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Revised Canadian Albacore Fishery Statistics, 1995-2010, and Provisional Fishery Statistics for the 2011 Albacore Troll Fishery[1]

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1.0 INTRODUCTION

The Canadian fishery for highly migratory species uses troll gear with jigs to target juvenile north Pacific albacore tuna (*Thunnus alalunga*) in the surface waters of the Pacific Ocean. The majority of catch and effort by the Canadian fleet has occurred in the coastal waters of Canada and the United States since 2000. However, some vessels in the fleet follow albacore tuna concentrations into offshore waters and into the central and western Pacific Ocean.

Management regulations for Canadian vessels fishing albacore tuna are documented in the Pacific Region Integrated Fisheries Management Plans (IFMP). These plans correspond to the fiscal year used by the Canadian government and cover the period 01 April to 31 March of the following calendar year. For example, the 2011 IFMP covers the period from 01 April 2011 to 31 March 2012 and is available at http://www.dfo-mpo.gc.ca/Library/343252.pdf. Although the Canadian albacore fishery in Pacific Ocean waters is open from 01 April to 31 March, historically the majority of catch and effort has occurred in a four month period from the beginning of June to the end of October. Canadian vessels are licensed to fish within the Canadian exclusive economic zone (EEZ), the EEZ of the United States, and the highseas (waters outside the EEZs) in both the north and south Pacific Oceans. Access to the United States Exclusive Economic Zone (EEZ) is permitted through a bilateral Treaty, which provides for reciprocal access by Canadian-flagged and US-flagged vessels licensed to fish for albacore and for the landing of albacore catches at designated ports within each country.

The objectives of this report are: (1) to provide revised fishery statistics (aggregated catch and effort) for the 1995 to 2010 period, (2) to provide the rationale for these revised figures, and (3) to summarize Category I (total annual catch and effort, catch per unit of effort (CPUE)), Category II (logbook catch and effort data summarized on 1° x 1° grid), and Category III (bycatch, catch size composition) data for the Canadian north Pacific albacore troll fishery in 2011. Similar data summaries for fisheries in 1995 through 2010 are provided by Shaw (1997, 1999), Shaw and Argue (1999, 2000), Argue and Shaw (2000), Shaw and Stocker (2002), Stocker and Shaw (2004a, 2004b, 2005), Stocker (2006, 2007), and Holmes (2008, 2009, 2010, 2011); some of the fishery data in these reports are being revised in the present report.

2.0 DATA SOURCES

Data on albacore tuna catch and effort from 1995 through to the present are compiled from hail records, logbooks, and sales slips from processing plants and stored in the Canadian Albacore Tuna Catch and Effort Relational Database (Stocker et al. 2007). This database generates the best available estimates of total annual catch and effort by geographic area for the Canadian fishery. All Canadian fishing vessels are required to hail a third party service provider when they intend to start fishing and when fishing ceases. At present, the hail data are used primarily to ensure that fishing activity in the United States EEZ ceases by 31 October as required by the Canada-United States Albacore Tuna Treaty, but they could be used to estimate fleet size in the three fishing zones if necessary. Canadian vessels must also carry logbooks in which daily catch and effort data (latitude, longitude, number of fish, estimated weight) are recorded for albacore and non-target species. These data have the highest temporal and spatial resolution are obtained from completed copies of the logbooks submitted at the end of the fishing season. The third data source, sales slips, record the weight of albacore landed and bought by a domestic Canadian buyer and provide the most accurate estimates of albacore catch in weight since these data are the basis for payment to harvesters. In some years, sales slips underestimate total catch because they do not fully account for landings at international ports, domestic public sales or take-home totals (Stocker et al. 2007). Logbooks, sales slips from domestic buyers, and at-sea trans-shipment slips, completed at the time fish are landed and sold, must be returned to Fisheries and Oceans Canada (DFO) for entry into the albacore catch database (Stocker et al. 2007).

Fork length data were collected from the Canadian catch landed in United States ports by the US port sampling program and forwarded to Canada prior to 2009. In 2009, Canada implemented an on-board harvester sampling program to obtain fork lengths of fish in the Canadian catch. Participation is voluntary and harvesters are asked to measure first 10 albacore landed on a daily basis and record these data in the spaces provided in their logbooks. Fork length data reported by Canada since 2009 (Holmes 2010, 2011, present report) are from the domestic on-board sampling program only.

The revised aggregated catch and effort data for the 1995-2010 period and the preliminary catch and effort data for 2011 are taken from database version 12.04.23. The data in this report up to and including 2010 are considered definitive and are derived from a reconciliation of trip log (best estimates of effort, catch in pieces, and geographic location) and sales slip (best estimate of catch weight) data (Stocker et al. 2007).

3.0 REVISED CATCH AND EFFORT DATA, 1995-2010

Revised catch and effort (vessel-days, number of vessels) data for the 1995 to 2010 period are shown in Table 1 and the magnitude and direction of change relative to data previously reported by Holmes (2011) are shown in Table 2. Logbook coverage is also documented in Table 1 and shows the level of expansion of reported data to estimate the annual totals. Up until 2005, the majority of changes are relatively minor in nature. Since 2005, changes in aggregated catch and to a lesser extent effort in vessel-days, have been somewhat larger. Three factors account for these changes relative to Holmes (2011): (1) late submission of logbooks in which fishing activity is recorded, (2) late submissions of logbooks in which no fishing activity is recorded or nil or no fishing reports, and (3) late reconciliation of sales slip weights.

Logbooks must be returned after the fishing season has ended and typically no later than the middle of November of the calendar year for which it was issued. Compliance with this requirement is usually about 95% or higher by April of the following year, with the missing logbooks related to vessels fishing in the Canadian EEZ or the highseas. Since harvesters are licenced to fish in specific areas and are required to hail into and out of a specific fishing area, *a priori* knowledge of the fleet size and composition by fishing area is high. In order to estimate aggregated catch and effort representing the entire fleet, average catch and effort is estimated for each fishing area (Canadian EEZ, US EEZ, highseas) and substituted for missing logbooks from those areas. When an outstanding logbooks are finally submitted, which may be months or years (in a few cases) after the normal deadline, the data recorded in the logbook are substituted into the annual catch estimate calculation, resulting in increases or reductions in catch and effort relative to the average estimates. Usually, reductions in catch and effort relative to the averages occur in vessels fishing within the Canadian EEZ because the captains of these vessels are less experienced than other participants in the fishery, taking part occasionally when albacore availability in Canadian waters is perceived to be relatively high. In contrast, vessels operating in the highseas tend to have more experienced and regularly participating captains and as a result catch and effort from these vessels tends to be higher than the average estimates. However, highseas catch and effort typically accounts for less than 10% of the annual totals in this fishery.

Often logbooks submitted well after the deadline are nil or no fishing reports. When this occurs, all fishery statistics are reduced as the average estimates are removed from the total catch and effort calculation for each vessel submitting this kind of report. Fleet size is also reduced.

The best estimate of catch weight is obtained from sales slips submitted by domestic buyers to Canada. These slips are usually submitted well after the fishing season has ended and then are entered into a sales slip database. Once in the sales slip database, the weight figures are reconciled against logbook data using the sales slip number, which is recorded in the logbook for each trip. In order to enter sales slip data into the sales slip database, a domestic management area code is required as this is a key field in the database. These domestic management areas do not apply to the majority of Canadian albacore catch and effort, which occur in the United States EEZ and high seas waters beyond domestic boundaries. The result is that there can be lengthy delays in reconciling our best catch weight data with data estimated by harvesters in their logbooks. Most of the changes in aggregated catch from 2005 onwards are the result of recent reconciliations of sales slip and logbook weights.

In summary, minor changes in catch and effort prior to 2005 are likely the result of the submission of one or two missing logbooks for years during this period. From 2005 onwards, a combination of late logbook submission and late sales slip reconciliation probably account for the changes documented in Tables 1 and 2. The absence of changes in the 1998-2003 period is because missing logbooks for this period are likely beyond retrieval, since logbook coverage is not as high as targeted during this period (Table 1). These changes are contained in Version 12.04.23 of the Canadian albacore database.

4.0 PROVISIONAL 2011 FISHERY DATA

4.1 Catch

The preliminary estimate of the Canadian catch of north Pacific albacore in 2011 is 5,393 metric tons (t) and is an 18% decrease relative to 2010 (Table 1; Figure 1). The total catch of north Pacific albacore tuna by the Canadian troll fishery has ranged from 1,761 t in 1995 to 7,857 t in 2004 and averaged 4,857 ± 1,753 (sd) t for the 1995 to 2010 period. The 2011 catch was distributed among the Canadian EEZ (12.5%), the United States EEZ (86%), and highseas waters (1.5%). The Canadian fishery operated north of the equator primarily within the IATTC convention area, but a minor amount of catch (1 t) was made in the WCPFC convention area, continuing a trend of concentrating catch and effort in eastern Pacific Ocean (EPO) that began in 2005. No Canadian vessels were active in the south Pacific Ocean in 2011.

4.2 Effort
The Canadian albacore troll fleet consisted of 177 unique vessels in 2011, which is an 11% increase in fleet size relative to 2010, but below the average of 212 for the 1995-2010 period (Table 1). All Canadian troll vessels targeted the north Pacific albacore stock exclusively.

Fishing effort in the Canadian tuna fishery is measured as the number of vessel fishing days (v-d). The 2010 estimate of fishing effort is 8,568 v-d and is a 13 % increase in effort relative to effort in 2010 (Table 1; Figure 1). Annual fishing effort has ranged between 4,320 v-d in 1997 and 10,021 v-d in 2001, averaging 7,490 ± 1,551 (sd) v-d since 1995.

5.0 CATEGORY II DATA

The Canadian troll fleet operated between 38 and 54 °N latitude and from the west coast of North America to 151° W in 2011 (Figures 2 and 3), which is further south and north than in the previous five years, but consistent with the pattern established since 2006 of fishing primarily within the Inter-American Tropical Tuna Commission (IATTC) convention area east of 150 °W. Approximately 76% of the fishing effort occurred within the US EEZ and resulted in 86% of the total catch in 2011, similar to average proportions of effort and catch of 78% and 79%, respectively, for the 2000-2009 period (period for which logbook coverage exceeds 80% of the catch annually). In contrast, 21% of the effort occurred in Canadian waters, resulting in only 13% of the catch and 2% of the catch and 3% of the effort occurred in adjacent highseas waters.

High catch and effort occurred later in the season (September and October) and within the coastal waters of Canada and the United States, particularly along the Oregon coastline (Figures 2 and 3).

Spatial catch rate anomalies for 2011 (A_{2011}) were calculated for each 1° x 1° block as observed catch rate in 2010 minus the average catch rate in that block for the 2000-2009 period:

$$A_{2011} = CPUE_{I,J,2011} - \overline{CPUE_{I,J,2000-2009}}$$

where *I* is latitude and *J* is longitude. These anomalies are plotted in Figure 4 and show that above average catch rates occurred primarily in coastal waters, especially within the US EEZ off of Washington and Oregon. The majority of 1° x 1° strata in which fishing effort occurred experience below average catch rates in 2011.

The seasonal pattern of nominal catch-rates in 2011 for the Canadian fishery departs substantially from the average seasonal pattern for 2000-2009 (Figure 5). On average, catch-rate increases to a peak in July-August and then declines to low values by late October. In contrast, nominal 2011 catch-rates exhibit a minor peak in early July followed by a steady increase from late August to the end of October, with the highest catch-rates occurring at the end of the fishing season (Figure 5).

Albacore were caught in waters with sea surface temperatures ranging between 10 and 20 °C in 2011, but the most productive waters were between 14 and 18 °C and accounted for 99% of the catch (Figure 6). In contrast, the majority of catch has occurred in waters between 16 and 18 °C in other years.

6.0 CATEGORY III DATA

6.1 By-catch

Reported bycatch in 2011 consisted of 71 fish and eight species (Table 3). Ten albacore considered to small to retain were recorded in June and July, 8 blue sharks , 2 shortfin mako sharks, 6 Pacific bluefin tuna, 1 bigeye tuna, 2 mahi mahi, and 42 yellowtail *Seriola lalandi* were captured and released alive. Total weight of all bycatch is estimated to be approximately 951 kg, of which the shortfin mako sharks accounted for 300 kg.

6.2 Biological

Forty-three (43) vessels measured fork lengths and compiled catch size frequency data in 2011. A total of 14,373 fork length measurements were recorded (Figure 7), representing a sample of 1.73% of the total reported catch (831,299 fish). This sampling rate is well above the target rate of 1.0% of the reported Canadian catch.

Albacore in the Canadian catch ranged from 50 cm to 90 cm in size, which is consistent with the size range reported in previous years. These measurements were dominated by a single mode corresponding to 2-year old fish at 64-68 cm FL in size frequencies from the highseas and US EEZ, but in the Canadian EEZ a second mode corresponding to 3-year old fish at 74-78 cm was also prominent (Figure 7). The most common length-frequency pattern in Canadian catches is a single mode between 64 and 68 cm FL, corresponding to 2-year old fish. A two-mode pattern is rarer, but has been observed several times and usually occurs when albacore shift their distribution in coastal waters northward in response to ocean conditions.

7.0 DISCUSSION

Revisions to previously submitted Canadian albacore fishery statistics were provided in Table 1 and these updated numbers were used in subsequent tables and figures in this report. These revisions are the result of the cumulative receipt of several logbooks from previous seasons over several years. In the majority of cases, changes to aggregated catch and effort are minor. However, changes since 2005 tend to be more substantial and are primarily the result of reconciling sales slip weight figures (our best estimate of catch) with estimated weights provided by harvesters in their logbooks.

The 2011 Canadian albacore fishery was remarkable for the fact that albacore availability in coastal waters was delayed until late in the fishing season (September-October) and the highest abundance occurred with 2-3° of longitude of the Oregon and Washington coastlines (Figures 2 and 4). This reduced availability is reflected by a reduction in catch and increase in effort in 2011 relative to the 2006-2010 period, in which catch was relatively stable and effort was declining (Figure 1). The highest catches of albacore occurred in cooler waters (14-18 °C) than usual (Figure 6) and the size frequency data reveal that albacore caught in the Canadian EEZ consisted of two age groups, rather than the single age-group in other areas (Figure 7). The larger age-3 fish commonly enter the Canadian catch if substantial effort occurs south of 40°N or the juvenile albacore shift north due to ocean conditions as occurred in 2010. The size frequency pattern in the Canadian EEZ is consistent with older and larger fish migrating further north than younger fish, but the explanation for absence of a second mode in the US EEZ size frequency data is not clear at present.

8.0 RESEARCH

Canada is beginning a tagging program using pop-up satellite tags to investigate the movement patterns of juvenile albacore in the eastern Pacific Ocean. This project is responding to a need to understand the movement patterns of albacore and bring movement into the stock assessment model that was identified by the Albacore Working Group during the 2011 stock assessment workshop. The goal is to deploy up to 50 tags on juvenile albacore in the eastern Pacific Ocean in a least two locations (near 150° W, coastal waters of North America, approximately 125-130° W) and two times (early spring at the western location, late summer or fall in the coastal location). Pop-up satellite tags are planned for this project in an attempt to ensure that biases associated with unexpectedly low returns that have affected interpretation of other albacore tagging programs, particularly in the western Pacific Ocean. Current effort is focused on developing handling and tagging protocols and minimizing premature tag release from fish.

Canada is also conducting research evaluating the impacts of biological and oceanographic variables on the population dynamics of albacore tuna in response to a need identified by the Albacore Working Group during the 2011 stock assessment workshop. A Bayesian production model previously presented to the Working Group is the basis of this research. Conventional biomass dynamics model assume that the carrying capacity (K) and the intrinsic rate of population growth (r) of a stock are temporally invariant and usually estimate these parameters based on catch rates (such as CPUE) and fishing effects from a single fishery. The model developed for this research uses data from multiple fisheries and gears and allows K and r to change over the years. As a first step, the effects of oceanographic indices such as the Pacific Decadal Oscillation (PDO), North Pacific Oscillation Index (NOI), Multivariate ENSO Index (MEI), and the North Pacific Gyre Oscillation (NPGO) on K and r are modeled and the significance of each oceanographic variable is examined based on the model fitting. Based on these first order results, other more complex stock assessment models, for example an age-structured production model, would also be constructed, and oceanographic variables would then be incorporated into the models and the behaviour of alternative models will be statistically compared to produce a reasonably reliable and robust ecological model for the north Pacific albacore tuna population.

Preliminary results show the NPGO significantly affects productivity in a positive manner for a time lag up to 5 years and the probability of this impact is highest when a 4-year time lag is used. At time lags exceeding 5 years, the NPGO has no significant impact on productivity and the model performance does not statistically improve relative the base model.

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Table 1. Fishery statistics from the Canadian troll fishery for north Pacific albacore tuna, 1995-2011.

Year	Total Catch (t)	Effort (vessel-days)	Total Vessels	Logbook Coverage[2] (%)
1995	1,761	5,923	287	22%
1996	3,321	8,164	295	50%
1997	2,166	4,320	200	57%
1998	4,177	6,018	214	79%
1999	2,734	6,970	238	89%
2000	4,531	8,769	243	83%
2001	5,248	10,021	248	94%
2002	5,379	8,323	232	84%
2003	6,861	8,429	193	98%
2004	7,857	9,942	221	97%
2005	4,888	8,578	213	99%
2006	6,008	6,277	174	100%
2007	6,667	6,961	207	100%
2008	5,476	5,919	134	95%
2009	5,690	6,553	138	99%
2010	6,552	7,592	159	98%
2011[1]	5,393	8,568	177	99%

1. 2011 data are preliminary based on Ver.12.04.23 of the *Canadian Albacore Tuna Catch and Effort Relational Database*.
2. (Reported Catch/Expanded Catch) x 100 from database Ver. 12.04.23 for all years.

Table 2. Magnitude and direction of changes in fishery statistics for the Canadian troll fishery for north Pacific albacore tuna reported in Table 1 relative to statistics previously reported by Holmes (2011). Reductions relative to previously reported data are highlighted in grey and increases are highlighted in blue.

Year	Change in Total catch (t)	Change in Effort (vessel-days)	Change in Fleet Size
1995	-2	-7	+3
1996	+5	+13	+3
1997	-2	-4	+3
1998	0	0	0
1999	0	0	+5
2000	0	0	-5
2001	0	0	+4
2002	0	0	+4
2003	0	0	+1
2004	+1	-1	+1
2005	+43	+13	0
2006	+176	+34	0
2007	+592	-152	+9
2008	+30	+12	0
2009	+48	-36	+3
2010	+55	+60	+2

1 Data are from Ver.12.04.23 of the *Canadian Albacore Tuna Catch and Effort Relational Database*.

Table 3. Reported catch of non-target species (by-catch) by the Canadian albacore troll fishery in 2011.

Month	Common name	Scientific Name	No. of fish
June	Albacore	*Thunnus alalunga*	**7**
	Mahi mahi	*Coryphaena hippurus*	2
July	Albacore	*Thunnus alalunga*	3
	Blue shark	*Prionace glauca*	3
	Pacific bluefin tuna	*Thunnus orientalis*	2
	Yellowtail amberjack	*Seriola lalandi*	8
August	Blue shark	*Prionace glauca*	3
	Pacific bluefin tuna	*Thunnus orientalis*	2
	Shortfin mako shark	*Isurus oxyrinchus*	1
	Yellowtail amberjack	*Seriola lalandi*	9
September	Bigeye tuna	*Thunnus obesus*	1
	Blue shark	*Prionace glauca*	2
	Pacific bluefin tuna	*Thunnus orientalis*	2
	Shortfin mako shark	*Isurus oxyrinchus*	1
	Yellowtail amberjack	*Seriola lalandi*	22
October	Yellowtail amberjack	*Seriola lalandi*	3

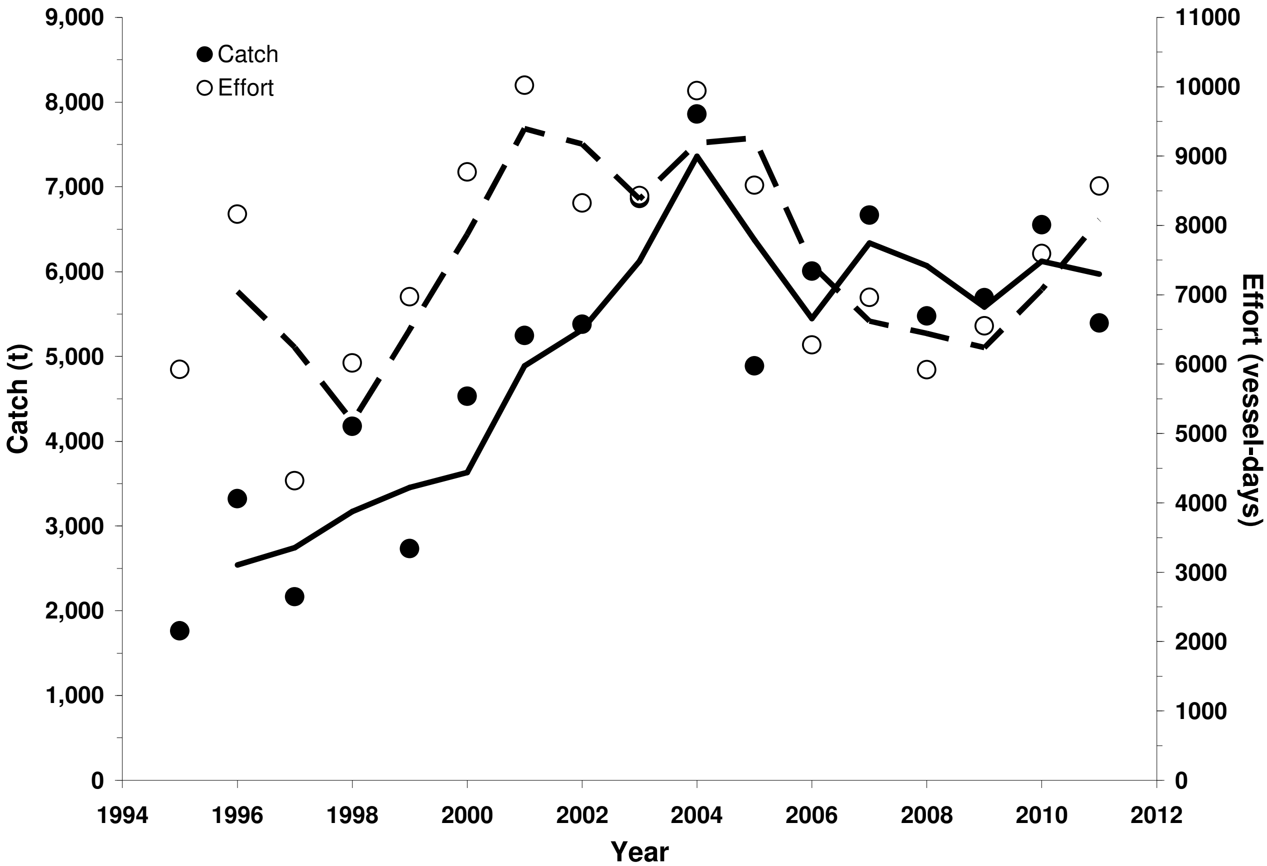

Figure 1. Historical trends in catch and effort by the Canadian north Pacific albacore troll fishery from 1995 to 2011. Lines are 2-yr moving averages of catch in t (▬) and effort in vessel-days (– –).

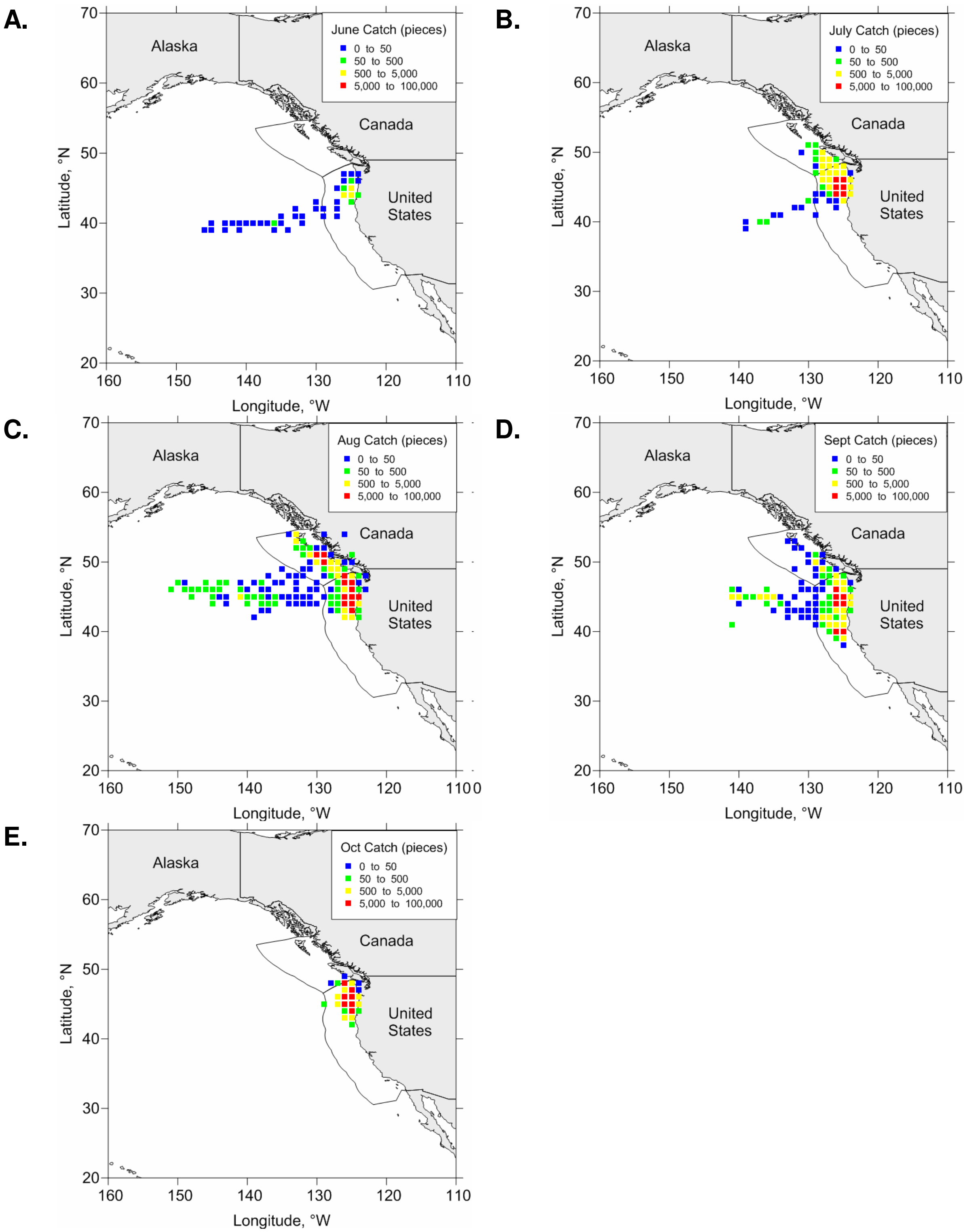

Figure 2. Monthly distribution of the Canadian albacore troll fishery catch (number of fish) in 2011. A – June, B – July, C – August, D – September, E – October. Data are plotted on a 1° x 1° grid with symbols located on the bottom-right corner of each cell. The boundaries of the Canadian and United States exclusive economic zones (200-mile limit) are shown.

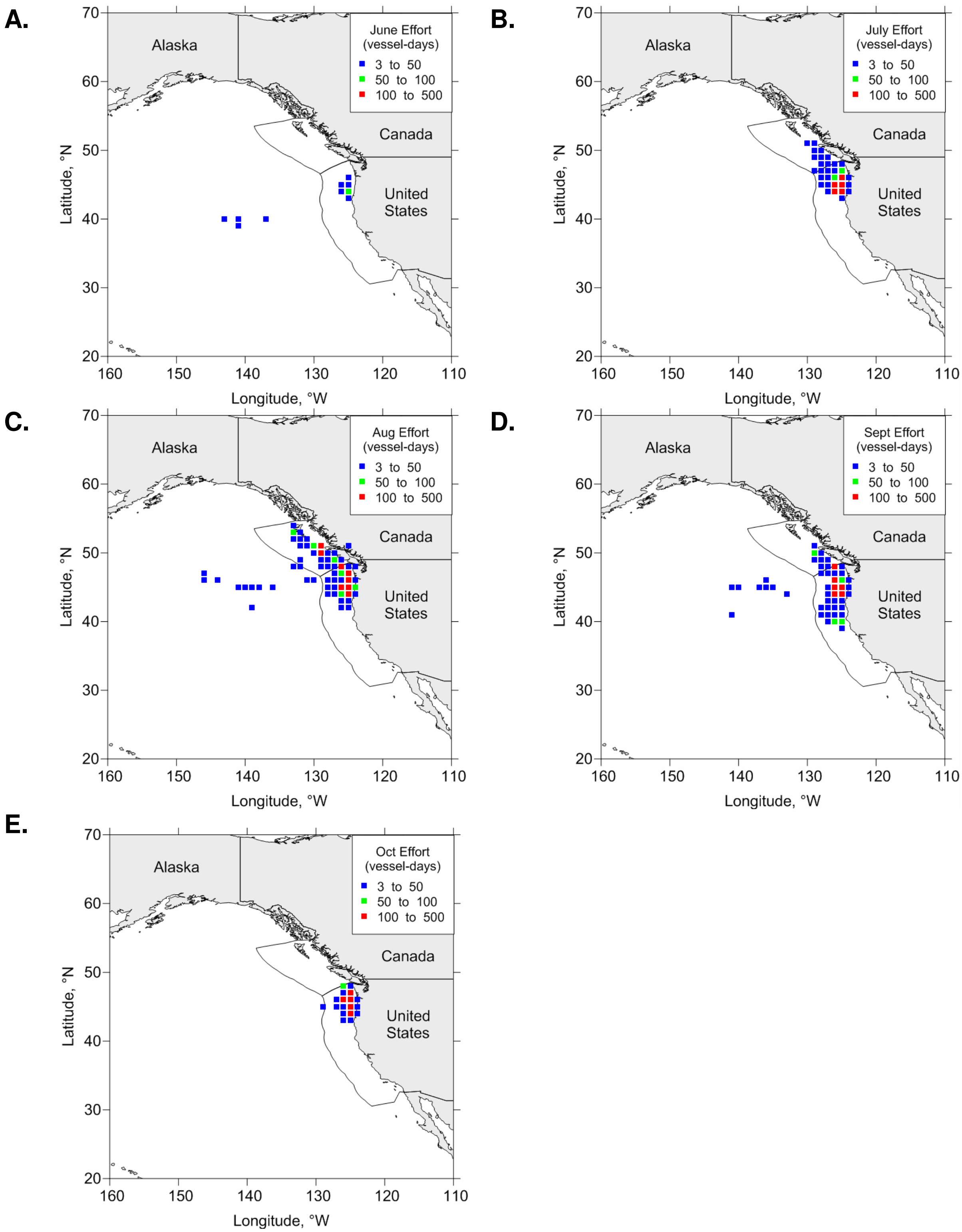

Figure 3. Monthly distribution of fishing effort (vessel-days) in the Canadian albacore troll fishery in 2011. A – June, B – July, C – August, D – September, E – October. Data are plotted on a 1° x 1° grid, where grid location is specified by the bottom-right corner of each grid cell. Colour of the cell is proportional to the effort. Only cells in which at least 3 vessels reported effort are shown. The black line marks the boundaries of the Canadian and United States exclusive economic zones (EEZ - 200-mile limits).

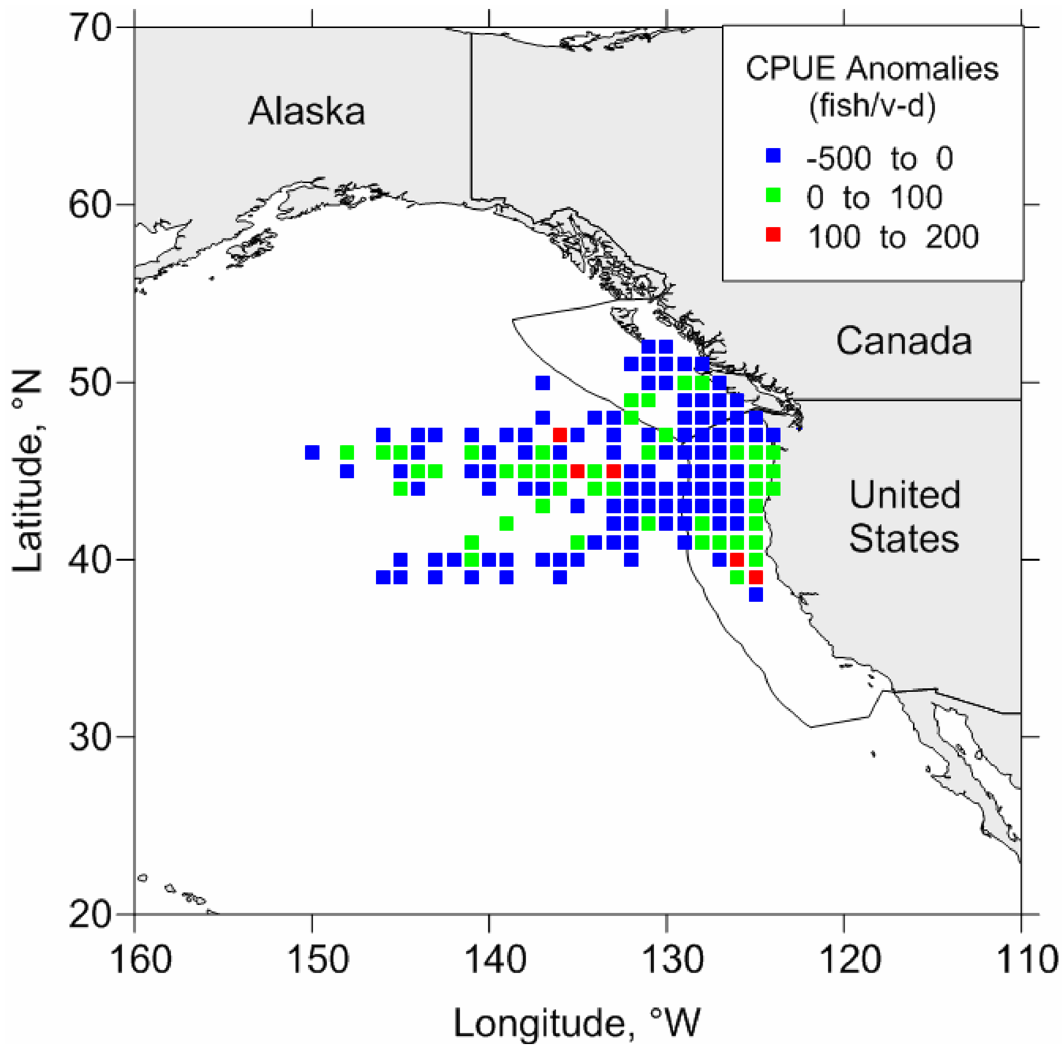

Figure 4. Nominal catch-rate anomalies (CPUE - fish/vessel-day) based on logbook data in areas fished by the Canadian fleet in 2011. Anomalies are calculated for each 1° x 1° spatial block as:

$$\text{CPUE Anomaly}_{I,J} = \text{Observed}_{I,J,2011} - \text{Average}_{I,J,2000\text{-}2009},$$

where I and J refer to latitude and longitude in whole degrees, respectively. Blocks in blue are below average CPUE; all other colours are above average CPUEs.

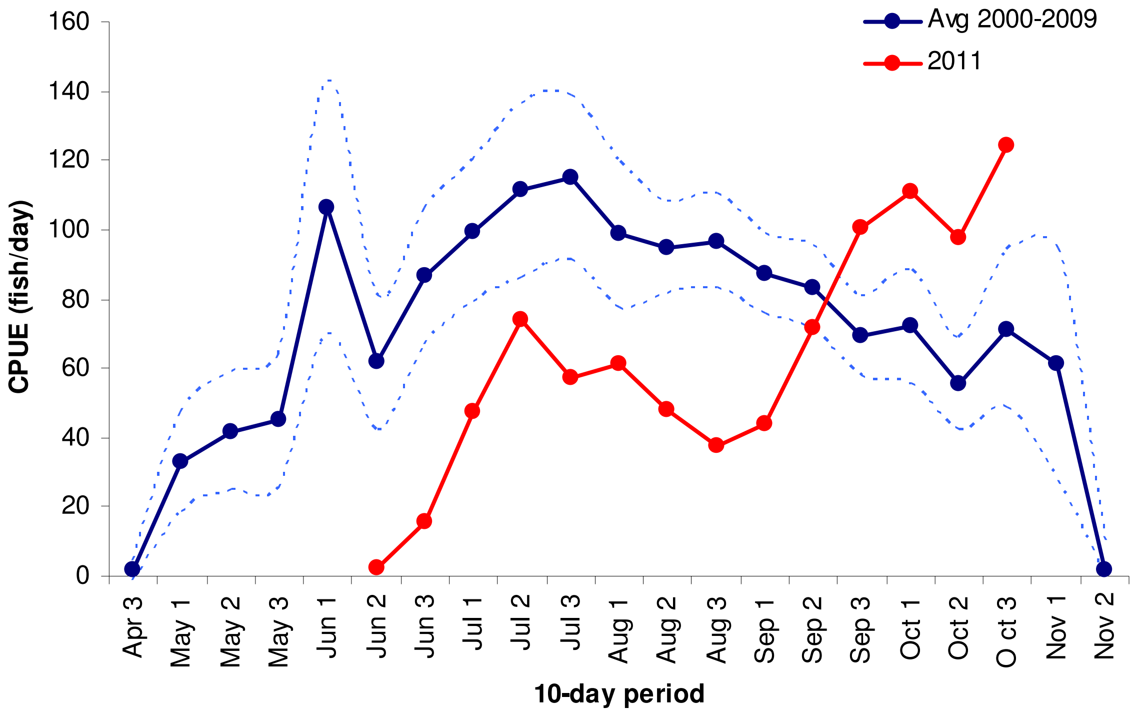

Figure 5. Average seasonal nominal catch-rate pattern from 2000-2009 (blue) for the Canadian albacore fishery and the 2011 seasonal catch-rate pattern. Catch-rate is calculated as the average of all 1x1 spatial strata in which fishing effort is reported during 10-day temporal strata (3 temporal strata per month). The blue dashed lines are the upper and lower 95% confidence limits around average values. Note that the x-axis (time) is divided into three 10-day periods per month from April through November. See Kleiber and Perrin (1991) for calculation details.

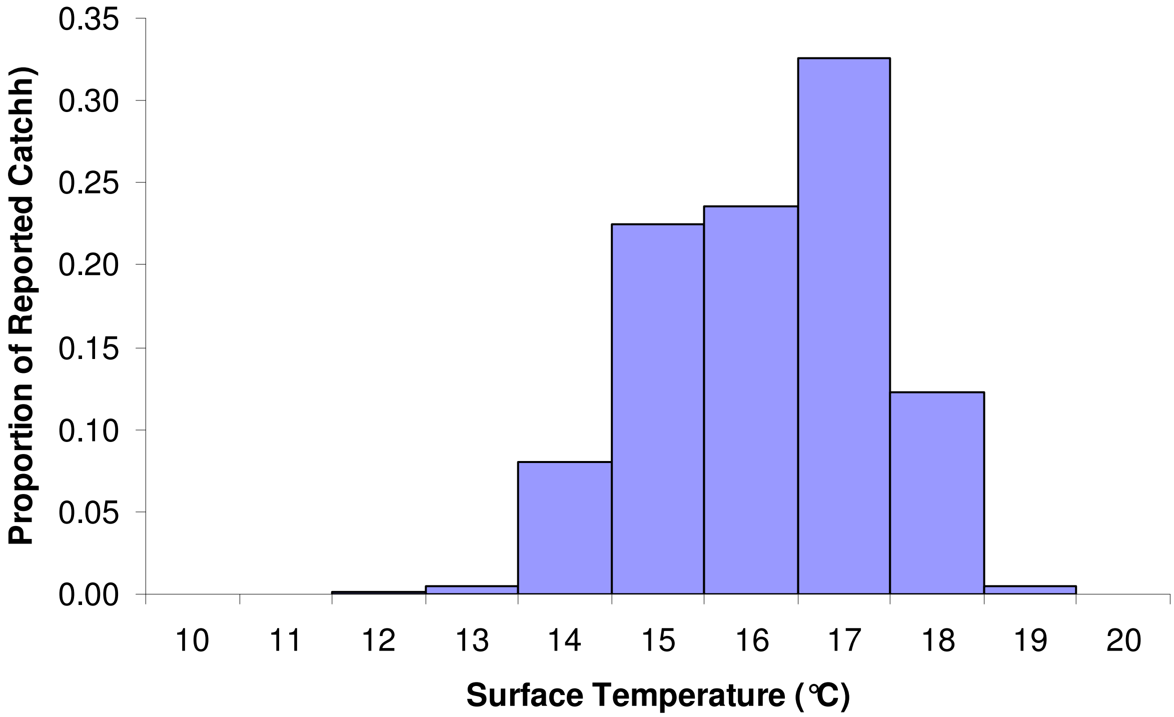

Figure 6. Sea surface temperatures at which albacore tuna were caught by the Canadian troll fishery in 2011. N = 683,206 fish with associated water temperature data. Total reported catch was 831,299 albacore in 2011.

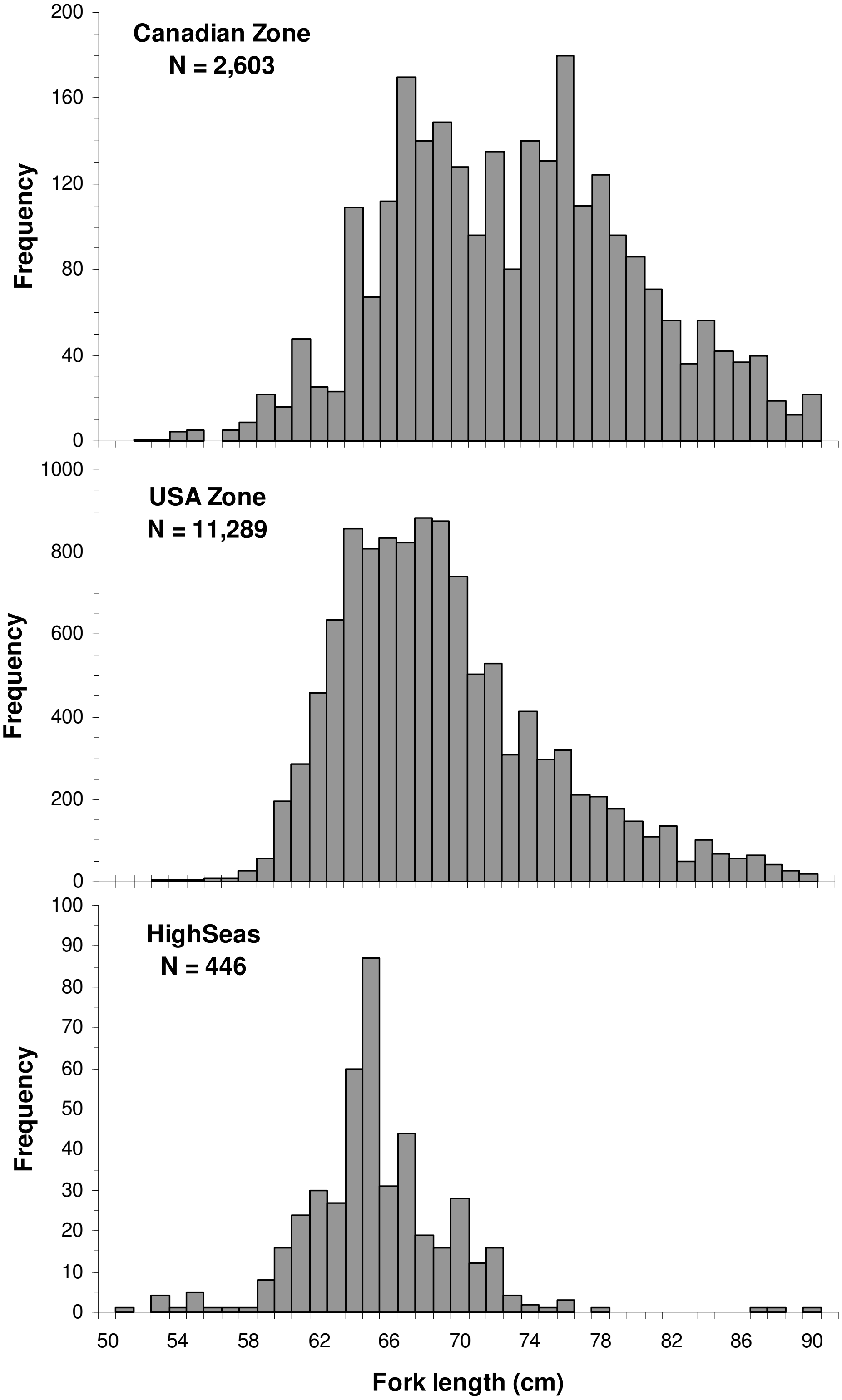

Figure 7. Fork lengths of North Pacific albacore harvested by the Canadian fishery in 2011 by fishing zone. A total of 14,338 measurements were made in 2011.