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ANALYSIS OF LARGE-SCALE SPATIAL PATTERNS IN YELLOWFIN TUNA CATCH DATA FROM PURSE-SEINE AND LONGLINE FISHERIES

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1. BACKGROUND

Fishery stratification is used in contemporary stock assessment models to address differences in stock and fishery dynamics. In general, fisheries data (catch, catch per unit of effort (CPUE), and age/size-composition data) are stratified after data collection to support the assumption that fishery-related parameters - catchability and selectivity - are constant over time. As fisheries evolve, it is useful to reevaluate definitions of stock assessment areas. For example, the current yellowfin tuna stock assessment areas for the purse-seine fishery were formed by aggregating the spatial strata of the IATTC port-sampling program (Figure 1; Suter 2010; Tomlinson 2004). Although these sampling strata were refined in the 1990s, they were primarily developed in the late 1960s (Suter 2010), when the purse-seine fishery was more coastal (Watters 1999).

This document presents an analysis of large-scale spatial patterns in yellowfin catch data from the purse-seine and longline fisheries of the eastern Pacific Ocean (EPO) for the purpose of the developing alternative fishery stratifications for the stock assessment model. Following the methods of Lennert-Cody *et al*. (2010; 2013), the analytic approach taken was to first identify similar large-scale spatial patterns in yellowfin length-frequency distributions and catch-per-unit-effort trends, by gear type. These results were then compared between the two gear types in order to develop alternative assessment stratifications.

2. DATA AND DATA PROCESSING

For the purse-seine fishery, the analysis was limited to catch data from sets on tunas associated with dolphins ("dolphin sets") by large (≥ 364 metric tons (t) fish-carrying capacity) purse-seine vessels, because this set type produces the majority of yellowfin catches in the EPO, and the effort associated with this set type is fairly broadly distributed within the EPO (IATTC 2012). The length-frequency data were obtained from the port-sampling program for 2000-2011, and the catch and effort (in number of days fishing) data were obtained from observer and logbook data bases for 1975-2011. Details of the purse-seine data processing can be found in Lennert-Cody *et al*. (2012).

For the longline fishery, Japanese length-frequency data for 2002-2010, and catch and effort data (in number of hooks) for 1975-2011 were used in this analysis. Details of the longline data processing can be found in Lennert-Cody *et al*. (2013).

Length-frequency distributions and catch-per-unit-effort (CPUE) trends were estimated from the raw catch data on a fine-scale spatial-temporal grid throughout the EPO for each gear type. For the purse-seine data, the spatial-temporal grid was 5º latitude by 5º longitude by quarter (January-March; April-June; July-September; October-December). For the longline data, the spatial-temporal grid was 5º latitude by 10º longitude by quarter. The length-frequency distributions used in the analysis were interval frequencies based on 11 length intervals. For the purse-seine data the length intervals were: ≤ 58 cm, 59-69 cm, …, 136-146 cm, 147-159 cm, and ≥ 160 cm. The interval frequencies for the longline data were similar, but could not be exactly the same due to the resolution of the unprocessed data, which were counts of fish in 2-cm intervals for longline, compared to 1-cm intervals for purse-seine. Smooth CPUE trends were estimated using penalized cubic regression splines (Wood 2006; details are provided in Lennert-Cody *et al*. 2012; 2013). To illustrate the types of inputs used in the analysis, a summary of interval frequencies and CPUE trends for the fourth quarter (October-December) for the purse-seine data are shown in Figures 2 and 3.

3. METHODS OF ANALYSIS

Large-scale spatial-temporal patterns in the length-frequency distributions and in the CPUE trends were explored using a tree-based method. 5° latitude, 5° longitude, and quarter, all treated as numeric, were used as predictor variables. In addition, cyclic combinations of quarters (*e.g*., October-December and January-March *versus* April-June and July-September) were also considered for the quarter variable. The response variables were the interval frequencies and the first-differenced smooth CPUE trends. The tree-based method simultaneously subdivides the collection of length-frequency distributions and CPUE trends into smaller subgroups that are more homogeneous, using the predictor variables. Only small trees are grown (without pruning) because the focus of the analysis is on large-scale patterns. Two analyses of length-frequency distributions and CPUE trends were conducted for each gear type: 1) one without accounting for error about the estimated CPUE trends (“unweighted” analysis), and the other taking into consideration variability about those trends (“weighted” analysis). Details of the methodology can be found in Lennert-Cody *et al*. (2010; 2013).

4. RESULTS AND DISCUSSION

4.1. Purse seine

The areas identified by the two tree analyses of the purse-seine data (Figures 4 and 5), which gave nearly identical results, show some similarity to the current stock assessment areas (Figure 1). In particular, there is an equatorial separation of the offshore region of the EPO into northern and southern areas, and also an inshore-offshore separation in the southern region of the EPO. However, the tree analyses indicate differences within the inshore area, north and south of 5ºN, whereas the coastal stock assessment area (Area 8) is continuous. In addition, the western boundaries of the inshore tree areas extend to the west of stock assessment Area 8 (Figure 1), both north and south of the equator, suggesting that stock assessment Area 8 could be expanded westward.

4.2. Longline

Even though the area of operation of the purse-seine fishery on dolphins and that of the longline fishery do not fully overlap (Figure 5), the large-scale spatial pattern identified by the tree analysis of the longline data (Figures 4-5) shows some similarities to the areas identified for the purse-seine data. For example, there is a separation of the EPO into northern and southern regions around 0º-5ºN, of inshore and offshore areas south of the equator around 95º-100ºW, and of inshore and offshore areas north of the equator at 120ºW. The weighted and unweighted tree analyses of the longline data gave generally similar results, aside from the partitions at 20ºS and 85ºW. In the unweighted analysis, unusual trends at the margins can more easily exert leverage because the typically smaller sample sizes at the margins lead to more variable trend estimates.

4.3. Candidate assessment strata

Five candidate stock assessment stratifications were constructed from the common features in Figure 5 (Figure 6). The stratifications were restricted to four areas to limit stock assessment model complexity: too many fishery strata can lead to insufficient catch composition sample sizes or make the computational demands impractical. Also, the candidate stratifications had to be constructed to accommodate the spatial resolution of the historical longline length-frequency data (some data prior to 2002 are only available at a 10º latitude x 20º longitude resolution). For each gear type (purse-seine, longline), the five candidate stratifications were ranked according to the average proportion of the variability explained for the two data types (length-frequency distributions, CPUE trends). Candidate stratification (1) had slightly better performance than the other four candidate stratifications, and is being considered as an alternative to the current stratifications (Figure 1).

The spatial structure could be accommodated within the yellowfin stock assessment model by either specifying separate fisheries for each stratum or by modeling sub-populations for each stratum. The current evidence from tagging data for yellowfin (Schaefer *et al*. 2011) suggests that movement of this species in the EPO is limited, which indicates that modeling sub-populations is preferable. Modeling of two separate stocks split at around 5ºN or 10ºN is being considered for future yellowfin assessments. The other splits identified in this analysis will be used to create separate fisheries within the stock assessment model.

ACKNOWLEDGEMENTS

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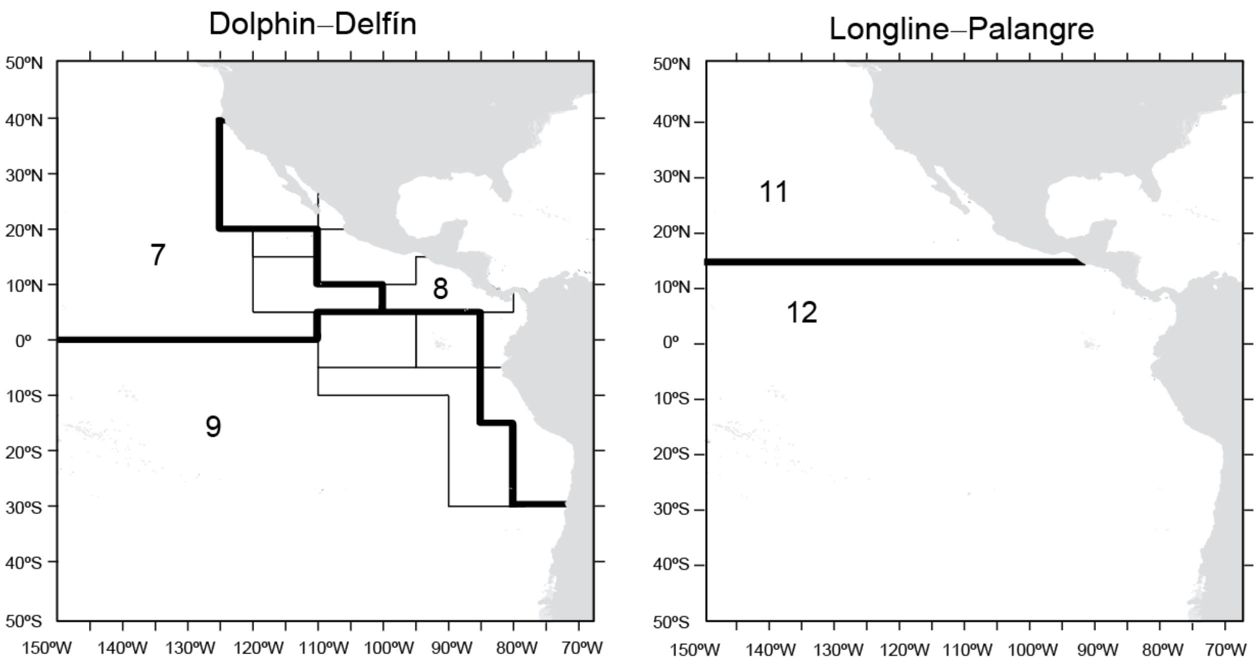

FIGURE 1. Current yellowfin tuna stock assessment areas for purse-seine dolphin sets (left) and longline (right). The thin lines indicate the boundaries of 13 length-frequency sampling areas, the bold lines the boundaries of the fisheries defined for the stock assessment, and the numbers the fisheries to which the latter boundaries apply.

FIGURA 1. Áreas usadas en la evaluación actual de la población de atún aleta amarilla para lances sobre delfines (izquierda) y palangre (derecha). Las líneas delgadas indican los límites de 13 zonas de muestreo de frecuencia de tallas, las líneas gruesas los límites de cada pesquería definida para la evaluación de la población, y los números en negritas las pesquerías correspondientes a estos últimos límites.

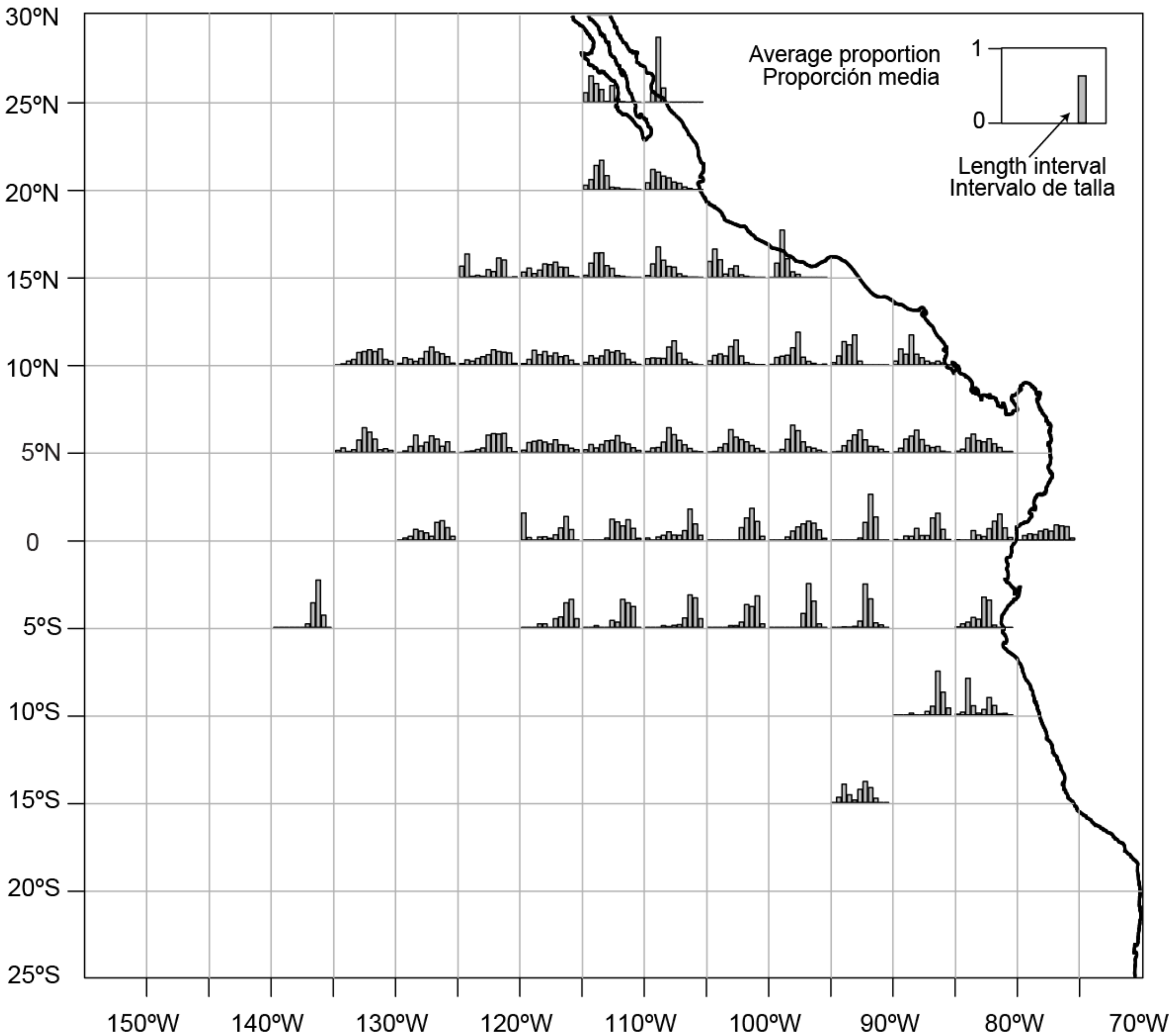

FIGURE 2. Summary of the purse-seine length-frequencies for the fourth quarter, 2000-2011. The values shown are the average proportion of the fish in each of the 11 length intervals, where the average was computed over all samples from months and years in the same grid cell. The y-axis for the length-frequency data ranges from 0-1.

FIGURA 2. Resumen de las frecuencias de talla de la pesquería de cerco correspondientes al cuarto trimestre, 2000-2011. Los valores representan la proporción media de los peces en cada uno de los 11 intervalos de talla, donde el promedio fue computado para todas las muestras de meses y años en la misma cuadrícula. El eje *y* de los datos de frecuencia de talla varía de 0 a 1.

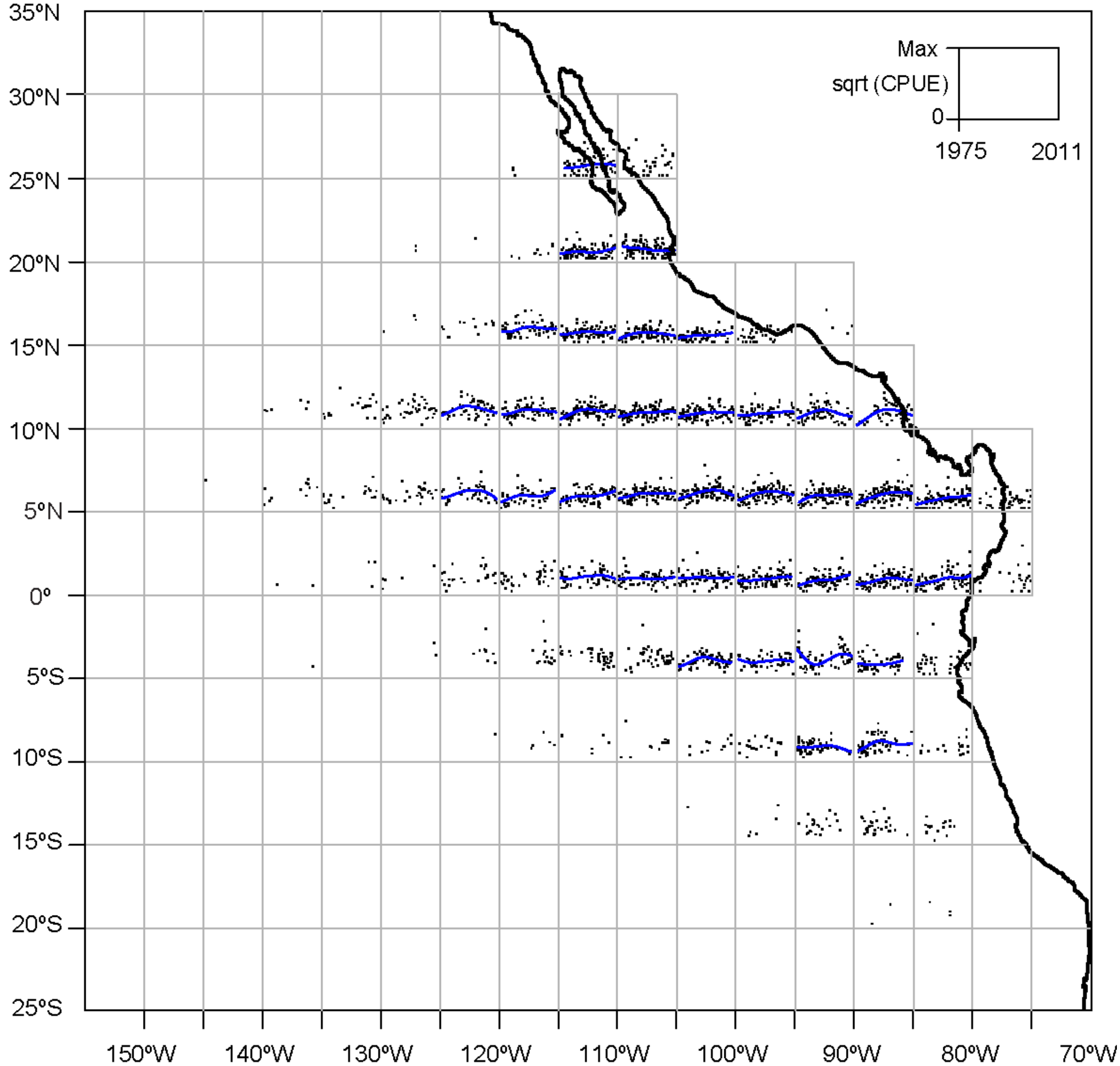

FIGURE 3. Purse-seine CPUE trend data for the fourth quarter, 1975-2011. The black dots are the data points (monthly catch per day fishing in the 4th quarter); the blue lines show the smoothed trends for grid cells with sufficient data. For each grid cell, the x-axis ranges from 1975 to 2011, and the y-axis from 0 to max(sqrt(CPUE)), the maximum value of the square root of the CPUE for all areas and quarters.

FIGURA 3. Datos de tendencias de CPUE cerquera correspondientes al cuarto trimestre, 1975-2011. Los puntos negros representan los puntos de datos (captura mensual por día de pesca en el cuarto trimestre); las líneas azules indican las tendencias suavizadas de las cuadrículas con suficientes datos. Para cada cuadrícula, el eje *x* va de 1975 a 2011, y el eje *y* de 0 a max(sqrt(CPUE)), el valor máximo de la raíz cuadrada de la CPUE de todas las áreas y trimestres.

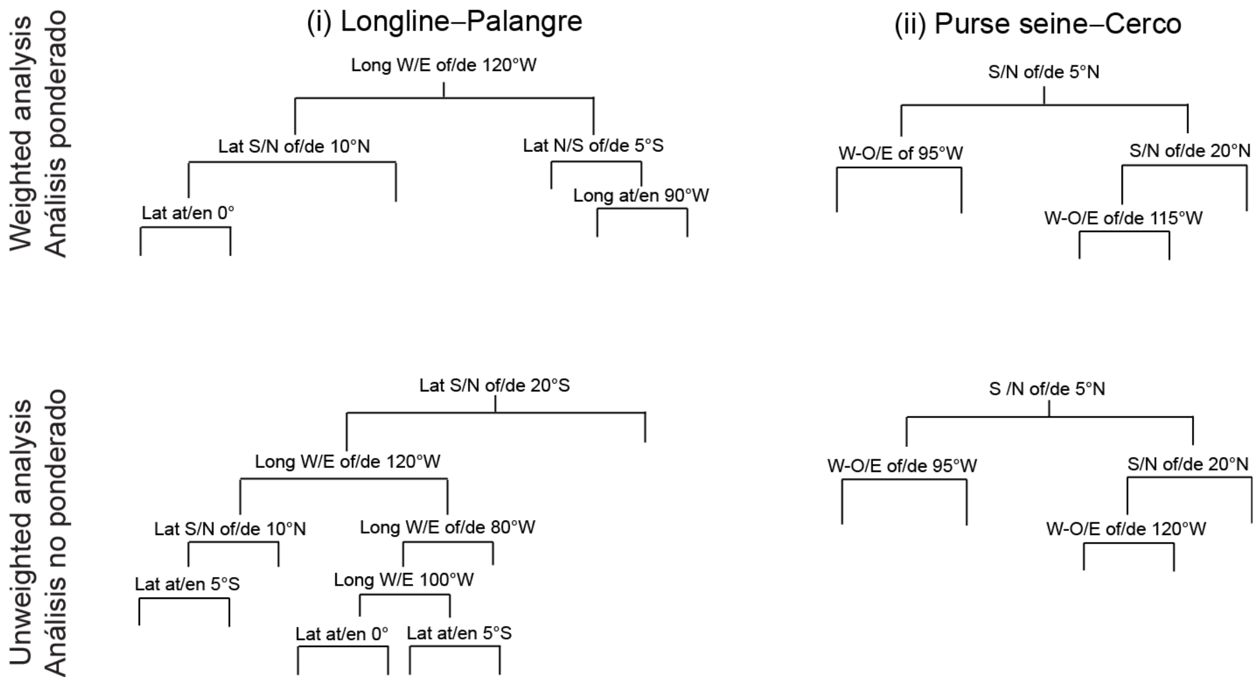

FIGURE 4. Trees produced by the weighted and unweighted analyses of yellowfin longline and purse-seine data.
FIGURA 4. Árboles producidos por los análisis ponderados y no ponderados de los datos de captura palangrera y cerquera de aleta amarilla.

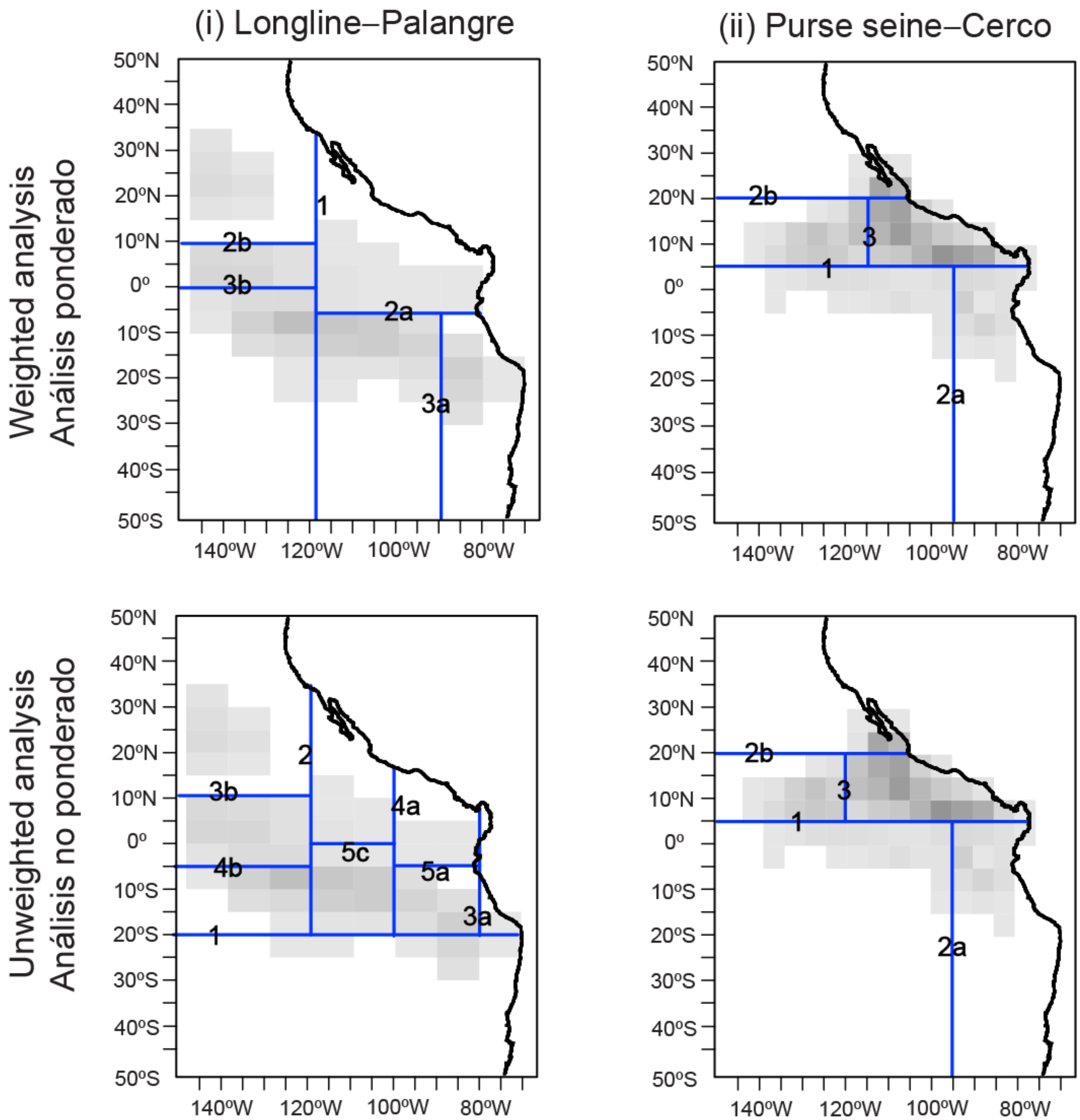

FIGURE 5. Areas from the tree analyses for (i) longline and (ii) purse-seine data. The numbers represent the partition order in the respective trees (see Figure 4). To provide an indication of the general area of operation of each fishery, shown in grayscale is the spatial coverage of the length-frequency data, with darker gray indicating regions with more data.

FIGURA 5. Áreas del análisis de árbol para datos de (i) palangre y (ii) cerco. Los números representan el orden de partición en los árboles respectivos (ver Figura 4). Para dar una indicación de la zona general de operación de cada pesquería, se señala en gris la cobertura espacial de los datos de frecuencia de talla; como más oscuro el color, mayor la cantidad de datos.

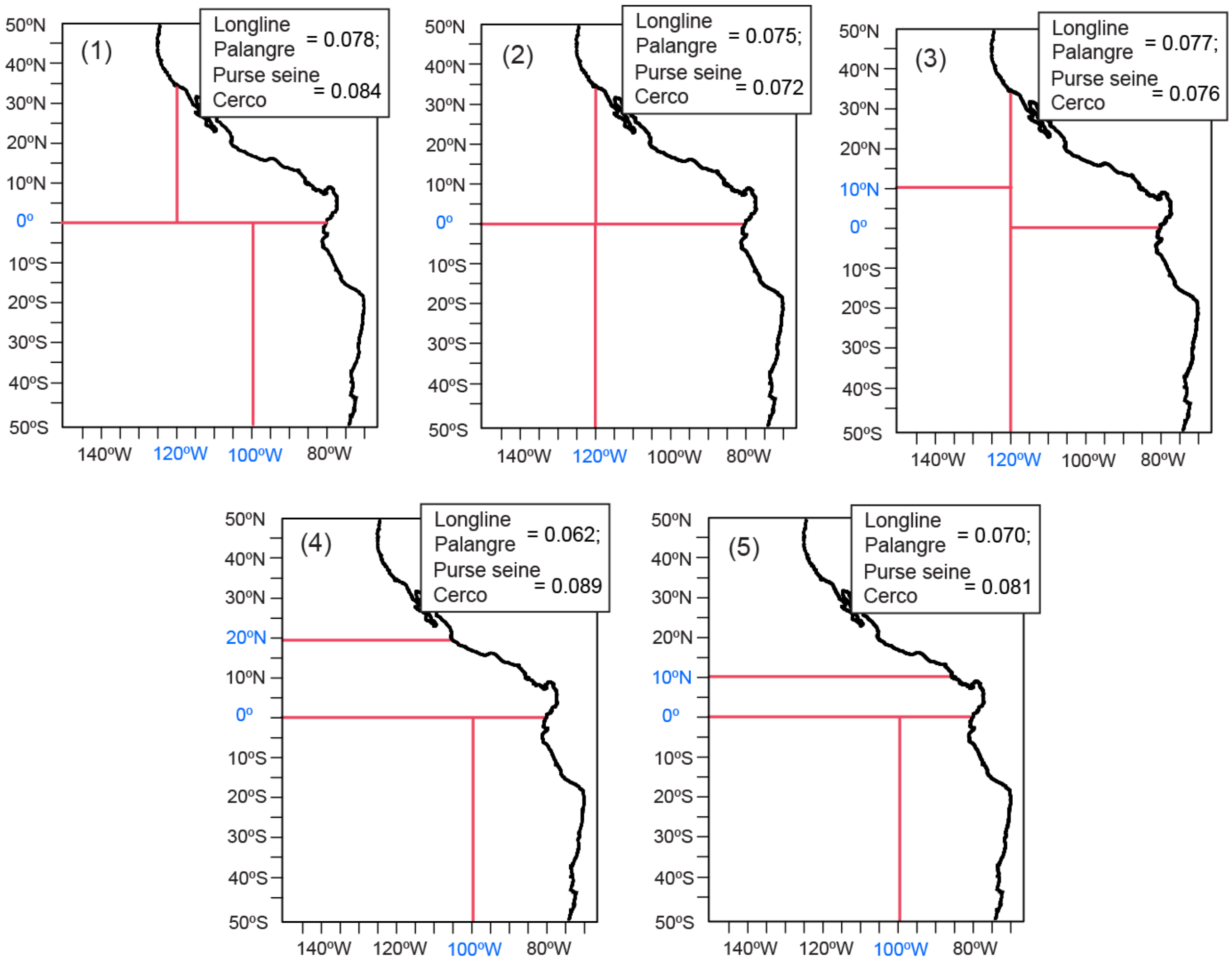

FIGURE 6. Candidate 4-area stratifications created from the tree results presented in Figure 5. The values in each map represent the average proportion of the variance explained for longline and purse seine.
FIGURA 6. Candidatos de estratificación en cuatro áreas creados a partir de los resultados del análisis de árbol ilustrado en la Figura 5. Los valores en cada mapa representan la proporción media de la varianza explicada para palangre y cerco.