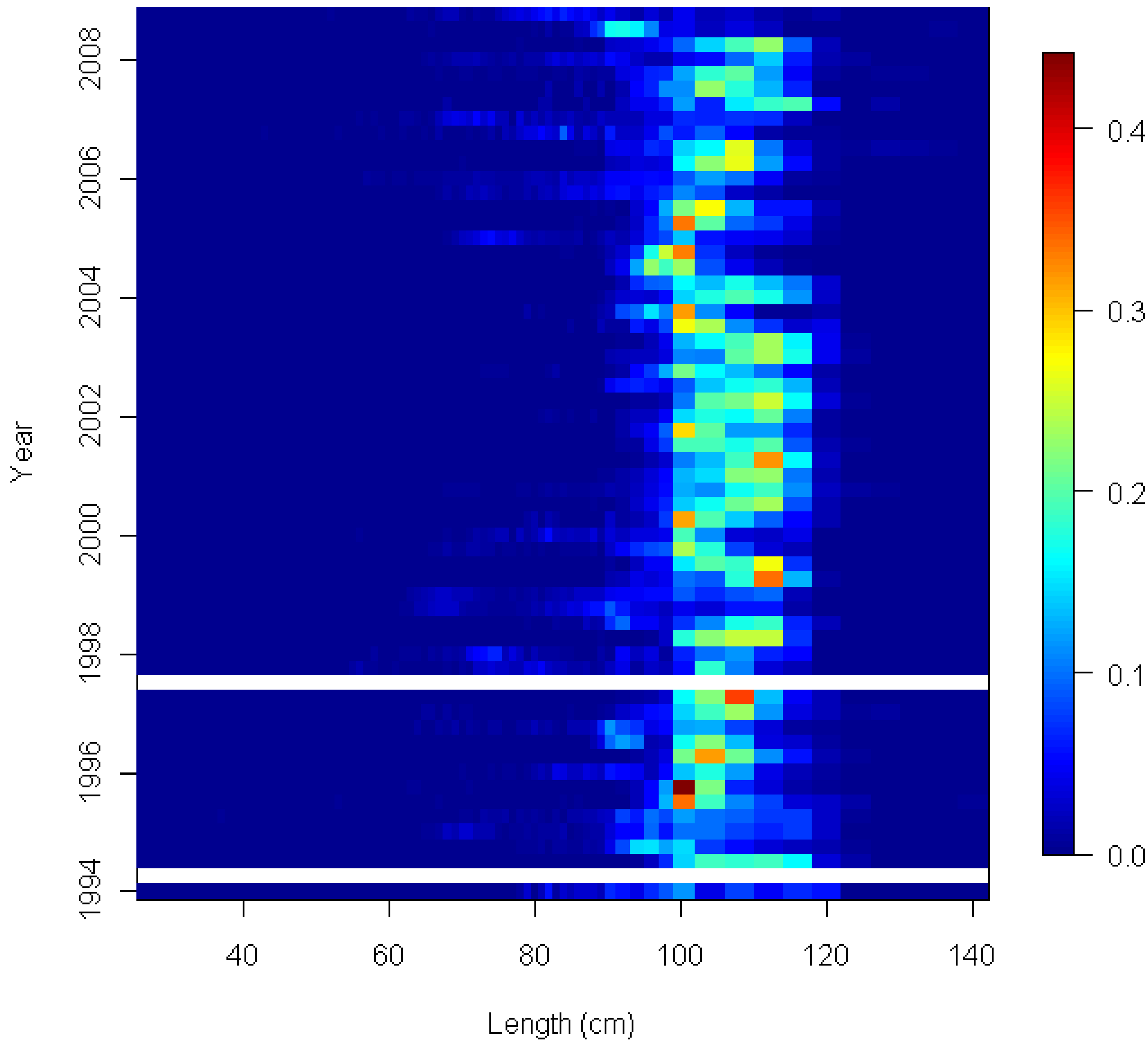

Figure 3. Quarterly size compositions (fork length, cm) of albacore for US longline (1994-2008) fishery. White bars indicate missing data.

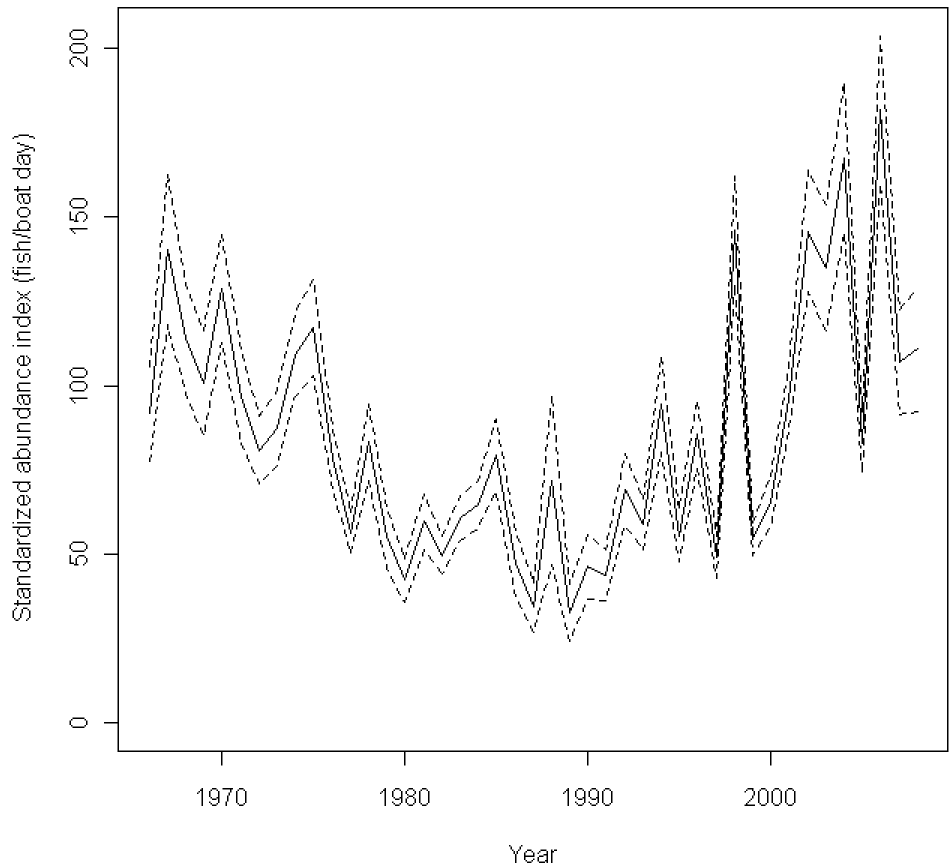

Figure 4. Standardized abundance index of North Pacific albacore for the US troll fishery (1991-2008). Dashed lines indicate 95% confidence intervals from 1000 bootstrap samples.

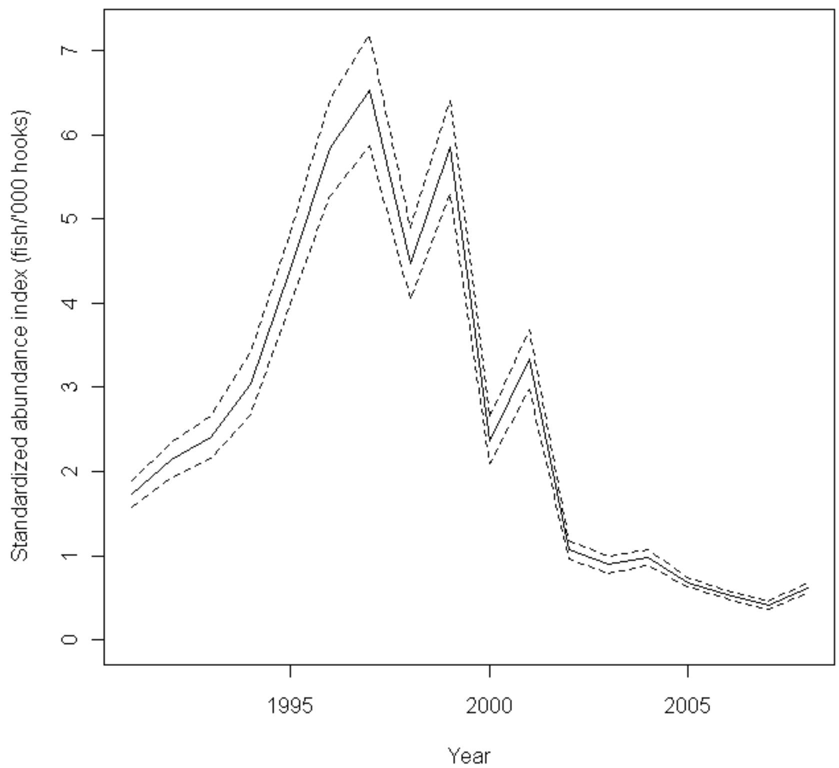

Figure 5. Standardized abundance index of North Pacific albacore for the US longline fishery (1991-2008). Dashed lines indicate 95% confidence intervals from 1000 bootstrap samples.

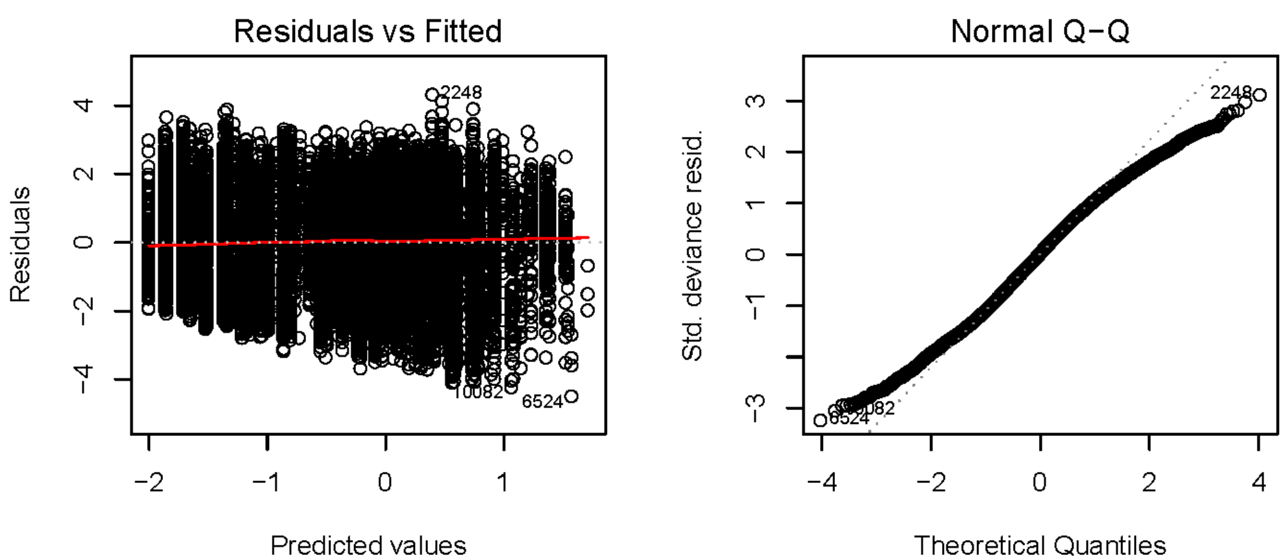

Figure 6. Residuals and Q-Q plots for the lognormal component (positive-catch only) of the US longline fishery abundance index GLM.

(A)

(B)

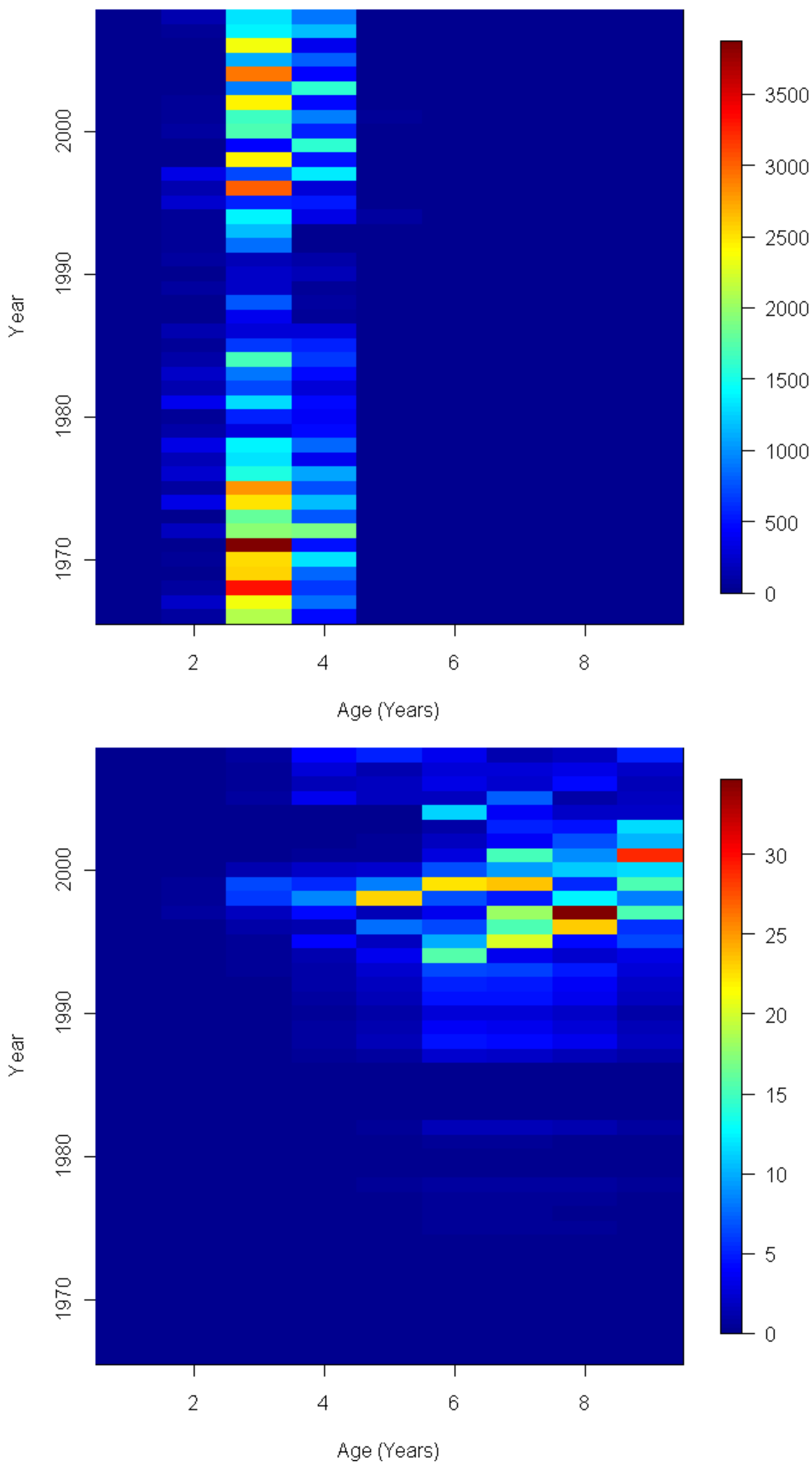

Figure 6. Catch-at-age (thousands of fish) of albacore for (A) EPO surface (1966-2008) and (B) US longline (1966-2008) fisheries.