Spatiotemporal definitions of the US albacore longline fleets in the North Pacific for the 2017 assessment[1]

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ABSTRACT

In the previous assessment in 2014, the albacore working group (ALBWG) modeled the deep-set and shallow-set components of the US pelagic longline fishery as separate fleets. The primary aim of this study was to re-examine the size composition data from the US pelagic longline fishery in finer detail and develop fleet definitions for the stock assessment with more consistent size compositions. These fishery definitions were subsequently used to develop quarterly size compositions that were raised to the catch, as well as the appropriate sample sizes. The eastern North Pacific Ocean was divided into 22 10x10° areas with available size composition data. A clustering approach was taken to discern areas with relatively consistent size compositions. In order to reduce the dimensionality of the problem, the size composition data was aggregated to approximate age group compositions using the size-at-age information in the 2014 assessment. The results of k-means and agglomerative hierarchical clustering of the size composition data were consistent with each other, suggesting between two to four clusters. There appears to be a core large adult area (areas 12, 13, 17, 18) with the vast majority of fish (>80%) being large adults ≥100 cm FL, and a peripheral area (areas 6, 14, 19, and 21) with a smaller proportion of large adult fish (~55%) and a larger proportion of small adult fish (85 – 100 cm FL). There also appears to be a core juvenile albacore area (areas 8, 9, 10, and 11), especially in seasons 1 and 4, with ~56% of the albacore being juveniles <85 cm FL, and a peripheral area with a lower proportion of juveniles (areas 7 and 15) (~29 %). Therefore, I recommend using the two clusters (F1: areas 6, 12, 13, 14, 17, 18, 19, and 21; F2: areas 7, 8, 9, 10, 11, and 15) as the two fleets for the US pelagic longline in the upcoming assessment. The seasonal size compositions (raised to the catch) for the proposed fleet definitions for the US pelagic longline fishery were shown. The proposed input sample sizes ranged from 1 to 16 for F1 (north area; predominantly juvenile), and 1 to 20.5 for F2 (south area; predominantly large adult).

INTRODUCTION

The US pelagic longline fishery in the North Pacific has been almost exclusively based out of Hawaii in recent years and primarily targets bigeye tuna and swordfish. Monitoring programs have been in place since 1990 and 1994 to collect data from logbooks and onboard observers, respectively. Although the US pelagic longline fishery is relatively small in terms of north Pacific albacore tuna (NPALB) landings (<1000 t and <1% of total NPALB annual landings for most years), it has been an important component of previous NPALB assessments (ISC, 2014) because the fishery captures large, adult NPALB, and data from the fishery provide information on the NPALB spawning stock biomass (SSB).

In the previous assessment in 2014, the albacore working group (ALBWG) decided to model the deep-set and shallow-set components of the fishery as separate fleets in the assessment model (ISC, 2014; Teo, Lee, & Kohin, 2010). The deep-set component primarily targets bigeye tuna using deep longline gear (≥12 hooks per float) and fishes in areas <30 °N. The shallow-set component primarily targets swordfish using shallow longline gear (<12 hooks per float) and fishes in areas >30 °N. The albacore caught by the deep-set component were primarily large adults (≥100 cm) while the shallow-set component caught a mixture of juveniles and adults. The size differences in the albacore tuna caught are likely due to ontogenetic shifts in spatial distribution of albacore tuna demonstrated in previous studies (Childers et al., 2011; Ichinokawa et al., 2008; Kimura et al., 1997). Large, mature albacore appear to prefer sub-tropical waters while smaller, juvenile albacore appear to prefer more temperate waters.

Although the separation of the US pelagic longline fishery into two fleets in the 2014 assessment was reasonable, the fleet definitions of the US pelagic longline fishery could be improved by examining the spatiotemporal characteristics of the albacore catch in more detail. A re-examination of the size composition data from the fishery could improve our understanding of the differences in spatiotemporal distributions of adult and juvenile albacore. This could in turn improve the fishery definitions of other longline fisheries if data for other longline fisheries are lacking. The size composition data for the 2014 assessment were also assumed to be randomly sampled and were therefore not raised to the catch when fitted in the model. However, this assumption is not likely to be appropriate for this fishery. In this study, I develop size composition data that are raised to the catch for the upcoming assessment in 2017.

The primary aim of this study was to examine the size composition data from the US pelagic longline fishery in finer detail and develop fleet definitions with more consistent size compositions. These fleet definitions were subsequently used to develop quarterly size compositions that were raised to the catch, as well as the appropriate sample sizes.

MATERIALS AND METHODS

Data sources

Two main sources of data were used in this paper: 1) catch-effort information from fishermen logbooks (1991-2015), and 2) biological (fork length) information from an observer sampling program for the US longline fishery in the North Pacific (1994-2015).

In this paper, I only used data from longline vessels operating out of Hawaii. The vast majority of US longline vessels operate out of and land fish in Hawaii (Hawaii-based landings reflect >95% of the total catch from US longline vessels) (McDaniel, Crone, & Dorval, 2006). A logbook monitoring program for the Hawaii-based longline fishery has been managed by the National Marine Fisheries Service since 1990. However, I did not use logbook data from 1990 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.

An observer sampling program has also been in operation for this fishery since 1994. Albacore tuna were measured to the nearest cm (fork length) by observers onboard the vessel. As with previous studies, I chose to develop size compositions from the observer program rather than a port-side sampling program at ‘fish auction’ sites to eliminate the potential of the size composition data being biased due to at-sea discards of smaller fish (McDaniel et al., 2006).

Spatiotemporal analysis

In this study, I divided the eastern North Pacific Ocean into 22 10x10° areas with size composition data available (Fig. 1). Consistent with previous studies, the average fork length in each 10x10° area suggested that albacore from the southern areas (<30°N) were larger than the albacore in the areas north of 30°N (Fig. 2 and Table 1). The vast majority of the albacore catch occurred in three areas near the main Hawaiian Islands (areas 13, 14 and 18; Table 1). The areas >40°N (areas 1 to 5) and several areas at the edge of the fishery distribution (areas 11, 16, 20, and 22) had very few size samples and very low numbers of albacore caught, and were therefore discarded from further analysis (Table 1).

A clustering approach was taken in this study to discern areas with consistent size compositions. In order to reduce the dimensionality of the problem and autocorrelation between bins, I grouped the size composition data into approximate age groups using size-at-age information from the 2014 assessment and methods detailed in MacCall and Teo (2013). Five approximate age groups were used in the cluster analyses: 1) ages-1&2 were [26,68) cm; 2) ages-3&4 were [68,85) cm; 3) ages-5&6 were [85,95) cm; 4) ages-7&8 were [95,100] cm; and 5) ages-9+ were ≥100 cm. For each 10x10° area, an overall age group composition was developed by averaging the age group compositions from all years and seasons with a minimum of 30 size samples. Seasonal (season 1: Jan – Mar; season 2: Apr – Jun; season 3: Jul – Sep; season 4: Oct – Dec) age group compositions were also developed for each area.

Firstly, I used the k-means clustering algorithm described in Hartigan and Wong (1979), with k (number of clusters) ranging from one to eight, and 100 random sets of initial centers each. For each k, the resulting clusters from the random initial set that resulted in the smallest within cluster sum of squares was assumed to be the optimal clusters for that k. The change in the within cluster sum of squares with increasing k was used to evaluate the appropriate k for the data set.

Secondly, I used agglomerative hierarchical clustering with complete linkage and Euclidean distance to examine the clusters in the age group composition data. The appropriate clusters were evaluated by visually examining the resulting dendogram from the cluster analysis. A pairs plot was used to examine the differences between the resulting clusters.

Development of size composition data

Spatiotemporal clusters from the cluster analyses were used to develop preliminary size composition data for the US pelagic longline fishery. I first assembled size composition data in 1 cm bins by 10x10° area/month/year strata. Strata with <5 samples were discarded because large spikes were evident in preliminary size compositions. Visual examination of the size compositions suggested that a minimum sample size of 5 fish de-spiked the data without altering the overall shape of the size compositions.

The size compositions of stratas in each spatiotemporal cluster were combined into seasonal size compositions by performing a weighted average of the size compositions of all stratas in each spatial cluster by year and season (season 1: Jan – Mar; season 2: Apr – Jun; season 3: Jul – Sep; season 4: Oct – Dec). The weights of each strata were calculated as the relative proportion of albacore catch in each strata within each spatiotemporal cluster, season, and year, using the albacore catch in number recorded in logbooks.

In the last assessment, the number of trips was used as the input sample size of the size compositions of the deep-set and shallow-set US pelagic longline fleets in the assessment model. Here, I instead used the weighted average of the number of trips of all stratas in each spatial cluster by year and season in order to be consistent with the size composition data. The weights of each strata were calculated in the same way as the size composition data.

RESULTS AND DISCUSSION

The results of k-means and agglomerative hierarchical clustering of the size composition data were consistent with each other, both suggesting between two to four clusters (Figure 3 & 4). There appeared to be a core large adult area (areas 12, 13, 17, 18) with the vast majority of fish (>80%) being large adults ≥100 cm FL, and a peripheral area (areas 6, 14, 19, and 21) with a smaller proportion of large adult fish (~55%) and a larger proportion of small adult fish (85 – 100 cm FL) (Table 2 & 3). Similarly, there appeared to be a core juvenile area (areas 8, 9, 10, and 11), with ~56% of the albacore being juveniles <85 cm FL, and a peripheral area with a lower proportion of juveniles (~29 %) (Table 2 & 3). The pairs plot of the clusters indicate similar differences in the size compositions of the two main clusters (Figure 5).

When the 10x10° areas were further disaggregated by seasons, the clustering pattern became more complex (Figure 6). However, there generally was a core area for large adult albacore (areas 12, 13, 14, 17, 18, and 19) that was relatively consistent through all seasons (Figure 7). Similarly, albacore in areas 8, 9, 10, and 11 in seasons 1 and 4 consistently consisted of mostly juveniles (Figure 6 & 7). Based on previous studies of juvenile albacore movement, juvenile albacore caught in these areas in seasons 1 and 4 were likely juvenile fish moving offshore from the North American coast (Childers et al., 2011; Ichinokawa et al., 2008). Interestingly, there was a cluster of areas (6, 7, 14, 15, and 21) that appeared to have albacore with a size composition somewhat in between the two previously described areas (Figure 6 & 7).

It is reasonably clear that there is a core area (areas 12, 13, 14, 17, 18, and 19) for large adult albacore ≥100 cm FL, and a core area (areas 8, 9, 10, and 11) for juveniles, especially during seasons 1 and 4. However, there is some uncertainty on the assignment for the areas in between the core areas (areas 6, 7, 14, 15, and 21). Given the relatively small proportion of catch in these areas (Table 1), it may not be worth the effort in data preparation and subsequent modelling to define a separate fleet for these areas. Therefore, I recommend using the two clusters defined in Table 2 as the two fleets for the US pelagic longline in the upcoming assessment (Figure 8).

The seasonal size compositions (raised to the catch) for the proposed fleet definitions for the US pelagic longline fishery are shown in Figure 9. The proposed input sample sizes ranged from 1 to 16 for F1 (north area; predominantly juvenile), and 1 to 20.5 for F2 (south area; predominantly large adult).

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Table 1. Average fork length, sample sizes, and percentage of catch of albacore tuna in each 10x10° area defined in Figure 1. Size information is calculated from observer data while catch is obtained from logbook data. Percentages of total and seasonal catch may not sum to 100% due to rounding.

Area	Number of years with samples	Number of trips sampled	Number of sets sampled	Number of fish sampled	Average fork length (cm)	Percentage of total catch (%)	Percentage of total catch in season 1 (%)	Percentage of total catch in season 2 (%)	Percentage of total catch in season 3 (%)	Percentage of total catch in season 4 (%)
1	<3	<5	<10	<30	98.5	<0.1	<0.1	<0.1	<0.1	<0.1
2	<3	<5	<10	<30	93.3	<0.1	<0.1	<0.1	<0.1	<0.1
3	7	9	19	60	87.4	<0.1	<0.1	<0.1	<0.1	<0.1
4	4	9	19	<30	80.9	<0.1	<0.1	<0.1	<0.1	<0.1
5	<3	<5	<10	<30	82.0	<0.1	<0.1	<0.1	<0.1	<0.1
6	6	14	61	228	99.4	2.4	0.5	0.1	<0.1	1.8
7	22	144	442	1938	93.6	5.0	1.0	0.1	0.3	3.6
8	21	381	1490	4222	83.8	3.7	1.7	0.1	0.6	1.3
9	20	316	1633	4900	82.2	3.6	1.8	0.1	0.2	1.5
10	14	129	469	1007	81.5	0.6	0.1	0.2	0.1	0.2
11	11	22	52	369	82.4	<0.1	<0.1	<0.1	<0.1	<0.1
12	18	65	209	671	107.6	1.7	0.8	0.5	0.1	0.2
13	22	629	2064	7638	105.7	15.0	6.5	5.0	1.0	2.5
14	22	847	2373	8593	101.9	20.0	5.2	2.8	5.0	7.1
15	20	162	364	814	91.0	1.9	0.4	0.5	0.8	0.2
16	<3	<5	<10	<30	94.0	0.1	<0.1	0.1	<0.1	,<0.1
17	17	46	122	839	106.5	1.0	0.2	0.4	0.2	0.2
18	22	1211	5675	26671	107.4	38.9	8.3	19.8	7.1	3.7
19	22	523	1261	2690	102.4	5.9	0.8	2.1	1.6	1.4
20	<3	<5	<10	<30	101.3	<0.1	<0.1	<0.1	<0.1	<0.1
21	10	50	98	165	101.9	0.1	<0.1	<0.1	<0.1	<0.1
22	<3	<5	<10	<30	97.0	<0.1	<0.1	<0.1	<0.1	<0.1

Table 2. K-means clusters of size class compositions (approximate age groups) of 10x10° areas defined in Figure 1, with k ranging from 2 to 4.

k	**Areas in cluster 1**	**Areas in cluster 2**	**Areas in cluster 3**	**Areas in cluster 4**	**Between cluster SS / Total SS (%)**
2	7, 8, 9, 10, 11, 15	6, 12, 13, 14, 17, 18, 19, 21	-	-	83.7
3	7, 8, 9, 10, 11, 15	12, 13, 17, 18	6, 14, 19, 21	-	91.9
4	7, 15	8, 9, 10, 11	12, 13, 17, 18	6, 14, 19, 21	95.8

Table 3. Cluster means of proportions of size classes (approximate age groups) in clusters identified in Table 2, with k ranging from 2 to 4. Values are in percentages

K	**Cluster**	**[26,68) cm (Ages-1&2)**	**[68,85) cm (Ages-3&4)**	**[85,95) cm (Ages-5&6)**	**[95,100) cm (Ages-7&8)**	**≥100 cm (Ages-9+)**
2	1	6.6	40.7	35.9	9.3	7.5
	2	0.2	2.1	9.9	19.1	68.6
3	1	6.6	40.7	35.9	9.3	7.5
	2	0.2	1.5	4.8	11.8	81.8
	3	0.3	2.8	15.0	26.5	55.4
4	1	2.2	27.1	43.0	16.1	11.6
	2	8.8	47.5	32.4	5.8	5.5
	3	0.2	1.5	4.8	11.8	81.8
	4	0.3	2.8	15.0	26.5	55.4

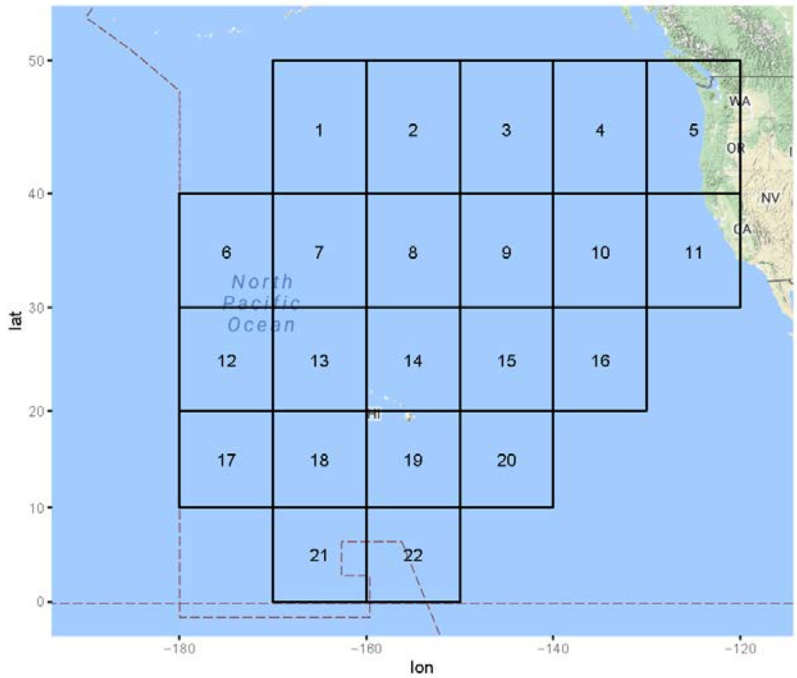


Figure 1. Map of the eastern North Pacific Ocean identifying 10x10° areas used in this study.

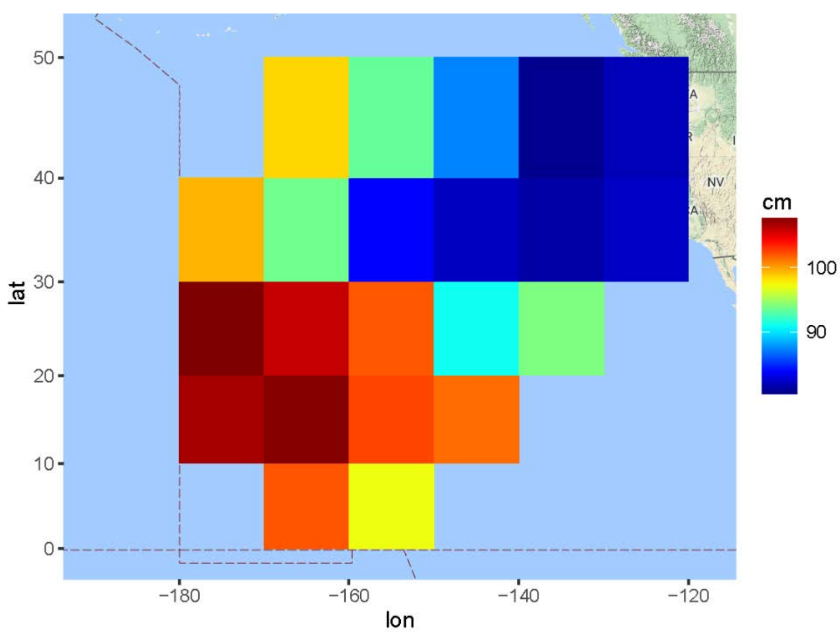


Figure 2. Average fork length (cm) of albacore tuna caught by US pelagic longlines in the eastern North Pacific Ocean.

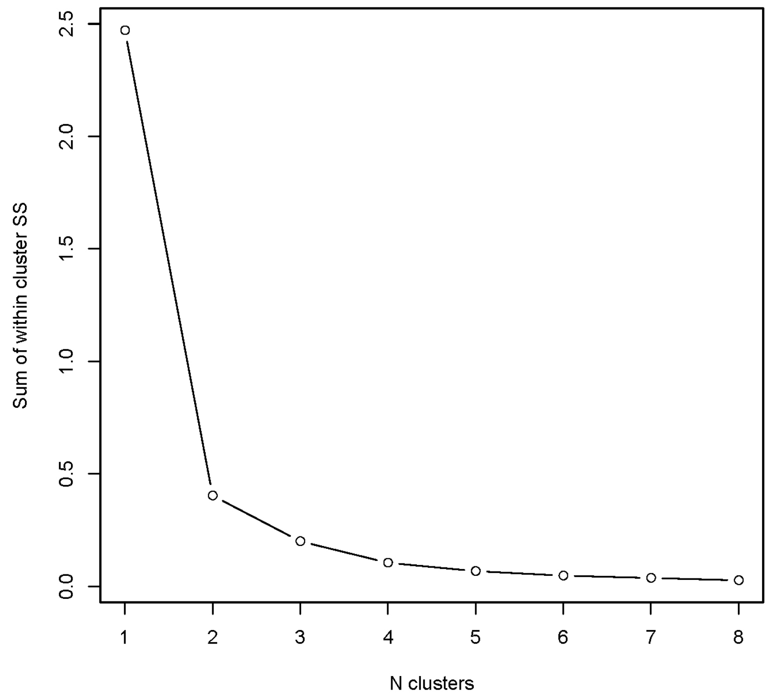


Figure 3. Change in the total within cluster sum of squares with increasing k (number of clusters; N clusters).

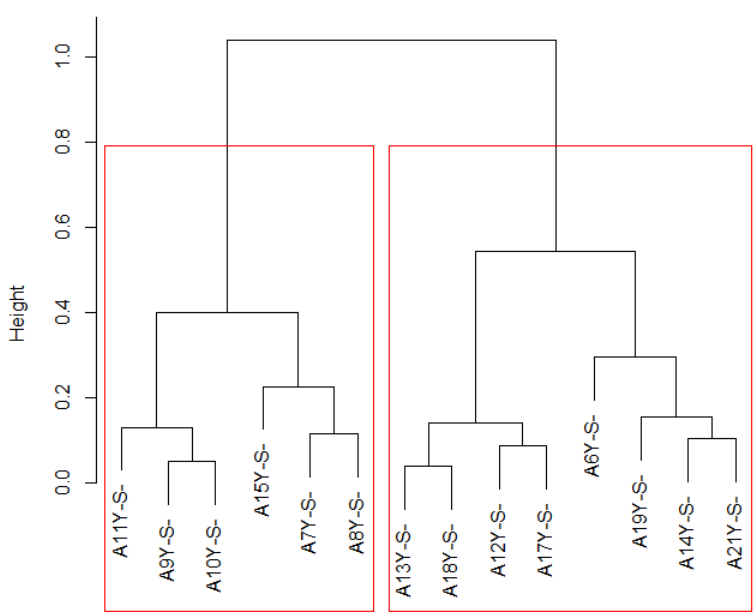


Figure 4. Dendogram of agglomerative hierarchical clustering performed on the size compositions of 10x10° areas defined in Figure 1. Labels identify the areas 'A' in the dendogram, with 'Y-' and 'S-' indicating that size compositions from all years and seasons were averaged in this analysis. Red boxes indicate the cluster groups when two clusters were defined in the analysis.

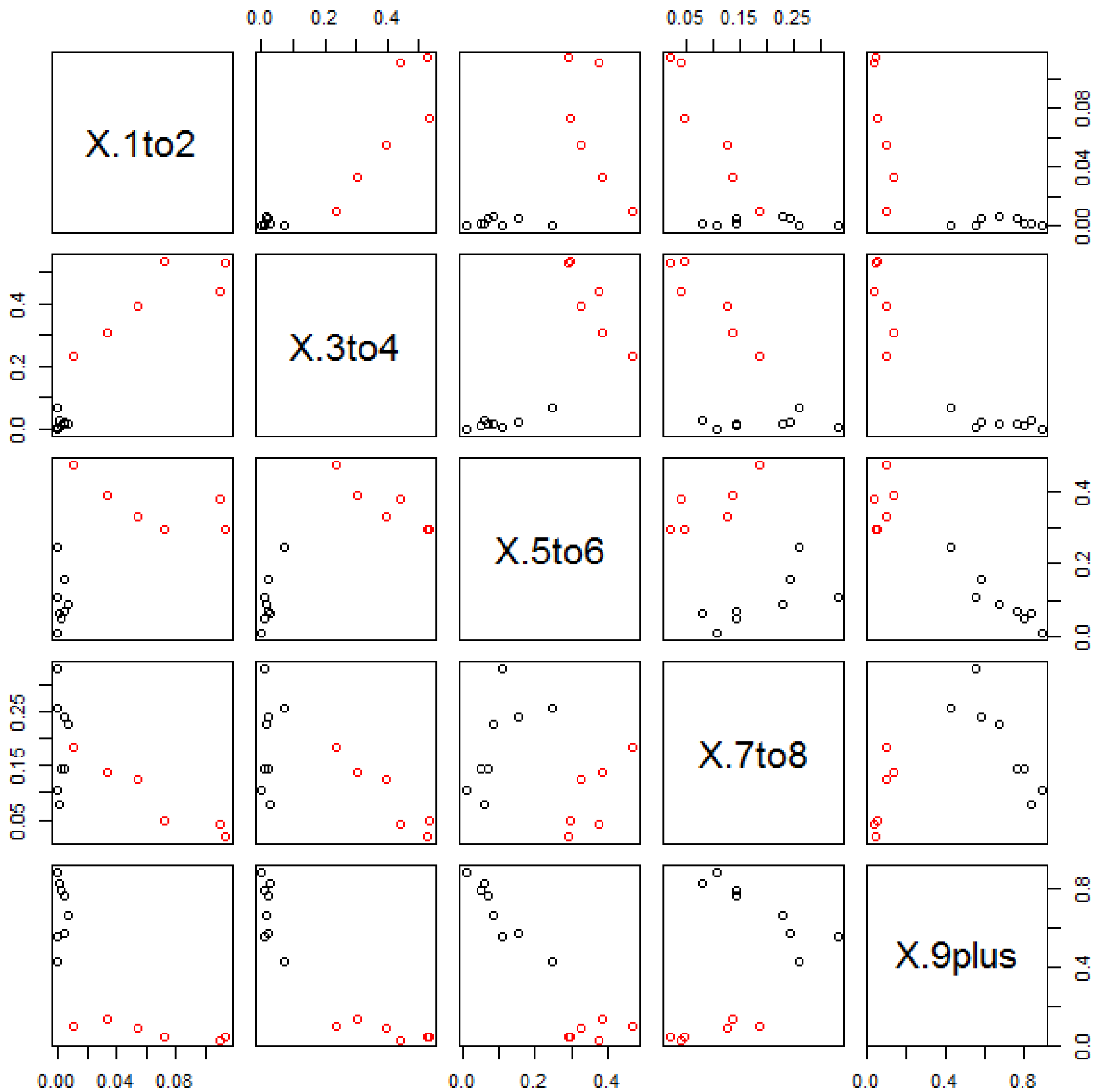


Figure 5. Pairs plot of the proportions of the five approximate age groups (ages-1&2; 3&4; 5&6; 7&8; and 9+) used in the agglomerative hierarchical cluster analyses in Figure 4. Red circles indicate areas 7, 8, 9, 10, 11, and 15. Black circles indicate areas 6, 12, 13, 14, 17, 18, 19, and 21.

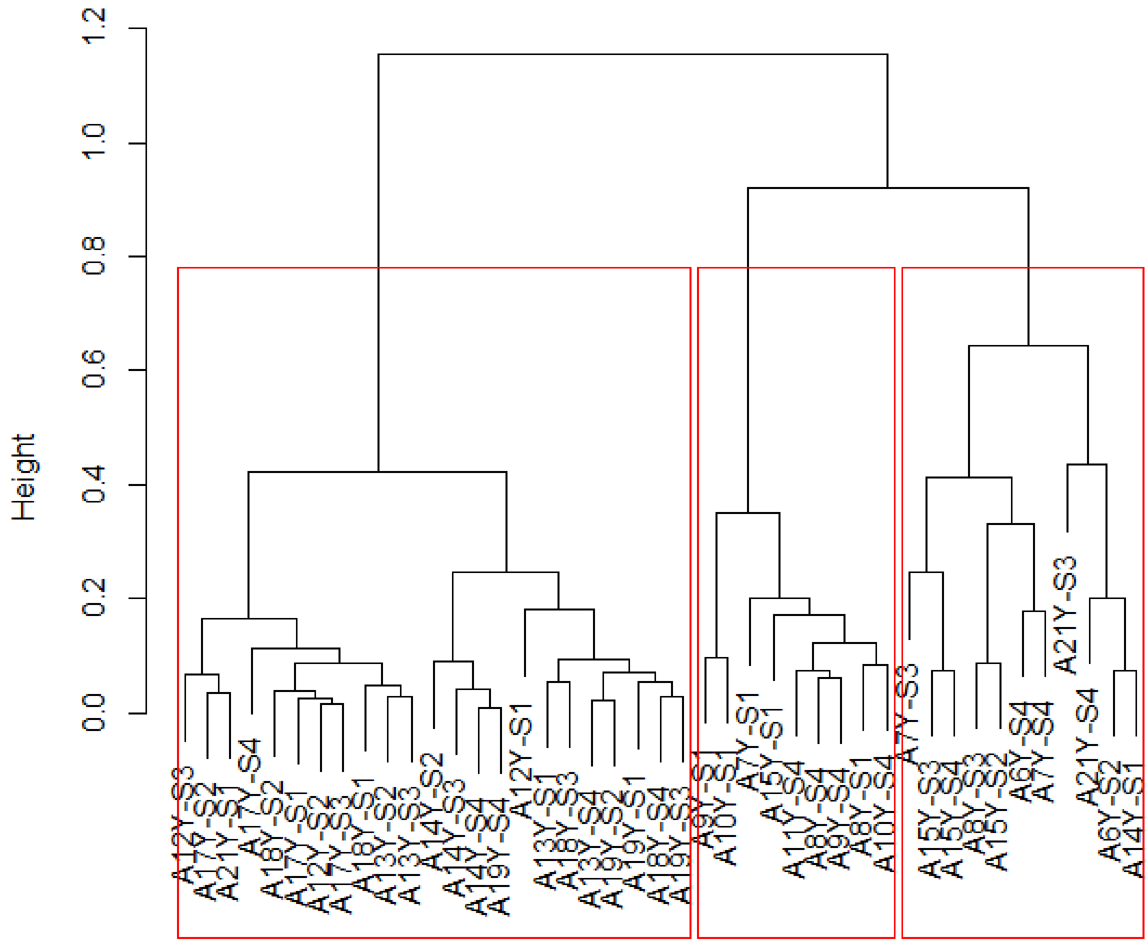


Figure 6. Dendogram of agglomerative hierarchical clustering performed on the size compositions of 10x10° areas defined in Figure 1 by season. Labels identify the areas 'A' and seasons 'S' in the dendogram, with 'Y-' indicating that size compositions from all years were averaged in this analysis. Red boxes indicate cluster groups when three clusters were defined in the analysis.

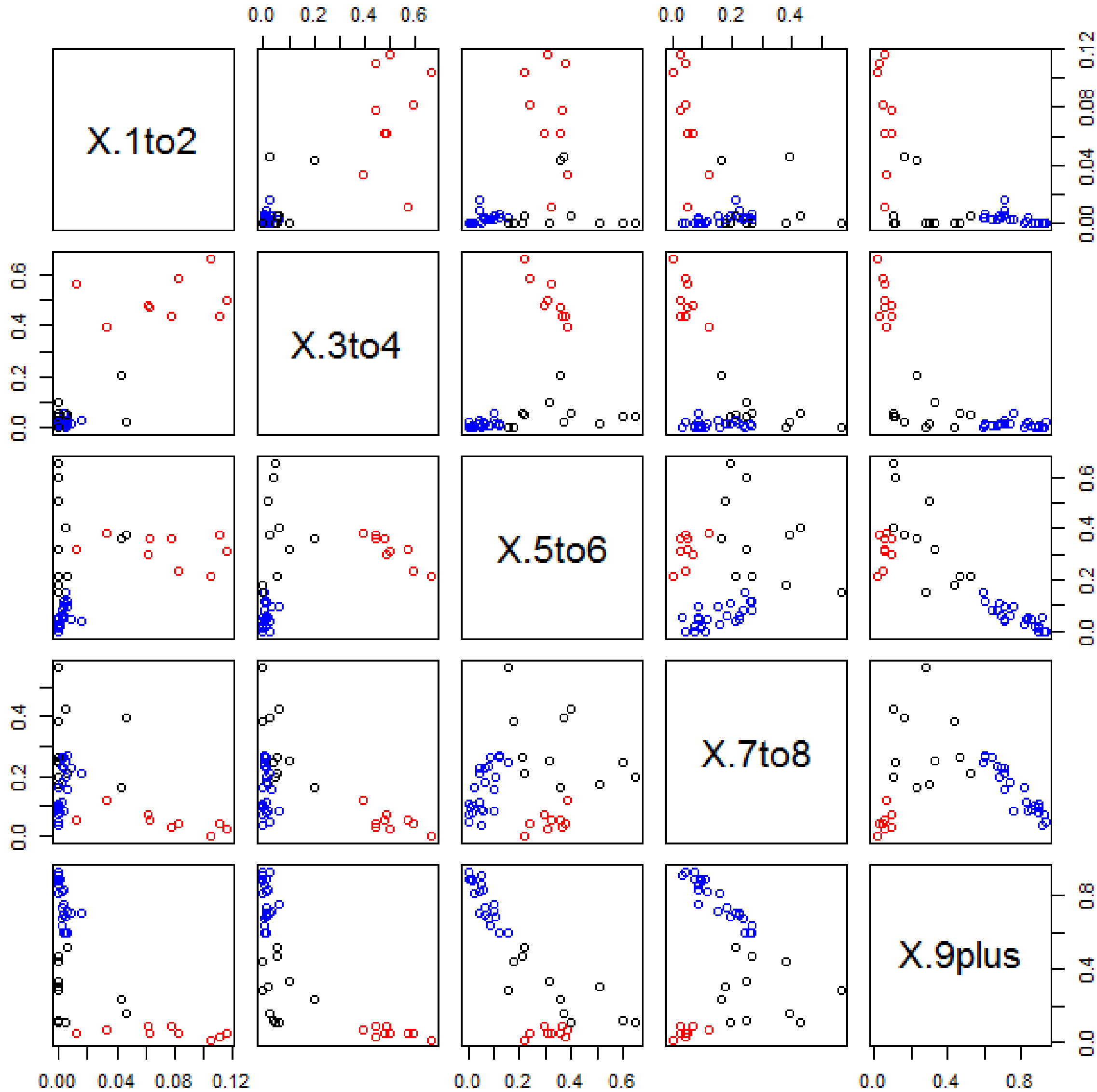


Figure 7. Pairs plot of the proportions of the five approximate age groups (ages-1&2; 3&4; 5&6; 7&8; and 9+) used in the agglomerative hierarchical cluster analyses by season in Figure 6. Color of circles indicate clusters identified in Figure 6.

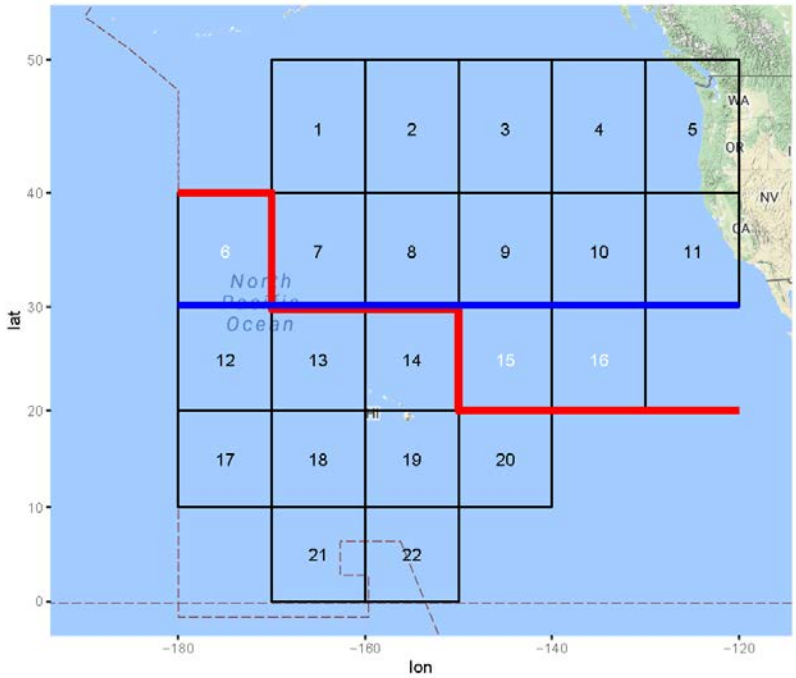


Figure 8. Proposed spatiotemporal fleet definition for the upcoming stock assessment (red line) and the previous stock assessment (blue line).

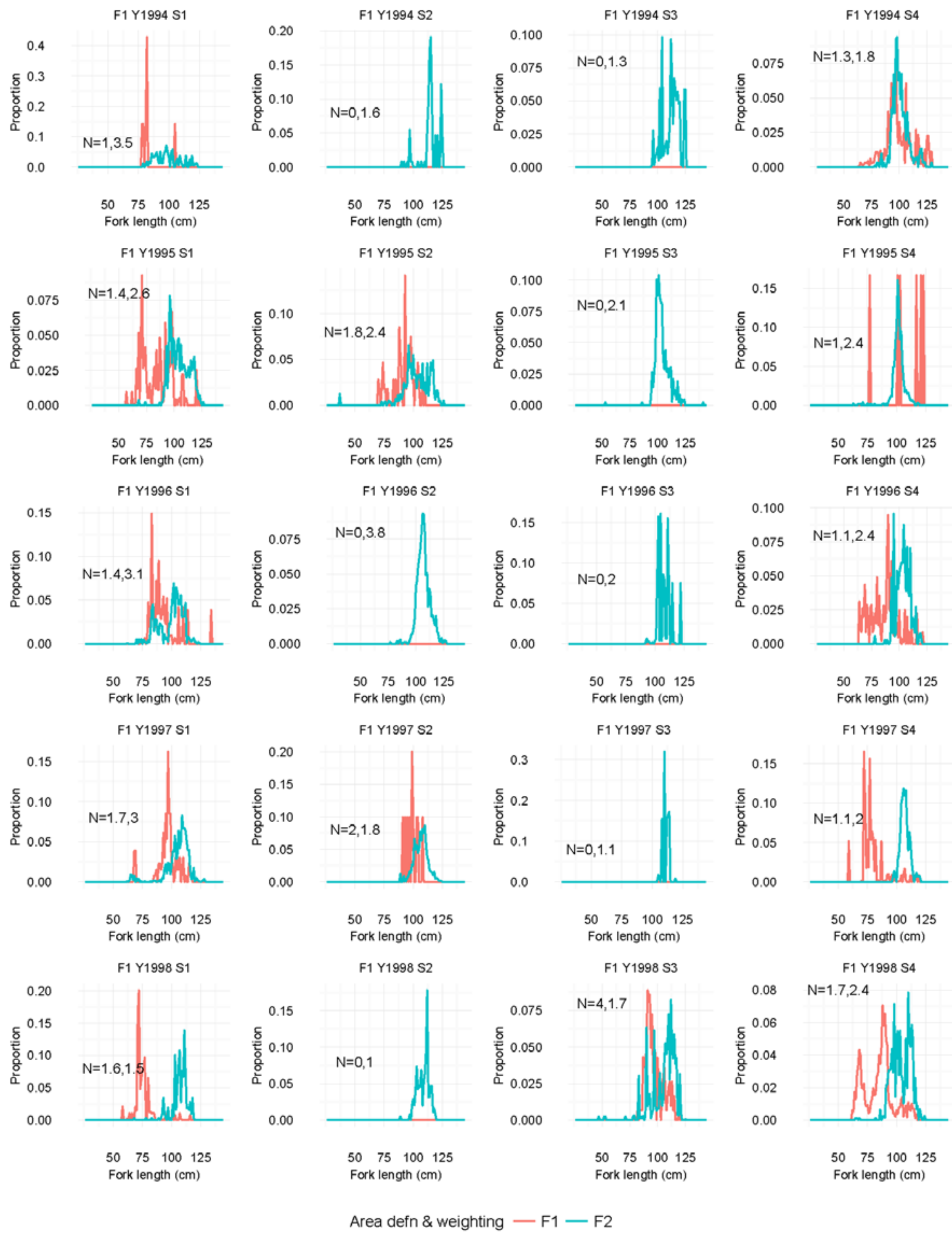
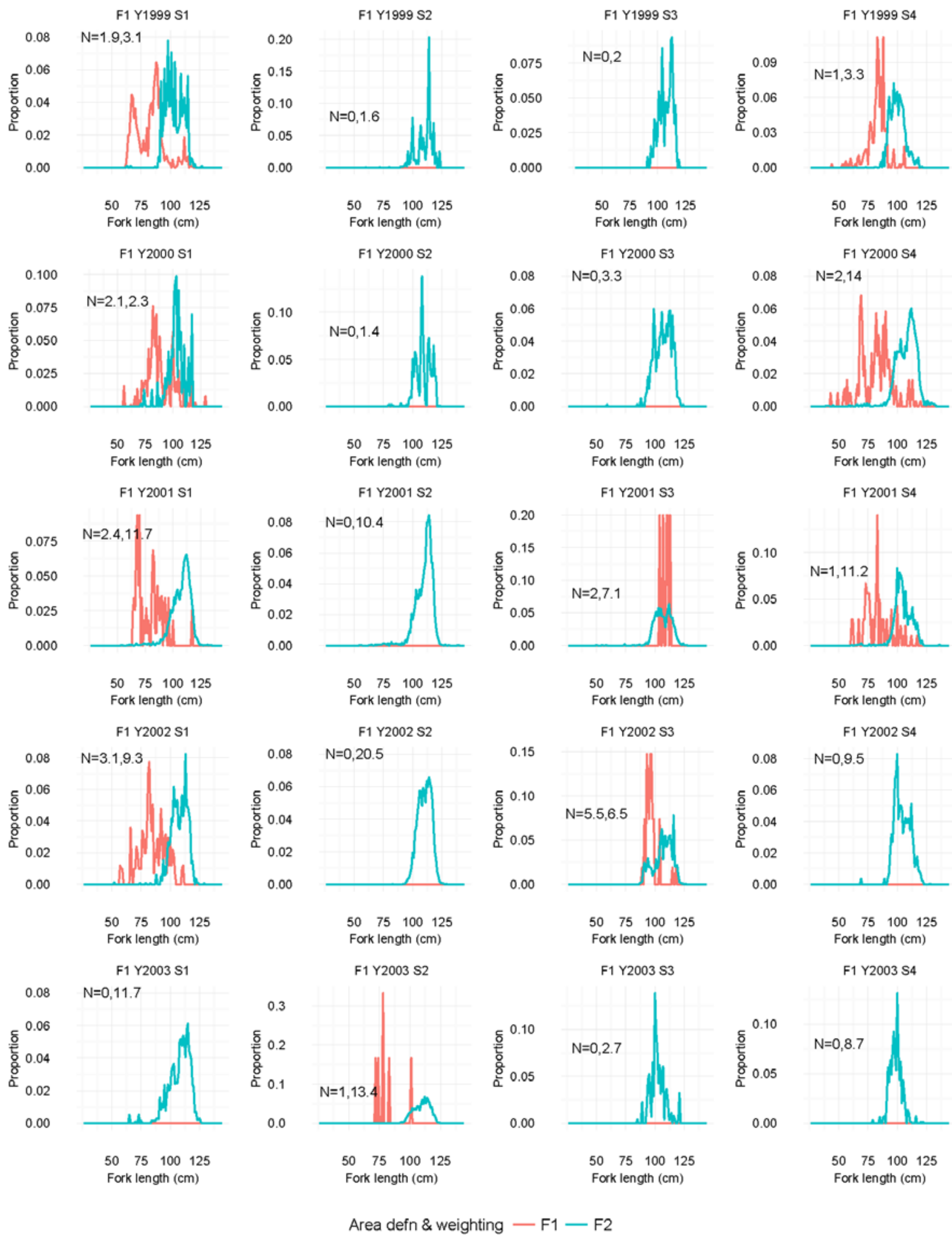


Figure 9. Seasonal size compositions (raised to the catch) for the proposed fleets for the US pelagic longline fishery (F1: north area with predominantly juvenile albacore; and F2: south area with predominantly large adults) for 1994 to 2015. The N indicate the proposed input sample size for F1 and F2 respectively.



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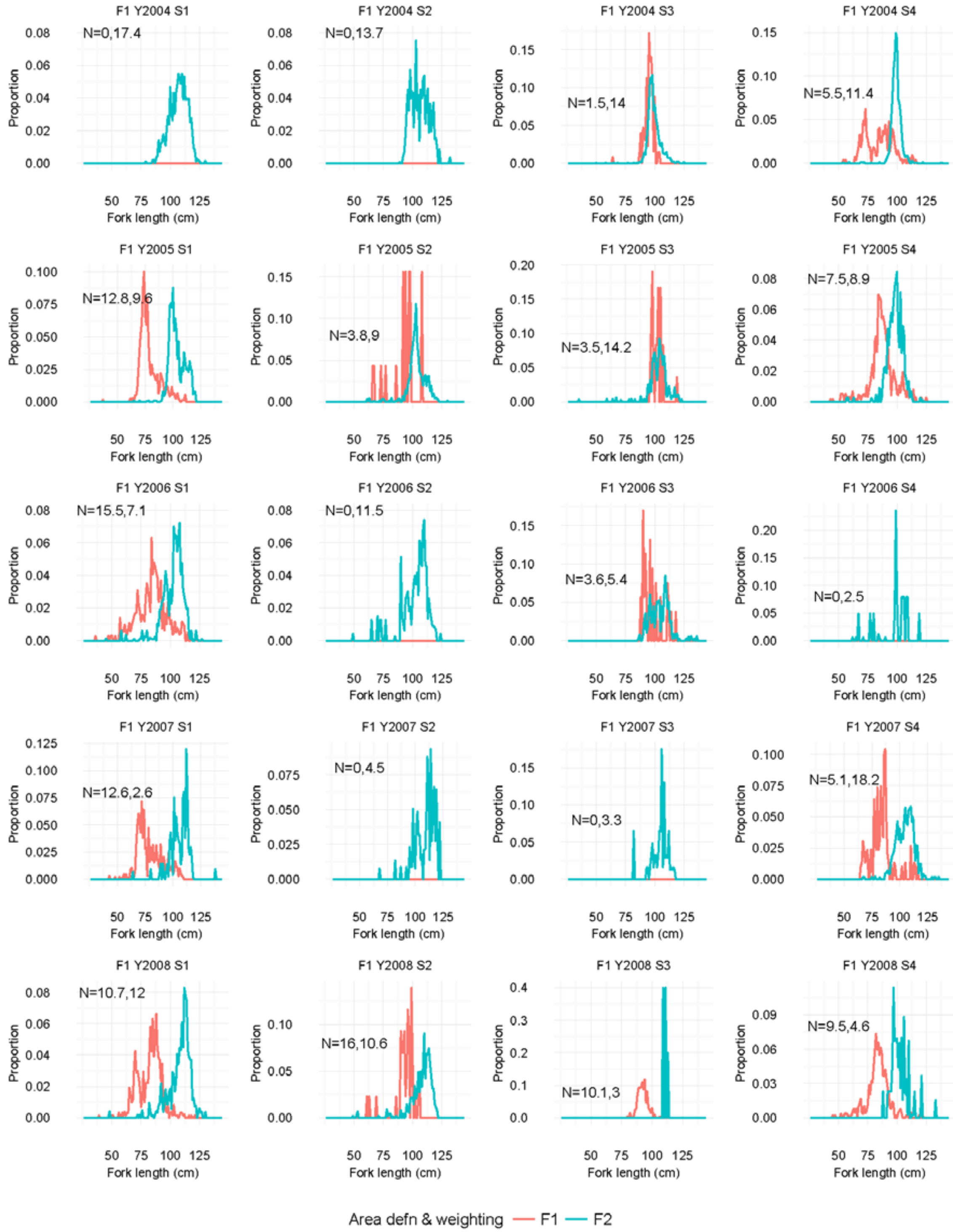

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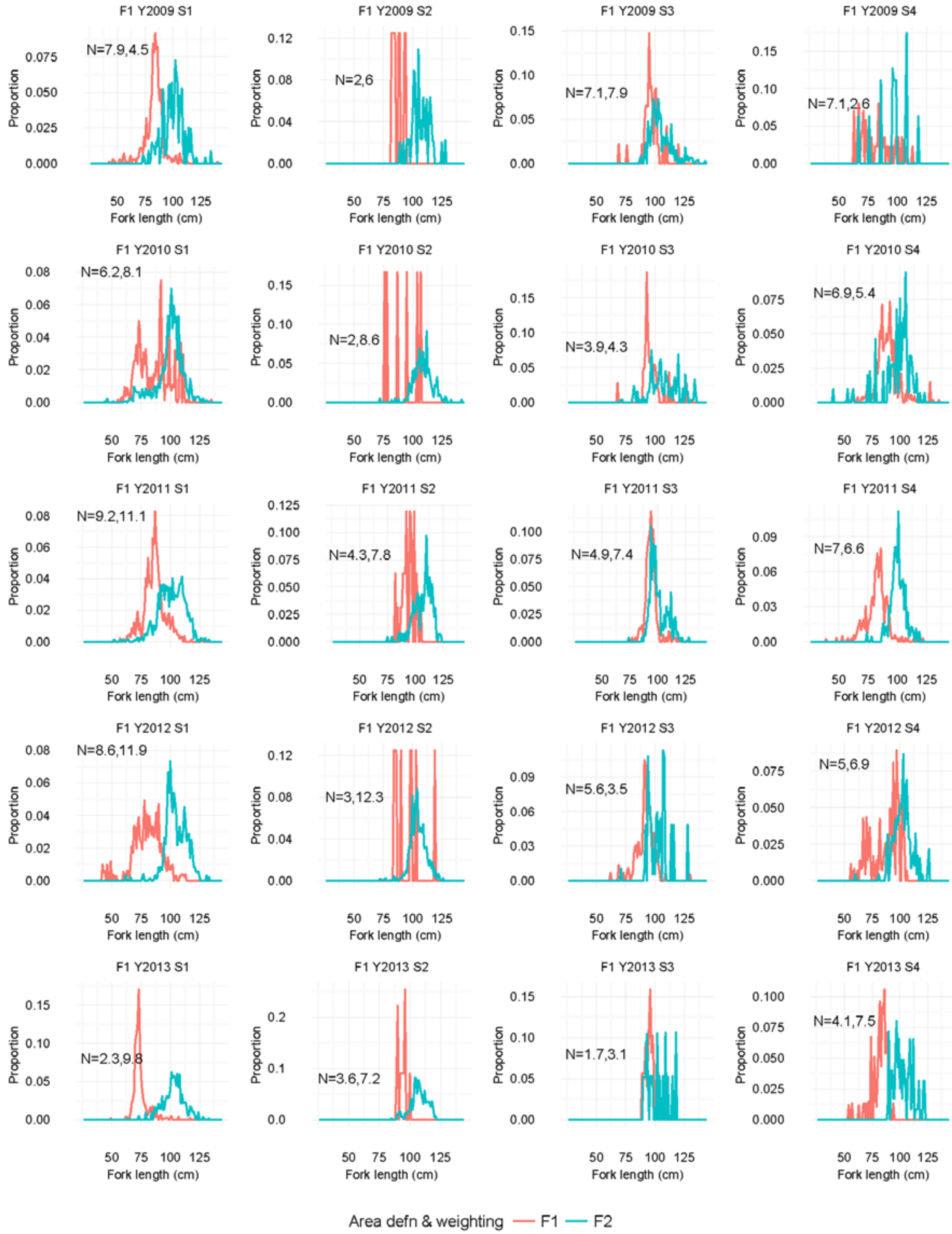

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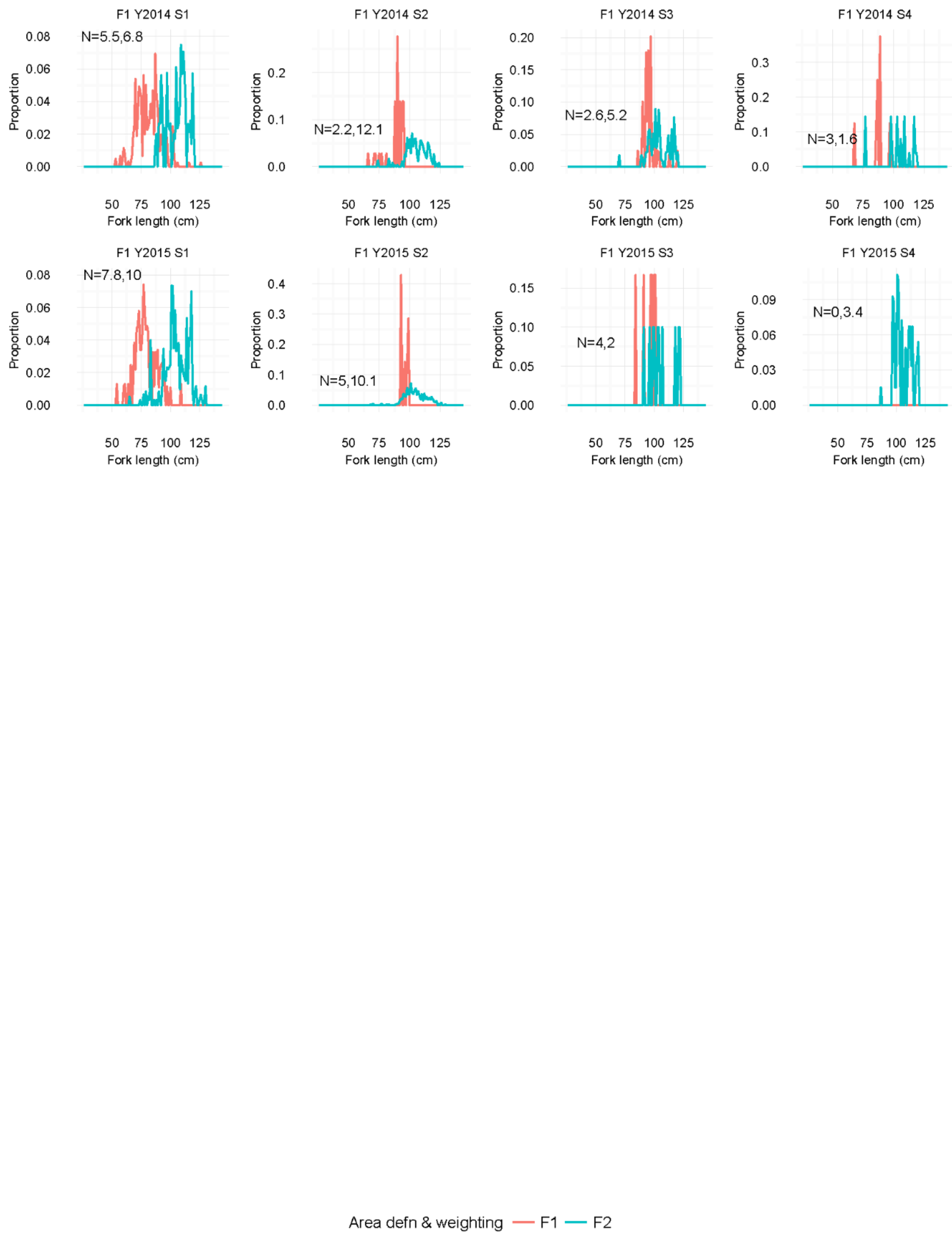

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