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Standardized CPUE for South Pacific Albacore[1]

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Keith Bigelow[2] Simon Hoyle[3]

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[2] Pacific Islands Fisheries Science Center, NOAA Fisheries, Honolulu, HI USA
[3] Secretariat of the Pacific Community, New Caledonia

1 Introduction

Longline catch and effort series represent the principal indices of relative abundance within the south Pacific albacore MULTIFAN-CL assessment. However, there have been temporal changes in the catchability of the longline fisheries, primarily in the distant-water fisheries as a result of changes in the species targeted. The 2005 assessment (Langley and Hampton 2005) used indices based on nominal 5º latitude x 5º longitude by month aggregated data for distant-water fishing nations and operational level dataset (logsheet data) from domestic longline fisheries.

The south Pacific albacore stock assessment (south of the equator, 140ºE−250ºW) is spatially stratified into four regions delineated by at 25ºS and 180º. Since 2008, there has been a progression towards developing standardized CPUE indices based on logsheet data and GLMs (Generalized Linear Models). Indices in the 2008 assessment (Hoyle et al. 2008) were based on a standardized CPUE index (Bigelow and Hoyle 2008) developed for distant-water fleets (Japan, Korea and Taiwan) targeting south Pacific albacore (east of 110°W) by analysing operational level data (logsheet data) of vessels landing at the two major canneries (Pago Pago, American Samoa and Levuka, Fiji). While the CPUE standardization using operational level data in Bigelow and Hoyle (2008) represented an improvement in constructing relative abundance indices for south Pacific albacore, there was concern that some Taiwan vessels had changed from targeting albacore to bigeye tuna. In the late 1990s, this targeting change was accompanied by a spatial change in the fishery, the use of deeper longline gear, and higher catch rates of bigeye tuna. The species being targeted by a longline set can be difficult to identify if it is not recorded explicitly. Operational characteristics of a longline set (e.g. hooks between floats) can be used to determine target species, but few operational characteristics were available for this entire time series.

To address the issue of targeting, indices in the 2009 (Hoyle and Davies 2009) and 2011 (Hoyle 2011) assessments used a cluster analysis (Bigelow and Hoyle 2009) to statistically disaggregate albacore and bigeye tuna targeting operations for the Taiwan fleet based on species composition from logsheet data. GLMs were then applied to the logsheet data for the entire Japan and Korea time-series and Taiwan fleet targeting south Pacific albacore to estimate relative abundance indices for the assessments. The 2009 and 2011 assessments did not standardize CPUE for the domestic (non distant-water) fleets.

Four predictors were considered in the previous GLMs applied in the 2009 and 2011 standardizations: year_quarter, vessel, and two interactions of 1) month and latitude, and 2) latitude and longitude. The dependent variable in the GLMs was the natural logarithm of albacore CPUE with a small constant (0.5) added to the catch. Each longline set was weighted by (1/sqrt(number of longline sets per trip)), because individual longline sets within a trip are often highly correlated. A criterion was used for each fleet and region which had 10,000 or more longline sets to include only vessels that had fished in four or more quarters. All vessels were used if a fleet and region had less than 10,000 longline sets. A total of 12 GLMs were conducted as combinations of three fleets and four regions.

The objective of the present study was to produce one standardized CPUE index per region for vessels targeting south Pacific albacore on a specific trip. Improvements to previous standardizations which included only distant-water fleets include: 1) all logsheet data south of the equator were used from all longline fleets, 2) trips targeting south Pacific albacore were identified by three alternative types of cluster analysis and 3) the GLMs considered a negative binomial distribution instead of the lognormal distribution.

2 Methods

2.1 Data compilation and cluster analysis of longline targeting

Effort and catches in numbers of fish by species were compiled from individual vessels submitting logsheet data of longline activity in the south Pacific. A total of 2,881 vessels reported landing fish from 1960 to 2011. Longline sets with an effort of less than 1,000 hooks were deleted, as were trips with fewer than 5 sets, leaving 2,300 vessels, 40,756 trips, and 943,756 sets.

Clustering routines were performed in R (version 2.15.0 for Windows) based on the proportion of albacore, yellowfin and bigeye tuna caught in each trip. The proportion of various 'other' species was not incorporated as the species composition is probably only valid for the three tuna species (P. Williams, SPC personal communication). Trips that caught zero tuna were removed from the cluster analysis as zero proportions were uninformative in the cluster analysis. A Ward Hierarchical clustering (hclust) or agglomerative approach was applied to each region to produce a dendrogram to illustrate the appropriate number of clusters (species targeting) represented in the data. Clustering was conducted by trip as clustering on each set may confuse the chance of failure of a set to capture albacore with active targeting of other species, whereas this is unlikely at the trip level. Clustering by set was also computationally too time -consuming. The clustering was applied to the entire time series within each region. Cluster results pertaining to south Pacific albacore and south Pacific albacore and yellowfin tuna were retained for analysis and the bigeye and yellowfin tuna cluster was discarded.

Since fishing activity occurred over a lengthy time period (>5 years) by many vessels, an activity filter was used to remove vessels that fished only briefly. To be considered in the GLMs, vessels had to be active in at least 6 quarters in regions 1 and 2 and at least 2 quarters in regions 3 and 4.

2.2 Generalized linear models (GLM)

A GLM with a negative bionomial distribution was fit in R with a MASS library. For region, the GLM predicts mean catch (μ_i) as number of individuals using four categorical variables with a log link:

$$\log(\mu_i) = N_i + CL_i + LATLON_i + V_i + \log(E_i)$$

where N is the mean local abundance or year_quarter effect; *CL*, cluster (either albacore or albacore and yellowfin tuna), *LATLON* are effects of 5º latitude and longitude squares, *V* is the vessel effect (boat_ID) and offset *E* is the number of hooks deployed during longline operation *i*. Standard deviations for the year_quarter effects were calculated from the GLM results using the 'predict.glm' routine.

3 Results

3.1 Cluster analysis of longline targeting

Dendrograms indicated three primary clusters for each region (Figure 1). The bigeye and yellowfin tuna cluster represented a larger percentage of trips (range=23.0–27.6%) in the northern regions (1 and 2) than the southern regions (3 and 4, range=6.0–13.2%, Table 1). Figure 2 illustrates annual percentages of each cluster through time. The bigeye and yellowfin cluster has a high proportion in region 1 until 1980 and a moderate proportion in region 2 throughout the time-series. The albacore and albacore and yellowfin tuna cluster dominate regions 3 and 4 throughout the time-series.

Figure 3 illustrates the spatial variability of the three clusters. In general there is some spatial separation in clusters, with the bigeye and yellowfin tuna (cluster 3) at low-latitudes, albacore and yellowfin tuna (cluster 1) at mid-latitudes and albacore (cluster 2) at high-latitudes. South Pacific albacore targeting trips were defined as the two clusters from each region that were composed of predominantly albacore and albacore and yellowfin tuna.

The south Pacific albacore clusters were then assigned to sets within an individual trip. Table 2 indicates the number of longline sets and vessels by flag targeting south Pacific albacore. These sets and vessels represent the data included in the GLM after clustering and vessel activity filter.

3.2 Generalized linear models (GLM)

Model results of the GLM analysis are provided in Table 3. The percentage of explained deviance by the GLMs ranged from 20.6 to 46.6%. Figure 4 illustrates a comparison of nominal and standardized CPUE for the four regions. The indices were similar for regions 1 and 3 to the west of 180 º. In regions 2 and 4, standardized CPUE was greater than nominal CPUE prior to 1970 and less than nominal from 2000 to 2011.

The mean of year_quarter indices and their standard deviations were incorporated into the 2012 albacore assessment (Hoyle et al. 2012). Figure 5 illustrates a comparison between current GLM indices and standardized indices used in the 2011 assessment (Hoyle 2011). The standardized CPUE indices from the current study are similar to previous indices although with less quarterly variability since they were not produced as fleet-specific indices.

There was a rapid decline in standardized CPUE from the early 1960s until 1975 followed by a slower decline thereafter. In the late 1990s, there was an increase in standardized CPUE in regions 2–4. There was a decline in most regions in 2003, thereafter standardized CPUE was stable in the east (regions 2 and 4) and increased in the west (regions 1 and 3).

4 Discussion

The south Pacific albacore stock is assessed with standardized CPUE indices constructed entirely with operational data. These operational data include identification of species targeting and use individual vessels which in the GLM framework implicitly accounts for a certain amount of change in fishing power and consistent activity through time.

Previous standardization methods generated fleet-specific indices for Japan, Korea and Taiwan; however no standardized indices were produced for domestic fleets. Previous indices among distant-water fleets have been shown to be similar (Bigelow and Hoyle 2009) suggesting that the trends represent longline sets targeting south Pacific albacore. The current standardization methodology constructed one CPUE index per region. Rather than subsetting by flag (fleet), vessel effects were considered to better capture fishing performance between vessels. Using individual vessel effects should be preferred as some vessels may be flagged to a particular country, but may not be representative of fishing operations or success within the fleet. The combined analysis of all data results in more precise indices with fewer gaps in the time series and less concern about bias from individual fleets changing their targeting strategies.

The current methodology may be improved by clustering on a smaller time-scale such as five or 10 years. The bigeye and yellowfin cluster dominated region 1 from 1960 until 1980; however the longline fishery is commonly thought to have been an albacore fishery during this early period. Assigning trips to the bigeye and yellowfin cluster may have represented an increased abundance of these species during the 1960s and 1970s rather than actual targeting efforts.

5 Acknowledgements

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6 References

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Table 1. Species composition (ALB, YFT and BET) by cluster and region estimated by clustering routine *clara*.

			Percentage		
Region	Cluster	Number of trips (percent)	ALB	BET	YFT
1	1	7,807 (42.5%)	91.9	1.9	6.2
1	2	6,329 (34.5%)	75.0	5.7	19.3
1	3	4,215 (23%)	41.4	16.0	42.6
2	1	7,617 (36%)	71.3	13.2	15.5
2	2	7,698 (36.4%)	90.6	4.1	5.4
2	3	5,839 (27.6%)	31.1	32.9	36.0
3	1	396 (32%)	89.1	5.2	5.7
3	2	680 (54.9%)	97.3	1.3	1.5
3	3	163 (13.2%)	44.6	20.8	34.6
4	1	1,107 (40.1%)	90.1	4.2	5.7
4	2	1,487 (53.9%)	97.5	1.3	1.3
4	3	165 (6.0%)	58.1	17.9	24.1

Table 2. Number of longline sets by fleet and region targeting south Pacific albacore as determined by cluster analysis. Vessel activity filter was used to estimate sets and vessels.

		Region 1		Region 2		Region 3		Region 4	
Fleet	Code	Longline sets	Vessels	Longline sets	Vessels	Longline sets	Vessels	Longline sets	Vessels
Am. Samoa	AS			62,019	85			315	10
Cook Islands	CK	492	2	14,613	26			33	1
China	CN	13,086	42	324	1	1,256	25	1,249	20
Fiji	FJ	125,004	139	7,671	37	2,333	45	446	13
Japan	JP			11,707	39	218	5	8,006	69
Korea	KR	1,710	11	73,235	162	11,937	129	41,568	226
New Caledonia	NC	22,744	41	5	1	7	1		
Niue	NU			746	2				
French Polynesia	PF			52,464	91				
Tonga	TO			7953	25			1058	10
Taiwan	TW	32,301	72	61,912	184	14,432	105	44,750	296
Vanuatu	VU	13,147	13	13,255	32	4,740	28	17,581	46
Samoa	WS			8807	28				
Total		208,484	320	314,711	713	34,923	338	115,006	691

Table 3. Model results for regional south Pacific albacore CPUE standardization models using residual deviance and Bayesian Information Criteria (BIC).

Region 1, 208,484 sets, Null deviance= 291,202				
Predictor variable	Residual deviance	d.f.	Percent deviance explained	Deviance per parameter
year_quarter+cl+latlon+vessel	231,213	519	20.6	115.6
Region 2, 314,711 sets, Null deviance= 528898				
Predictor variable	Residual deviance	d.f.	Percent deviance explained	Deviance per parameter
year_quarter+cl+latlon+vessel	319,453	1270	39.6	164.9
Region 3, 34,923 sets, Null deviance= 59,210				
Predictor variable	Residual deviance	d.f.	Percent deviance explained	Deviance per parameter
year_quarter+cl+latlon+vessel	37,079	481	37.3	46.0
Region 4, 115,006 sets, Null deviance= 227,690				
Predictor variable	Residual deviance	d.f.	Percent deviance explained	Deviance per parameter
year_quarter+cl+latlon+vessel	121,568	896	46.6	118.4

Figure 1. Dendrogram of agglomerative clustering based on catch proportions of three tuna species (south Pacific albacore, yellowfin and bigeye tuna) per trip. Three clusters are illustrated for each region.

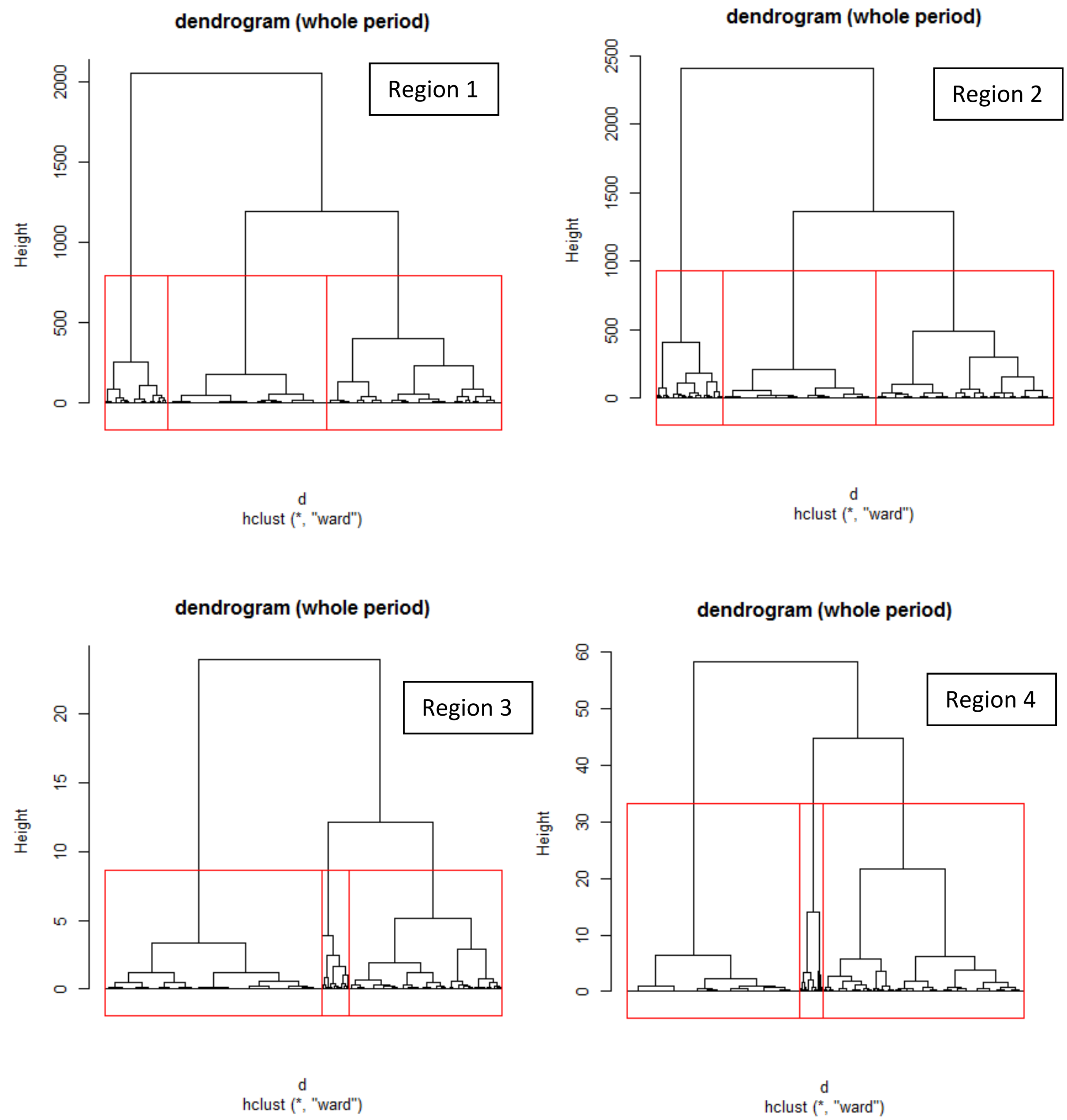

Figure 2. Time-series of the proportion of cluster types by region. Cluster 1 is albacore and yellowfin, cluster 2 is albacore and cluster 3 is bigeye and yellowfin.

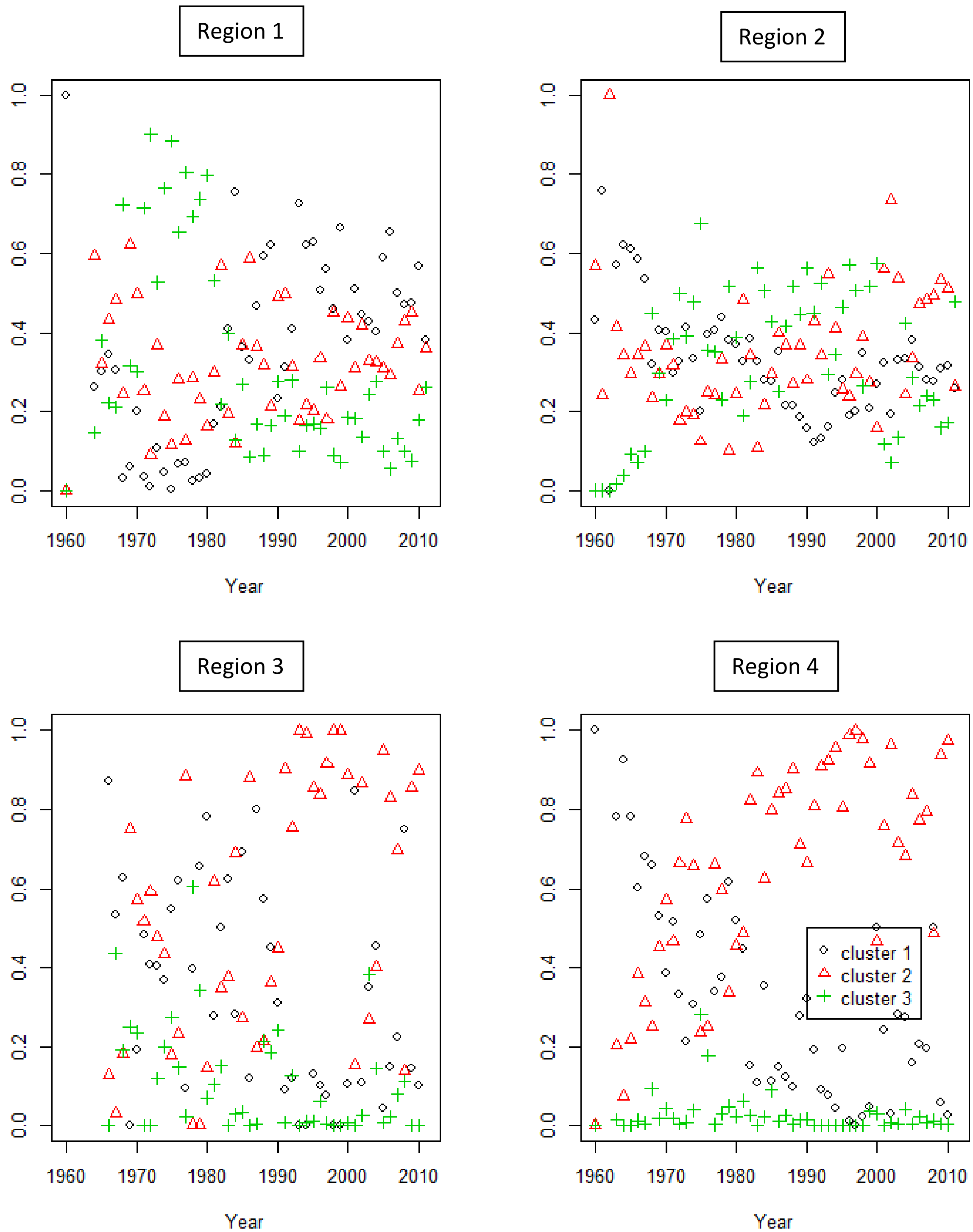

Figure 3. Spatial distribution of fishing effort for three clusters (Cluster 1 is albacore and yellowfin, cluster 2 is albacore and cluster 3 is bigeye and yellowfin) from 1960 to 2011.

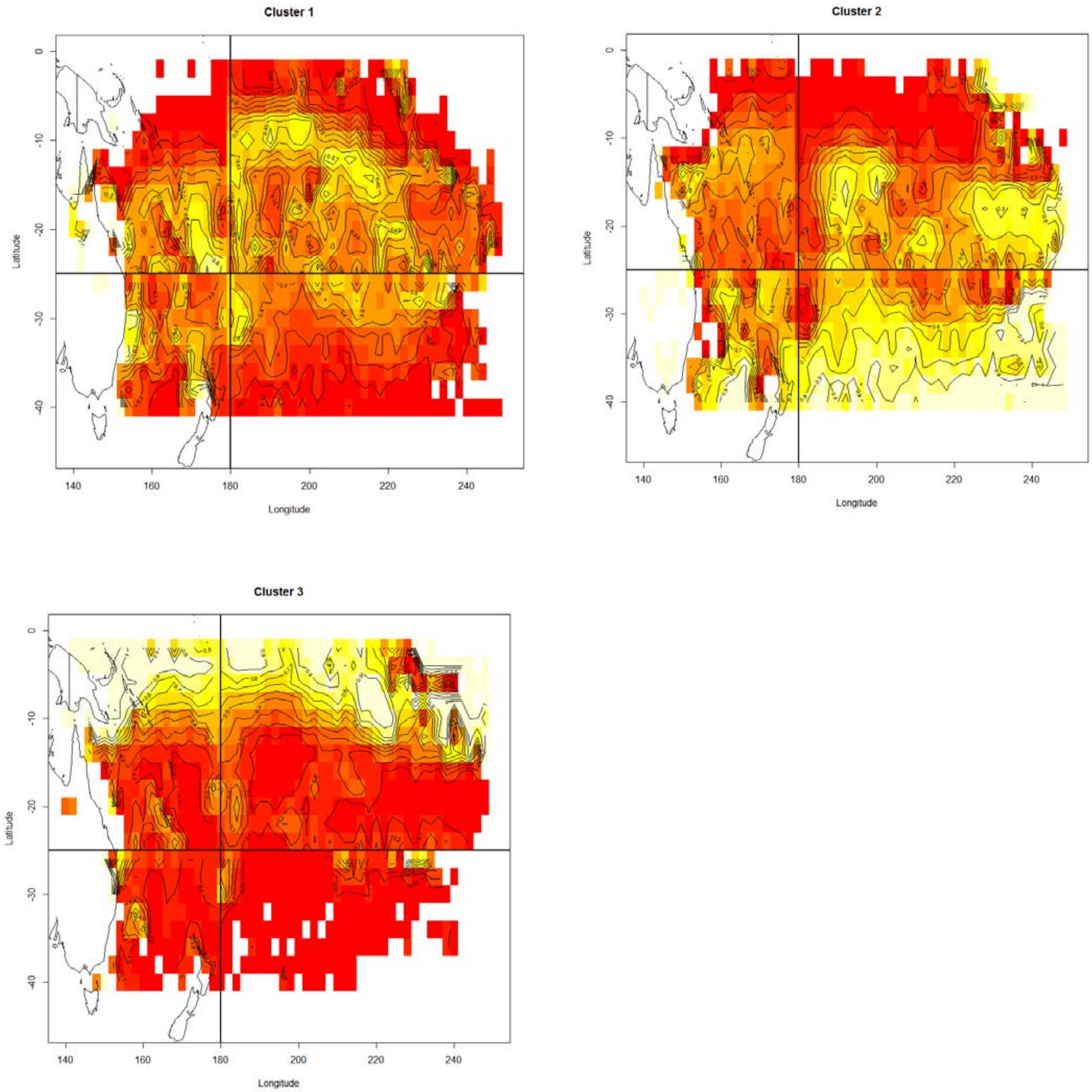

Figure 4. Nominal and standardized CPUE for south Pacific albacore by region.

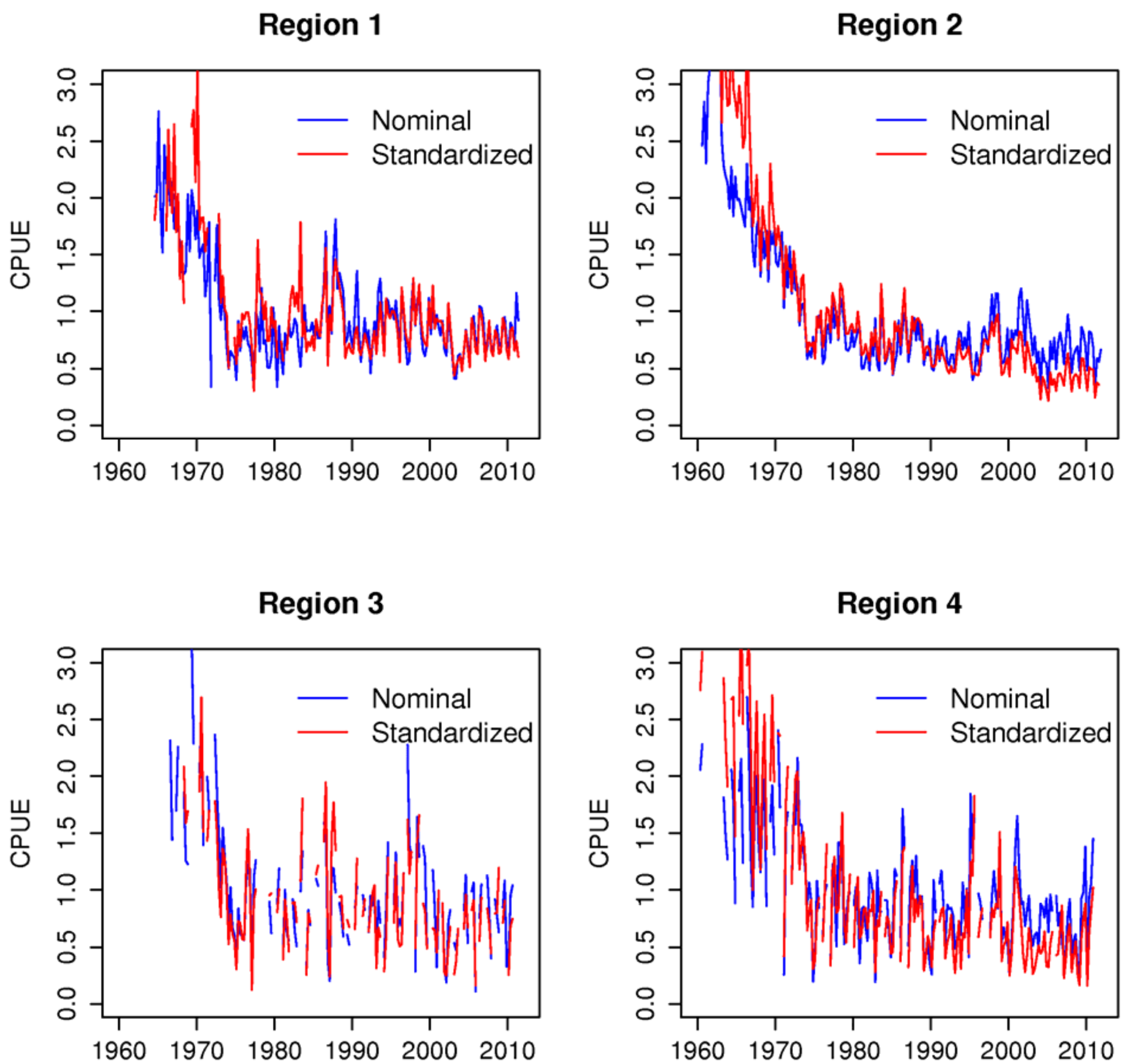

Figure 5. Comparison of standardized CPUE indices generated for the 2011 and 2012 assessments.