An update of the standardized abundance index of US and Canada albacore troll fisheries in the North Pacific (1966-2012)[1]

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ABSTRACT

A merged US-Canada albacore troll/pole-and-line (surface) fisheries data was used to obtain a standardized abundance index from 1966 to 2012 for the upcoming 2014 stock assessment of North Pacific albacore tuna. We aggregated catch and effort data into 1x1° spatial blocks on a monthly basis from logbooks, and used a generalized linear model to standardize the catch-per-unit-effort (CPUE) and use bootstrapping to determine the confidence intervals. Based on previous studies on the effects of temperature gradients on albacore CPUE, we further split the data into different areas and periods to examine the catchability changes over time and space. The results showed that open ocean abundance index has a different trend from the coastal ocean index. The abundance index based on the entire dataset is highly determined by the coastal time series because that is where most of the effort occurs and there is insufficient effort in the open ocean to provide a representative index. In addition, there was a substantial change in fishery operations in 2012 that might have influenced the abundance index. Canadian vessels were not allowed in US waters to fish for albacore tuna due to a lack of a fishing regime pursuant to the US-Canada albacore treaty, and appeared to have experienced lower CPUE as a result. Based on the results of this study, we recommend that the US-Canada surface fisheries abundance index be used in the sensitivity runs of the stock assessment because the local abundance of albacore in the coastal area not only depends upon population changes but also on migration rates to the coastal areas, which are likely variable and not accounted for in the standardization. In addition, the authors recommend that either the 2012 data point be dropped for this assessment or that only the US data be used for the index to account for the large change in fishery operations for these fisheries.

INTRODUCTION

Albacore tuna have been targeted by the US and Canadian troll/pole-and-line (surface) fisheries in the North Pacific over a half century. In the last albacore stock assessment, a generalized linear model (GLM) was used on a merged US-Canadian surface fisheries logbook dataset to obtain a standardized abundance index of North Pacific albacore tuna (ISC, 2011). The model considered areas and seasons as factors in the GLM with two general areas (north of 40°N and south of 40°N) and estimated a standardized CPUE index from 1966 to 2009. Our objective of this paper is to 1) update the standardized catch-per-unit-effort (CPUE) index time series to 2012 using the same analysis, 2) define finer spatial regions based on an earlier analysis of the environment and CPUE distribution and examine the effect of these new spatial definitions, and 3) define time periods based on fishery operation and catchability changes and develop CPUE index time series for the stock assessment.

DATA AND METHODS

Data

A database of catch and effort was assembled from the logbook records of US and Canadian albacore surface vessels. We used the same data structure as Teo et al. (2010a) with updated US data from 1966-2012 and Canadian data from 1995-2012. Data without latitude and longitude and locations on land were removed. Retained and discarded catch were summed up to get total catch. We further aggregated the merged data into 1x1° spatial blocks by month. Effort less than 3 boat days were also removed from further analysis.

CPUE standardization

First, we calculated the standardized CPUE indices for the merged US-Canada, US-only and Canada-only datasets using a GLM (the same method as Teo, et al., 2010a), and updated the time series to 2012. Second, we assigned the merged US-Canada data into eight areas (Fig. 1) and used these area factors in the GLM to study the area effect on the abundance indices over time. These regions are: inshore-north (region-1, 200nm or less, north of 48°N), inshore-central (region-2, 200nm or less, 40-48°N), inshore-south (region-3, 200nm or less, south of 40°N), transition zone (region-4, more than 200nm, east of 140°W), offshore-northeast (region-5, north of 40°N, 140-160°W), offshore-southeast (region-6, south of 40°N, 140-160°W), offshore-northwest (region-7, north of 40°N, 160°E-160°W), and offshore-southwest (region-8, south of 40°N, 160°E-160°W). This analysis is an extended study based on Teo et al. (2010b) with two regions. Xu et al. (2013) suggested that there is spatial heterogeneity of catchability in the Northeast Pacific due to environmental conditions. For example, the transition zone (region-4) between the high SST gradients of the open ocean and the coastal ocean has an area with low SST gradients, which corresponded to an area of low albacore CPUE and likely low catchability over the past 30 years. In addition, the CPUE showed a latitudinal dome-shaped distribution with the peak around 40°N. Therefore, we defined the above regions in an attempt to account for these CPUE patterns. Third, we subset the data into coastal (region1-3) and open ocean (region 4-8) datasets and ran the GLM on these datasets separately. Our objective is to determine which region (open or coastal ocean) is the driving factor for the overall abundance index. Last, we further split the time series to three periods: 1966-1978, 1979-1998, and 1999-2012. These splits are based on the changes in the spatial distribution of effort over time (Fig. 2). At the beginning of the period, most of the fishing activities were near shore. Starting from the late 1970s, the fishery operated in much of the open ocean until the late 1990s. Because of increasing fuel prices and other factors, most of the fishing effort after 2000 has occurred in the coastal ocean. By splitting the time series and running GLMs separately, more flexibility in catchability changes will be allowed between the different time periods.

RESULTS AND DISCUSSION

Similar to previous findings, the trend of the abundance indices from the merged US-Canada, US-only and Canada-only datasets were highly comparable except for 2012 (Fig. 3). In 2012, the US-only index showed a strong upward trend, while the Canada-only index showed an equally strong downward trend, and the joint US-Canada index had a slight increase. These differences are likely due to the lack of a fishing regime pursuant to the US-Canada albacore treaty. The lack of a fishing regime in 2012 meant that Canadian vessels were not permitted to enter US waters to fish for albacore as they had done in the past. Therefore, continued use of the US-Canada merged abundance index in 2012 may bias the assessment results. We recommend for this assessment either removing the 2012 data point or using only the US data for the index to mitigate the impact the large change in fishery operations for these fisheries.

The standardized CPUE index with additional area factors showed a similar trend to the previous index using only two areas (Fig. 4a). Region-3 and region-4 have lower coefficients compared to the rest of the regions (Appendix: glm results summary), which is consistent with the previous study on the effects of SST gradients on albacore CPUE (Xu et al., 2013). This result suggested that the effect of additional area factors is not large enough to change the trend of the CPUE time series.

The coastal and open ocean indices showed different CPUE trends (Fig. 4b and 4c). The CPUE time series from the entire dataset is very similar to the coastal ocean ($R=0.93$, $p<<0.001$). This similarity is primarily because the majority of data came from the coastal ocean. Therefore, we recommend separating two time series (open and coastal ocean) and perhaps only selecting the coastal ocean index given that open ocean data are limited, sparse, and may not be representative of the stock. However, the working group should note that there is variability in the coastal index not only because of changes in the stock abundance as a whole but also likely due to migration rates into the coastal region as well. Thus, the coastal index may also not be highly representative of the North Pacific albacore abundance as a whole but may be more representative of local abundance. Nevertheless, the additional area factors related to the effect of SST gradients and limiting the index to the coastal ocean in this study appeared to have reduced interannual variability in the index. In comparison to nominal CPUE indices (Fig. 5), the standardized CPUE appeared to have a reduced variability, which is similar to previous findings.

The overall trends in the abundance indices did not change substantially when we split the time series into three periods (Fig. 6). The confidence intervals for 1966-1978 is larger compare to 1979-1998 and 1998-2012 because when bootstrapping was performed separately, the 1966-1978 period had fewer data with larger variability. Compared to the 2009 CPUE standardization results (Fig. 6a, black line), splitting the index into different periods does not substantially reduce the variability. However, splitting the time series is consistent with the changes in historical fishery operations noted above and allows more flexibility in catchability changes between the different time periods in the assessment model. The working group should take note that the lack of flexibility to accommodate catchability changes in the previous stock assessment model was a major criticism of the CIE reviewers of that assessment. Overall, we recommend using the coastal ocean index, which was broken up into 3 time periods, in a sensitivity run of the upcoming stock assessment rather than as a primary abundance index in the base-case model.

REFERENCES

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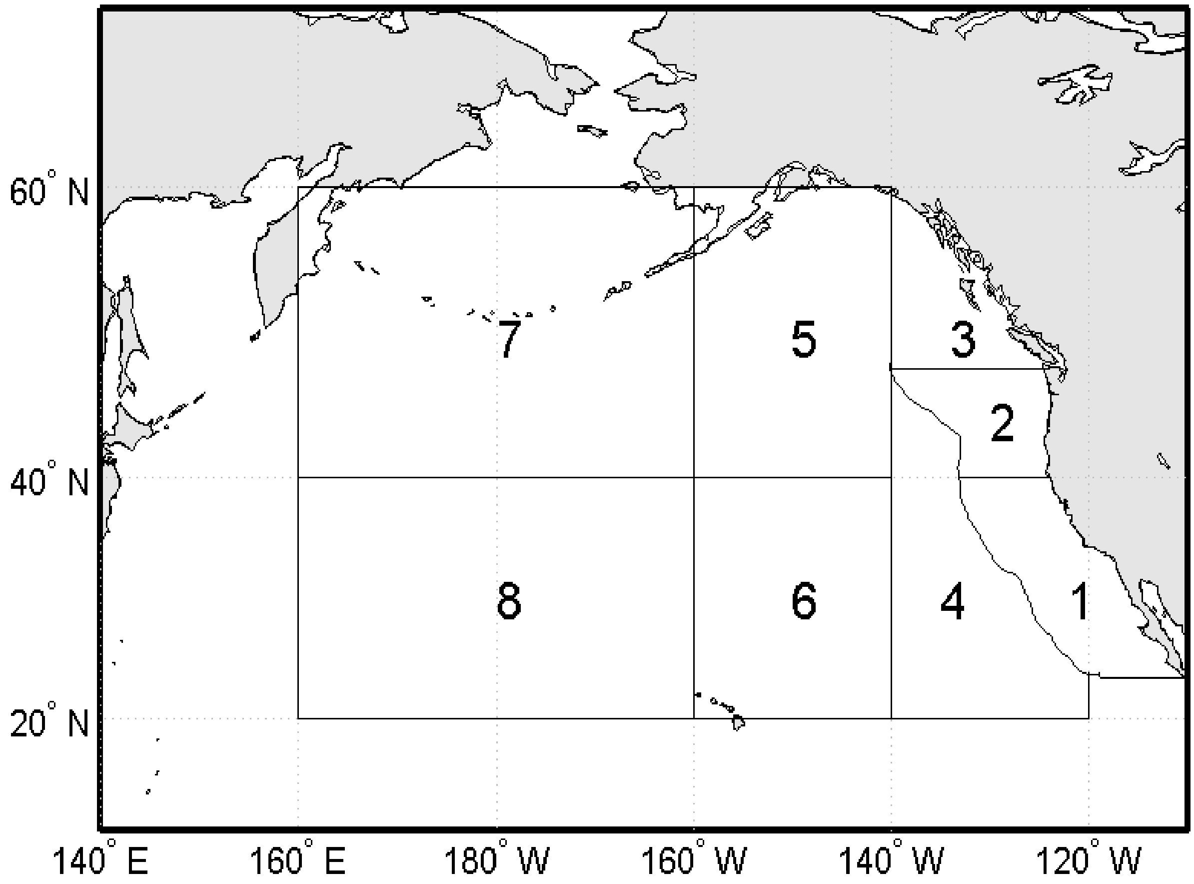

Figure 1. Map showing subdivision regions for constructing standardized CPUE abundance indices: inshore-north (region-1, 200nm or less, north of 48°N), inshore-central (region-2, 200nm or less, 40-48°N), inshore-south (region-3, 200nm or less, south of 40°N), transition zone (region-4, more than 200nm, east of 140°W), offshore-northeast (region-5, north of 40°N, 140-160°W), offshore-southeast (region-6, south of 40°N, 140-160°W), offshore-northwest (region-7, north of 40°N, 160°E-160°W), and offshore-southwest (region-8, south of 40°N, 160°E-160°W).

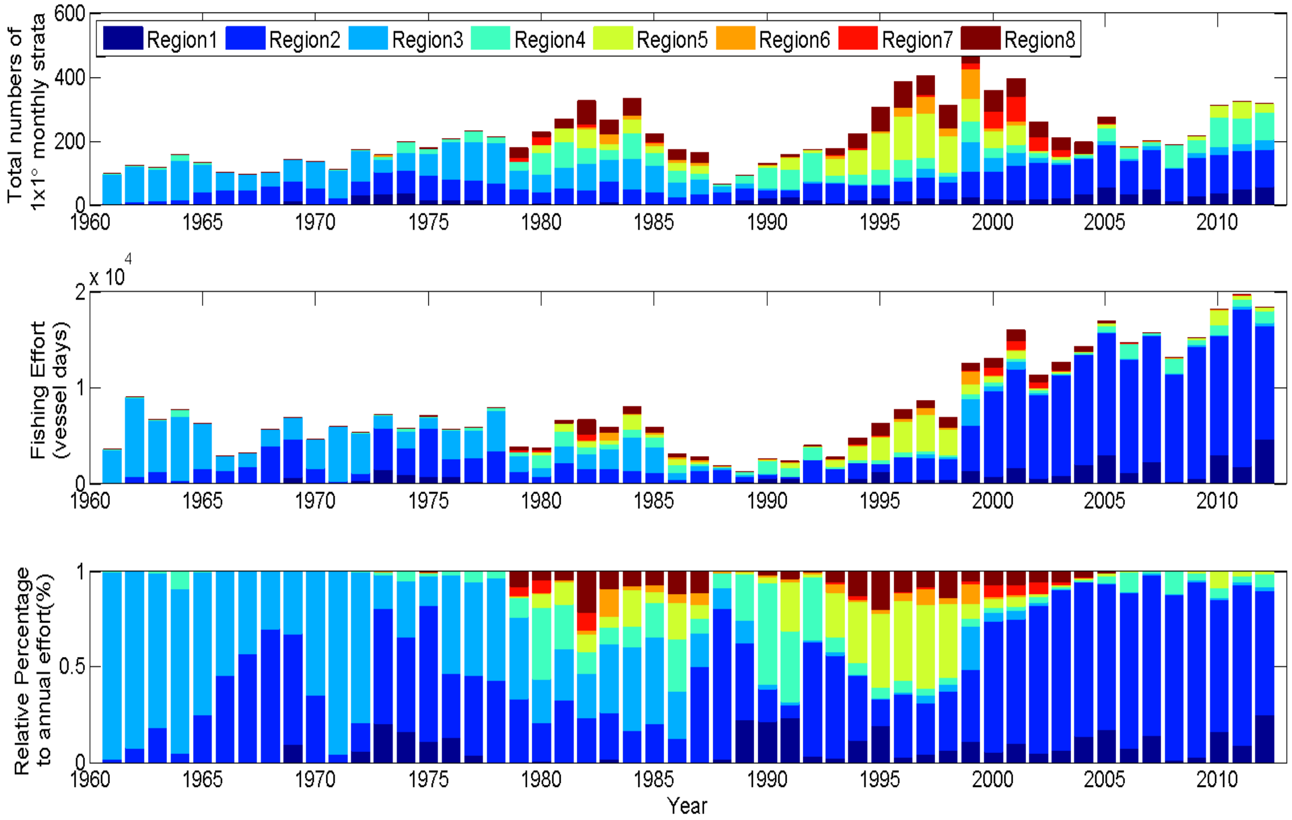

Figure 2. Barplots of a) Numbers of 1x1° monthly strata b) fishing effort (vessel days), and c) relative proportion to annual effort (%) of eight regions. Eight regions were defined in Figure 1.

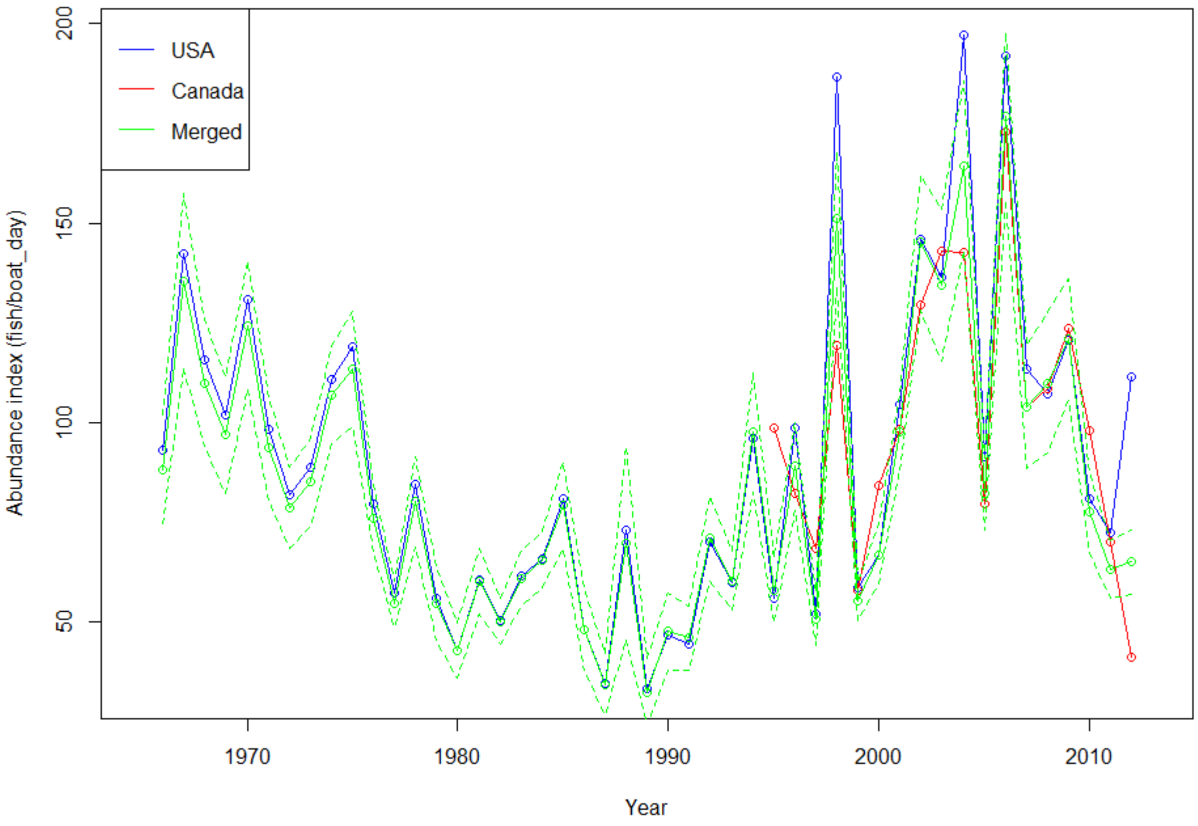

Figure 3. Standardized abundance indices of North Pacific albacore derived from 1) USA-only (blue, 1966-2012) 2) Canada-only (red, 1995-2012), and 3) merged US-Canada (green, 1966-2012) data. Green dashed lines indicate 95% confidence intervals of the joint US-Canada abundance index from 1000 bootstrap samples.

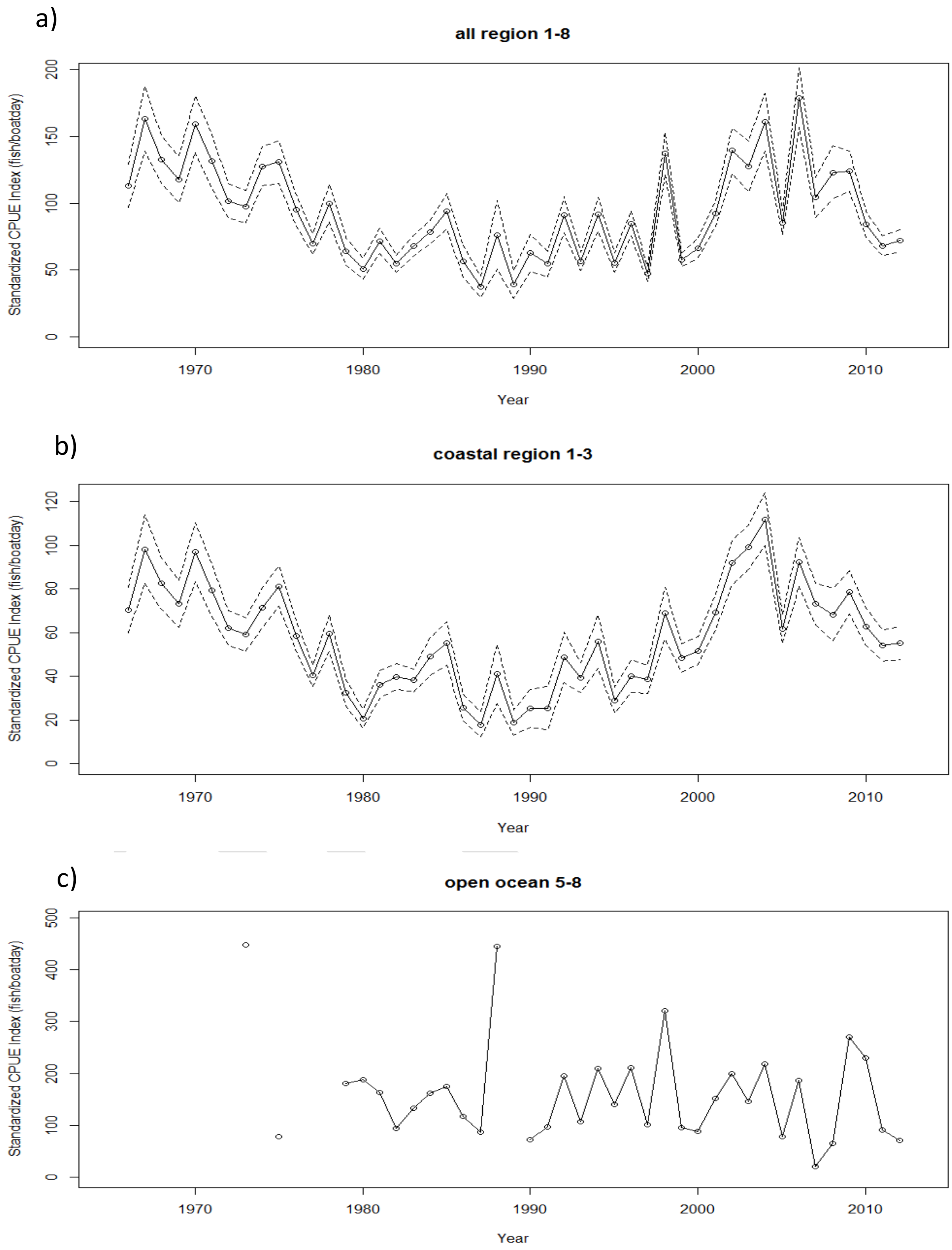

Figure 4. Comparison of standardized CPUE indices with area and season effect for a) all regions, b) coastal ocean and c) open ocean.

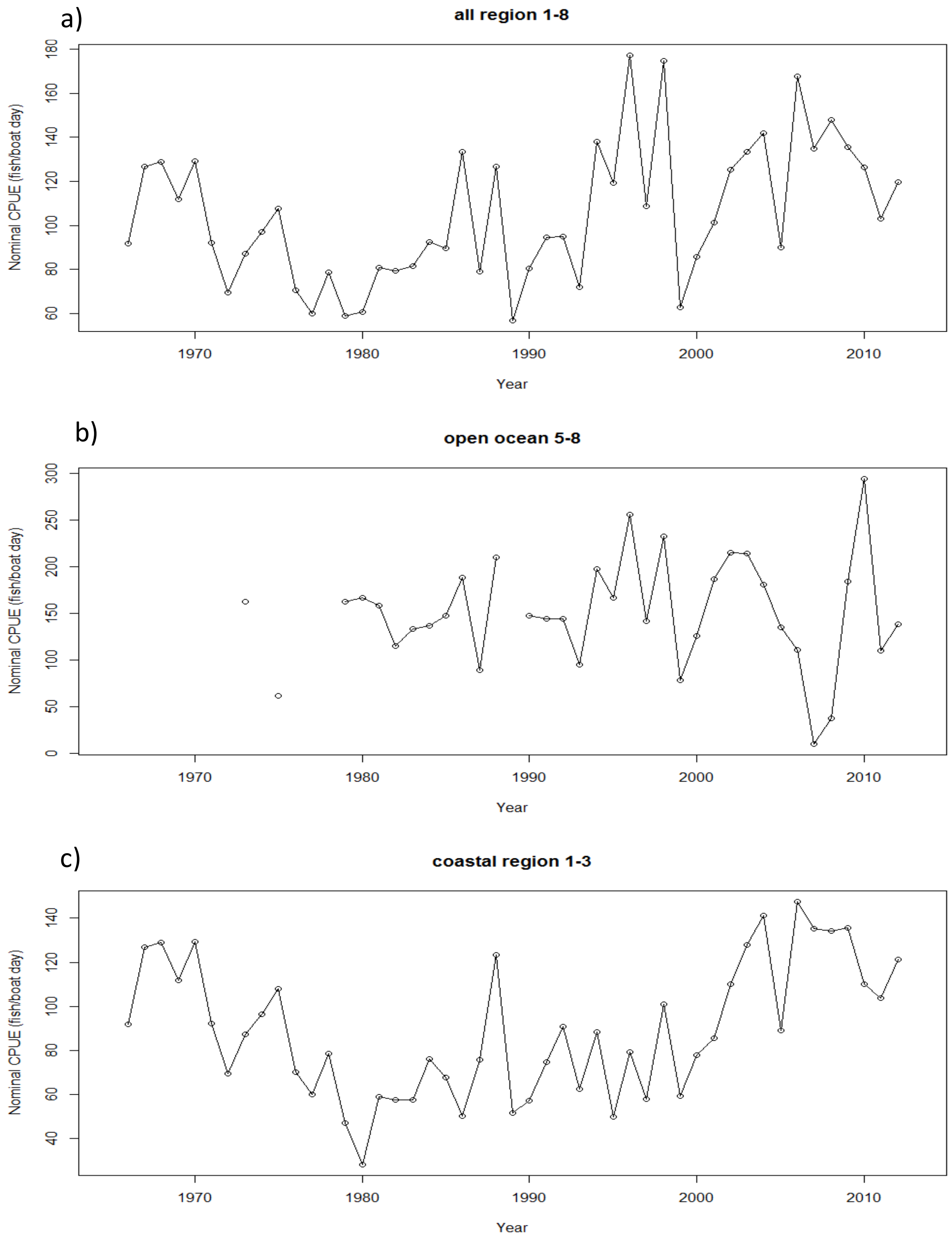

Figure 5. Comparison of nominal CPUE indices for a) all regions, b) coastal ocean and c) open ocean.

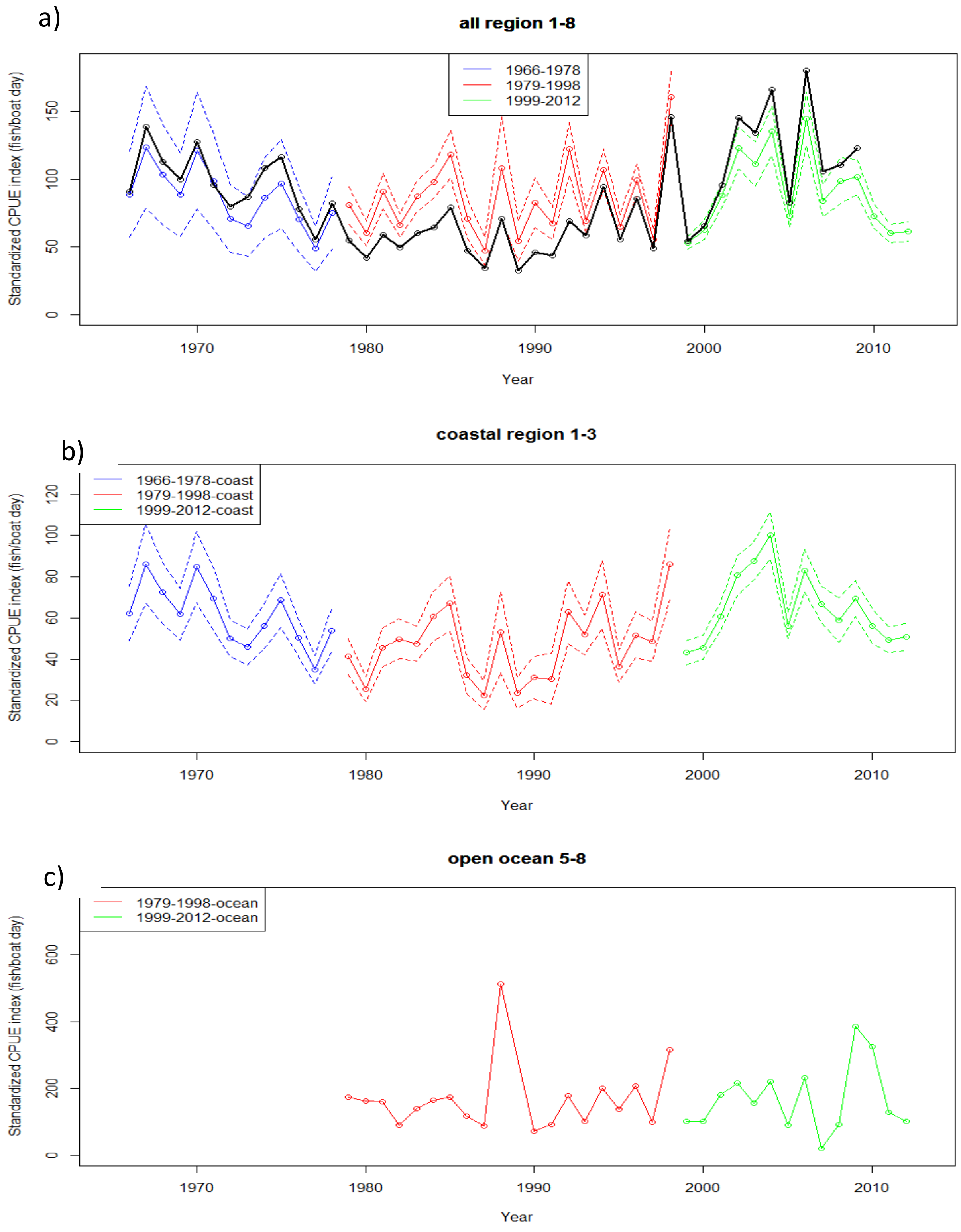

Figure 6. Comparison of standardized CPUE indices for a) all regions, b) coastal ocean and c) open ocean. Glm model run separately for time periods to 1966-1978(blue), 1979-1998(red), 1999-2012(green). Black line was the old glm results from 2009 CPUE standardization.

Appendix: glm results summary for Fig 4a, CPUE standardization with area and season effect.

```
Call:
glm(formula = alb.model, family = gaussian, data = CPUE.IN)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-4.7310  -0.5280   0.1443   0.6709   3.1415  

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept)  4.20731    0.10535  39.936  < 2e-16 ***
year.f1967   0.36744    0.14101   2.606 0.009181 ** 
year.f1968   0.15798    0.13849   1.141 0.254025    
year.f1969   0.04007    0.12872   0.311 0.755603    
year.f1970   0.34381    0.12994   2.646 0.008161 ** 
year.f1971   0.15223    0.13656   1.115 0.264986    
year.f1972  -0.10593    0.12420  -0.853 0.393726    
year.f1973  -0.14820    0.12678  -1.169 0.242458    
year.f1974   0.12179    0.12151   1.002 0.316222    
year.f1975   0.14467    0.12325   1.174 0.240518    
year.f1976  -0.17543    0.12000  -1.462 0.143798    
year.f1977  -0.48483    0.11807  -4.106 4.05e-05 ***
year.f1978  -0.12471    0.12092  -1.031 0.302398    
year.f1979  -0.56594    0.12371  -4.575 4.82e-06 ***
year.f1980  -0.79774    0.11923  -6.691 2.33e-11 ***
year.f1981  -0.45641    0.11625  -3.926 8.69e-05 ***
year.f1982  -0.72500    0.11355  -6.385 1.79e-10 ***
year.f1983  -0.50409    0.11623  -4.337 1.46e-05 ***
year.f1984  -0.36737    0.11305  -3.250 0.001159 ** 
year.f1985  -0.18528    0.11929  -1.553 0.120399    
year.f1986  -0.69337    0.12487  -5.553 2.88e-08 ***
year.f1987  -1.10596    0.12587  -8.786  < 2e-16 ***
year.f1988  -0.39255    0.15731  -2.495 0.012599 *  
year.f1989  -1.06257    0.14357  -7.401 1.45e-13 ***
year.f1990  -0.58627    0.13273  -4.417 1.01e-05 ***
year.f1991  -0.73004    0.12763  -5.720 1.09e-08 ***
year.f1992  -0.21295    0.12535  -1.699 0.089375 .  
year.f1993  -0.69581    0.12471  -5.579 2.48e-08 ***
year.f1994  -0.20970    0.12033  -1.743 0.081409 .  
year.f1995  -0.71149    0.11556  -6.157 7.68e-10 ***
year.f1996  -0.28812    0.11240  -2.563 0.010384 *  
year.f1997  -0.87422    0.11180  -7.819 5.81e-15 ***
year.f1998   0.19472    0.11517   1.691 0.090941 .  
year.f1999  -0.67373    0.10899  -6.182 6.58e-10 ***
year.f2000  -0.53680    0.11268  -4.764 1.92e-06 ***
year.f2001  -0.20330    0.11184  -1.818 0.069132 .  
year.f2002   0.20911    0.11745   1.780 0.075026 .  
year.f2003   0.12017    0.12078   0.995 0.319810    
year.f2004   0.35211    0.12235   2.878 0.004013 ** 
year.f2005  -0.27911    0.11619  -2.402 0.016310 *  
year.f2006   0.45870    0.12394   3.701 0.000216 ***
year.f2007  -0.07863    0.12193  -0.645 0.519002    
year.f2008   0.08379    0.12310   0.681 0.496099    
year.f2009   0.09329    0.12030   0.776 0.438052    
year.f2010  -0.29564    0.11419  -2.589 0.009638 ** 
year.f2011  -0.50903    0.11369  -4.477 7.64e-06 ***
year.f2012  -0.45259    0.11408  -3.967 7.32e-05 ***
season.f2   -0.35419    0.04198  -8.437  < 2e-16 ***
season.f3   -0.24076    0.03328  -7.235 4.99e-13 ***
area.f2      0.16811    0.03926   4.282 1.87e-05 ***
area.f3     -0.36077    0.04442  -8.122 5.10e-16 ***
area.f4     -0.16731    0.04373  -3.826 0.000131 ***
area.f5      0.73344    0.04692  15.631  < 2e-16 ***
area.f6      0.49090    0.07299   6.725 1.84e-11 ***
area.f7      0.61458    0.07213   8.520  < 2e-16 ***
area.f8      0.28813    0.06130   4.700 2.63e-06 ***
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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.9967745)

    Null deviance: 12924  on 10547  degrees of freedom
Residual deviance: 10458  on 10492  degrees of freedom
  (2 observations deleted due to missingness)
AIC: 29958

Number of Fisher Scoring iterations: 2
```