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Using Historical Data to Assign a Calendar Age to Red Porgy Otoliths without an Edge Type Assigned

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Abstract

Increment count has been the age estimate used for previous Red Porgy SEDAR stock assessments in the Atlantic waters off the Southeastern United States (South Atlantic), but a more appropriate age estimate is calendar age, when data are available. Calendar age calculations require edge types, but Red Porgy otoliths were historically aged whole and an edge type was not assigned for all specimens collected by South Carolina Department of Natural Resources. A method was explored to assign an edge type proxy to whole-read otoliths lacking edge types. Using a data set from 13,388 Red Porgy otoliths read sectioned and assigned both increment counts and edge types, the most important variables influencing edge type were identified for the South Atlantic region and this data set was split into training (75%) and testing (25%) sets. Following identification of increment count and month of capture as important factors for impacting edge type, we assigned edge types to the test set using proportions of edge types by month of capture and increment count from the training set. Derived calendar ages were then calculated for the test set. Comparisons were made between these derived calendar ages and increment counts with the true calendar ages. Both the frequency of derived calendar ages and increment counts showed relatively similar results to the true calendar ages, but there was a bias associated with the increment counts that was not present with the derived calendar ages. These observations hold true when examining these age types on an annual basis.

Background

Age estimates for stock assessments generally are provided as “increment count”, “calendar age”, or “fractional age”. Calendar age can be deduced using increment count, the width of the marginal increment (edge type), time of marginal increment formation, and the month of capture. Calendar (or annual) age differs from increment count in that it generally is increased by one (“bumping”) in fish that have been alive for a significant part of the year and have an otolith with a wide translucent margin (edge code 3 or 4) and no indication of an opaque margin forming (the next increment). Calendar age generally is considered a more appropriate age estimate for use in stock assessments as it reduces uncertainty relative to increment age and assigns fish to specific annual cohorts. Members of the SEDAR 60 Assessment Panel versed in life history and the assessment scientists discussed which age to use on a conference call on November 13 and agreed that if possible, calendar age should be used over increment count in the SEDAR 60 Red Porgy assessment.

Increment count has been the age type used for previous Red Porgy SEDAR stock assessments in the Atlantic waters off the Southeastern United States (SEDAR-1 2003; SEDAR-1 2006, SEDAR-1 2012). This was due primarily to lack of edge types for age estimates obtained from reading whole otoliths. Due to limited time to age Red Porgy otoliths following a validation study prior to the SEDAR 60 assessment (Potts et al. 2018), the opportunity to re-examine (re-age) sectioned otoliths that initially were aged whole was impossible within the provided time-frame for SEDAR 60, but subsequent analysis showed age estimates from whole otoliths were similar to those obtained from sectioned otoliths utilizing the protocol developed from the validation study and thus could be utilized (Fig. 1). As a result, ~14,000 otolith samples have increment counts but do not have an associated edge type, meaning that a calendar age could not be assigned directly. However, information from sectioned and aged otoliths with assigned edge types may be used to obtain a proxy for assigning a calendar age to otoliths that have no edge types.

Objectives

By utilizing ages from sectioned otoliths with associated edge types, there were three objectives of this study:

1. Examine the effects of increment count, year and month of capture, and latitude on edge type to develop a method to estimate edge type for whole-read otoliths
2. Using proportions of edge types from a training set, apply this method to a test set to assign edge types
3. Test the estimated edge types and subsequent derived calendar ages with sectioned otoliths and if performance is validated, assign edge types to whole read otoliths

Methods

Analyses were done with R (R Core Team 2018). Age estimates and edge types utilized for this analysis were from Red Porgy sagittal otoliths obtained between 2008 and 2017 that were sectioned and subsequently read using SERFS standard protocol (Smart et al. 2015). Each specimen had an associated edge type, year of capture, month of capture, latitude of capture rounded to the nearest whole number, and increment count. A generalized additive model (GAM) assessing edge type in relation to year of capture, month of capture, latitude of capture, and increment count was fit to the SERFS data using the R package mgcv (Wood 2019). This was done to identify the most important variables affecting edge type that may be non-linear so that they could be accounted for in the assignment of edge types. A value for the smoothing term (k) was limited to 5 for biological relevance. A month of increment formation also had to be determined by an examination of edge types by month for assignment of calendar age in following analyses.

Following identification of the important factors for edge type determination, a method to apply derived edge type values to unassigned edge types was developed. The age data with empirically assigned edge types were split randomly into a training set (75%) and a testing set (25%) to validate the method. The proportion of otoliths from the training set with a wide translucent edge (edge code > 2) was calculated to create a matrix for all combinations of the selected variables identified in the GAM analysis. This matrix was then applied to the testing set by randomly assigning a wide translucent edge type to the specified proportion of otoliths from each grouping. A wide translucent edge type was chosen because that is what is relevant in calendar age calculations. Calendar age then was calculated using these derived wide translucent edge types and the month of increment deposition that had been determined from sectioned otoliths. Therefore, fish collected prior to the month of opaque zone deposition that had a wide translucent edge were assigned a derived calendar age = increment count +1, while all other fish were assigned a calendar age = increment count.

Visual tests of the testing set examined the performance of the derived calendar ages and increment counts in relation to the true calendar ages (those determined by the sectioned empirical increment counts, edge types, and months of capture) over all years combined. Age- frequency compositions during months that potentially could have bumping occurring were created for the true calendar ages, derived calendar ages, and increment counts, and compared. Proportion and direction of error from true calendar age frequencies also were plotted to identify relative magnitude of the error and any biases with the derived calendar ages or increment counts relative to the true calendar ages. The proportional difference of derived calendar age frequencies and increment count frequencies compared to true calendar age frequencies were equal to:

Derived Calendar Age: $(T_C - D_C)/T_C$

Increment Count: $(T_C - T_I)/T_C$

Where T_C = True calendar age frequency

D_C = Derived calendar age frequency

T_I = True increment count frequency

To examine annual trends in a similar fashion, all estimated ages obtained from sectioned otoliths that also contained an edge code were utilized to increase sample size (training and testing sets combined) because there were 10 years of data that would be separated. We then visually examined how age classes could be tracked through time using increment counts and derived calendar ages compared to true calendar ages.

Finally, if appropriate, the methodology described above was applied to the roughly 14,000 otoliths that do not have an assigned edge type using proportions of wide translucent edge types from the full data set from 2008 – 2017. Calendar ages were then calculated for the full SCDNR age data set based on the empirical or derived edge types. These calculated calendar ages were then applied to age compositions and life history inputs for this assessment, that include both true and derived calendar ages.

Results and Discussion

The GAM for edge type was significant for the variables examined (n = 13,388; T-value = 235; $p < 0.001$) and identified month of capture ($F = 48.35$; $p < 0.001$) and increment count ($F = 117.84$; $p < 0.001$) as the factors which played the largest role in determining edge type. Not surprisingly, month of capture played a role in observed edge type of Red Porgy, because there is seasonality in opaque zone formation within the otolith. Slightly more unexpected was the inclusion of increment count as a variable in the model. This study was not designed to address this question, but survey timing, month of opaque zone formation, and width of marginal increments as the fish gets older could all play a role in its inclusion.

July was utilized as the month of opaque zone formation for calendar age calculations. This was determined from examination of mean edge type by month from SERFS data (Fig. 2) and corroborated with the ageing lab at the Southeast Fisheries Science Center in Beaufort, NC using their data set (J.

Potts, personal communication). Therefore, fish collected prior to August 1 that had an edge type > 2 were assigned a calendar age = increment count +1, while all other fish were assigned a calendar age = increment count.

The proportions of otoliths with a wide translucent edge (edge type >2) were calculated by increment count and month captured from the training set (n = 10,041). These proportions within each grouping were then applied to the testing set (n = 3,347). Derived calendar ages calculated in the testing set showed similarities to the true calendar ages from these same otoliths (Fig. 3) and showed no bias (Fig. 4). Increment count was similar to true calendar age (Fig. 5), but did not match up as well relative to derived calendar ages and showed a tendency to inflate the frequency of occurrence in relation to the true calendar ages for ages ≤ 5 and underestimate the frequency for ages older than 5 (Fig. 6).

The proportions of otoliths with a wide translucent edge (edge type >2) were calculated by increment count and month captured from the combined training set (n = 10,041) and testing set (n = 3,347) providing a more robust sample size (n = 13,388) for annual examinations. Derived calendar ages calculated in the testing set showed similarities to the true calendar ages from these same otoliths (Fig. 7) and showed no bias (Fig. 8). Increment count was similar to true calendar age (Fig. 9), but did not match up as well relative to derived calendar ages and showed a tendency to inflate the frequency of occurrence in relation to the true calendar ages for ages ≤ 5 and underestimate the frequency for ages older than 5 (Fig. 7).

For SEDAR 60, these derived calendar ages would be combined with true calendar ages and would affect growth equations, maturity ogives by age, and age compositions. While the systematic deviations in the older aged fish using increment count will have a minimal effect on age compositions due to the volume of these fish in comparison to the younger ages, it could have larger effects on growth or maturity analyses in which those individuals would have more weight due to the smaller sample sizes at those ages. If the panel chooses to utilize this method to obtain calendar ages, it will be applied to 14,280 ages from historic samples which were read using whole otoliths (Table 1). This results in calendar ages of 3,619 fish being bumped by 1 from the number of increments counted. The calendar ages vary by year as they are affected by the differences in time of year of capture and increment count obtained from the fish.

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Table 1. By year, the number of historic increment counts produced by reads of whole otoliths, including the number which would be not bumped or bumped when calculating the calendar ages.

Year	Otoliths Read Whole	No Bump	Bump
1979	196	196	0
1980	726	486	240
1981	251	198	53
1982	673	476	197
1983	495	481	14
1984	612	488	124
1985	840	540	300
1986	671	411	260
1987	838	534	304
1988	369	293	76
1989	344	263	81
1990	557	341	216
1991	424	361	63
1992	417	280	137
1993	380	284	96
1994	443	297	146
1995	612	511	101
1996	972	781	191
1997	807	602	205
1998	708	512	196
1999	427	340	87
2000	928	727	201
2001	1,021	780	241
2002	568	478	90
2003	1	1	0
Total	**14,280**	**10,661**	**3,619**

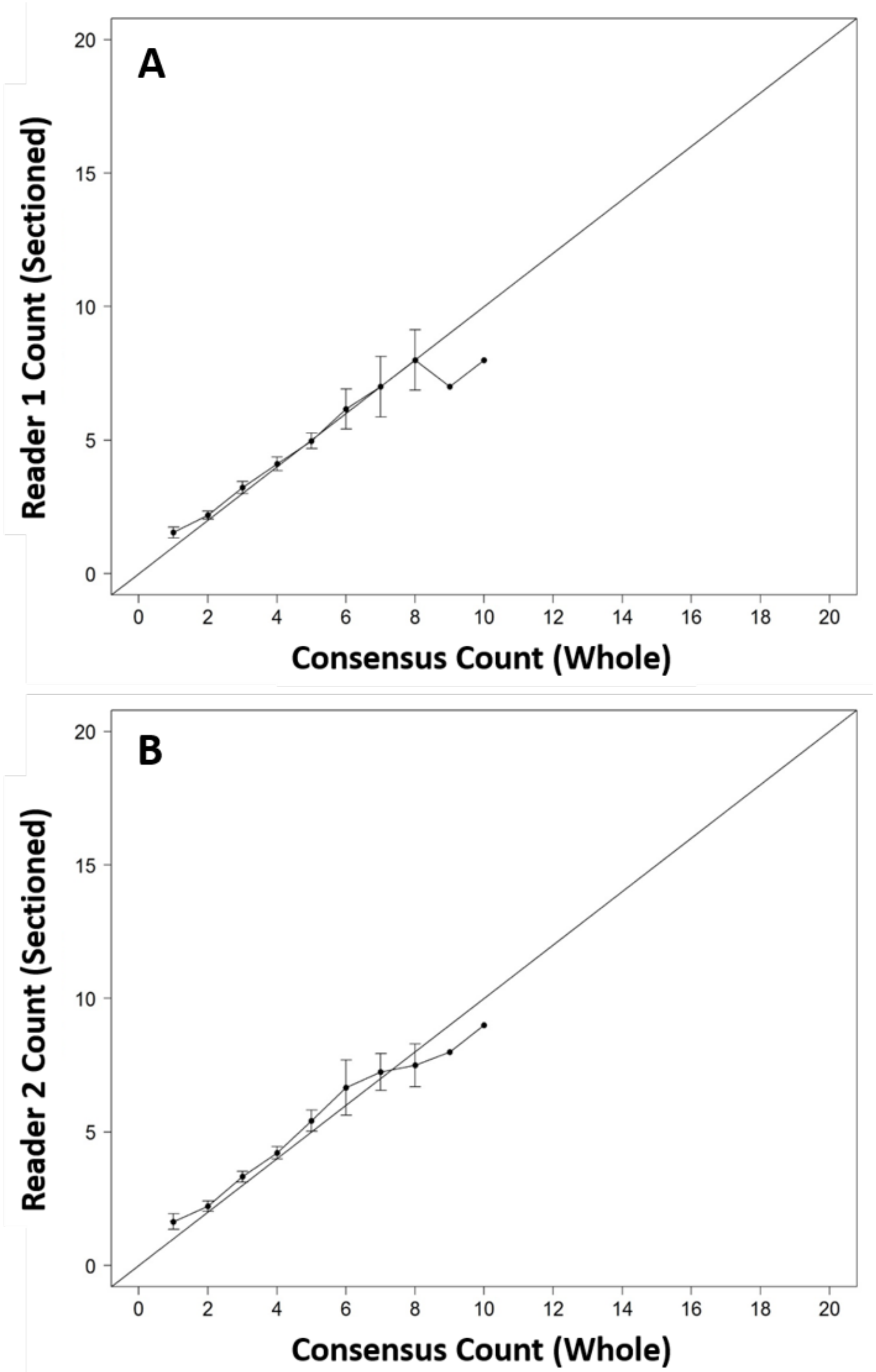

Figure 1. Bias plots for Reader 1 (A) and Reader 2 (B) comparing increment counts obtained from ageing sectioned otoliths using current protocols and consensus increment counts from otoliths read whole from our historic data. Error bars represent 2 standard errors.

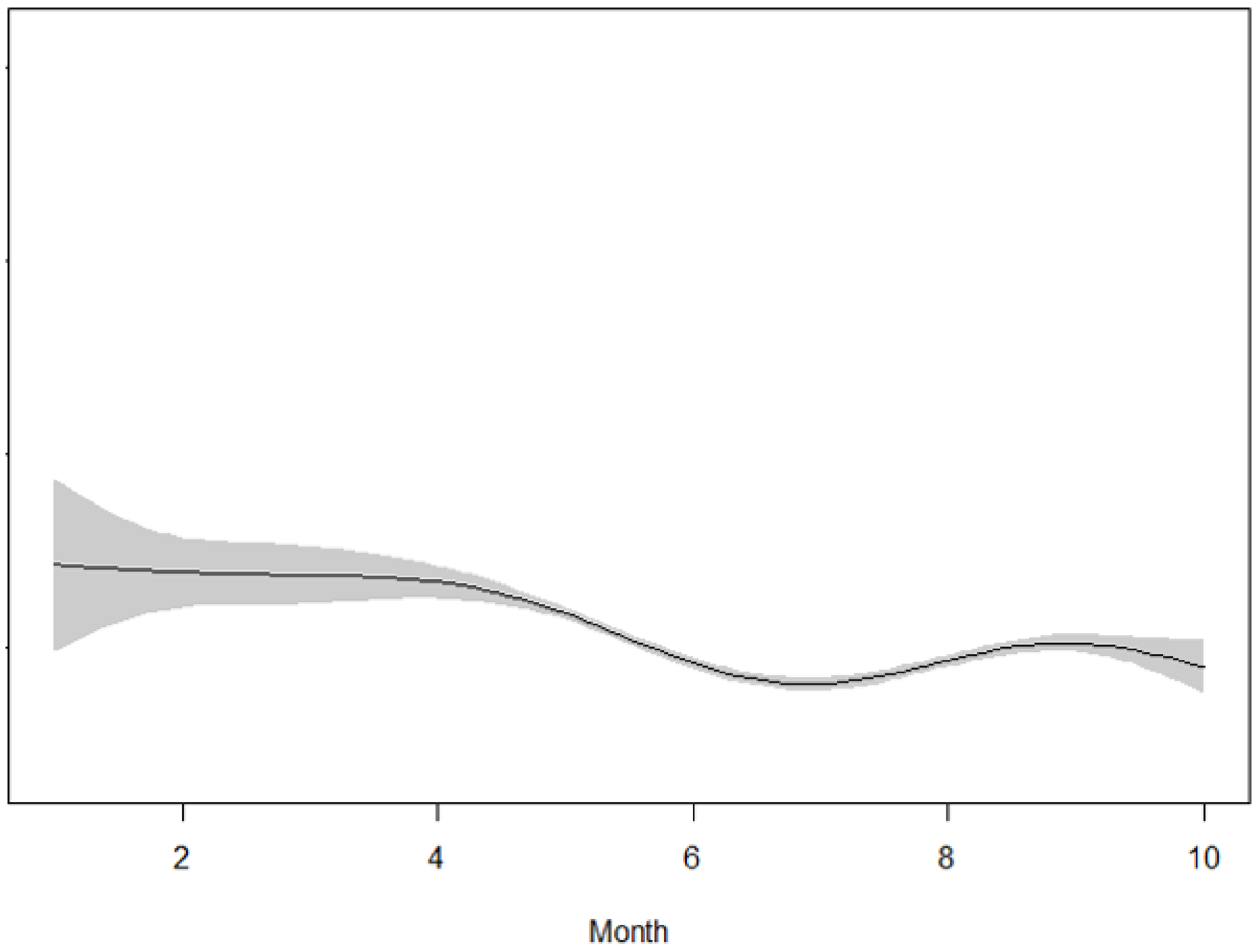

Figure 2. Smoothed output from the generalized additive model (GAM) showing edge type by month, with the lowest mean average month being July. Gray bars represent ± 1 standard error around the smoothed result.

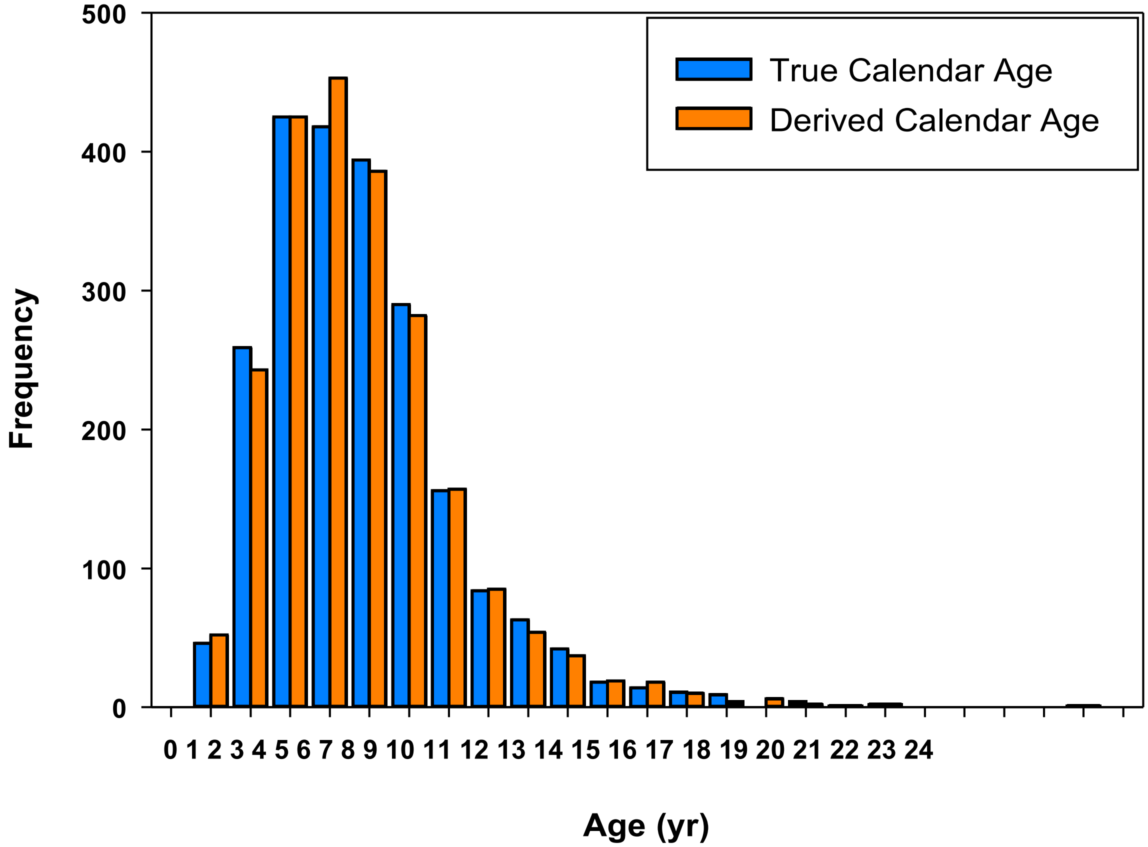

Figure 3. Age frequency plot comparing true calendar ages calculated using the increment count and assigned edge type from the testing set, with derived calendar ages from those same data that were calculated using a derived edge type from the proportion of fish by month and age with large translucent edges.

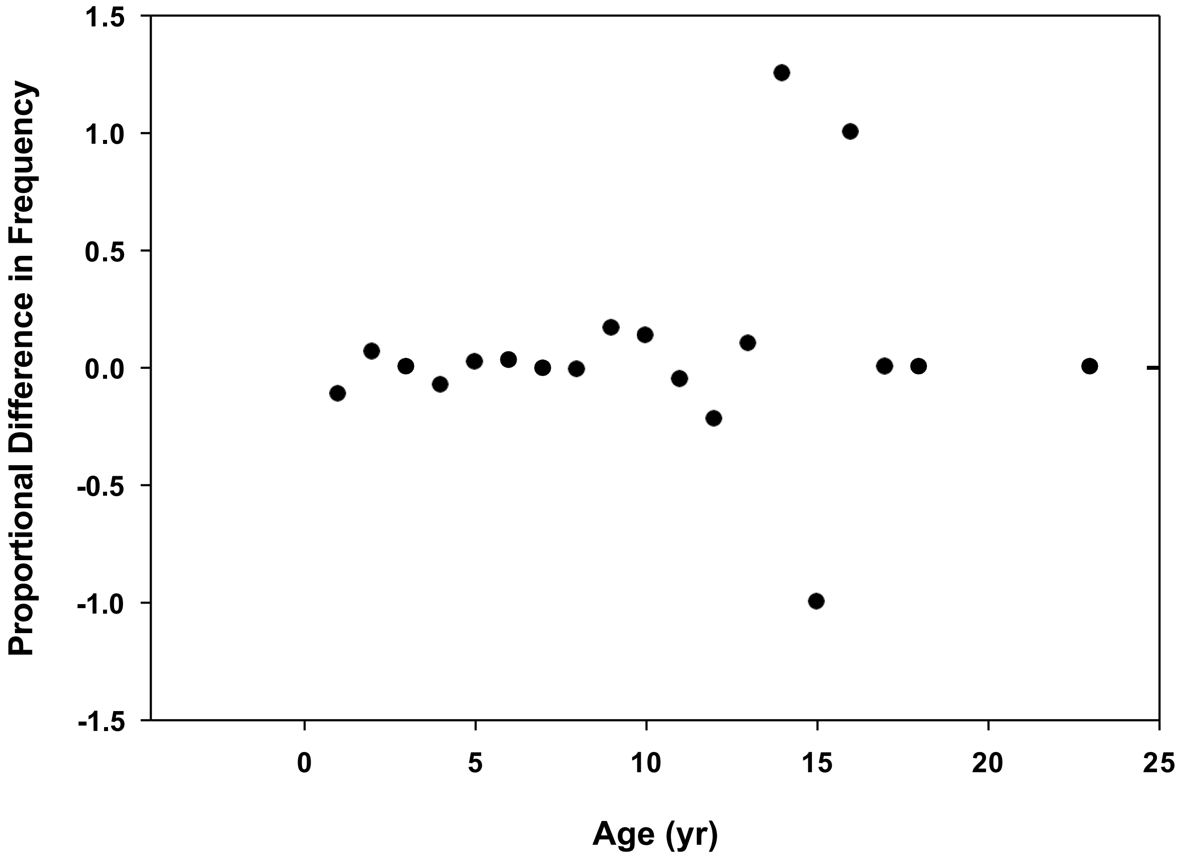

Figure 4. Proportion of deviation of true calendar age frequencies from derived calendar age frequencies for the testing set.

Calculation: $(T_C - D_C)/T_C$

Where: T_C = True calendar age frequency and D_C = Derived calendar age frequency

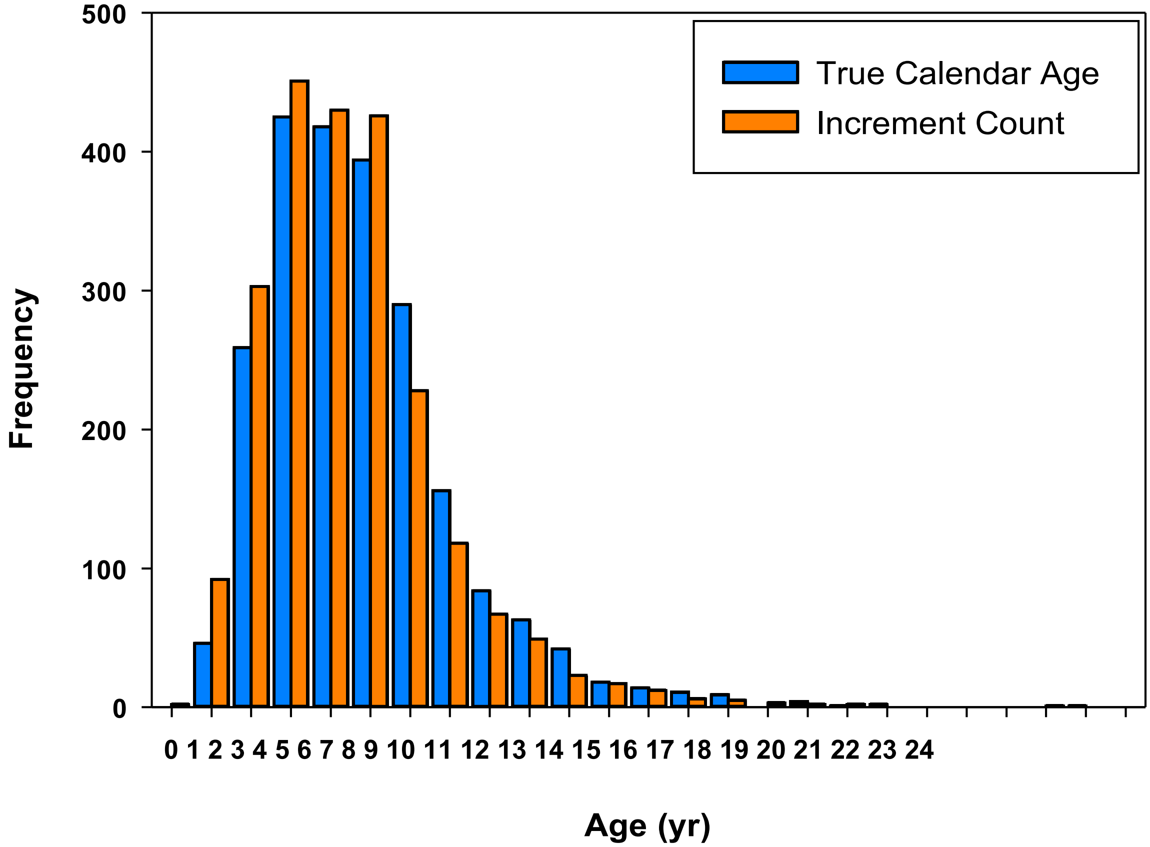

Figure 5. Age frequency plot comparing true calendar ages calculated using the increment count and assigned edge type from the testing set, with increment counts from those same data, with no calendar age calculations performed.

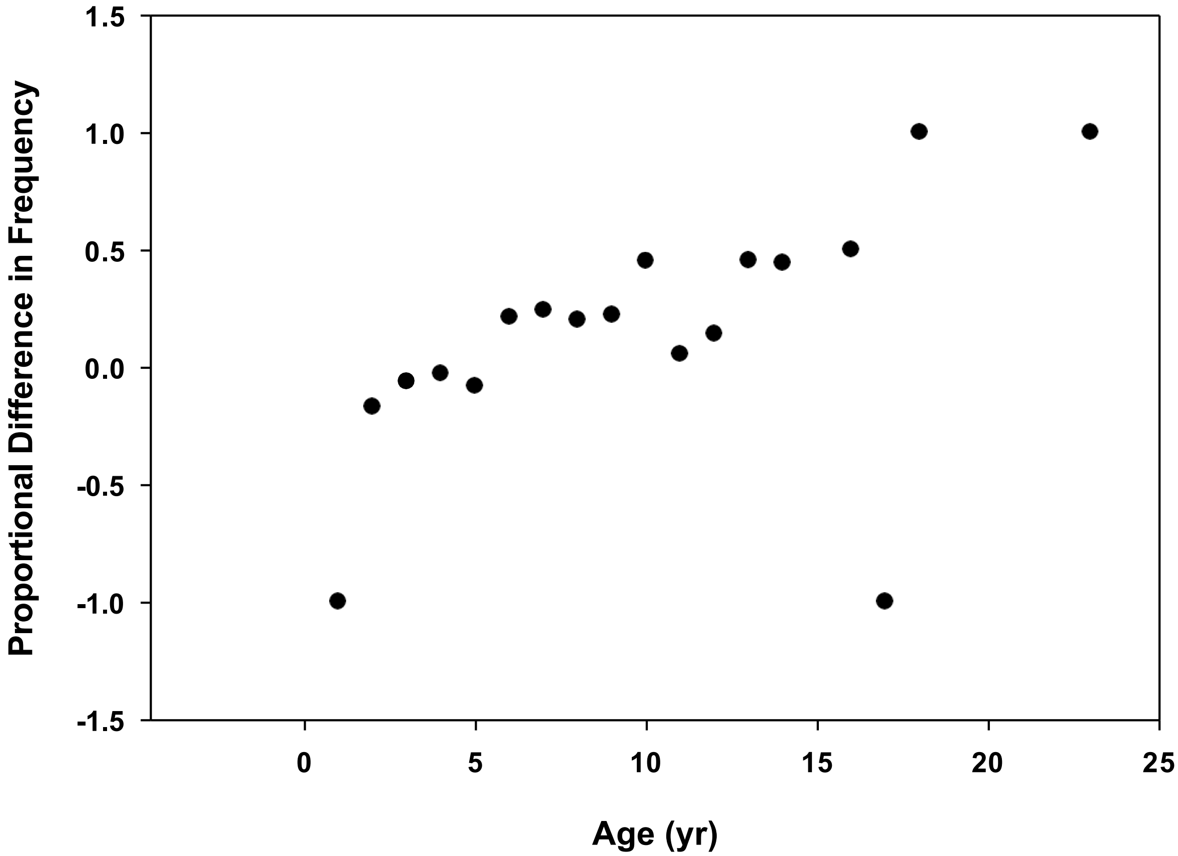

Figure 6. Proportion of deviation of true calendar age frequencies from increment count frequencies for the testing set.

Calculation: $(T_C - T_I)/T_C$

Where: T_C = True calendar age frequency and T_I = True increment count frequency

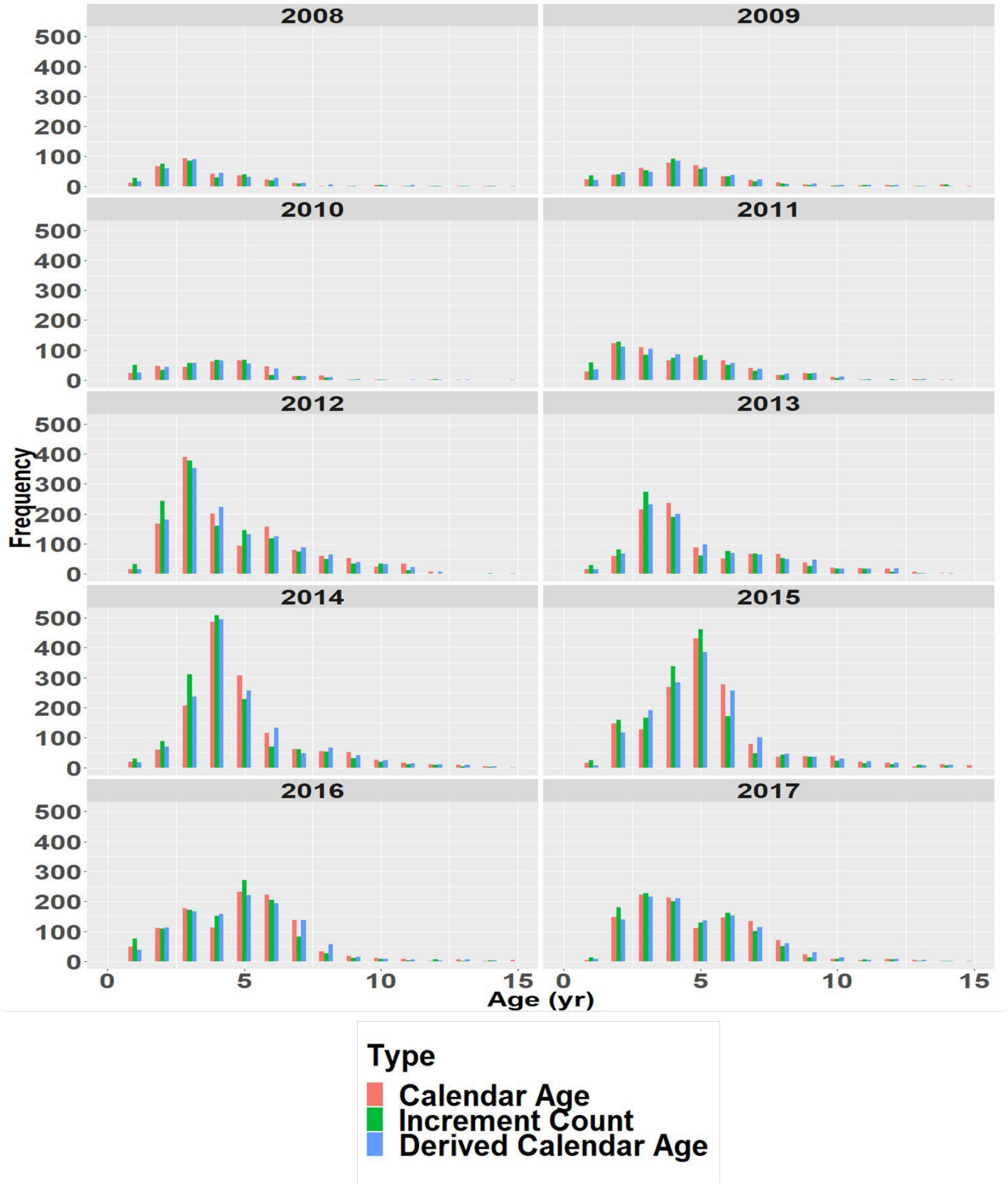

Figure 7. Annual age frequency plots comparing true calendar ages, increment counts, and derived calendar ages from all otoliths with an estimated age and edge type. Plots are truncated at 15 years of age to minimize loss of information while better visualizing the data.

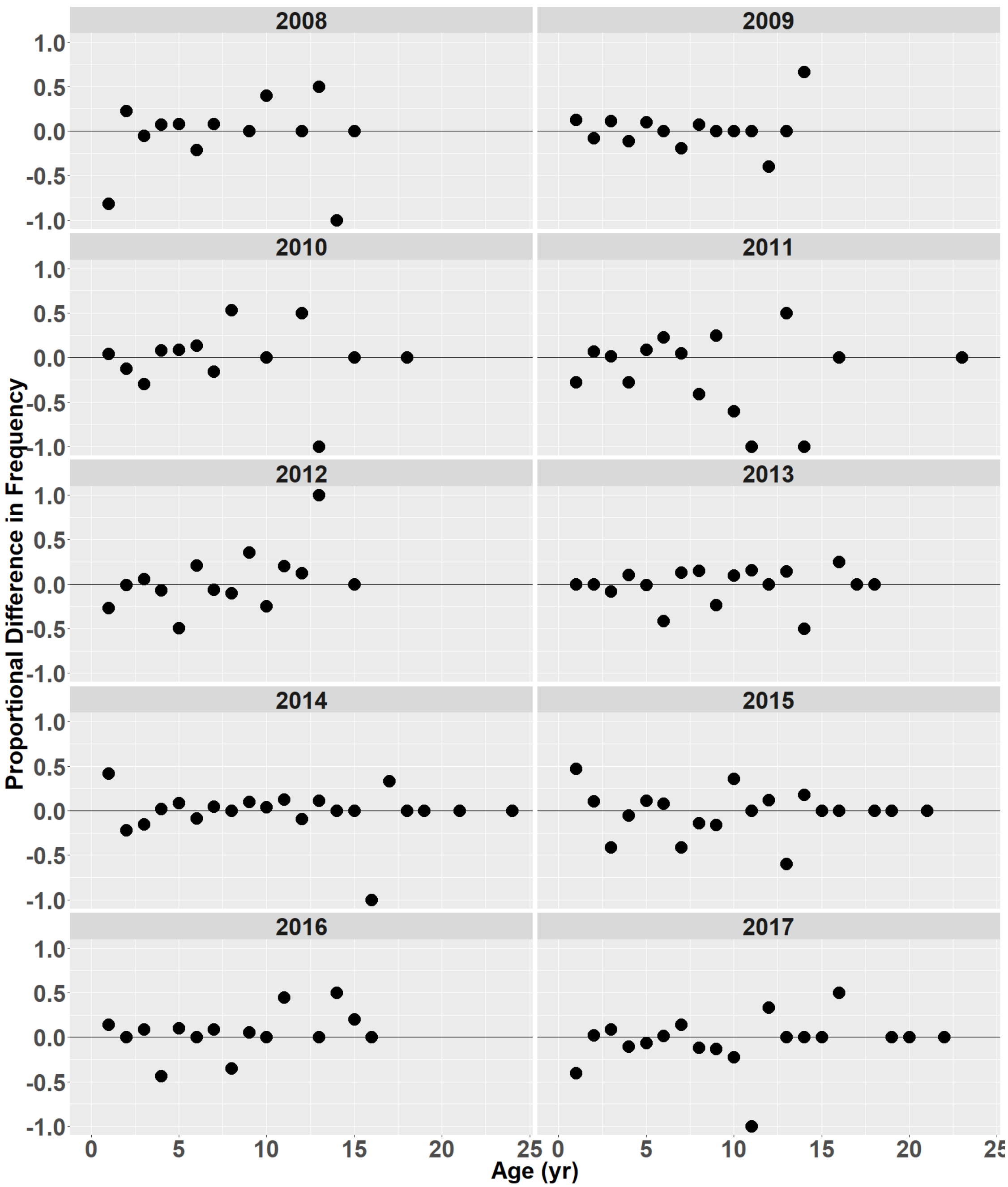

Figure 8. Proportion of deviation of true calendar age frequencies from derived calendar age frequencies for all otoliths that have an age estimate and edge type assigned. The Y-axes are truncated at 1.0 and -1.0 to minimize loss of information while better visualizing the data.

Calculation: $(T_C - D_C)/T_C$

Where: T_C = True calendar age frequency and D_C = Derived calendar age frequency

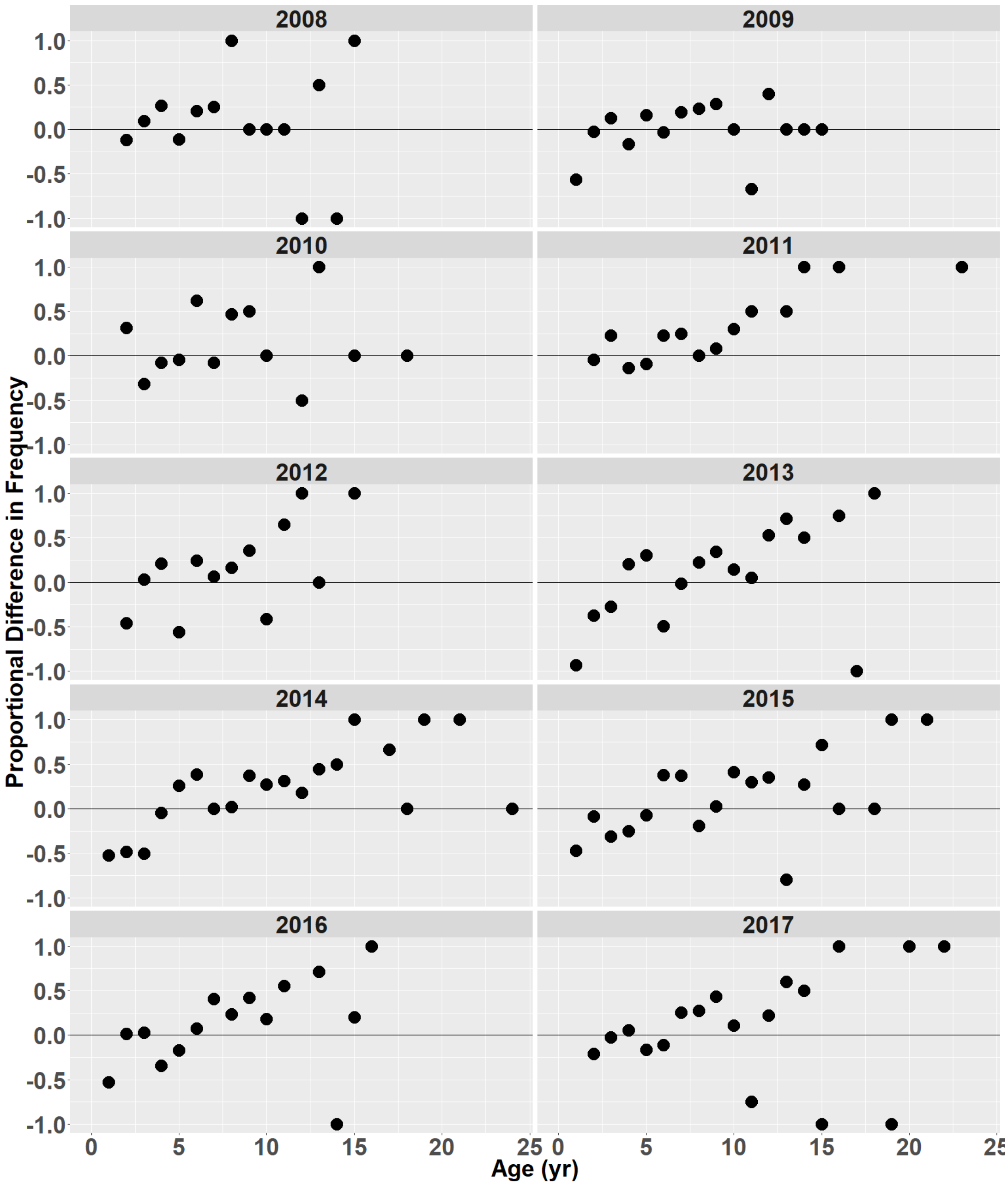

Figure 9. Proportion of deviation of true calendar age frequencies from increment count frequencies for all otoliths that have an age estimate and edge type assigned. The Y-axes are truncated at 1.0 and -1.0 to minimize loss of information while better visualizing the data.

Calculation: $(T_C - T_I)/T_C$

Where: T_C = True calendar age frequency and T_I = True increment count frequency