Standardization of striped marlin (*Kajikia audax*) CPUE in the Hawaiian longline fishery: II. Additional covariates, distribution, and use of data from the deep-set fishery sector only.[1]

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Abstract

This working paper is a complement to Walsh and Chang (2015), and adds additional considerations to the standardization of catch per unit effort (CPUE) for striped marlin (*Kajikia audax*) in the Hawaii longline fishery. First, set type and second order interactions of year-quarter, quarter-region, set type-hooks per float, and set type-vessel length, were included as additional explanatory covariates. Second, the zero-inflated negative binomial (ZINB) model was used in addition to the Poisson and delta-lognormal distributions. Third, due to the closure of the shallow-set sector of the fishery in 2001-2004, standardizations from the deep-set sector were compared to standardizations from both sectors. All covariates were included in the best models for each distribution based on forward model selection, but year, region, and season explained the most deviance. Indices were similar across all three distributions and across the two data choices, with only slight differences in the first five years between the indices produced using deep-set data and the indices produced using all data. Residual plots showed uniform patterning across covariates, with the exception of a bimodal pattern in hooks per float when using all data, and smaller residuals for the first five years when using deep-set

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data. Overall, the results suggested that the trend in striped marlin CPUE was robust to the choice of distribution and the choice of which data to analyze and that meaningful covariates were not excluded from previous standardizations. It is recommended that the existing methodology for standardizing striped marlin CPUE for the Hawaiian longline fishery be maintained for the stock assessment update. For future standardizations, use of the delta-lognormal is recommended, as is the use data from both fishery sectors with set type included as a covariate.

Introduction

This working paper is a complement to Walsh and Chang (2015), and adds additional considerations to the standardization of catch per unit effort (CPUE) for striped marlin (*Kajikia audax*) in the Hawaii longline fishery. Additional covariates were used in this analyses that were not considered in the CPUE standardization (Walsh and Lee, 2011) used in the last benchmark assessment for striped marlin (Lee et al., 2012). An additional distributional assumption was used, the zero-inflated negative binomial (ZINB), which was the preferred distribution for CPUE standardization of oceanic whitetip shark (*Carcharhinus longimanus*; Brodziak and Walsh, 2013) and many billfish species including striped marlin (Walsh and Brodziak, 2014) in the Hawaii longline fishery. Lastly, standardizations from both the deep- and shallow-set sectors of the fishery, which were used in past analyses, were compared to standardizations from only the deep-set sector. Recommendations in Table 2 of Brodziak and Dreyfus (2011) were followed for reporting CPUE standardizations. The data used in this report were collected by scientific observers deployed on Hawaii longline trips and are identical to those used in Walsh and Chang (2015). Refer to any of the aforementioned references for a description of the observer data.

Methods

Generalized linear models (GLM) were used to standardize CPUE using the R statistical software (version 3.1.2; R Core Team 2014). The analyses in this working paper expand on the analyses in Walsh and Chang (2015) in three ways: 1) use of additional covariates, 2) use of a ZINB model, and 3) standardization using only the deep-set fishery sector.

Covariates

Year, region, quarter of the year, and sea surface temperature (SST) were retained as covariates from the original analyses in Walsh and Lee (2011). Year (1995–2013), region (1–8), and quarter (1–4) were modeled as factor variables while SST was modeled as a continuous variable. A second order term for SST was also included based on explorations with generalized additive models. Walsh and Lee (2011) originally used a third order polynomial for SST.

Additional covariates were used in this analysis. A factor variable of set type was added to distinguish between the shallow-set sector (defined as < 15 hooks per float) and the deep-set sector (defined as ≥ 15 hooks per float). Interactions between year and quarter, region and quarter, set type and hooks per float, and set type and vessel length were also added. Hooks per float and vessel length were continuous variables. Neither hooks per float nor vessel length were included as main effects, but only as interactions with set type. Other interactions were not included due to incomplete factor combinations. Other covariates not included in the analyses were assumed to have minimal effects on striped marlin CPUE. See Chang et al. (2015) for further information regarding the covariates.

Distributions

The Poisson and delta-lognormal (DLN) distributions, which were used by Walsh and Chang (2015), as well as the ZINB distribution (Brodziak and Walsh, 2013) were used in this analysis. Both the DLN and ZINB distributions include a "zero process" that is modeled as a Bernoulli random variable, and a "positive process" for the DLN or "count process" for the ZINB that assume separate distributions. The positive process for the DLN was modeled as a normal distribution, with a response variable of the natural logarithm of CPUE, where CPUE was catch per 1000 hooks. The count process for the ZINB was modeled as a negative binomial, with response variable of catch per set in numbers. The response variable for the Poisson distribution was also catch per set. The "glm" function in R was used for the Poisson and DLN distributions, and the "zeroinfl" function in the "pscl" library (Jackman, 2014) was used for the ZINB distribution.

Effort in the fishery in hooks per set was included as an offset variable for the Poisson and ZINB distributions. A log link function was used for the Poisson and the count process of the ZINB so the offset was the log of effort.

Model selection

The best set of covariates for each distribution was determined using forward selection stepwise regression based on the Akaike Information Criterion (AIC). The null model for the analyses included the offset term, where applicable. At each step in the model selection procedure, the factor that resulted in the greatest reduction in AIC from the model in the previous step was added to the model. Interactions were considered only when all factors in the interaction were selected in previous steps. Separate sets of covariates were considered for the two processes in the delta-lognormal and ZINB models. For the ZINB, covariates were selected first for the count process, after which covariates were selected for the zero process. There were convergence problems for the zero process of the ZINB, so both forward and backward selection were used for selecting covariates. Once the best model for the ZINB was determined, backward selection of the covariates in the count process was done to ensure that the overall selection procedure resulted in the best model. The contribution of each covariate to the reduction of AIC and explanation of deviance from the null model were also provided to determine importance of each covariate.

Model diagnostics

Model fit was assessed through examination of residuals to fitted values and to each covariate in the best model. A histogram of residuals was used to assess normality for all models, as was a quantile-quantile normal probability plot for the positive process of the DLN. Pearson residuals were used for all models except the zero process of the DLN, for which quantile residuals were used (Dunn and Smyth 1996). A *pseudo*-coefficient of determination was calculated for the Poisson and each component of the DLN to determine the proportion of deviance in the null model explained by the best model.

Index

An index of relative abundance was calculated for each distribution. The index (I_y) and its variance were calculated as the mean and variance, respectively, of the predicted values on the scale of the response in year *y* using the “predict” function in R. The variance of the delta-lognormal distribution was calculated as the Taylor series expansion of the variance of the product of two independent random variables (Brodziak and Walsh, 2013; Eq. 7). Bias-correction was applied when back-transforming the positive process of the DLN model from ln(CPUE) to CPUE. Coefficients of variation (CV) were also calculated for each year for all distributions. Pearson correlations between each index pair were calculated to determine similarities among the indices.

In instances where the year-quarter effect was included in the best model, a weighted average of the index was also calculated based on the year-quarter specific index ($I_{q,y}$) as $I_y = \sum_q p_{q,y} I_{q,y}$, where $p_{q,y}$ was the proportion of sets in each quarter q by year y. The resulting index was identical to that when taking the yearly average, so results are presented from only the yearly averaged index when analyzing the full dataset.

Deep-set fishery sector

The above methodology was simplified for analyses using data from only the deep-set fishery sector. Model selection was not done, but rather the best models when using both the shallow-set and deep-set sectors with set type removed were refit with data from only the deep-set sector. Indices were calculated and compared to those from models with data from both sectors. The explanation of deviance or AIC contributed by each covariate was not included because model selection was not done when analyzing the deep-set data. Also, the index averaged over year-quarters was slightly different for the positive process of the DLN but only the yearly averaged index is presented.

Results

This section presents the results of the model selection process and the resulting indices. Diagnostic residual plots and summary output of the model with selected covariates are provided in the appendices.

Poisson

All covariates were selected for the best model for the Poisson distribution, which explained 31.9% of the null deviance. The ratio of the deviance to the degrees of freedom (1.48) indicated the presence of overdispersion ($P < 0.001$). Time (year and quarter) and area (region) main effects and interactions were selected first in the model selection process and explained the most deviance among all covariates (Table 1). The deviance explained for these covariates was due in part to their high degrees of freedom, but deviance explained per degree of freedom supported the importance of year, region, and quarter. Pearson residual plots show non-normality in the distribution of the residuals (Appendix 1). Residuals across factor covariates showed no obvious pattern, but residuals across continuous covariates showed some bimodality (Appendix 1). The standardized index followed the pattern in the nominal index very closely (Figure 1).

Negative binomial

All covariates were selected for the best model for the count process, but only set type and the linear and quadratic terms for SST were chosen for the best model for the zero process. There were convergence problems fitting the zero process, but covariates selected for the best model did converge. The order of selection for covariates, and reduction in AIC were similar to the Poisson (Table 2). Reductions in AIC of covariates for the zero process were small. Pearson residual plots showed positive skewness in the distribution of the residuals, and similar patterns in residuals with the covariates as the Poisson (Appendix 2). The standardized index was very similar to the index for the Poisson (Figure 2).

Delta-lognormal

All covariates were selected for the best model for the zero process of the delta-lognormal, which explained 15.8% of the null deviance. Year, quarter, and region were the first covariates selected, followed by their interactions. Interactions explained the most null deviance among covariates, although on the basis of per degrees of freedom, explained less than the other covariates (Table 3). Quantile residual plots showed normality in the distribution of the residuals and no patterns within covariates (Appendix 3a). The index of standardized probability of capture was very similar to the nominal probability of capture (Figure 3).

Sea surface temperature was the only covariate not selected for the best model for the positive process of the delta-lognormal, which explained 34.0% of the null deviance. The order in which covariates were selected differed from other models in that set type was the first selected. Set type, as well as interactions with set type explained high amounts of null deviance compared to other covariates both overall and per degrees of freedom (Table 3). The year-quarter interaction also explained similar amounts of overall null deviance compared to set type. Pearson residual plots showed some skewness in the distribution of the residuals, and patterns in the covariates were similar to the Poisson and ZINB, although some patterning was visible in the lower portion of the plot of residual versus predicted values

(Appendix 3b). The overall standardized index of CPUE was similar in shape to the nominal index, but confidence bounds (+/- one standard deviation) were smaller in comparison to the Poisson and ZINB models (Figure 4).

Comparisons among distributions

When scaled to their mean values, the indices produced by the Poisson, DLN, and ZINB were very similar (Figure 5). Differences were most pronounced between the DLN, and the Poisson and ZINB indices. The Pearson correlation between pairs of indices was 0.998 for the Poisson-ZINB pair, 0.91 for the Poisson-DLN pair, and 0.92 for the ZINB-DLN pair. The AIC of the best model for the ZINB (131478) was less than that of the Poisson's (145795), which indicates preference for the ZINB. Yearly values of the indices in table form, along with their corresponding CVs are provided in Table 4 for the models using combined data, and in Table 5 for the models using deep-set data only.

Deep-set only analyses

Residual plots from the standardized indices when using only the deep-set data were similar to those when using the combined data. Residuals for the Poisson (Appendix 4) and ZINB (Appendix 5) distributions remained positively skewed. No patterns were present in the residuals for the zero process of the DLN (Appendix 6a), and skewness was still present for residuals for the positive process of the DLN (Appendix 6b). There were also dome-shaped patterns in the residuals for the continuous variables for the Poisson and ZNB distributions. Bimodality in the residuals was removed when analyzing only the deep-set data in hooks and hooks per float, but was still present in SST and in the residuals of the positive process for the DLN.

Standardized indices from analyses on only the deep-set data were similar to indices from the combined data. Differences in the patterns of the indices were more noticeable for the Poisson (Figure 6) and the ZINB (Figure 7) than for the DLN (Figure 8), especially in the early part of the time series (1995–2000) and in 2006 where the nominal data differed. Differences between the indices from the deep-set and combined data for the DLN were very similar across all years. The Pearson correlation between the indices from the combined data and the indices from the deep-set data was 0.95 for the Poisson models, 0.96 for the ZINB models, and 0.97 for the DLN models. The variance around each index was slightly smaller for the ZINB than for the Poisson, and smaller still for the DLN.

The indices calculated from each of the three distributions using only the deep-set data were very similar, with only slight differences in the early years of the time series between the DLN and the Poisson and ZINB (Figure 9). Correlations between each of the deep-set indices were higher than those when using data from both sectors, and were 0.999, 0.98, and 0.97 for Poisson-ZINB, Poisson-DLN, and DLN-ZINB, respectively.

Overall, all indices from all analyses were very similar (Figure 10).

Discussion

The results showed that the previous approach to standardize CPUE for striped marlin in the Hawaii longline fishery was robust. The choice of distribution to use and fishing sector to include had very little effect on the overall standardized index in the analyses. Data were overdispersed so the ZINB or DLN, which are able to account for overdispersion, may be preferred to the Poisson. On the other hand, the simplicity of the Poisson and the similarity of its index to those of the ZINB and DLN suggest the Poisson is also a reasonable choice, although comparisons between AIC suggested the ZINB was preferred to the Poisson. Choices based on AIC between the Poisson or ZINB with the DLN however, were not possible. Both the ZINB and DLN involved two processes, each of which required further model selection. There were convergence issues for the zero process of the ZINB, which warrants some caution with its use.

Skewness in the residuals of the Poisson and ZINB were of concern, particularly given residuals in Brodziak and Walsh (2013) and Walsh and Brodziak (2014) were less skewed. Differences in catch numbers for oceanic whitetip shark and striped marlin contributed to the differences in the range of the residuals for Brodziak and Walsh (2013), and residual plots were calculated on a per trip basis for Walsh and Brodziak (2014). Quantile residuals for the Poisson and ZINB were also calculated (results not shown). The histograms of quantile residuals were more normal; however, predicted versus residual plots indicated that the variance in the residuals became smaller as predicted values increased, especially for the ZINB. Consequently, the Poisson model may be preferable to the ZINB in the sense of residuals. Skewness in residuals was less problematic for the DLN.

Residual patterns for the deep-set sector models did not indicate substantial improvement over models fitted with the combined data. Although bimodality in hooks per float and hooks were not present due the removal of the small values from the shallow-set sector, patterns in SST persisted. Smaller SST values were associated with observations from primarily the first quarter, however the reason for reduced variance around 20 degrees was not known. Bimodality in the plots of residuals to predicted values in the positive process of the DLN was also not addressed by analyzing only the deep-set data. Residuals in the lower portion of the plot appeared to group together, however there was no clear reason for why these residuals grouped together. Domed patterns in the residuals for the Poisson and ZINB models suggested the models could be improved; possibly by using model selection procedures or reconsidering the choice of covariates included in the analysis.

The confidence bounds for the DLN were narrower than those for the Poisson and the ZINB, which indicated better predictive ability for the DLN. Caution is recommended with this however, because the DLN used ln(CPUE) as the response variable whereas the Poisson and ZINB used catch with effort as an offset. Differences in the response variables themselves, as well as their scales could have contributed to the tighter predictions for the DLN. Comparing the Poisson and ZINB with the DLN remains a complicated issue.

All covariates that were included in the analyses were selected in the best models for at least one of the processes for each distribution. Although added covariates were statistically significant, they were less important to the primary covariates of year, region, and quarter, which consistently contributed the greatest reductions in AIC and deviance for all models.

This analysis is part on an ongoing process of exploring assumptions and achieving best available science. Consequently, future exploration is encouraged. Possible considerations for future studies include using random vessel effects and finer spatial resolution. Data are available in one by one degree cells from the Hawaii longline fishery, but using five by five degree cells to match the resolution of data across the entire western Pacific striped marlin fishery may be more reasonable.

Conclusions

The similar patterns of the indices produced by the Poisson, ZINB, and the DLN suggested that the overall trend in striped marlin CPUE was robust to the choice of distribution and the choice of which data to analyze. Additional covariates, although statistically significant, did not indicate that meaningful covariates were excluded from the previous analyses. Consequently, it is recommended that the existing methodology for standardizing striped marlin CPUE for the Hawaii longline fishery be maintained for the stock assessment update.

For future assessments, it is recommended that the DLN be used for standardizing the Hawaii longline data. The residuals of the DLN were more normal and generally non-patterned, and the resulting variance around the index was smaller than with the Poisson and ZINB for both datasets. Although model selection was required for both the zero and positive process, convergence was not an issue and the selection procedure was straightforward. In addition, it is recommended that the combined dataset be used, but that the effect of set type be included in the model as an appropriate balance between including information in the shallow-set sector while accounting for known differences between sectors.

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Table 1: The degrees of freedom (df = df null – df model), the reduction in AIC (ΔAIC = AIC null – AIC model), and the explanation of null deviance overall and per degrees of freedom for the Poisson model when each covariate selected in the best model was added to the null model. The order of the covariates reflects the order in which they were selected for the best model.

Poisson				
Covariate	df	ΔAIC	Explanation of null deviance	Deviance reduced per df
Year	18	18458	14.1%	1027
Region	7	9195	7.0%	1316
Quarter	3	5481	4.2%	1829
Year:Quarter	75	30951	23.7%	415
Region:Quarter	31	15885	12.2%	514
Set type	1	549	0.4%	551
Set type:Hooks per float	2	625	0.5%	315
SST (linear)	1	293	0.2%	295
SST (quadratic)	1	224	0.9%	226
Set type:Vessel length	2	559	0.4%	281

Table 2: Degrees of freedom (df = df null – df model), reduction in AIC (ΔAIC = AIC null – AIC model), the percentage reduction in AIC from the null model, and the reduction in AIC per degrees of freedom for the zero and count components of the zero inflated negative binomial model when each covariate selected in the best model was added to the null model. The null model for the zero process included all covariates in the count process. The order of the covariates reflects the order in which they were selected for the best models. Models with only year:quarter and quarter:region interactions on their own could not be calculated with “zeroinfl”.

Zero inflated Negative Binomial				
Covariate	df	ΔAIC	% ΔAIC	% ΔAIC per df
Zero process				
Set type	1	45.8	0.03%	0.03%
SST (linear)	1	32.3	0.02%	0.02%
SST (quadratic)	1	40.6	0.03%	0.03%
Count process				
Year	18	6530	4.4%	0.24%
Region	7	3721	2.5%	0.36%
Quarter	3	1946	1.3%	0.44%
Year:Quarter	75	-	-	-
Region:Quarter	31	-	-	-
Set type	1	212	0.14%	0.14%
Set type:Hooks per float	2	229	0.16%	0.08%
Set type:Vessel length	2	240	0.14%	0.07%
SST (linear)	1	217	0.15%	0.15%
SST (quadratic)	1	185	0.12%	0.12%

Table 3: The degrees of freedom (df = df null – df model), the reduction in AIC (ΔAIC = AIC null – AIC model) and the explanation of null deviance overall and per degrees of freedom for the components of the delta-lognormal model when each covariate selected in the best model was added to the null model. The order of the covariates reflects the order in which they were selected for the best models.

Delta Lognormal				
Covariate	df	ΔAIC	Explanation of null deviance	Deviance reduced per df
Zero process				
Year	18	4393	5.6%	246
Region	7	3765	4.7%	540
Quarter	3	1455	1.8%	487
Region:Quarter	31	6698	8.5%	218
Year:Quarter	75	7962	10.2%	108
Set type	1	968	1.2%	970
Set type:Hooks per float	2	907	1.1%	456
SST (linear)	1	514	0.6%	516
SST (quadratic)	1	433	0.5%	435
Set type:Vessel length	2	999	1.3%	501
Positive process				
Set type	1	3109	13.0%	1596
Year	18	2527	10.8%	74
Region	7	1222	5.4%	94
Set type:Hooks per float	2	3083	12.9%	792
Quarter	3	377	1.7%	69
Year:Quarter	75	4616	19.2%	31
Region:Quarter	31	2146	9.4%	37
Set type:Vessel length	2	3106	13.0%	798

Table 4: Standardized indices (I_y) and coefficient of the variations (CV) for the best model for the Poisson, zero-inflated negative binomial (ZINB), and the delta-lognormal distributions when using the combined data.

	Index (I_y)			CV		
Year	Poisson	ZINB	DLN	Poisson	ZINB	DLN
1995	2.09	2.20	1.67	0.81	0.81	0.59
1996	1.62	1.77	1.19	0.63	0.77	0.58
1997	1.11	1.18	0.89	0.61	0.66	0.41
1998	1.16	1.18	0.79	0.9	0.97	0.61
1999	1.12	1.11	0.87	0.63	0.65	0.24
2000	0.55	0.53	0.39	0.55	0.62	0.33
2001	1.70	1.71	0.91	0.58	0.59	0.37
2002	0.66	0.66	0.35	0.59	0.60	0.50
2003	2.21	2.26	1.03	0.65	0.67	0.44
2004	0.93	0.92	0.44	0.7	0.68	0.44
2005	0.92	0.94	0.66	0.68	0.71	0.26
2006	1.15	1.15	0.53	0.73	0.74	0.36
2007	0.31	0.32	0.2	0.78	0.80	0.49
2008	0.82	0.8	0.46	0.78	0.77	0.37
2009	0.39	0.39	0.26	0.63	0.64	0.26
2010	0.19	0.19	0.12	0.54	0.56	0.27
2011	1.05	1.04	0.5	0.81	0.8	0.58
2012	0.55	0.56	0.28	0.67	0.67	0.48
2013	0.77	0.76	0.34	0.82	0.83	0.50

Table 5: Standardized indices (I_y) and coefficient of the variations (CV) for the best model for the Poisson, zero-inflated negative binomial (ZINB), and the delta-lognormal distributions when using the deep-set data only.

	Index (I_y)			CV		
Year	Poisson	ZINB	DLN	Poisson	ZINB	DLN
1995	2.83	2.75	1.85	0.71	0.70	0.53
1996	2.30	2.41	1.34	0.78	0.80	0.52
1997	1.66	1.67	0.89	0.58	0.58	0.42
1998	1.87	1.83	0.92	0.67	0.68	0.52
1999	1.23	1.21	0.63	0.49	0.49	0.34
2000	0.47	0.48	0.24	0.57	0.57	0.53
2001	1.71	1.72	0.86	0.55	0.56	0.39
2002	0.66	0.66	0.35	0.61	0.62	0.50
2003	2.21	2.25	1.03	0.65	0.67	0.44
2004	0.96	0.97	0.46	0.68	0.67	0.43
2005	0.87	0.87	0.42	0.57	0.57	0.41
2006	1.41	1.38	0.62	0.52	0.53	0.31
2007	0.35	0.35	0.17	0.78	0.78	0.59
2008	0.86	0.85	0.38	0.67	0.67	0.44
2009	0.38	0.38	0.18	0.46	0.48	0.38
2010	0.20	0.20	0.10	0.36	0.37	0.33
2011	1.20	1.21	0.50	0.79	0.81	0.58
2012	0.61	0.61	0.27	0.66	0.66	0.50
2013	0.76	0.76	0.31	0.83	0.84	0.56

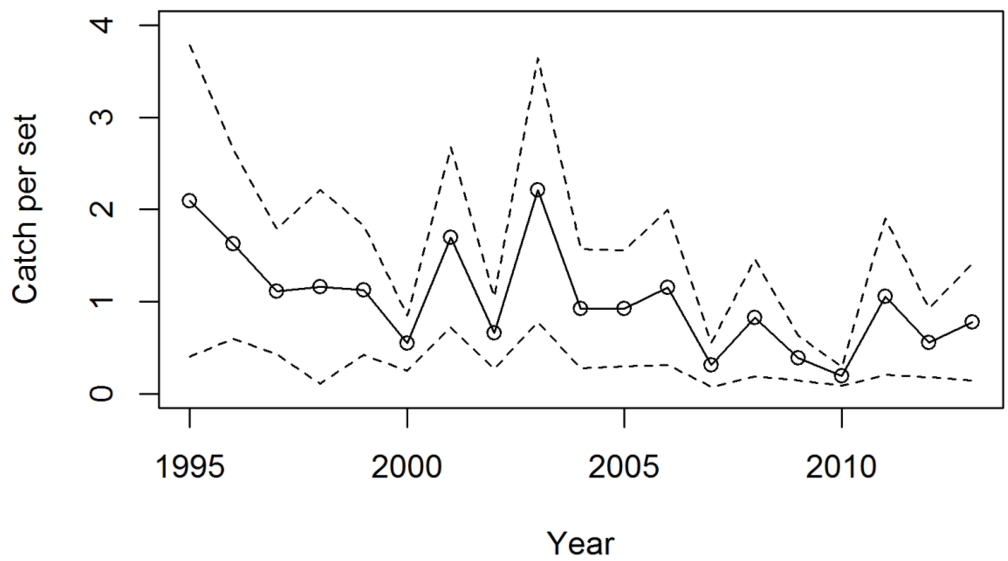


Figure 1: Catch per set for the nominal index (open circles) and for the standardized index (black line) from the Poisson model with +/- one standard deviation (dashed lines). Data from both fishery sectors were used.

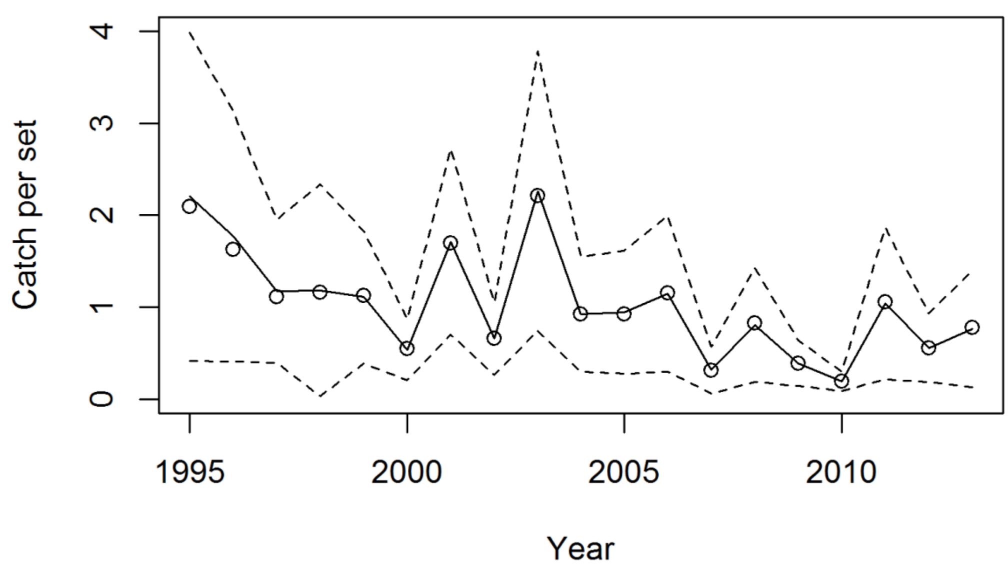


Figure 2: Catch per set for the nominal index (open circles) and for the standardized index (black line) from the zero-inflated negative binomial model with +/- one standard deviation (dashed lines). Data from both fishery sectors were used.

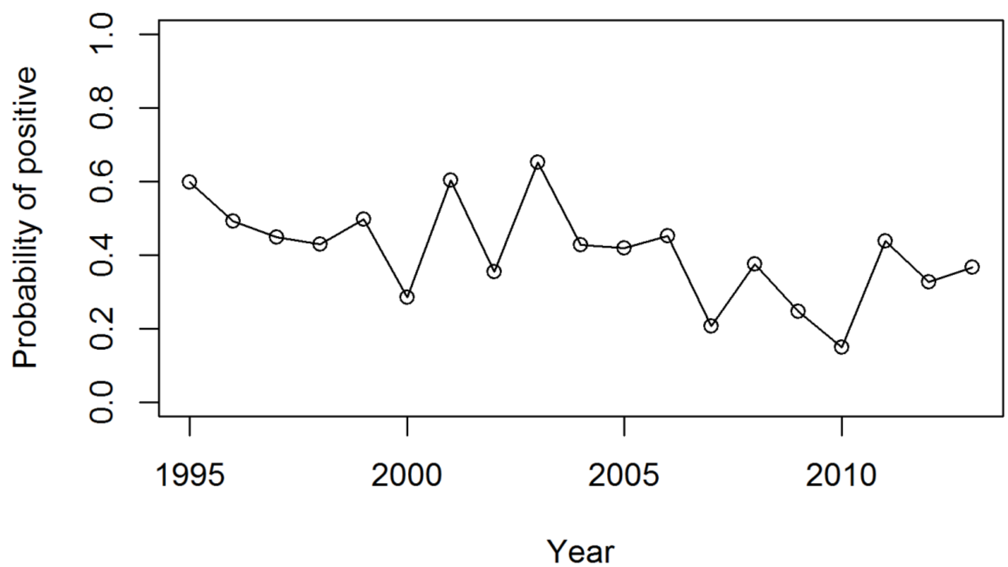


Figure 3: The nominal probability of a striped marlin capture (open circles) and the standardized probability of capture (black line) from the zero process for the delta-lognormal model. Data from both fishery sectors were used.

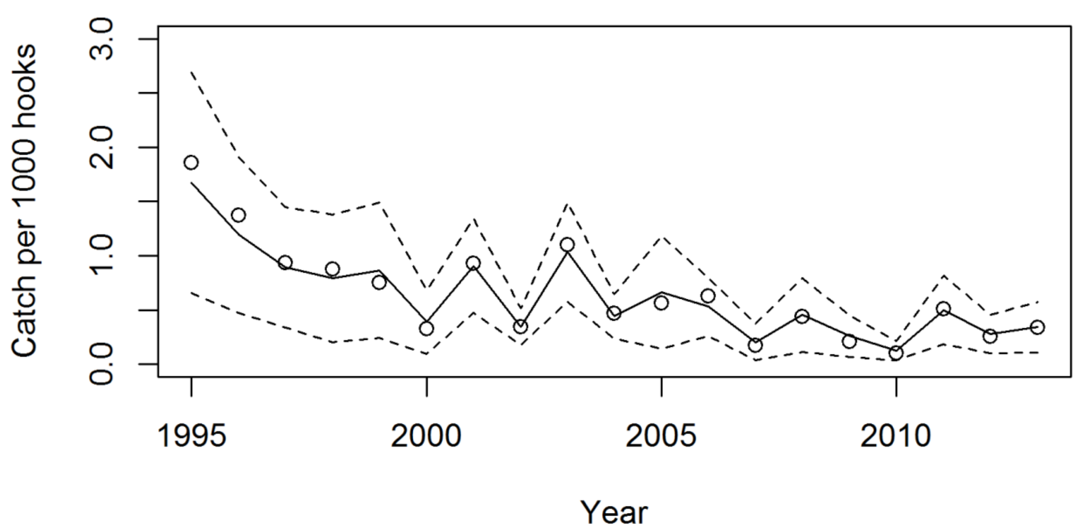


Figure 4: Catch per 1000 hooks for the nominal index (open circles) and for the standardized index (black line) from the delta-lognormal model with +/- one standard deviation (dashed lines). Data from both fishery sectors were used.

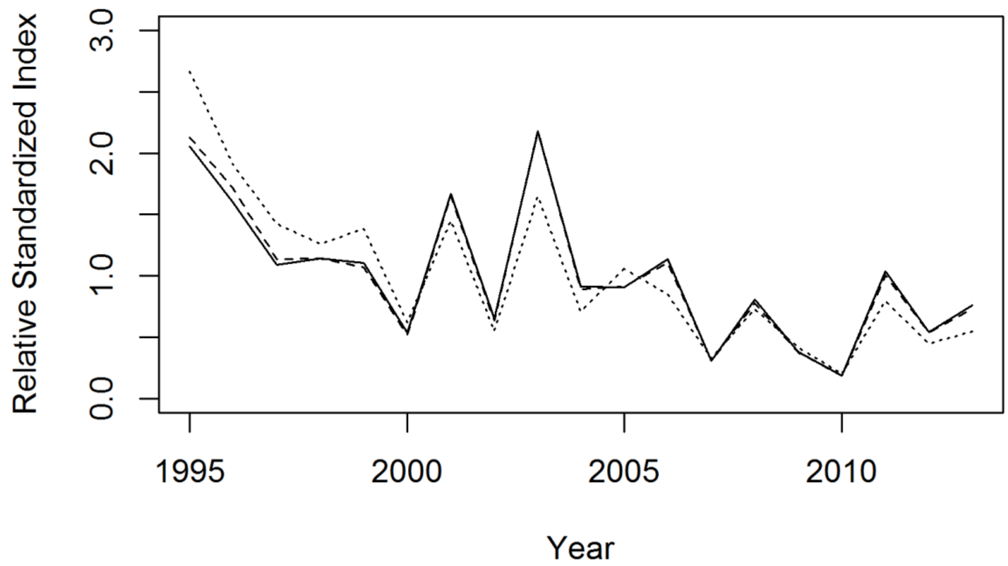


Figure 5: Standardized indices of abundance scaled to their mean from the Poisson model (black line), the zero-inflated negative binomial model (dashed line), and the delta-lognormal model (dotted line). Data from both fishery sectors were used.

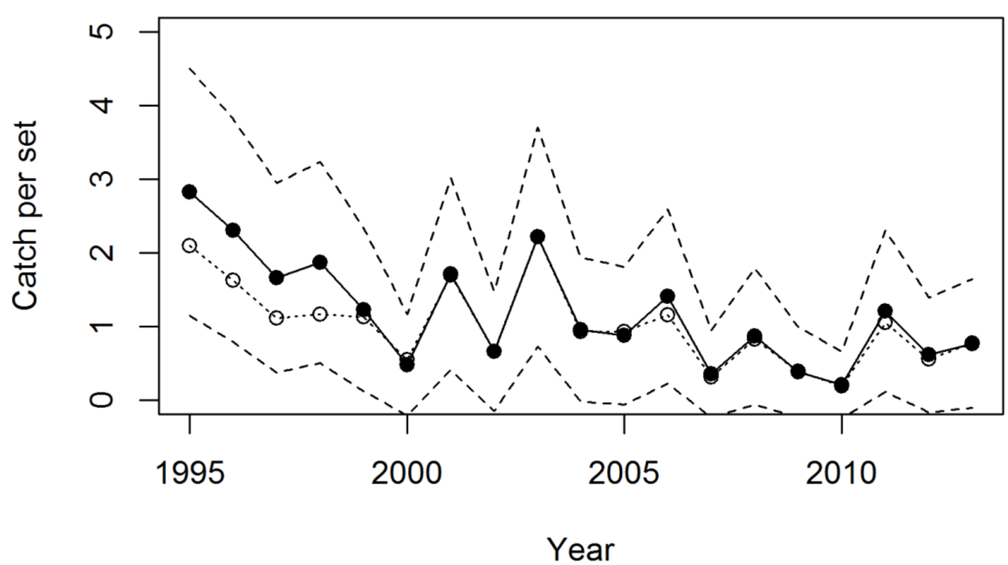


Figure 6: Catch per set for the nominal data (open circles) and standardized index from the Poisson distribution (dotted line) when using the shallow-set and deep-set

sector data combined, and the nominal data (closed circles) and standardized index from the Poisson distribution (solid line), along with +/- one standard deviation (dashed lines) when using the deep-set sector data only.

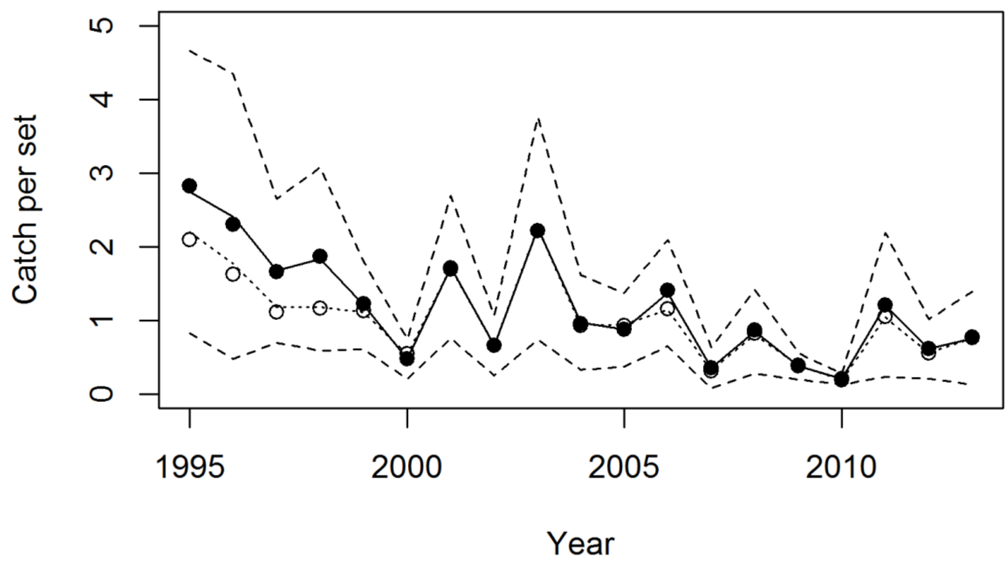


Figure 7: Catch per set for the nominal data (open circles) and standardized index from the zero-inflated negative binomial (ZINB) distribution (dotted line) when using the shallow-set and deep-set sector data combined, and the nominal data (closed circles) and standardized index from the ZINB (solid line), along with +/- one standard deviation (dashed lines) when using the deep-set sector data only.

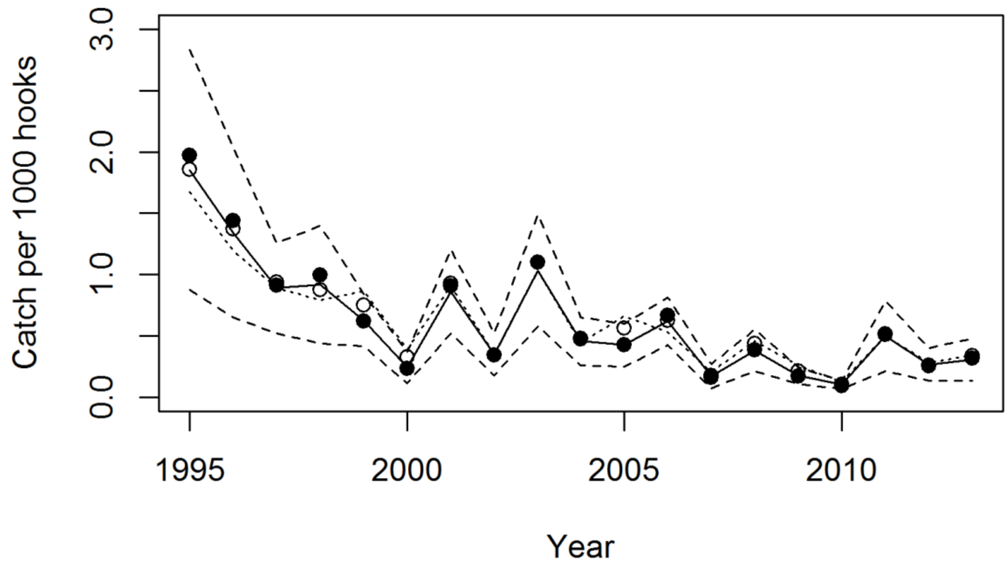


Figure 8: Catch per 1000 hooks for the nominal data (open circles) and standardized index from the delta-lognormal (DLN) distribution (dotted line) when using the shallow-set and deep-set sector data combined, and the nominal data (closed circles) and standardized index from the DLN (solid line), along with +/- one standard deviation (dashed lines) when using the deep-set sector data only.

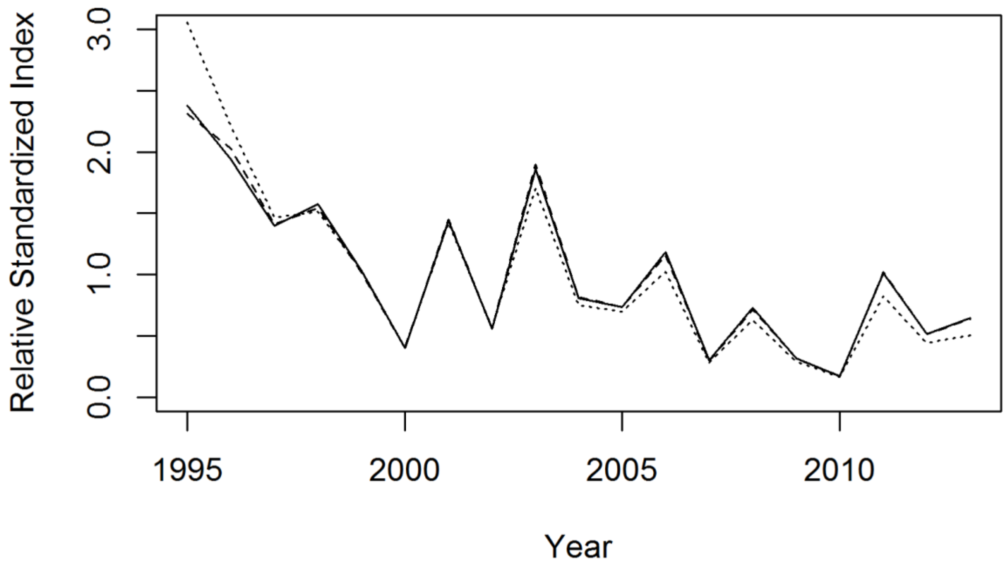


Figure 9: Standardized indices of abundance scaled to their mean from the Poisson model (black line), the zero-inflated negative binomial model (dashed line), and the delta-lognormal model (dotted line) when using data from only the deep-set sector.

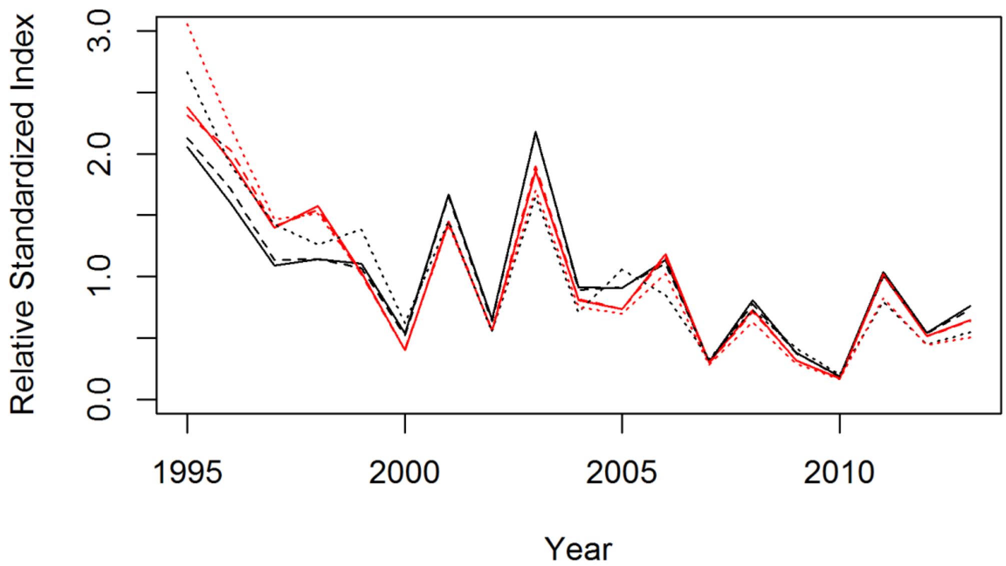


Figure 10: Standardized indices of abundance scaled to their mean from the Poisson model for combined data (solid black line) and deep-set data (solid red line), the zero-inflated negative binomial model for combined data (dashed black line) and deep-set data (dashed red line), and the delta-lognormal model for combined data (dotted black line) and deep-set data (dashed red line).

Appendices

Overview

These appendices include residual diagnostic plots as well as summary output from R on the best models for each distribution under both choices of data (deep-set and shallow-set data combined, and deep-set data only).

For analyses using the combined data the appendices are:

Appendix 1: Pearson residual plots and R summary output for the Poisson distribution.

Appendix 2: Pearson residual plots and R summary output for the zero inflated negative binomial.

Appendix 3a: Quantile residual plots and R summary output for the zero process of the delta lognormal.

Appendix 3b: Pearson residual plots, quantile-quantile plot, and R summary output for the positive process of the delta-lognormal.

For analyses using the deep-set data only the appendices are:

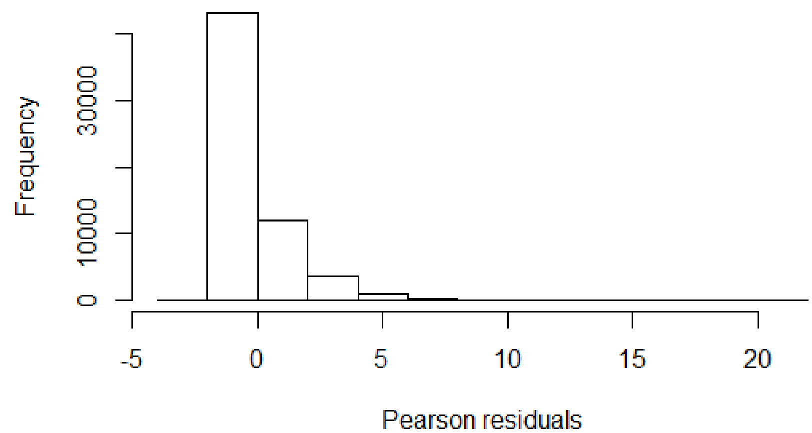
Appendix 4: Pearson residual plots and R summary output for the Poisson distribution.

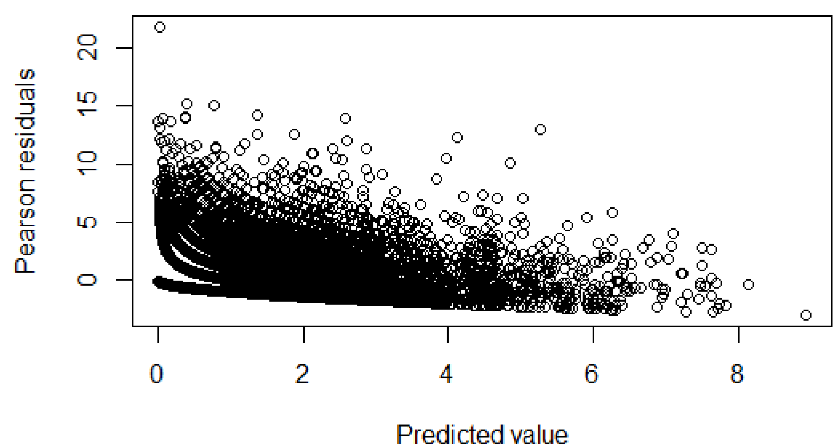
Appendix 5: Pearson residual plots and R summary output for the zero-inflated negative binomial.

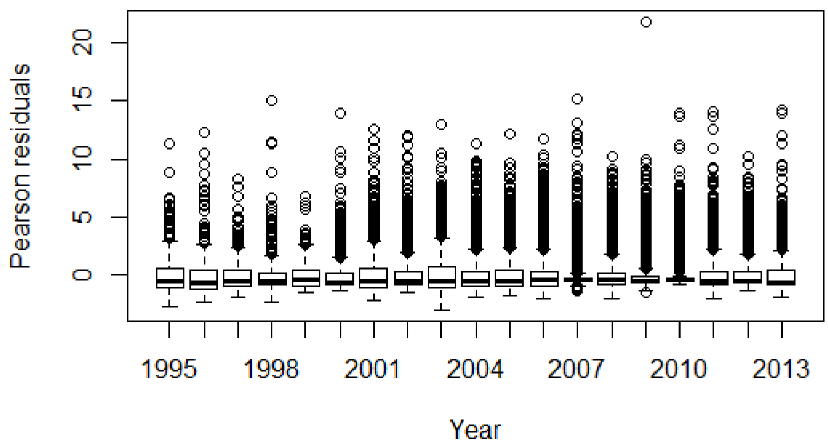
Appendix 6a: Quantile residual plots and R summary output for the zero process of the delta-lognormal.

Appendix 6b: Pearson residual plots, quantile-quantile plot, and R summary output for the positive process of the delta-lognormal.

Appendix 1: Pearson residual plots and R summary output for the Poisson distribution for the combined data. Boxplots represent the median (line), the 1st and 3rd quartiles (box), data up to 1.5 times the interquartile range (IQR) from the quartiles (whiskers), and data beyond 1.5 times the IQR from the quartiles (open circles).






Pearson residuals
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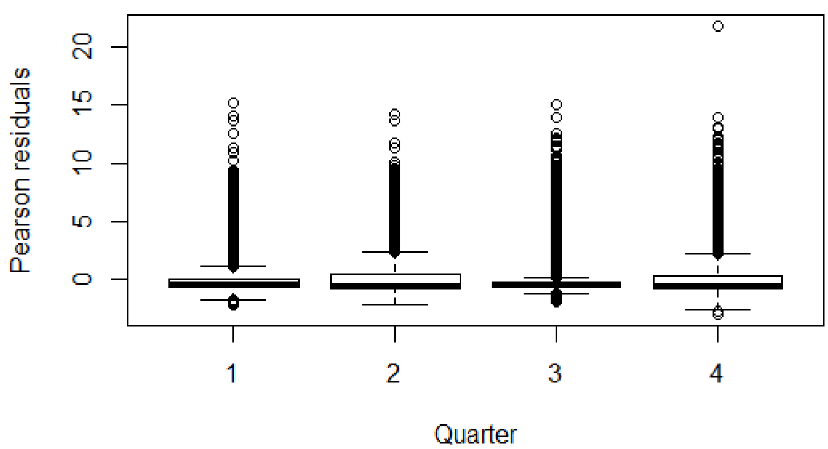
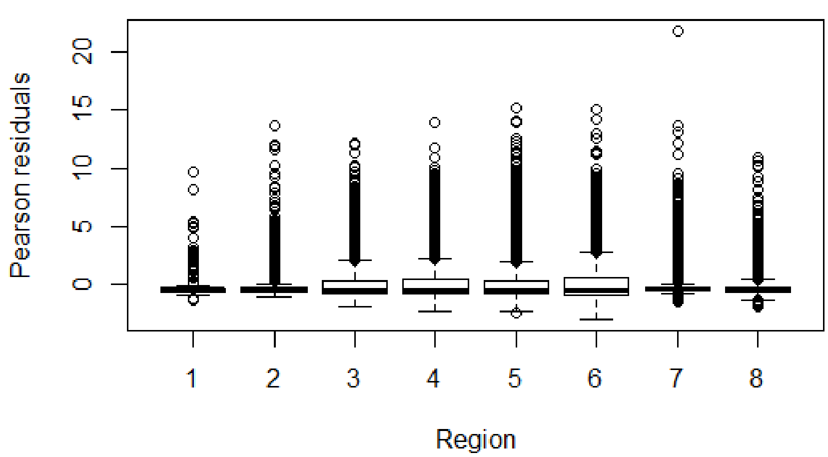
5
10
15
20
1995
1998
2001
2004
2007
2010
2013
Year


Pearson residuals
0
5
10
15
20
1
2
3
4
Quarter


Pearson residuals
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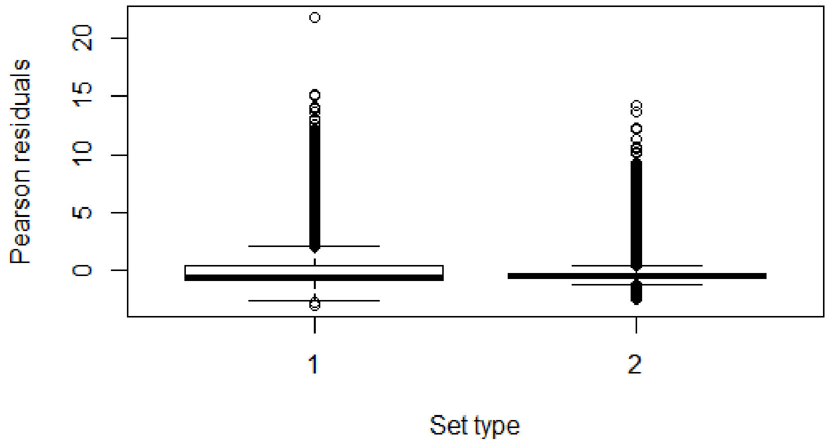
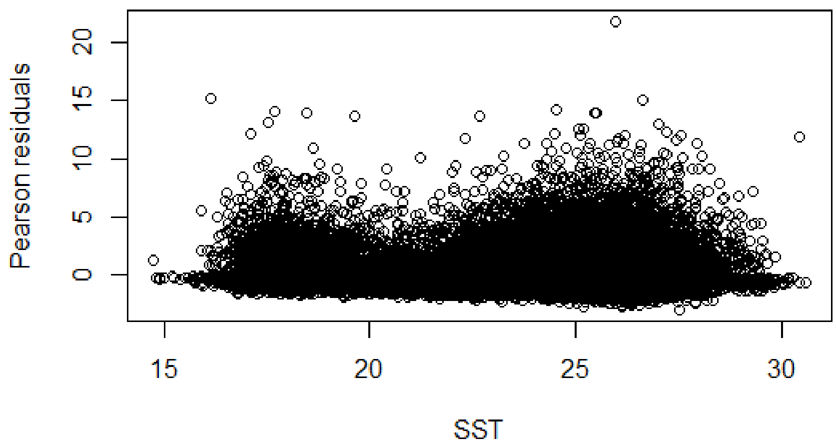
5
10
15
20
1
2
3
4
5
6
7
8
Region


Pearson residuals
0
5
10
15
20
1
2
Set type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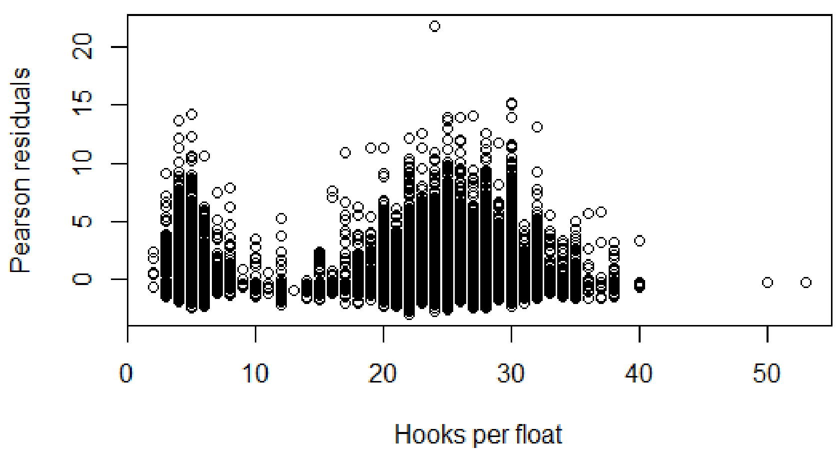
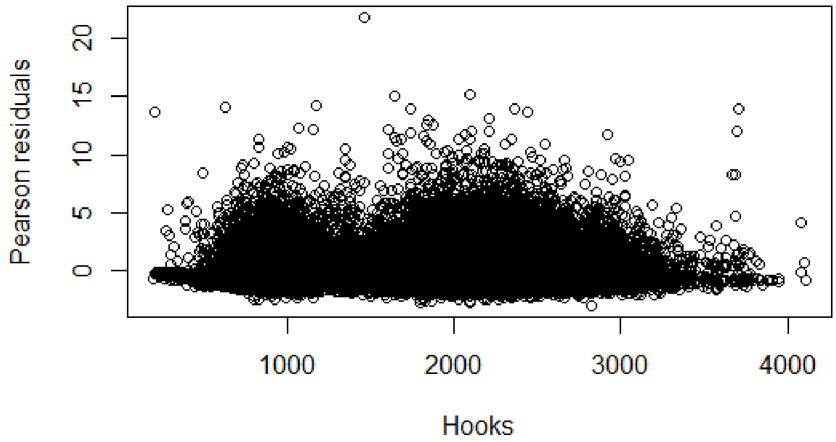
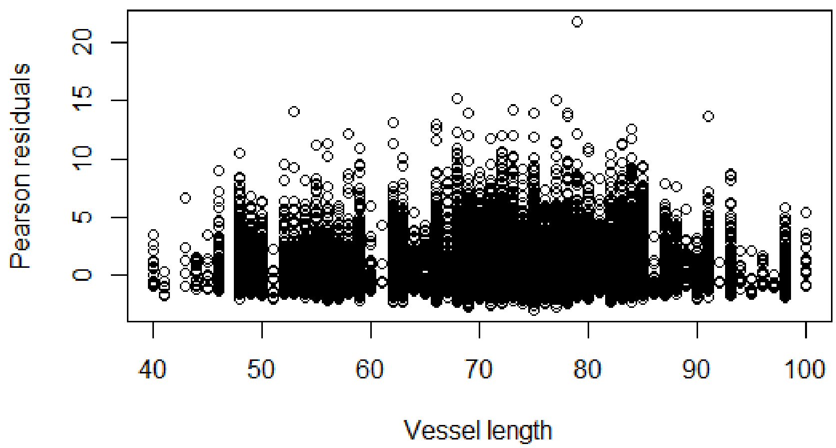
5
10
15
20
15
20
25
30
SST


Pearson residuals
0
5
10
15
20
0
10
20
30
40
50
Hooks per float






```
>summary(P_full)
Call:
glm(formula = Striped_Marlin ~ Haulyr1 + Quarter1 + Region1 +
    Set_type1 + SST + I(SST^2) + Set_type1:Hkpfl + Set_type1:Vesslen +
    Haulyr1:Quarter1 + Region1:Quarter1 + offset(log(Hooks)),
    family = poisson(link = "log"), data = simp_obs)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4.2260  -1.0234  -0.6299   0.2639   8.5439
```

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.294e+01	6.245e-01	-20.713	< 2e-16	***
Haulyr11996	7.880e-02	8.234e-02	0.957	0.338603	
Haulyr11997	-6.352e-01	1.005e-01	-6.321	2.60e-10	***
Haulyr11998	-3.952e-01	1.062e-01	-3.721	0.000198	***
Haulyr11999	-1.074e+00	1.243e-01	-8.641	< 2e-16	***
Haulyr12000	-1.085e+00	1.102e-01	-9.839	< 2e-16	***
Haulyr12001	-6.281e-01	7.103e-02	-8.844	< 2e-16	***
Haulyr12002	-8.606e-01	7.276e-02	-11.828	< 2e-16	***
Haulyr12003	-3.692e-01	7.028e-02	-5.254	1.49e-07	***
Haulyr12004	-3.984e-01	7.033e-02	-5.665	1.47e-08	***
Haulyr12005	-8.646e-01	7.246e-02	-11.932	< 2e-16	***
Haulyr12006	-1.075e+00	8.384e-02	-12.821	< 2e-16	***
Haulyr12007	-1.269e+00	8.472e-02	-14.978	< 2e-16	***
Haulyr12008	-1.686e+00	7.719e-02	-21.837	< 2e-16	***
Haulyr12009	-1.913e+00	8.117e-02	-23.571	< 2e-16	***
Haulyr12010	-2.760e+00	9.631e-02	-28.655	< 2e-16	***
Haulyr12011	-5.101e-01	6.891e-02	-7.403	1.34e-13	***
Haulyr12012	-1.195e+00	7.209e-02	-16.573	< 2e-16	***
Haulyr12013	-2.196e+00	8.213e-02	-26.737	< 2e-16	***
Quarter12	1.346e-01	5.798e-01	0.232	0.816373	
Quarter13	1.747e+00	5.376e-01	3.251	0.001152	**
Quarter14	9.521e-01	7.127e-01	1.336	0.181570	
Region12	1.114e+00	5.050e-01	2.206	0.027373	*
Region13	2.078e+00	5.012e-01	4.146	3.39e-05	***

Region14	2.295e+00	5.012e-01	4.579	4.68e-06	***
Region15	2.113e+00	5.014e-01	4.214	2.51e-05	***
Region16	2.326e+00	5.013e-01	4.640	3.49e-06	***
Region17	4.267e-01	5.037e-01	0.847	0.396870	
Region18	3.934e-01	5.110e-01	0.770	0.441299	
Set_type12	7.370e-02	1.794e-01	0.411	0.681129	
SST	4.811e-01	3.226e-02	14.913	< 2e-16	***
I(SST^2)	-1.010e-02	7.050e-04	-14.323	< 2e-16	***
Set_type11:Hkpfl	-5.064e-02	1.643e-03	-30.829	< 2e-16	***
Set_type12:Hkpfl	8.557e-02	1.120e-02	7.637	2.22e-14	***
Set_type11:Vesslen	-1.305e-03	4.865e-04	-2.682	0.007323	**
Set_type12:Vesslen	-1.584e-02	1.871e-03	-8.468	< 2e-16	***
Haulyr11996:Quarter12	-3.494e-01	1.162e-01	-3.007	0.002642	**
Haulyr11997:Quarter12	6.163e-01	1.339e-01	4.603	4.16e-06	***
Haulyr11998:Quarter12	-1.138e+00	2.650e-01	-4.295	1.74e-05	***
Haulyr11999:Quarter12	7.174e-01	1.536e-01	4.671	3.00e-06	***
Haulyr12000:Quarter12	1.695e-01	1.562e-01	1.085	0.277860	
Haulyr12001:Quarter12	5.571e-01	1.001e-01	5.564	2.64e-08	***
Haulyr12002:Quarter12	-2.005e-01	1.056e-01	-1.898	0.057684	.
Haulyr12003:Quarter12	2.832e-02	9.734e-02	0.291	0.771055	
Haulyr12004:Quarter12	-4.747e-01	9.999e-02	-4.747	2.06e-06	***
Haulyr12005:Quarter12	4.539e-01	9.465e-02	4.796	1.62e-06	***
Haulyr12006:Quarter12	5.782e-01	1.065e-01	5.429	5.66e-08	***
Haulyr12007:Quarter12	1.608e-02	1.107e-01	0.145	0.884517	
Haulyr12008:Quarter12	9.895e-01	9.878e-02	10.016	< 2e-16	***
Haulyr12009:Quarter12	6.311e-01	1.051e-01	6.002	1.95e-09	***
Haulyr12010:Quarter12	4.657e-01	1.256e-01	3.707	0.000210	***

Haulyr12011:Quarter12 -6.560e-01 9.524e-02 -6.888 5.66e-12 ***

Haulyr12012:Quarter12 -5.791e-01 1.007e-01 -5.752 8.83e-09 ***

Haulyr12013:Quarter12 8.778e-01 1.060e-01 8.278 < 2e-16 ***

Haulyr11996:Quarter13 -1.155e-01 1.827e-01 -0.632 0.527182

Haulyr11997:Quarter13 1.190e+00 2.127e-01 5.595 2.21e-08 ***

Haulyr11998:Quarter13 1.446e-01 1.805e-01 0.801 0.423167

Haulyr11999:Quarter13 9.690e-01 2.617e-01 3.703 0.000213 ***

Haulyr12000:Quarter13 2.950e-01 2.168e-01 1.361 0.173628

Haulyr12001:Quarter13 7.868e-01 1.478e-01 5.323 1.02e-07 ***

Haulyr12002:Quarter13 -5.771e-01 1.606e-01 -3.593 0.000327 ***

Haulyr12003:Quarter13 1.459e-02 1.406e-01 0.104 0.917326

Haulyr12004:Quarter13 -6.068e-02 1.438e-01 -0.422 0.673142

Haulyr12005:Quarter13 -1.492e-01 1.435e-01 -1.040 0.298549

Haulyr12006:Quarter13 1.388e+00 1.447e-01 9.591 < 2e-16 ***

Haulyr12007:Quarter13 -2.560e-01 1.603e-01 -1.597 0.110359

Haulyr12008:Quarter13 6.465e-01 1.454e-01 4.446 8.75e-06 ***

Haulyr12009:Quarter13 5.678e-01 1.504e-01 3.776 0.000159 ***

Haulyr12010:Quarter13 9.171e-01 1.643e-01 5.582 2.37e-08 ***

Haulyr12011:Quarter13 -1.216e+00 1.492e-01 -8.150 3.63e-16 ***

Haulyr12012:Quarter13 -5.893e-01 1.517e-01 -3.884 0.000103 ***

Haulyr12013:Quarter13 9.240e-01 1.489e-01 6.205 5.48e-10 ***

Haulyr11996:Quarter14 -5.266e-01 1.152e-01 -4.571 4.86e-06 ***

Haulyr11997:Quarter14 -9.680e-01 1.618e-01 -5.983 2.18e-09 ***

Haulyr11998:Quarter14 -2.410e-01 1.269e-01 -1.898 0.057644 .

Haulyr11999:Quarter14 -7.149e-02 1.539e-01 -0.464 0.642331

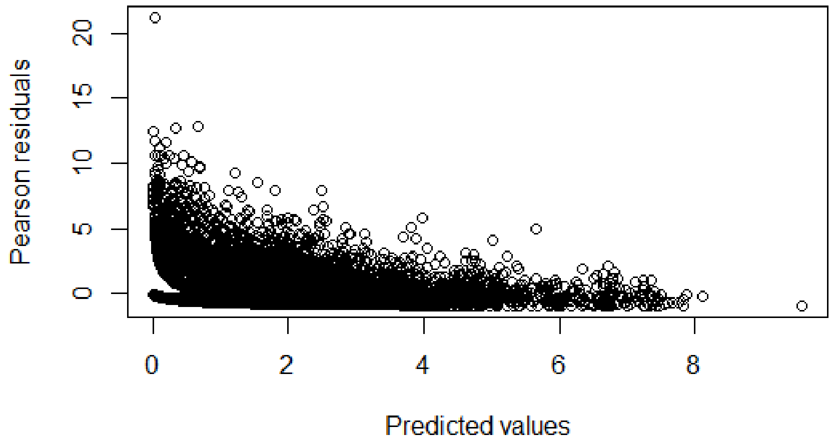
Haulyr12000:Quarter14 -9.530e-01 1.283e-01 -7.427 1.11e-13 ***

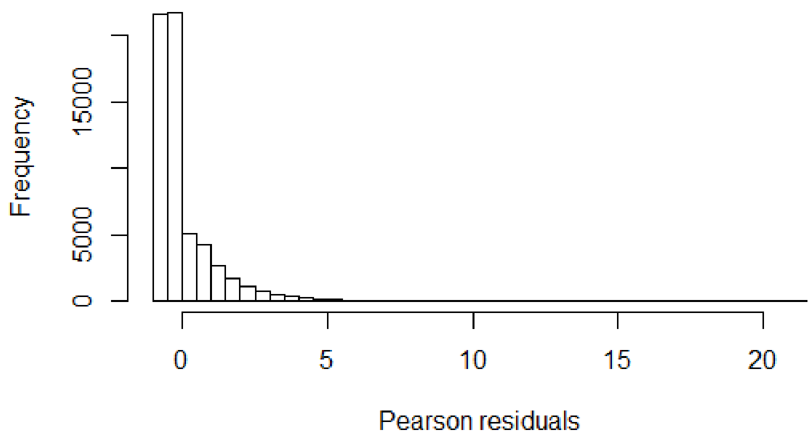
Haulyr12001:Quarter14 -5.890e-02 8.628e-02 -0.683 0.494801

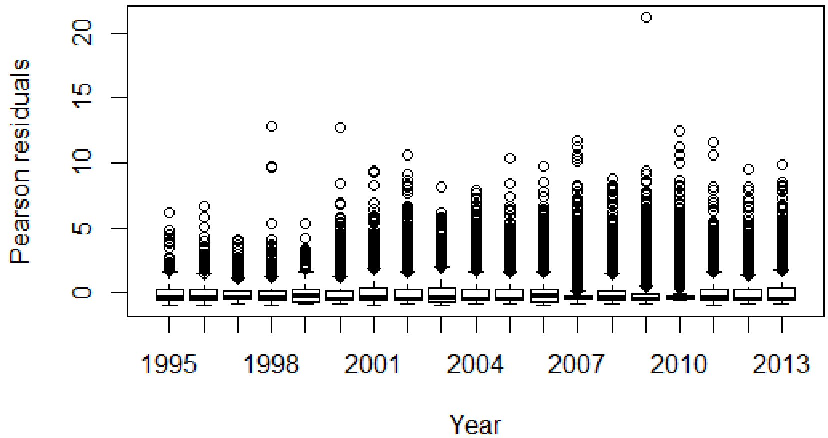
Haulyr12002:Quarter14	-9.974e-01	9.366e-02	-10.649	< 2e-16	***
Haulyr12003:Quarter14	8.964e-02	8.459e-02	1.060	0.289253	
Haulyr12004:Quarter14	-1.246e+00	8.833e-02	-14.108	< 2e-16	***
Haulyr12005:Quarter14	-7.043e-01	9.169e-02	-7.681	1.58e-14	***
Haulyr12006:Quarter14	4.453e-02	9.740e-02	0.457	0.647532	
Haulyr12007:Quarter14	-1.792e+00	1.063e-01	-16.857	< 2e-16	***
Haulyr12008:Quarter14	1.588e-01	9.445e-02	1.682	0.092627	.
Haulyr12009:Quarter14	-1.081e+00	1.083e-01	-9.976	< 2e-16	***
Haulyr12010:Quarter14	-6.674e-01	1.274e-01	-5.237	1.63e-07	***
Haulyr12011:Quarter14	-1.213e+00	8.707e-02	-13.936	< 2e-16	***
Haulyr12012:Quarter14	-1.410e+00	9.459e-02	-14.906	< 2e-16	***
Haulyr12013:Quarter14	7.798e-01	9.679e-02	8.057	7.83e-16	***
Quarter12:Region12	-8.459e-01	5.863e-01	-1.443	0.149063	
Quarter13:Region12	-2.618e+00	5.345e-01	-4.899	9.63e-07	***
Quarter14:Region12	-5.813e-01	7.217e-01	-0.806	0.420517	
Quarter12:Region13	-8.171e-01	5.738e-01	-1.424	0.154427	
Quarter13:Region13	-3.626e+00	5.249e-01	-6.908	4.92e-12	***
Quarter14:Region13	-6.608e-01	7.088e-01	-0.932	0.351209	
Quarter12:Region14	-6.486e-01	5.733e-01	-1.131	0.257906	
Quarter13:Region14	-3.643e+00	5.234e-01	-6.961	3.38e-12	***
Quarter14:Region14	-7.778e-01	7.087e-01	-1.097	0.272429	
Quarter12:Region15	-5.766e-01	5.738e-01	-1.005	0.314961	
Quarter13:Region15	-2.728e+00	5.219e-01	-5.227	1.72e-07	***
Quarter14:Region15	-2.772e-01	7.085e-01	-0.391	0.695658	
Quarter12:Region16	-2.601e-02	5.736e-01	-0.045	0.963826	
Quarter13:Region16	-2.580e+00	5.232e-01	-4.932	8.14e-07	***
Quarter14:Region16	-1.994e-01	7.085e-01	-0.281	0.778340	

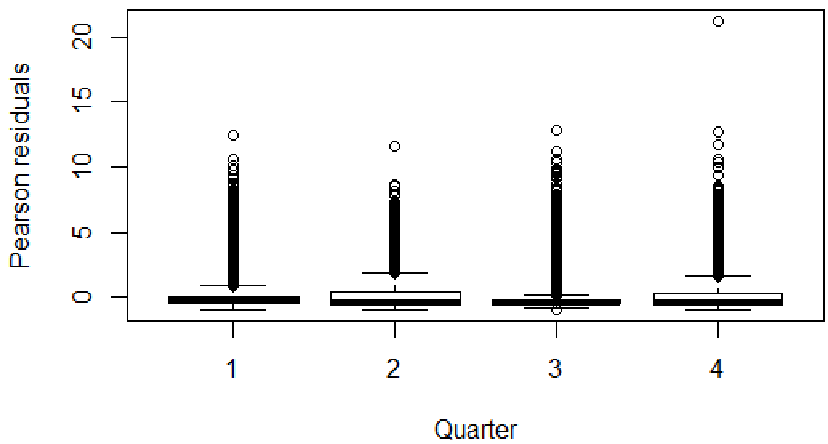
```
Quarter12:Region17     3.067e-01  5.835e-01   0.526 0.599157
Quarter13:Region17    -1.083e+00  5.249e-01  -2.064 0.039065 *
Quarter14:Region17    -5.109e-01  7.165e-01  -0.713 0.475770
Quarter12:Region18     1.115e+00  5.853e-01   1.906 0.056651 .
Quarter13:Region18    -5.374e-01  5.320e-01  -1.010 0.312421
Quarter14:Region18     5.394e-01  7.240e-01   0.745 0.456241
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
(Dispersion parameter for poisson family taken to be 1)
    Null deviance: 131078  on 60314  degrees of freedom
Residual deviance:  89212  on 60204  degrees of freedom
AIC: 145795
Number of Fisher Scoring iterations: 6
```

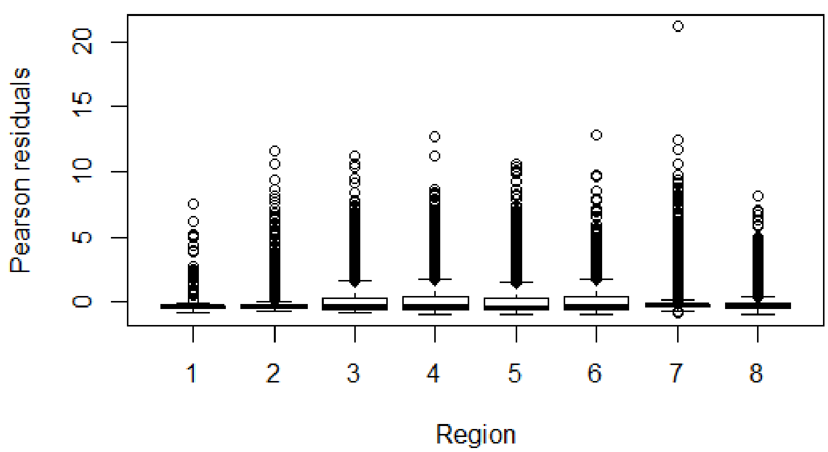
Appendix 2: Pearson residual plots and R summary output for the zero inflated negative binomial for the combined data. Boxplots represent the median (line), the 1st and 3rd quartiles (box), data up to 1.5 times the interquartile range (IQR) from the quartiles (whiskers), and data beyond 1.5 times the IQR from the quartiles (open circles).

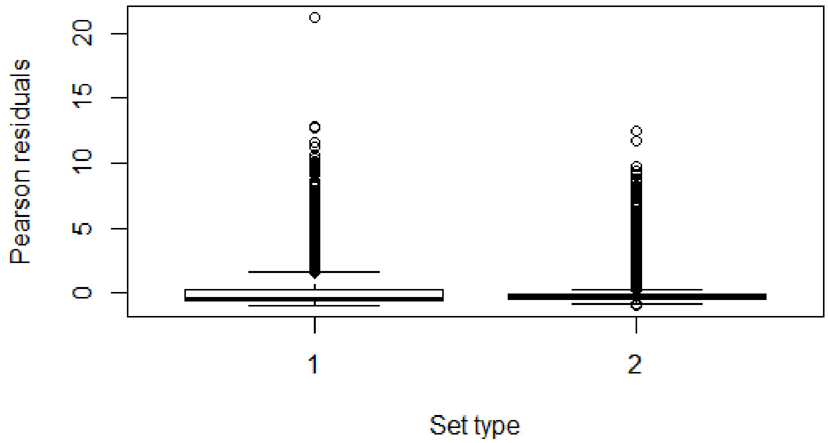




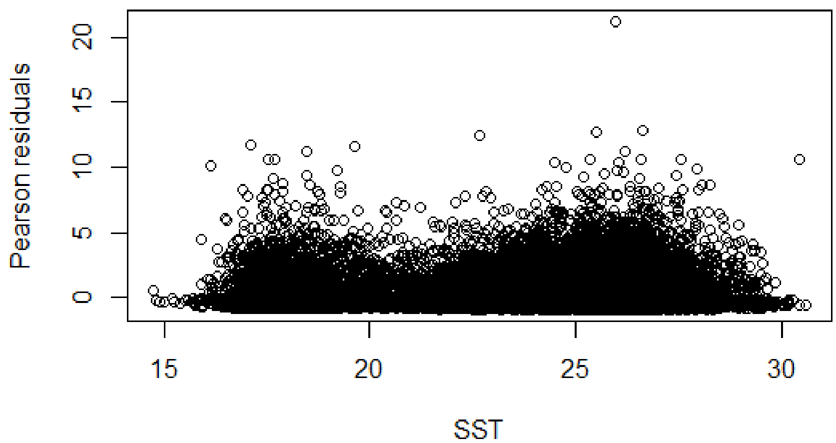

Pearson residuals
0
5
10
15
20
1995
1998
2001
2004
2007
2010
2013
Year


Pearson residuals
0
5
10
15
20
1
2
3
4
Quarter

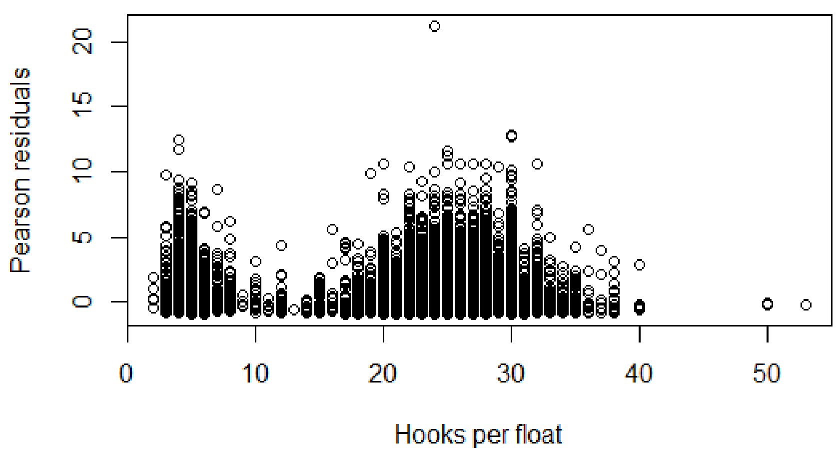

Pearson residuals
0
5
10
15
20
1
2
3
4
5
6
7
8
Region



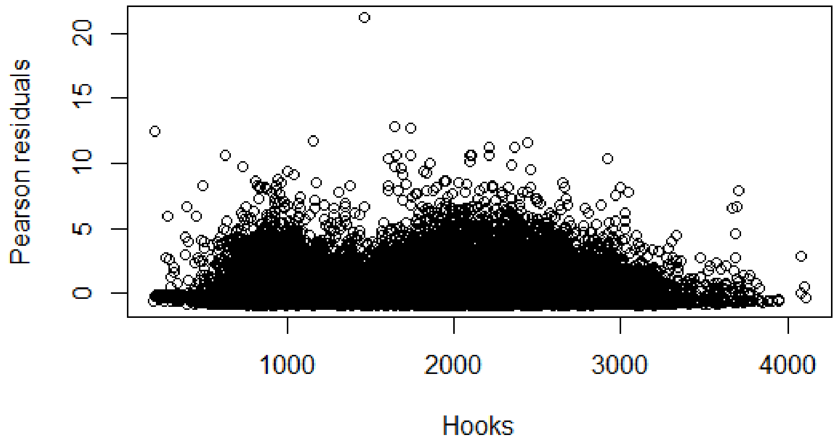
Pearson residuals
0
5
10
15
20
1
2
Set type

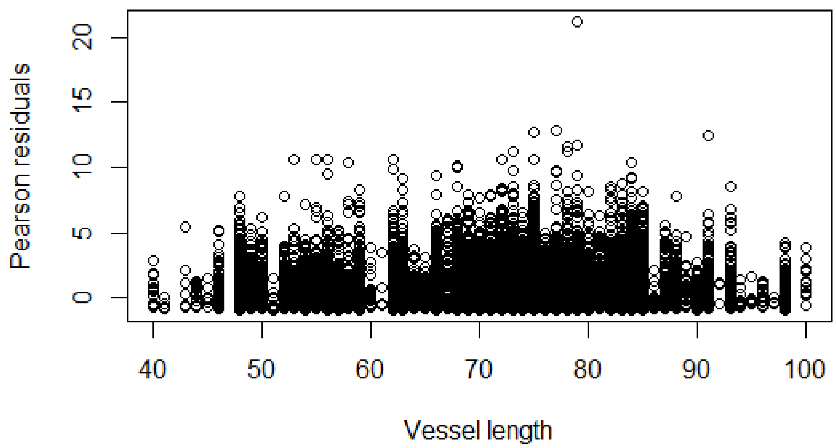


Pearson residuals
0
5
10
15
20
15
20
25
30
SST



Pearson residuals
0
5
10
15
20
0
10
20
30
40
50
Hooks per float






```
>summary(ZNB_full)
Call:
zeroinfl(formula = Striped_Marlin ~ Haulyr1 + Region1 + Quarter1 +
    Haulyr1:Quarter1 + Region1:Quarter1 + Set_type1 + Set_type1:Hkpfl +
    Set_type1:Vesslen + SST + I(SST^2) + offset(log(Hooks)) | Set_type1 +
    SST + I(SST^2), data = simp_obs, dist = "negbin", link = "logit")

Pearson residuals:
    Min      1Q  Median      3Q     Max
-0.9861 -0.5764 -0.3985  0.1873 21.2627
```

Count model coefficients (negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-9.9874980	0.5381269	-18.560	< 2e-16	***
Haulyr11996	0.3176974	0.1588331	2.000	0.045479	*
Haulyr11997	-0.4540763	0.1782870	-2.547	0.010869	*
Haulyr11998	-0.5448917	0.1832345	-2.974	0.002942	**
Haulyr11999	-1.1174192	0.1885276	-5.927	3.08e-09	***
Haulyr12000	-1.1490743	0.1672611	-6.870	6.42e-12	***
Haulyr12001	-0.6857755	0.1235384	-5.551	2.84e-08	***
Haulyr12002	-0.9185074	0.1243284	-7.388	1.49e-13	***
Haulyr12003	-0.3997571	0.1236047	-3.234	0.001220	**
Haulyr12004	-0.4533455	0.1237108	-3.665	0.000248	***
Haulyr12005	-0.9368540	0.1237290	-7.572	3.68e-14	***
Haulyr12006	-1.1755223	0.1339343	-8.777	< 2e-16	***
Haulyr12007	-1.3694574	0.1341324	-10.210	< 2e-16	***
Haulyr12008	-1.7892529	0.1264578	-14.149	< 2e-16	***
Haulyr12009	-2.0277616	0.1294992	-15.658	< 2e-16	***
Haulyr12010	-2.8830486	0.1393224	-20.693	< 2e-16	***
Haulyr12011	-0.6545101	0.1217916	-5.374	7.70e-08	***
Haulyr12012	-1.3012936	0.1237550	-10.515	< 2e-16	***
Haulyr12013	-2.2780948	0.1302159	-17.495	< 2e-16	***
Region12	1.1070738	0.5344610	2.071	0.038323	*
Region13	2.0359932	0.5299732	3.842	0.000122	***
Region14	2.2399389	0.5299034	4.227	2.37e-05	***
Region15	2.0402721	0.5302952	3.847	0.000119	***
Region16	2.3578802	0.5303458	4.446	8.75e-06	***

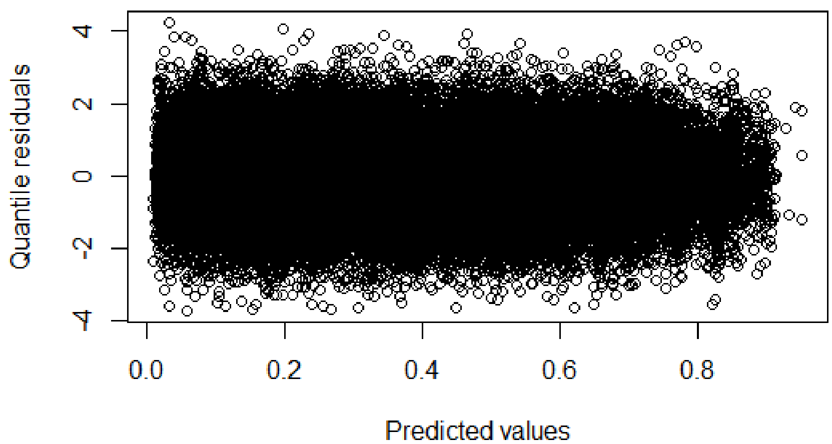
Region17	0.4452067	0.5335733	0.834	0.404063	
Region18	0.4300103	0.5416655	0.794	0.427273	
Quarter12	0.1888424	0.6297602	0.300	0.764281	
Quarter13	1.5948883	0.5937983	2.686	0.007233	**
Quarter14	0.8650765	0.7935962	1.090	0.275682	
Set_type12	0.3850990	0.2843677	1.354	0.175663	
SST	0.2722282	NA	NA	NA	
I(SST^2)	-0.0062555	NA	NA	NA	
Haulyr11996:Quarter12	-0.6574048	0.2124298	-3.095	0.001970	**
Haulyr11997:Quarter12	0.4688114	0.2385962	1.965	0.049429	*
Haulyr11998:Quarter12	-0.9197882	0.3638754	-2.528	0.011479	*
Haulyr11999:Quarter12	0.5892383	0.2458490	2.397	0.016541	*
Haulyr12000:Quarter12	0.1363044	0.2399408	0.568	0.569984	
Haulyr12001:Quarter12	0.5097008	0.1763522	2.890	0.003849	**
Haulyr12002:Quarter12	-0.2315989	0.1758745	-1.317	0.187892	
Haulyr12003:Quarter12	-0.0100172	0.1721896	-0.058	0.953609	
Haulyr12004:Quarter12	-0.4786729	0.1721232	-2.781	0.005419	**
Haulyr12005:Quarter12	0.3715042	0.1670636	2.224	0.026167	*
Haulyr12006:Quarter12	0.5607232	0.1771111	3.166	0.001546	**
Haulyr12007:Quarter12	-0.0153724	0.1796964	-0.086	0.931827	
Haulyr12008:Quarter12	0.9405833	0.1690313	5.565	2.63e-08	***
Haulyr12009:Quarter12	0.5809664	0.1738280	3.342	0.000831	***
Haulyr12010:Quarter12	0.4234190	0.1872629	2.261	0.023753	*
Haulyr12011:Quarter12	-0.6737001	0.1686413	-3.995	6.47e-05	***
Haulyr12012:Quarter12	-0.6003908	0.1715584	-3.500	0.000466	***
Haulyr12013:Quarter12	0.7941246	0.1751895	4.533	5.82e-06	***
Haulyr11996:Quarter13	-0.5128265	0.2755146	-1.861	0.062696	.

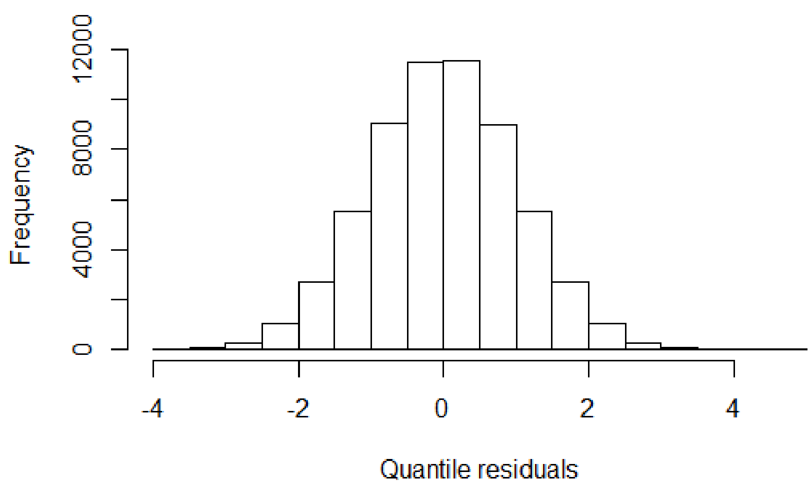
Haulyr11997:Quarter13	0.6188993	0.3291686	1.880	0.060082	.
Haulyr11998:Quarter13	0.2087311	0.2710918	0.770	0.441321	
Haulyr11999:Quarter13	0.9826839	0.3625465	2.711	0.006718	**
Haulyr12000:Quarter13	0.1797684	0.2883139	0.624	0.532945	
Haulyr12001:Quarter13	0.8527101	0.2152704	3.961	7.46e-05	***
Haulyr12002:Quarter13	-0.4076146	0.2221224	-1.835	0.066492	.
Haulyr12003:Quarter13	0.1723124	0.2075767	0.830	0.406474	
Haulyr12004:Quarter13	0.1127522	0.2103387	0.536	0.591924	
Haulyr12005:Quarter13	0.0337833	0.2075807	0.163	0.870717	
Haulyr12006:Quarter13	1.5247278	0.2116870	7.203	5.90e-13	***
Haulyr12007:Quarter13	-0.1287997	0.2229738	-0.578	0.563504	
Haulyr12008:Quarter13	0.7483616	0.2098641	3.566	0.000363	***
Haulyr12009:Quarter13	0.7164168	0.2137373	3.352	0.000803	***
Haulyr12010:Quarter13	1.0867093	0.2236914	4.858	1.19e-06	***
Haulyr12011:Quarter13	-1.0209069	0.2120524	-4.814	1.48e-06	***
Haulyr12012:Quarter13	-0.4162528	0.2143161	-1.942	0.052108	.
Haulyr12013:Quarter13	1.0893362	0.2118159	5.143	2.71e-07	***
Haulyr11996:Quarter14	-0.9594602	0.2253145	-4.258	2.06e-05	***
Haulyr11997:Quarter14	-1.1666409	0.2619275	-4.454	8.43e-06	***
Haulyr11998:Quarter14	0.0085241	0.2305963	0.037	0.970513	
Haulyr11999:Quarter14	0.0161181	0.2470695	0.065	0.947985	
Haulyr12000:Quarter14	-0.8731333	0.2043634	-4.272	1.93e-05	***
Haulyr12001:Quarter14	0.0726668	0.1633799	0.445	0.656485	
Haulyr12002:Quarter14	-0.9102102	0.1676980	-5.428	5.71e-08	***
Haulyr12003:Quarter14	0.2298087	0.1625622	1.414	0.157460	
Haulyr12004:Quarter14	-1.1472620	0.1642763	-6.984	2.87e-12	***
Haulyr12005:Quarter14	-0.5794528	0.1661229	-3.488	0.000486	***

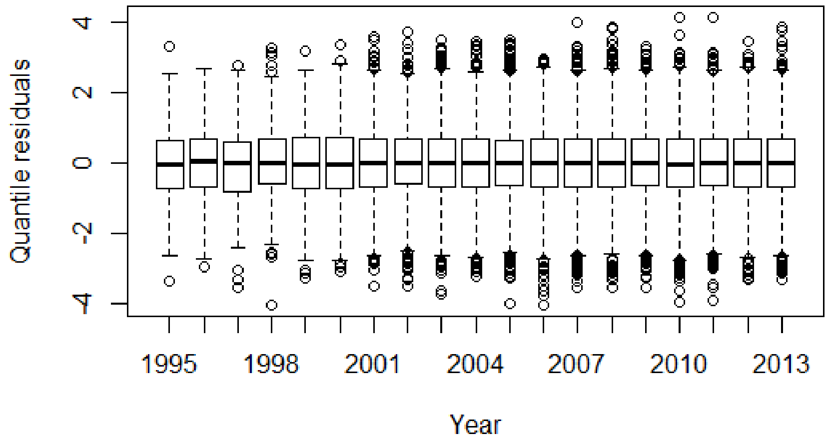
Haulyr12006:Quarter14	0.2081397	0.1716901	1.212	0.225398	
Haulyr12007:Quarter14	-1.6199192	0.1751175	-9.250	< 2e-16	***
Haulyr12008:Quarter14	0.2207102	0.1678848	1.315	0.188627	
Haulyr12009:Quarter14	-0.9251631	0.1759727	-5.257	1.46e-07	***
Haulyr12010:Quarter14	-0.4965756	0.1883514	-2.636	0.008378	**
Haulyr12011:Quarter14	-1.0522893	0.1631969	-6.448	1.13e-10	***
Haulyr12012:Quarter14	-1.2772449	0.1672560	-7.636	2.23e-14	***
Haulyr12013:Quarter14	0.8904616	0.1693127	5.259	1.45e-07	***
Region12:Quarter12	-0.8631272	0.6247323	-1.382	0.167096	
Region13:Quarter12	-0.7897757	0.6107767	-1.293	0.195988	
Region14:Quarter12	-0.6309107	0.6099985	-1.034	0.301004	
Region15:Quarter12	-0.5684175	0.6110301	-0.930	0.352236	
Region16:Quarter12	-0.1493850	0.6110516	-0.244	0.806865	
Region17:Quarter12	0.3523371	0.6237934	0.565	0.572190	
Region18:Quarter12	1.0882333	0.6260577	1.738	0.082170	.
Region12:Quarter13	-2.5078173	0.5784795	-4.335	1.46e-05	***
Region13:Quarter13	-3.4966473	0.5655242	-6.183	6.29e-10	***
Region14:Quarter13	-3.5118386	0.5636146	-6.231	4.64e-10	***
Region15:Quarter13	-2.7095992	0.5620059	-4.821	1.43e-06	***
Region16:Quarter13	-2.5802647	0.5646706	-4.570	4.89e-06	***
Region17:Quarter13	-1.0680723	0.5660007	-1.887	0.059153	.
Region18:Quarter13	-0.5188395	0.5739665	-0.904	0.366020	
Region12:Quarter14	-0.5964091	0.7953531	-0.750	0.453335	
Region13:Quarter14	-0.7491658	0.7797975	-0.961	0.336694	
Region14:Quarter14	-0.8058904	0.7797674	-1.034	0.301369	
Region15:Quarter14	-0.2558901	0.7793706	-0.328	0.742663	
Region16:Quarter14	-0.2479488	0.7795337	-0.318	0.750429	

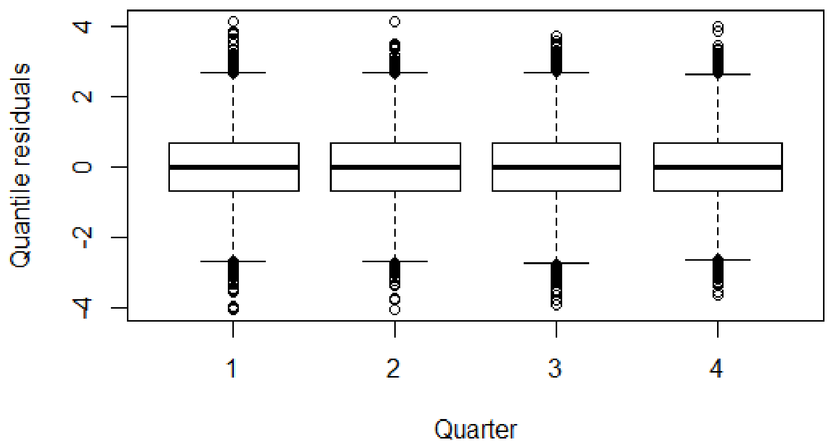
```
Region17:Quarter14    -0.5297023  0.7880793  -0.672 0.501492
Region18:Quarter14     0.7463843  0.8044661   0.928 0.353511
Set_type11:Hkpfl      -0.0520413  0.0025059 -20.767  < 2e-16 ***
Set_type12:Hkpfl       0.0584749  0.0187747   3.115 0.001842 **
Set_type11:Vesslen    -0.0014959  0.0007189  -2.081 0.037456 *
Set_type12:Vesslen    -0.0157267  0.0030564  -5.145 2.67e-07 ***
Log(theta)             0.0790827  0.0037443  21.121  < 2e-16 ***

Zero-inflation model coefficients (binomial with logit link):
            Estimate Std. Error z value Pr(>|z|)
(Intercept) -57.91625   15.72487  -3.683  0.00023 ***
Set_type12    9.71631   14.08011   0.690  0.49015
SST           5.22881    0.66777   7.830 4.87e-15 ***
I(SST^2)     -0.14089    0.01554  -9.066  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Theta = 1.0823
Number of iterations in BFGS optimization: 138
Log-likelihood: -6.562e+04 on 116 Df
```

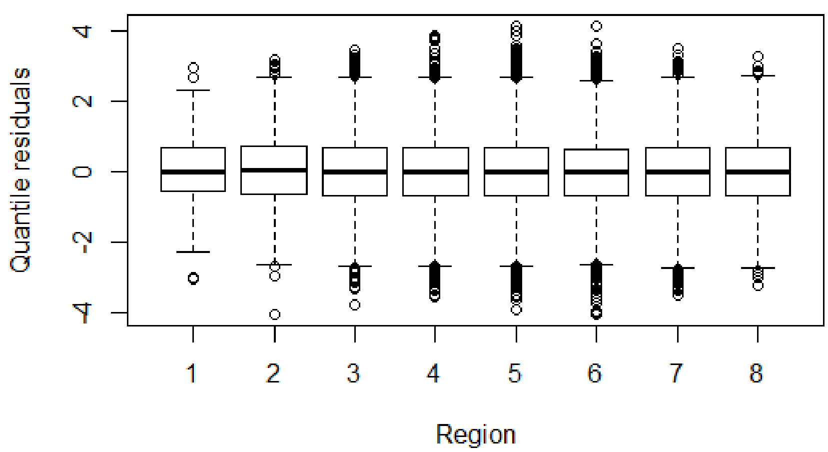
Appendix 3a: Quantile residual plots and R summary output for the zero process of the delta-lognormal for the combined data. Boxplots represent the median (line), the 1st and 3rd quartiles (box), points within 1.5 times the interquartile range (IQR) from the quartiles (whiskers), and points further than 1.5 times the IQR from the quartiles (open circles).

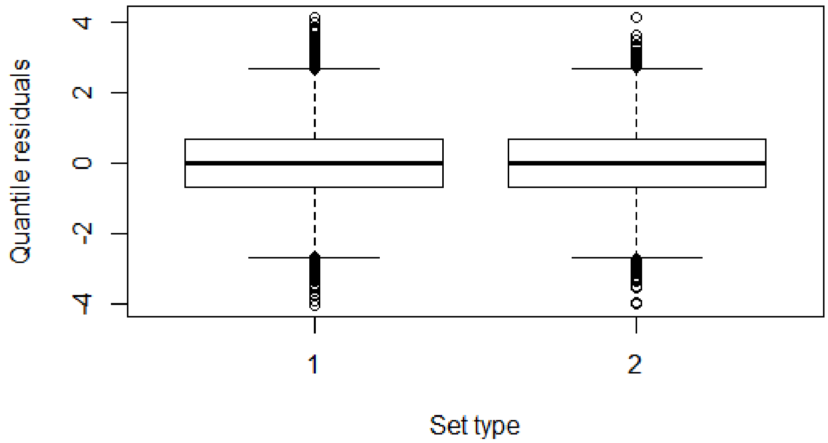


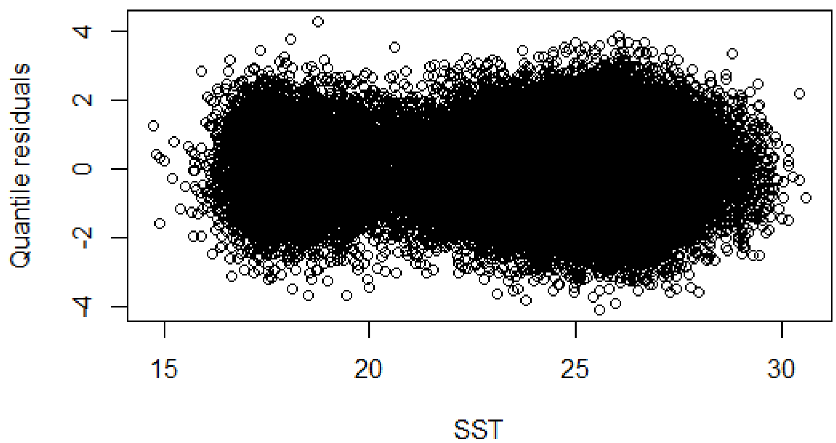


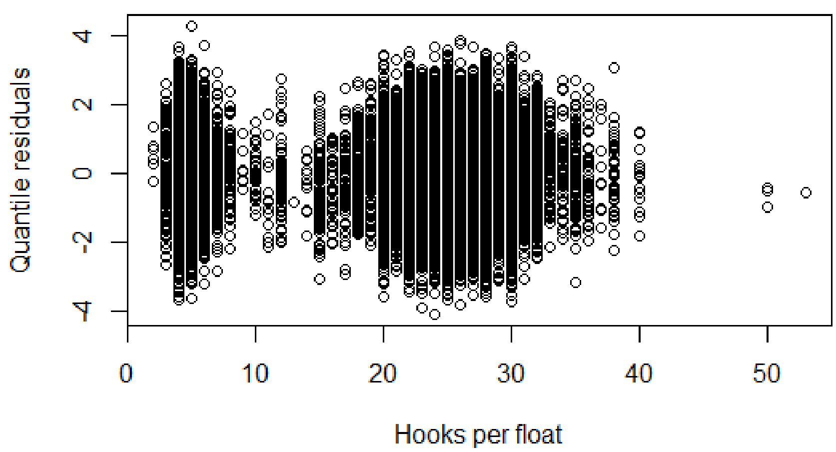

Quantile residuals
4
2
0
-2
-4
1995
1998
2001
2004
2007
2010
2013
Year

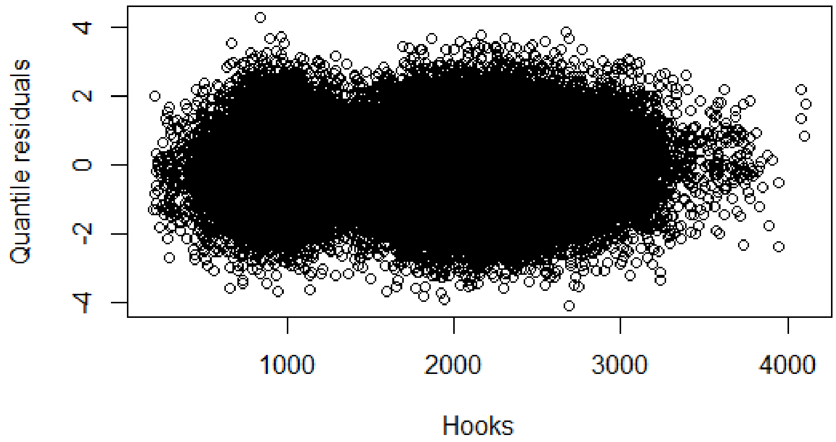

Quantile residuals
4
2
0
-2
-4
1
2
3
4
Quarter

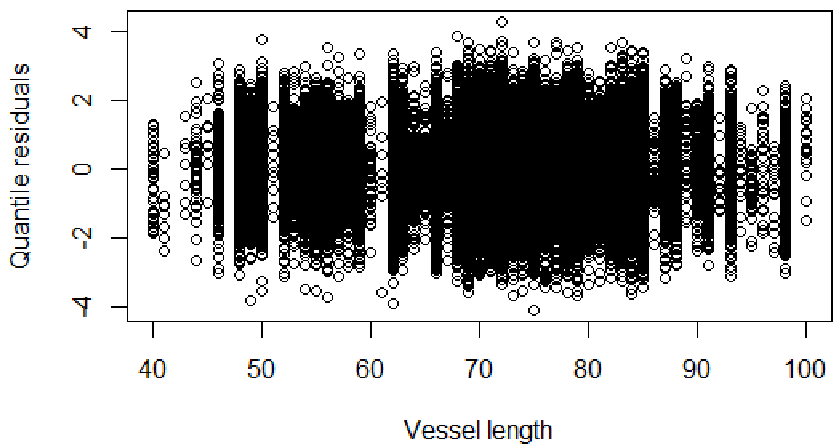

Quantile residuals
4
2
0
-2
-4
1
2
3
4
5
6
7
8
Region


Quantile residuals
4
2
0
-2
-4
1
2
Set type


Quantile residuals
4
2
0
-2
-4
15
20
25
30
SST


Quantile residuals
4
2
0
-2
-4
0
10
20
30
40
50
Hooks per float






```
>summary(LNBin_full)
Call:
glm(formula = Z ~ Haulyr1 + Quarter1 + Region1 + Set_type1 +
   SST + I(SST^2) + Set_type1:Hkpfl + Set_type1:Vesslen + Haulyr1:Quarter1 +
   Region1:Quarter1, family = binomial(link = "logit"), data = simp_obs)

Deviance Residuals:
   Min       1Q   Median       3Q      Max
-2.1748  -0.8794  -0.5385   0.9935   2.8664
```

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-7.609253	0.885581	-8.592	< 2e-16	***
Haulyr11996	-1.020768	0.263028	-3.881	0.000104	***
Haulyr11997	-1.298459	0.266194	-4.878	1.07e-06	***
Haulyr11998	-1.048752	0.286421	-3.662	0.000251	***
Haulyr11999	-1.268843	0.281593	-4.506	6.61e-06	***
Haulyr12000	-1.926154	0.262420	-7.340	2.14e-13	***
Haulyr12001	-0.893751	0.217858	-4.102	4.09e-05	***
Haulyr12002	-1.355426	0.216139	-6.271	3.59e-10	***
Haulyr12003	-0.537425	0.222389	-2.417	0.015666	*
Haulyr12004	-0.970779	0.219320	-4.426	9.59e-06	***
Haulyr12005	-1.418349	0.213017	-6.658	2.77e-11	***
Haulyr12006	-1.415915	0.217955	-6.496	8.23e-11	***
Haulyr12007	-1.728987	0.218578	-7.910	2.57e-15	***
Haulyr12008	-2.032709	0.213340	-9.528	< 2e-16	***
Haulyr12009	-2.316315	0.216035	-10.722	< 2e-16	***
Haulyr12010	-2.991397	0.220565	-13.562	< 2e-16	***
Haulyr12011	-1.003991	0.213219	-4.709	2.49e-06	***
Haulyr12012	-1.452952	0.213491	-6.806	1.01e-11	***
Haulyr12013	-2.428912	0.217136	-11.186	< 2e-16	***
Quarter12	-0.698494	0.682611	-1.023	0.306181	
Quarter13	0.412076	0.675167	0.610	0.541642	
Quarter14	-0.068937	0.866173	-0.080	0.936565	
Region12	0.912908	0.543872	1.679	0.093243	.
Region13	2.036085	0.538789	3.779	0.000157	***
Region14	2.276107	0.538669	4.225	2.38e-05	***

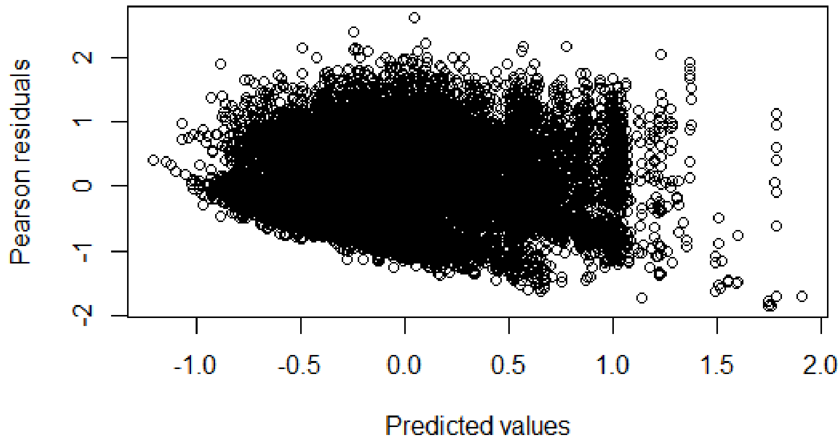
Region15	1.769917	0.539025	3.284	0.001025	**
Region16	2.094650	0.539408	3.883	0.000103	***
Region17	0.371129	0.542000	0.685	0.493508	
Region18	0.398448	0.549744	0.725	0.468582	
Set_type12	-0.331660	0.361418	-0.918	0.358795	
SST	0.665391	0.060503	10.998	< 2e-16	***
I(SST^2)	-0.014149	0.001335	-10.602	< 2e-16	***
Set_type11:Hkpfl	-0.031287	0.003658	-8.553	< 2e-16	***
Set_type12:Hkpfl	0.179664	0.025765	6.973	3.10e-12	***
Set_type11:Vesslen	0.003531	0.001026	3.443	0.000576	***
Set_type12:Vesslen	-0.017496	0.003845	-4.551	5.34e-06	***
Haulyr11996:Quarter12	1.086280	0.339201	3.202	0.001363	**
Haulyr11997:Quarter12	1.364296	0.351572	3.881	0.000104	***
Haulyr11998:Quarter12	-0.220333	0.451653	-0.488	0.625665	
Haulyr11999:Quarter12	1.195257	0.370811	3.223	0.001267	**
Haulyr12000:Quarter12	1.171469	0.350637	3.341	0.000835	***
Haulyr12001:Quarter12	1.129333	0.291460	3.875	0.000107	***
Haulyr12002:Quarter12	0.534932	0.279795	1.912	0.055893	.
Haulyr12003:Quarter12	0.522315	0.286545	1.823	0.068334	.
Haulyr12004:Quarter12	0.345972	0.280001	1.236	0.216603	
Haulyr12005:Quarter12	1.291312	0.270822	4.768	1.86e-06	***
Haulyr12006:Quarter12	1.192629	0.277494	4.298	1.72e-05	***
Haulyr12007:Quarter12	0.765573	0.278226	2.752	0.005930	**
Haulyr12008:Quarter12	1.581997	0.270611	5.846	5.03e-09	***
Haulyr12009:Quarter12	1.428630	0.273882	5.216	1.83e-07	***
Haulyr12010:Quarter12	1.023512	0.281337	3.638	0.000275	***
Haulyr12011:Quarter12	0.437022	0.273153	1.600	0.109616	

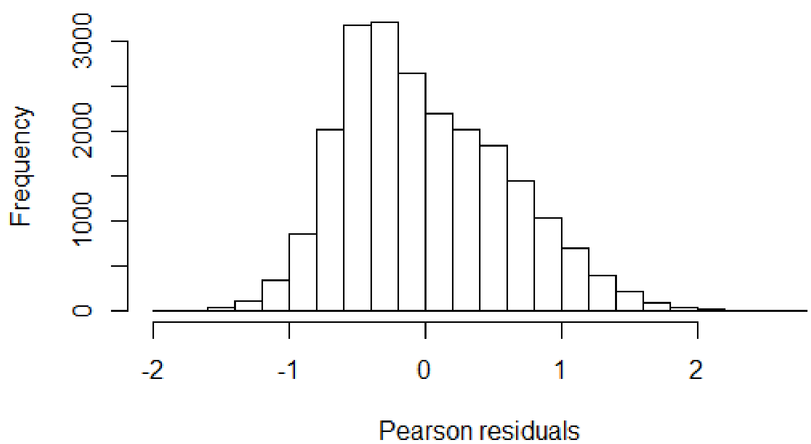
Haulyr12012:Quarter12	0.207390	0.272933	0.760	0.447340	
Haulyr12013:Quarter12	1.387602	0.276577	5.017	5.25e-07	***
Haulyr11996:Quarter13	1.202208	0.401935	2.991	0.002780	**
Haulyr11997:Quarter13	1.435338	0.494893	2.900	0.003728	**
Haulyr11998:Quarter13	0.358155	0.397871	0.900	0.368025	
Haulyr11999:Quarter13	1.238054	0.510969	2.423	0.015395	*
Haulyr12000:Quarter13	0.715597	0.405824	1.763	0.077847	.
Haulyr12001:Quarter13	0.661390	0.325747	2.030	0.042318	*
Haulyr12002:Quarter13	-0.163760	0.323620	-0.506	0.612838	
Haulyr12003:Quarter13	0.092414	0.318120	0.290	0.771434	
Haulyr12004:Quarter13	0.496006	0.316617	1.567	0.117213	
Haulyr12005:Quarter13	0.491316	0.309627	1.587	0.112557	
Haulyr12006:Quarter13	1.526394	0.313517	4.869	1.12e-06	***
Haulyr12007:Quarter13	0.189385	0.320981	0.590	0.555178	
Haulyr12008:Quarter13	1.013875	0.310262	3.268	0.001084	**
Haulyr12009:Quarter13	0.997092	0.313629	3.179	0.001477	**
Haulyr12010:Quarter13	1.270673	0.319146	3.981	6.85e-05	***
Haulyr12011:Quarter13	-0.526310	0.313601	-1.678	0.093293	.
Haulyr12012:Quarter13	-0.122842	0.315029	-0.390	0.696581	
Haulyr12013:Quarter13	1.249929	0.313316	3.989	6.63e-05	***
Haulyr11996:Quarter14	-0.155711	0.395764	-0.393	0.693992	
Haulyr11997:Quarter14	0.209421	0.411178	0.509	0.610529	
Haulyr11998:Quarter14	1.053920	0.400485	2.632	0.008498	**
Haulyr11999:Quarter14	0.540403	0.408791	1.322	0.186183	
Haulyr12000:Quarter14	0.066090	0.351741	0.188	0.850960	
Haulyr12001:Quarter14	0.644029	0.317930	2.026	0.042796	*
Haulyr12002:Quarter14	-0.459574	0.316381	-1.453	0.146336	

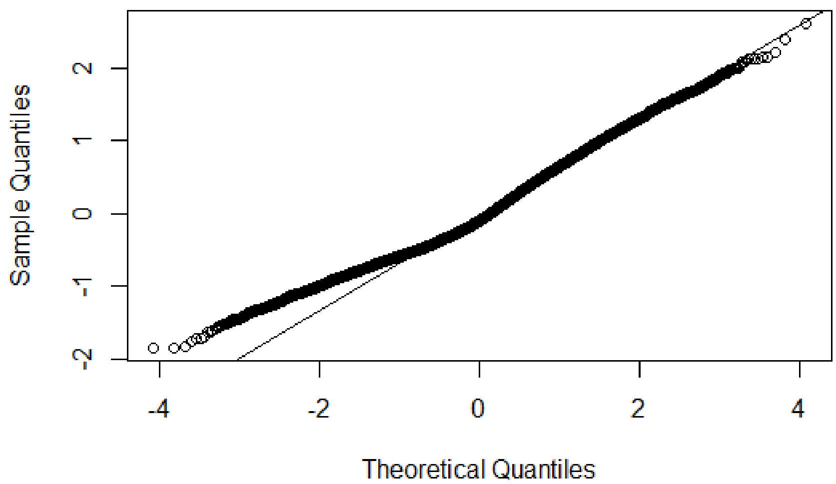
Haulyr12003:Quarter14	0.889050	0.322717	2.755	0.005871	**
Haulyr12004:Quarter14	-0.232435	0.315492	-0.737	0.461281	
Haulyr12005:Quarter14	0.262226	0.313179	0.837	0.402422	
Haulyr12006:Quarter14	0.856823	0.317202	2.701	0.006909	**
Haulyr12007:Quarter14	-0.909492	0.315508	-2.883	0.003944	**
Haulyr12008:Quarter14	0.827606	0.314746	2.629	0.008553	**
Haulyr12009:Quarter14	-0.263125	0.317383	-0.829	0.407079	
Haulyr12010:Quarter14	-0.012600	0.323831	-0.039	0.968963	
Haulyr12011:Quarter14	-0.074735	0.313038	-0.239	0.811308	
Haulyr12012:Quarter14	-0.608375	0.313230	-1.942	0.052105	.
Haulyr12013:Quarter14	1.745616	0.316935	5.508	3.63e-08	***
Quarter12:Region12	-0.900839	0.652050	-1.382	0.167110	
Quarter13:Region12	-1.558845	0.631535	-2.468	0.013574	*
Quarter14:Region12	-0.808562	0.838643	-0.964	0.334980	
Quarter12:Region13	-0.783422	0.633428	-1.237	0.216162	
Quarter13:Region13	-2.902482	0.613568	-4.730	2.24e-06	***
Quarter14:Region13	-0.932047	0.814687	-1.144	0.252601	
Quarter12:Region14	-0.726630	0.632406	-1.149	0.250559	
Quarter13:Region14	-2.861950	0.611030	-4.684	2.82e-06	***
Quarter14:Region14	-0.824012	0.814687	-1.011	0.311803	
Quarter12:Region15	-0.247496	0.633856	-0.390	0.696196	
Quarter13:Region15	-1.902815	0.608820	-3.125	0.001776	**
Quarter14:Region15	0.116517	0.813621	0.143	0.886126	
Quarter12:Region16	0.269784	0.634286	0.425	0.670592	
Quarter13:Region16	-1.634279	0.613626	-2.663	0.007737	**
Quarter14:Region16	0.216604	0.814458	0.266	0.790279	
Quarter12:Region17	0.412033	0.647275	0.637	0.524408	

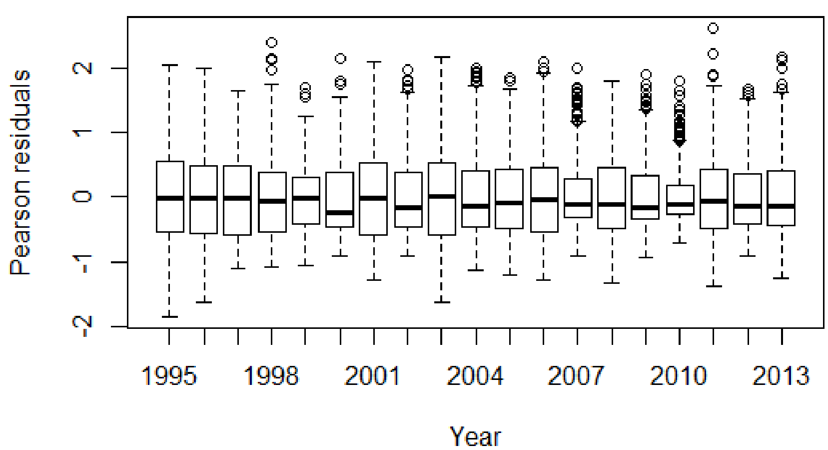
```
Quarter13:Region17    -0.325370   0.613015  -0.531 0.595578
Quarter14:Region17    -0.391735   0.823215  -0.476 0.634174
Quarter12:Region18     0.835347   0.650442   1.284 0.199046
Quarter13:Region18     0.402954   0.620457   0.649 0.516049
Quarter14:Region18     0.374575   0.847512   0.442 0.658510
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
(Dispersion parameter for binomial family taken to be 1)
    Null deviance: 79586  on 60314  degrees of freedom
Residual deviance: 67047  on 60204  degrees of freedom
AIC: 67269
Number of Fisher Scoring iterations: 5
```

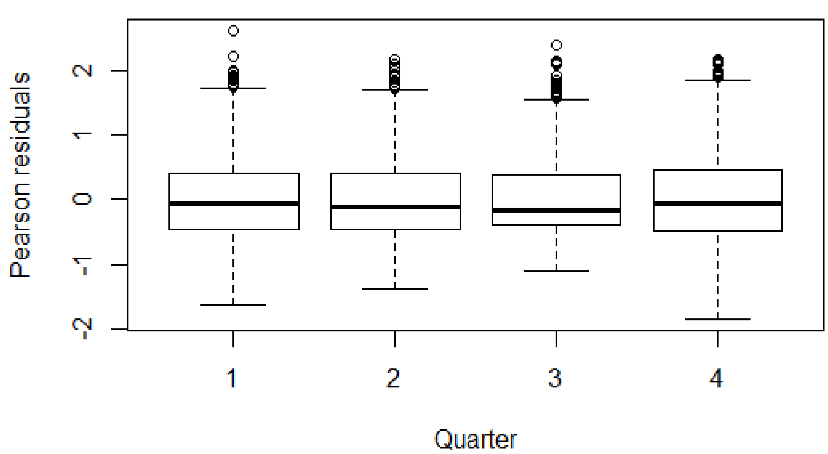
Appendix 3b: Pearson residual plots, quantile-quantile plot, and R summary output for the positive process of the delta-lognormal for the combined data. Boxplots represent the median (line), the 1st and 3rd quartiles (box), data up to 1.5 times the interquartile range (IQR) from the quartiles (whiskers), and data beyond 1.5 times the IQR from the quartiles (open circles).

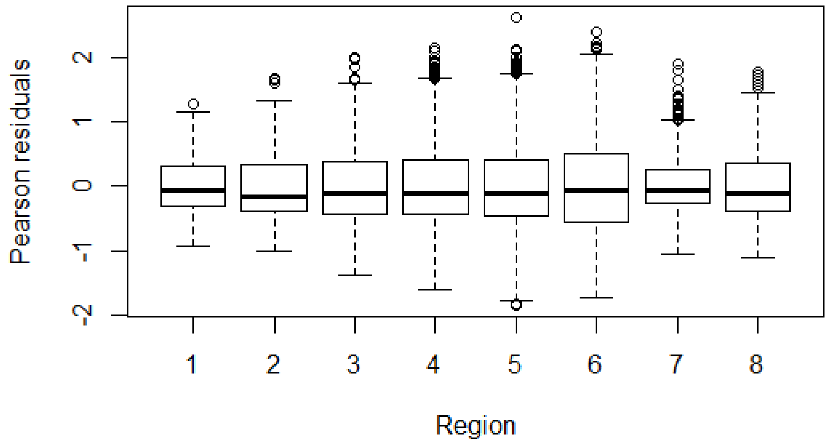


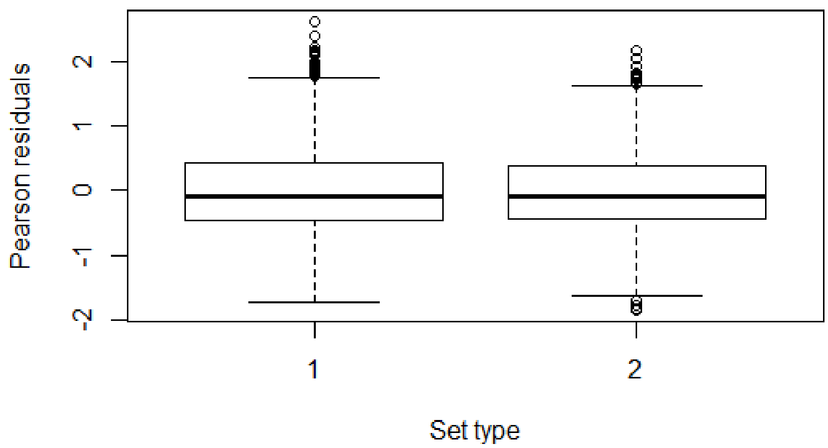


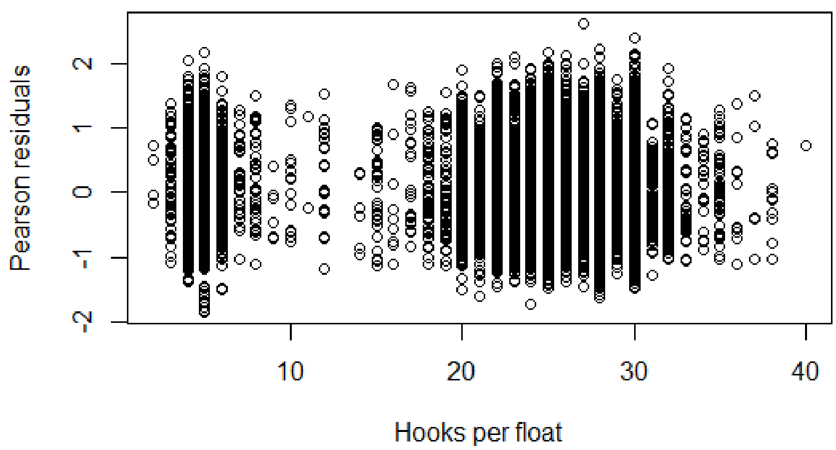

Sample Quantiles
-2
-1
0
1
2
-4
-2
0
2
4
Theoretical Quantiles

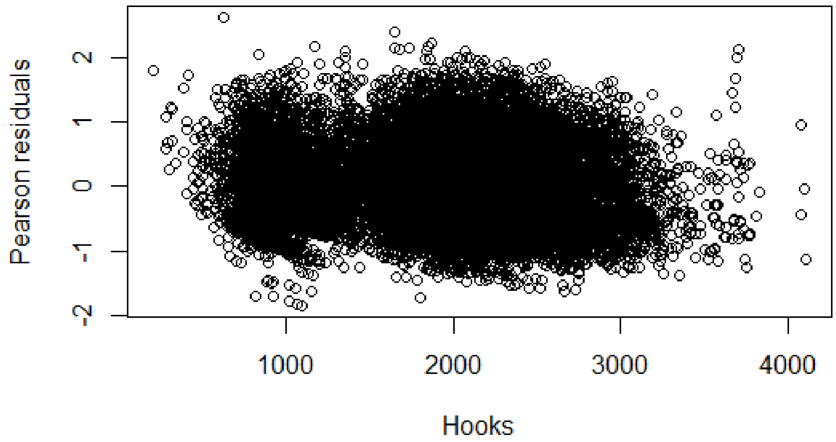

Pearson residuals
-2
-1
0
1
2
1995
1998
2001
2004
2007
2010
2013
Year

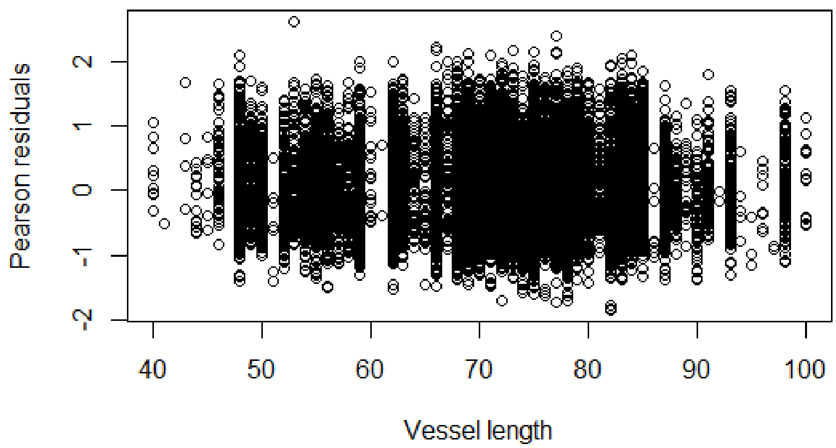

Pearson residuals
-2
-1
0
1
2
1
2
3
4
Quarter


Pearson residuals
2
1
0
-1
-2
1
2
3
4
5
6
7
8
Region


Pearson residuals
2
1
0
-1
-2
1
2
Set type


Pearson residuals
2
1
0
-1
-2
10
20
30
40
Hooks per float






```
> summary(LNPos_full)
Call:
glm(formula = log(SM_cpue) ~ Haulyr1 + Quarter1 + Region1 + Set_type1 +
    SST + I(SST^2) + Set_type1:Hkpfl + Set_type1:Vesslen + Haulyr1:Quarter1 +
    Region1:Quarter1, family = gaussian, data = positives)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.8518  -0.4608  -0.0963   0.4195   2.6193
```

Coefficients:

```
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)    -0.0949706  0.4411661  -0.215 0.829557
Haulyr11996     0.3619758  0.0897592   4.033 5.53e-05 ***
Haulyr11997    -0.2215152  0.0959384  -2.309 0.020957 *
Haulyr11998    -0.2646765  0.1037845  -2.550 0.010771 *
Haulyr11999    -0.5461304  0.1037746  -5.263 1.43e-07 ***
Haulyr12000    -0.2635589  0.1010012  -2.609 0.009075 **
Haulyr12001    -0.3276645  0.0678956  -4.826 1.40e-06 ***
Haulyr12002    -0.3975288  0.0688656  -5.773 7.91e-09 ***
Haulyr12003    -0.1941442  0.0680272  -2.854 0.004322 **
Haulyr12004    -0.1929893  0.0686072  -2.813 0.004913 **
Haulyr12005    -0.3904127  0.0687000  -5.683 1.34e-08 ***
Haulyr12006    -0.5655964  0.0741812  -7.625 2.55e-14 ***
Haulyr12007    -0.5614661  0.0753913  -7.447 9.87e-14 ***
Haulyr12008    -0.7532015  0.0698636 -10.781  < 2e-16 ***
Haulyr12009    -0.7766064  0.0723687 -10.731  < 2e-16 ***
Haulyr12010    -0.9832222  0.0778551 -12.629  < 2e-16 ***
Haulyr12011    -0.2816645  0.0674269  -4.177 2.96e-05 ***
Haulyr12012    -0.6806647  0.0683718  -9.955  < 2e-16 ***
Haulyr12013    -1.0142963  0.0722198 -14.045  < 2e-16 ***
Quarter12       0.0573049  0.3650037   0.157 0.875248
Quarter13       0.4993818  0.3568120   1.400 0.161657
Quarter14       0.5883349  0.4372481   1.346 0.178464
Region12        0.1924358  0.3064269   0.628 0.530011
Region13        0.4339475  0.3030715   1.432 0.152206
Region14        0.5185259  0.3029284   1.712 0.086964 .
```

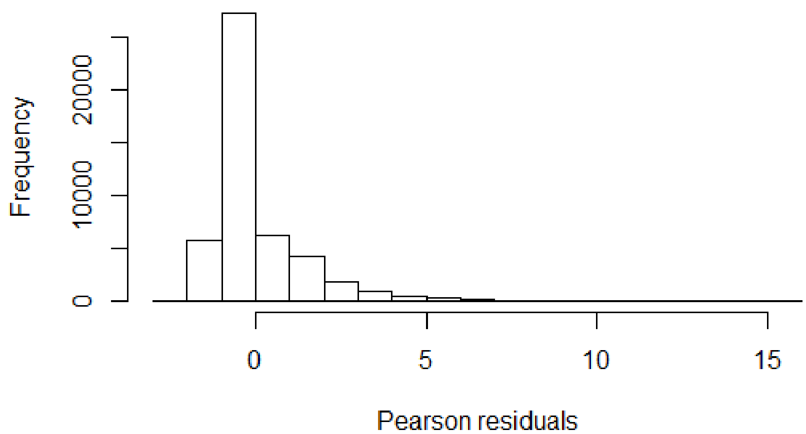
Region15	0.5261698	0.3032200	1.735	0.082706	.
Region16	0.6084822	0.3032288	2.007	0.044796	*
Region17	0.1610373	0.3050356	0.528	0.597553	
Region18	0.1639586	0.3097457	0.529	0.596580	
Set_type12	0.0364855	0.1651532	0.221	0.825157	
SST	0.0864597	0.0277972	3.110	0.001871	**
I(SST^2)	-0.0018498	0.0006123	-3.021	0.002522	**
Set_type11:Hkpfl	-0.0317477	0.0015446	-20.554	< 2e-16	***
Set_type12:Hkpfl	-0.0088944	0.0106823	-0.833	0.405063	
Set_type11:Vesslen	-0.0037390	0.0004425	-8.450	< 2e-16	***
Set_type12:Vesslen	-0.0033558	0.0017566	-1.910	0.056088	.
Haulyr11996:Quarter12	-0.5080520	0.1212026	-4.192	2.78e-05	***
Haulyr11997:Quarter12	0.2231624	0.1319161	1.692	0.090717	.
Haulyr11998:Quarter12	-0.2677995	0.1976539	-1.355	0.175466	
Haulyr11999:Quarter12	0.3582526	0.1380144	2.596	0.009444	**
Haulyr12000:Quarter12	-0.1601798	0.1427526	-1.122	0.261841	
Haulyr12001:Quarter12	0.2955870	0.0999450	2.957	0.003105	**
Haulyr12002:Quarter12	-0.0697015	0.1001712	-0.696	0.486546	
Haulyr12003:Quarter12	0.0398397	0.0974260	0.409	0.682601	
Haulyr12004:Quarter12	-0.1896985	0.0979260	-1.937	0.052738	.
Haulyr12005:Quarter12	0.1655303	0.0942602	1.756	0.079085	.
Haulyr12006:Quarter12	0.2479408	0.1000966	2.477	0.013256	*
Haulyr12007:Quarter12	-0.0091191	0.1024304	-0.089	0.929061	
Haulyr12008:Quarter12	0.3799323	0.0954121	3.982	6.86e-05	***
Haulyr12009:Quarter12	0.1396140	0.0986559	1.415	0.157035	
Haulyr12010:Quarter12	0.1144743	0.1066961	1.073	0.283327	
Haulyr12011:Quarter12	-0.4346710	0.0950861	-4.571	4.87e-06	***

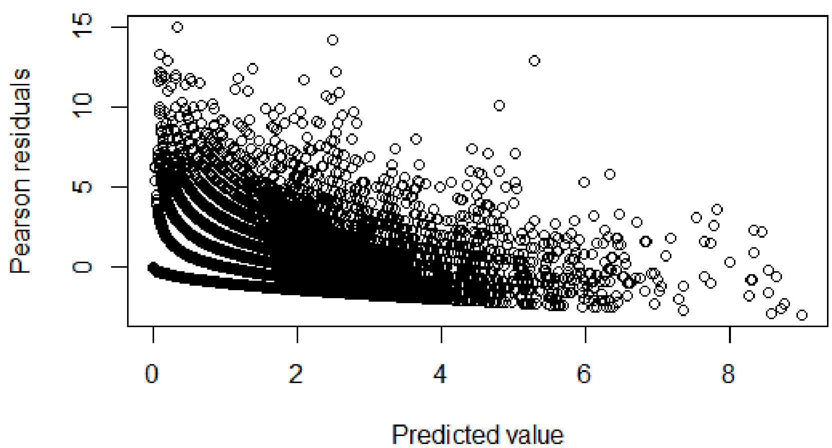
Haulyr12012:Quarter12	-0.1936913	0.0967462	-2.002	0.045291	*
Haulyr12013:Quarter12	0.3322260	0.0995803	3.336	0.000851	***
Haulyr11996:Quarter13	-0.5222056	0.1594062	-3.276	0.001055	**
Haulyr11997:Quarter13	0.4110992	0.2154130	1.908	0.056349	.
Haulyr11998:Quarter13	0.1882145	0.1631360	1.154	0.248624	
Haulyr11999:Quarter13	0.4865203	0.2181427	2.230	0.025738	*
Haulyr12000:Quarter13	0.1352510	0.1839327	0.735	0.462147	
Haulyr12001:Quarter13	0.4026750	0.1282334	3.140	0.001691	**
Haulyr12002:Quarter13	0.0713261	0.1325214	0.538	0.590428	
Haulyr12003:Quarter13	0.1026403	0.1219605	0.842	0.400029	
Haulyr12004:Quarter13	0.0566241	0.1240991	0.456	0.648192	
Haulyr12005:Quarter13	0.0601129	0.1218870	0.493	0.621886	
Haulyr12006:Quarter13	0.6664793	0.1238676	5.381	7.50e-08	***
Haulyr12007:Quarter13	0.0863191	0.1315339	0.656	0.511670	
Haulyr12008:Quarter13	0.3611562	0.1233759	2.927	0.003423	**
Haulyr12009:Quarter13	0.3078602	0.1262114	2.439	0.014726	*
Haulyr12010:Quarter13	0.3704835	0.1310515	2.827	0.004703	**
Haulyr12011:Quarter13	-0.3115126	0.1249316	-2.493	0.012657	*
Haulyr12012:Quarter13	0.0395632	0.1265477	0.313	0.754561	
Haulyr12013:Quarter13	0.5396276	0.1250358	4.316	1.60e-05	***
Haulyr11996:Quarter14	-0.7736290	0.1425950	-5.425	5.84e-08	***
Haulyr11997:Quarter14	-0.8798789	0.1484014	-5.929	3.09e-09	***
Haulyr11998:Quarter14	-0.3486934	0.1338295	-2.606	0.009180	**
Haulyr11999:Quarter14	-0.2597142	0.1427670	-1.819	0.068902	.
Haulyr12000:Quarter14	-0.9160868	0.1253117	-7.310	2.75e-13	***
Haulyr12001:Quarter14	-0.2622184	0.0951678	-2.755	0.005868	**
Haulyr12002:Quarter14	-0.6859986	0.0992142	-6.914	4.83e-12	***

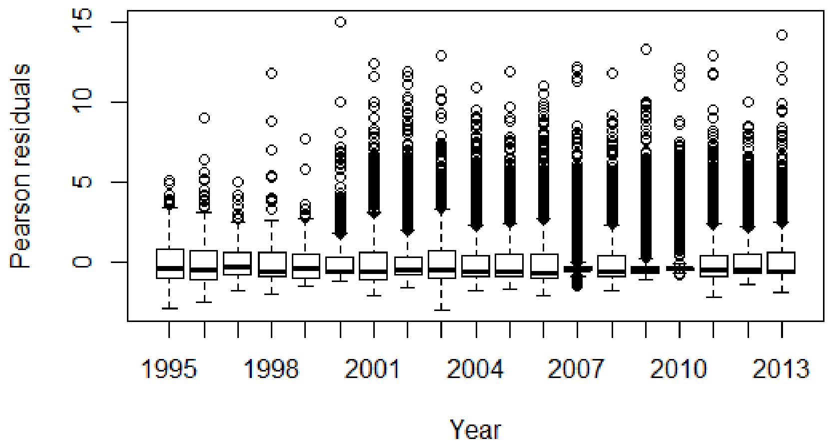
Haulyr12003:Quarter14	-0.1526818	0.0946815	-1.613	0.106849	
Haulyr12004:Quarter14	-0.9582601	0.0962078	-9.960	< 2e-16	***
Haulyr12005:Quarter14	-0.6931645	0.0974847	-7.110	1.19e-12	***
Haulyr12006:Quarter14	-0.2819085	0.0999571	-2.820	0.004802	**
Haulyr12007:Quarter14	-0.9569995	0.1032202	-9.271	< 2e-16	***
Haulyr12008:Quarter14	-0.3633579	0.0986293	-3.684	0.000230	***
Haulyr12009:Quarter14	-0.7994679	0.1038691	-7.697	1.45e-14	***
Haulyr12010:Quarter14	-0.6231324	0.1114806	-5.590	2.30e-08	***
Haulyr12011:Quarter14	-0.9791448	0.0956667	-10.235	< 2e-16	***
Haulyr12012:Quarter14	-0.9091367	0.0980834	-9.269	< 2e-16	***
Haulyr12013:Quarter14	-0.1586442	0.0988043	-1.606	0.108367	
Quarter12:Region12	-0.0815510	0.3655350	-0.223	0.823460	
Quarter13:Region12	-0.7419786	0.3505110	-2.117	0.034284	*
Quarter14:Region12	0.1139926	0.4436065	0.257	0.797206	
Quarter12:Region13	-0.2566115	0.3549300	-0.723	0.469692	
Quarter13:Region13	-0.9711176	0.3414656	-2.844	0.004460	**
Quarter14:Region13	0.0066309	0.4289397	0.015	0.987666	
Quarter12:Region14	-0.1944591	0.3542709	-0.549	0.583080	
Quarter13:Region14	-1.0687176	0.3399165	-3.144	0.001668	**
Quarter14:Region14	-0.0907695	0.4287955	-0.212	0.832355	
Quarter12:Region15	-0.2759329	0.3550493	-0.777	0.437068	
Quarter13:Region15	-0.9056077	0.3390798	-2.671	0.007573	**
Quarter14:Region15	0.0166246	0.4284507	0.039	0.969049	
Quarter12:Region16	-0.0695630	0.3549821	-0.196	0.844642	
Quarter13:Region16	-0.9328959	0.3407247	-2.738	0.006187	**
Quarter14:Region16	0.0812479	0.4285923	0.190	0.849648	
Quarter12:Region17	-0.1198073	0.3623979	-0.331	0.740953	

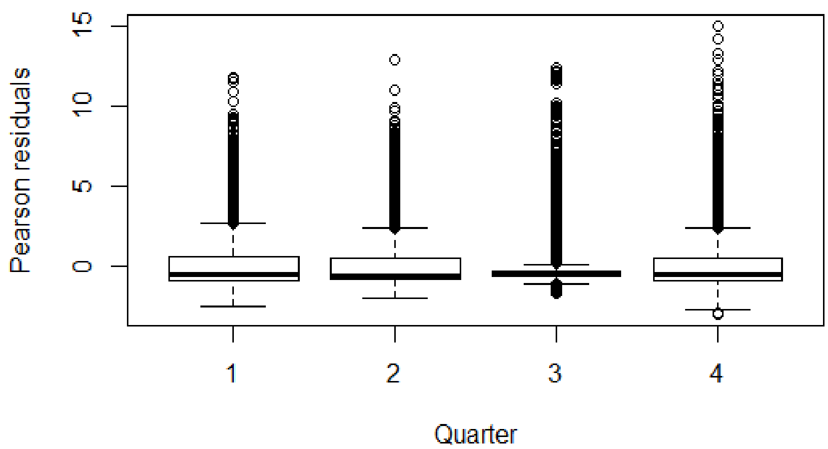
```
Quarter13:Region17    -0.6145152  0.3411529  -1.801 0.071671 .
Quarter14:Region17     0.0962691  0.4344583   0.222 0.824640
Quarter12:Region18     0.1863366  0.3640626   0.512 0.608778
Quarter13:Region18    -0.4974850  0.3453830  -1.440 0.149772
Quarter14:Region18     0.2129451  0.4448915   0.479 0.632196
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
(Dispersion parameter for gaussian family taken to be 0.3643098)
    Null deviance: 12310.6  on 22406  degrees of freedom
Residual deviance:  8122.7  on 22296  degrees of freedom
AIC: 41076
Number of Fisher Scoring iterations: 2
```

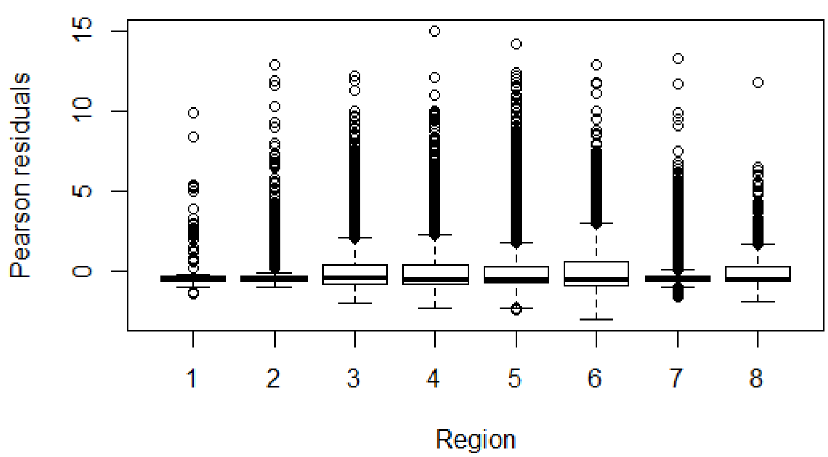
Appendix 4: Pearson residual plots and R summary output for the Poisson distribution from the deep-set data only. Boxplots represent the median (line), the 1st and 3rd quartiles (box), data up to 1.5 times the interquartile range (IQR) from the quartiles (whiskers), and data beyond 1.5 times the IQR from the quartiles (open circles).

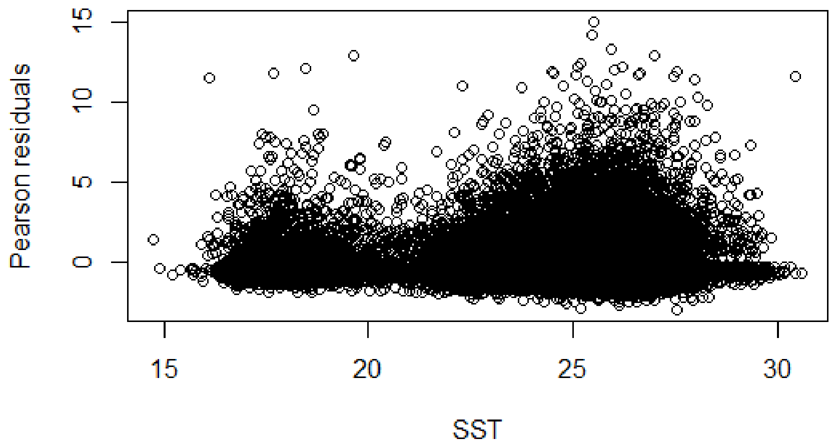




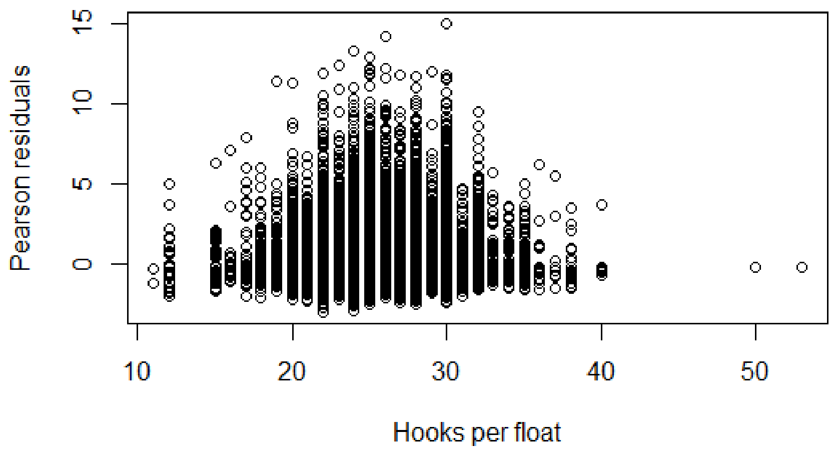

Pearson residuals
0
5
10
15
1995
1998
2001
2004
2007
2010
2013
Year


Pearson residuals
0
5
10
15
1
2
3
4
Quarter

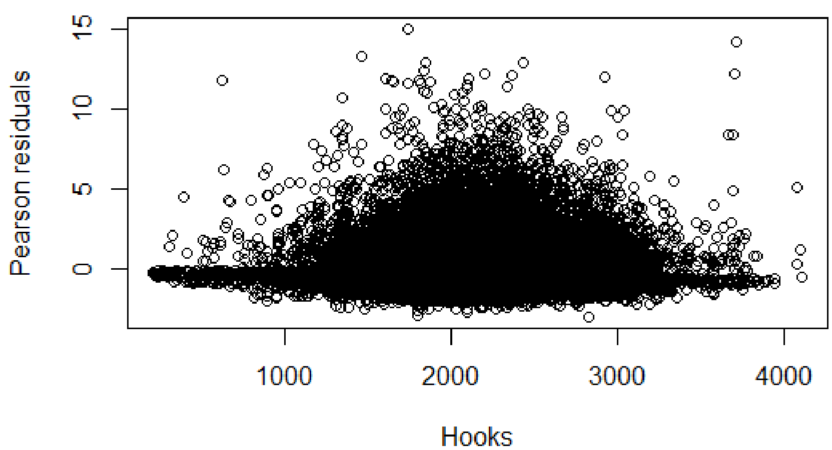

Pearson residuals
0
5
10
15
1
2
3
4
5
6
7
8
Region



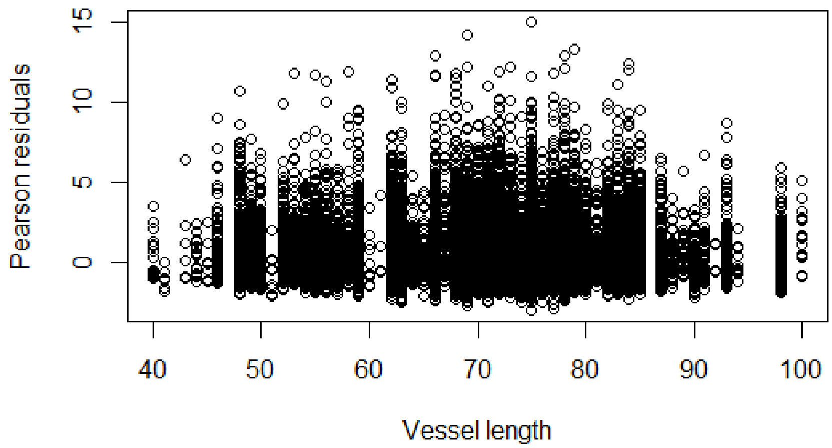
Pearson residuals
15
10
5
0
15
20
25
30
SST



Pearson residuals
15
10
5
0
10
20
30
40
50
Hooks per float



Pearson residuals
15
10
5
0
1000
2000
3000
4000
Hooks




```
>summary(P_full_ds)
Call:
glm(formula = Striped_Marlin ~ Haulyr1 + Quarter1 + Region1 +
    SST + I(SST^2) + Hkpfl + Vesslen + Haulyr1:Quarter1 + Region1:Quarter1 +
    offset(log(Hooks)), family = poisson(link = "log"), data = simp_obs_ds)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-4.2416  -1.0544  -0.6828   0.3672   8.5463

Coefficients:
                     Estimate Std. Error z value Pr(>|z|)
(Intercept)        -1.026e+01  6.389e-01 -16.059  < 2e-16 ***
Haulyr11996         5.988e-01  8.614e-02   6.951 3.63e-12 ***
Haulyr11997        -2.240e-01  1.066e-01  -2.100 0.035700 *
Haulyr11998        -1.890e-01  1.154e-01  -1.639 0.101317
Haulyr11999        -1.059e+00  1.479e-01  -7.162 7.94e-13 ***
Haulyr12000        -1.019e+00  1.191e-01  -8.550  < 2e-16 ***
Haulyr12001        -5.819e-01  7.554e-02  -7.703 1.33e-14 ***
```

Haulyr12002	-8.273e-01	7.664e-02	-10.795	< 2e-16	***
Haulyr12003	-3.042e-01	7.429e-02	-4.095	4.23e-05	***
Haulyr12004	-3.315e-01	7.438e-02	-4.457	8.31e-06	***
Haulyr12005	-6.919e-01	7.698e-02	-8.988	< 2e-16	***
Haulyr12006	-1.184e+00	9.350e-02	-12.661	< 2e-16	***
Haulyr12007	-1.173e+00	9.389e-02	-12.490	< 2e-16	***
Haulyr12008	-1.818e+00	8.397e-02	-21.657	< 2e-16	***
Haulyr12009	-1.918e+00	8.716e-02	-22.006	< 2e-16	***
Haulyr12010	-2.804e+00	1.062e-01	-26.396	< 2e-16	***
Haulyr12011	-4.717e-01	7.332e-02	-6.434	1.25e-10	***
Haulyr12012	-1.176e+00	7.643e-02	-15.387	< 2e-16	***
Haulyr12013	-2.183e+00	8.615e-02	-25.339	< 2e-16	***
Quarter12	8.852e-01	5.878e-01	1.506	0.132046	
Quarter13	7.234e-01	6.231e-01	1.161	0.245621	
Quarter14	1.078e+00	7.133e-01	1.511	0.130847	
Region12	1.092e+00	5.050e-01	2.161	0.030666	*
Region13	2.005e+00	5.013e-01	4.000	6.33e-05	***
Region14	2.219e+00	5.012e-01	4.428	9.52e-06	***
Region15	2.095e+00	5.014e-01	4.179	2.93e-05	***
Region16	2.418e+00	5.013e-01	4.823	1.41e-06	***
Region17	4.484e-01	7.642e-01	0.587	0.557310	
Region18	-1.633e+00	1.118e+00	-1.460	0.144255	
SST	2.858e-01	3.429e-02	8.333	< 2e-16	***
I(SST^2)	-6.551e-03	7.510e-04	-8.723	< 2e-16	***
Hkpfl	-5.255e-02	1.657e-03	-31.710	< 2e-16	***
Vesslen	-9.348e-04	4.898e-04	-1.908	0.056341	.
Haulyr11996:Quarter12	-1.503e+00	1.598e-01	-9.407	< 2e-16	***

Haulyr11997:Quarter12 -5.924e-01 1.882e-01 -3.148 0.001646 **

Haulyr11998:Quarter12 -1.555e+00 3.716e-01 -4.184 2.86e-05 ***

Haulyr11999:Quarter12 -8.031e-02 2.160e-01 -0.372 0.710085

Haulyr12000:Quarter12 -1.039e+00 2.610e-01 -3.980 6.90e-05 ***

Haulyr12001:Quarter12 -2.219e-01 1.406e-01 -1.579 0.114387

Haulyr12002:Quarter12 -9.523e-01 1.433e-01 -6.645 3.04e-11 ***

Haulyr12003:Quarter12 -7.636e-01 1.378e-01 -5.540 3.02e-08 ***

Haulyr12004:Quarter12 -1.247e+00 1.387e-01 -8.989 < 2e-16 ***

Haulyr12005:Quarter12 -5.478e-01 1.398e-01 -3.918 8.94e-05 ***

Haulyr12006:Quarter12 -4.014e-02 1.473e-01 -0.272 0.785253

Haulyr12007:Quarter12 -6.589e-01 1.540e-01 -4.279 1.88e-05 ***

Haulyr12008:Quarter12 2.704e-01 1.417e-01   1.908 0.056451 .

Haulyr12009:Quarter12 -2.361e-01 1.514e-01 -1.560 0.118741

Haulyr12010:Quarter12 -3.179e-01 1.744e-01 -1.823 0.068251 .

Haulyr12011:Quarter12 -1.492e+00 1.392e-01 -10.718 < 2e-16 ***

Haulyr12012:Quarter12 -1.234e+00 1.442e-01 -8.559 < 2e-16 ***

Haulyr12013:Quarter12 -1.462e-01 1.481e-01 -0.987 0.323609

Haulyr11996:Quarter13 3.688e-02 5.136e-01   0.072 0.942754

Haulyr11997:Quarter13 -9.038e+00 6.350e+01 -0.142 0.886807

Haulyr11998:Quarter13 1.593e+00 3.778e-01   4.217 2.47e-05 ***

Haulyr11999:Quarter13 1.691e+00 4.584e-01   3.690 0.000225 ***

Haulyr12000:Quarter13 4.574e-01 4.750e-01   0.963 0.335626

Haulyr12001:Quarter13 1.889e+00 3.472e-01   5.441 5.29e-08 ***

Haulyr12002:Quarter13 5.801e-01 3.529e-01   1.644 0.100262

Haulyr12003:Quarter13 1.152e+00 3.442e-01   3.345 0.000822 ***

Haulyr12004:Quarter13 1.047e+00 3.456e-01   3.029 0.002454 **

Haulyr12005:Quarter13 7.741e-01 3.459e-01   2.238 0.025215 *

Haulyr12006:Quarter13 2.708e+00 3.476e-01   7.791 6.63e-15 ***

Haulyr12007:Quarter13 7.060e-01 3.569e-01   1.978 0.047887 *

Haulyr12008:Quarter13 1.722e+00 3.484e-01   4.942 7.74e-07 ***

Haulyr12009:Quarter13 1.577e+00 3.503e-01   4.501 6.76e-06 ***

Haulyr12010:Quarter13 2.063e+00 3.582e-01   5.758 8.49e-09 ***

Haulyr12011:Quarter13 -1.750e-01 3.487e-01 -0.502 0.615686

Haulyr12012:Quarter13 5.290e-01 3.494e-01   1.514 0.130040

Haulyr12013:Quarter13 2.032e+00 3.479e-01   5.840 5.22e-09 ***

Haulyr11996:Quarter14 -1.973e+00 1.715e-01 -11.509 < 2e-16 ***

Haulyr11997:Quarter14 -1.489e+00 1.794e-01 -8.302 < 2e-16 ***

Haulyr11998:Quarter14 -4.432e-01 1.367e-01 -3.243 0.001184 **

Haulyr11999:Quarter14 -1.867e-01 1.744e-01 -1.070 0.284454

Haulyr12000:Quarter14 -1.292e+00 1.404e-01 -9.205 < 2e-16 ***

Haulyr12001:Quarter14 -2.150e-01 9.168e-02 -2.345 0.019028 *

Haulyr12002:Quarter14 -1.125e+00 9.840e-02 -11.432 < 2e-16 ***

Haulyr12003:Quarter14 -6.454e-02 8.964e-02 -0.720 0.471552

Haulyr12004:Quarter14 -1.414e+00 9.322e-02 -15.170 < 2e-16 ***

Haulyr12005:Quarter14 -1.014e+00 9.700e-02 -10.452 < 2e-16 ***

Haulyr12006:Quarter14 4.290e-02 1.072e-01   0.400 0.688928

Haulyr12007:Quarter14 -2.013e+00 1.151e-01 -17.491 < 2e-16 ***

Haulyr12008:Quarter14 1.574e-01 1.015e-01   1.550 0.121059

Haulyr12009:Quarter14 -1.221e+00 1.143e-01 -10.682 < 2e-16 ***

Haulyr12010:Quarter14 -7.488e-01 1.364e-01 -5.489 4.03e-08 ***

Haulyr12011:Quarter14 -1.390e+00 9.234e-02 -15.054 < 2e-16 ***

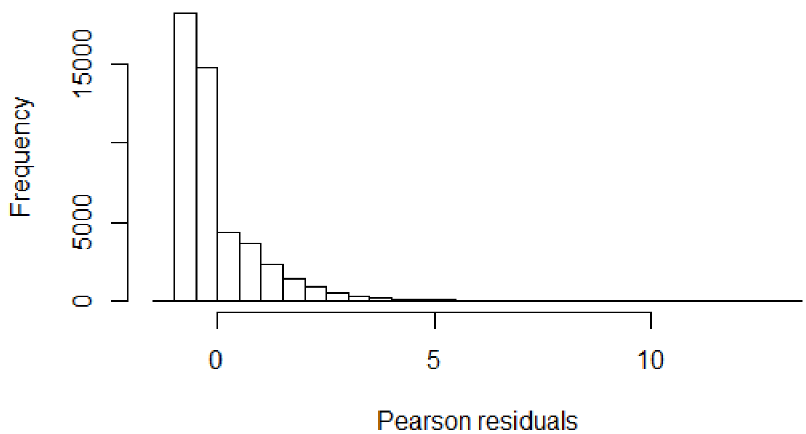
Haulyr12012:Quarter14 -1.553e+00 9.953e-02 -15.600 < 2e-16 ***

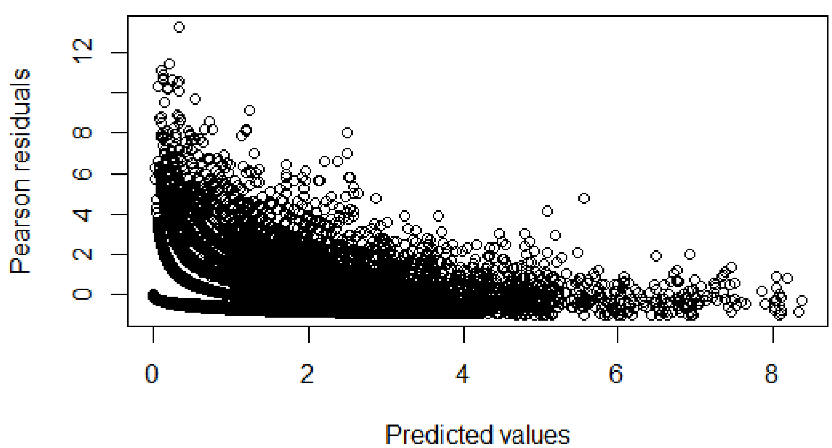
Haulyr12013:Quarter14 6.461e-01 1.018e-01   6.346 2.22e-10 ***

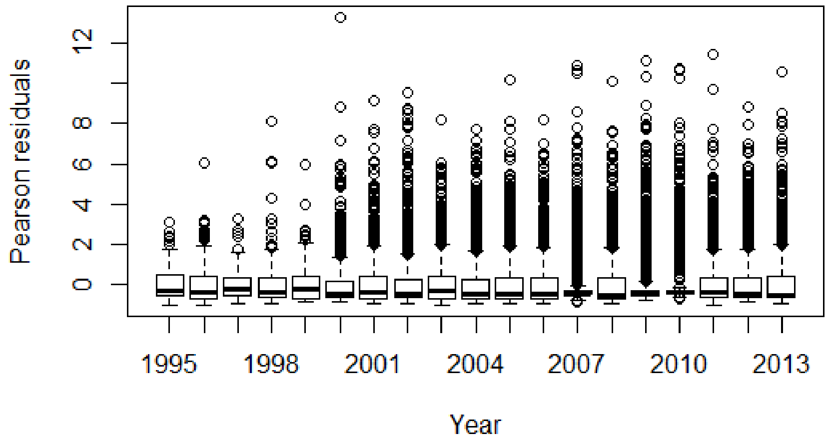
Quarter12:Region12   -8.603e-01 5.865e-01 -1.467 0.142391

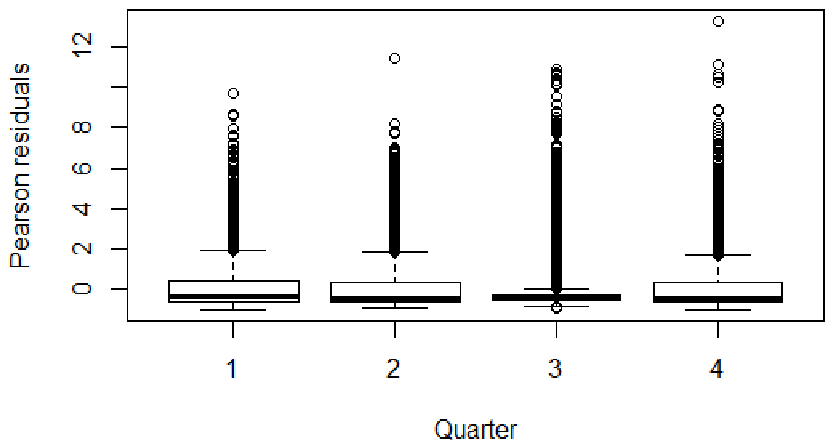
```
Quarter13:Region12    -2.719e+00  5.348e-01  -5.084 3.69e-07 ***
Quarter14:Region12    -5.203e-01  7.217e-01  -0.721 0.470969
Quarter12:Region13    -7.685e-01  5.738e-01  -1.339 0.180474
Quarter13:Region13    -3.596e+00  5.255e-01  -6.843 7.73e-12 ***
Quarter14:Region13    -5.824e-01  7.088e-01  -0.822 0.411234
Quarter12:Region14    -5.619e-01  5.733e-01  -0.980 0.326968
Quarter13:Region14    -3.644e+00  5.237e-01  -6.957 3.48e-12 ***
Quarter14:Region14    -6.738e-01  7.087e-01  -0.951 0.341781
Quarter12:Region15    -7.042e-01  5.740e-01  -1.227 0.219916
Quarter13:Region15    -2.810e+00  5.223e-01  -5.379 7.48e-08 ***
Quarter14:Region15    -2.782e-01  7.085e-01  -0.393 0.694610
Quarter12:Region16    -1.211e-01  5.737e-01  -0.211 0.832864
Quarter13:Region16    -2.850e+00  5.239e-01  -5.440 5.33e-08 ***
Quarter14:Region16    -2.922e-01  7.085e-01  -0.412 0.680006
Quarter12:Region17     9.412e-01  8.218e-01   1.145 0.252134
Quarter13:Region17    -1.232e+00  7.786e-01  -1.582 0.113598
Quarter14:Region17     4.641e-01  9.283e-01   0.500 0.617068
Quarter12:Region18     3.582e+00  1.156e+00   3.099 0.001941 **
Quarter13:Region18     9.251e-01  1.129e+00   0.819 0.412649
Quarter14:Region18     3.365e+00  1.231e+00   2.735 0.006242 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
(Dispersion parameter for poisson family taken to be 1)
    Null deviance: 107388  on 47321  degrees of freedom
Residual deviance:  73005  on 47214  degrees of freedom
AIC: 121412
Number of Fisher Scoring iterations: 9
```

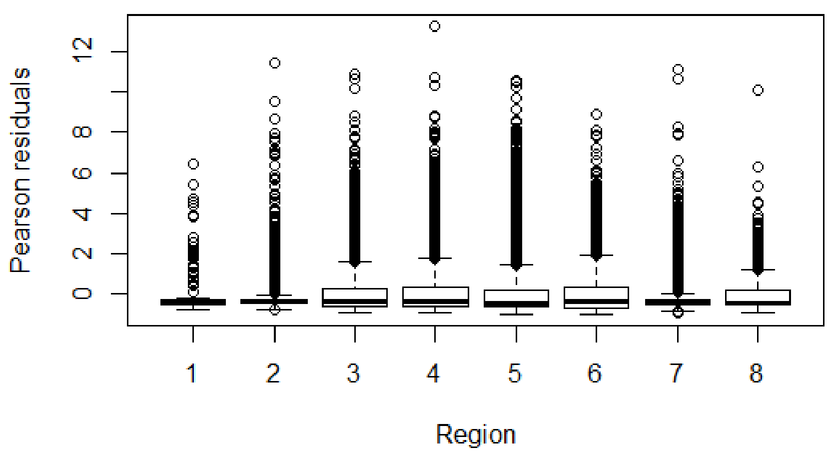
Appendix 5: Pearson residual plots and R summary output for the zero-inflated negative binomial from the deep-set data only. Boxplots represent the median (line), the 1st and 3rd quartiles (box), data up to 1.5 times the interquartile range (IQR) from the quartiles (whiskers), and data beyond 1.5 times the IQR from the quartiles (open circles).

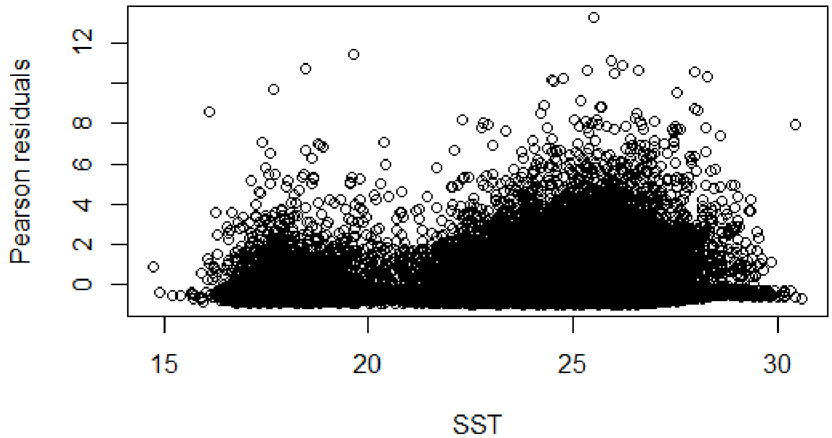


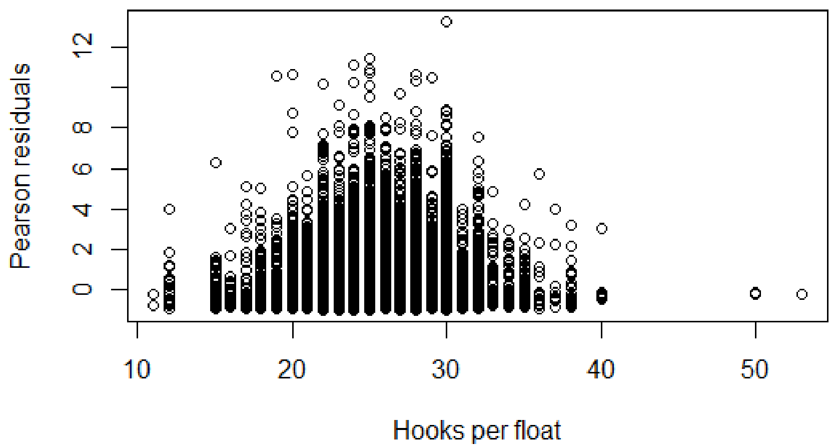


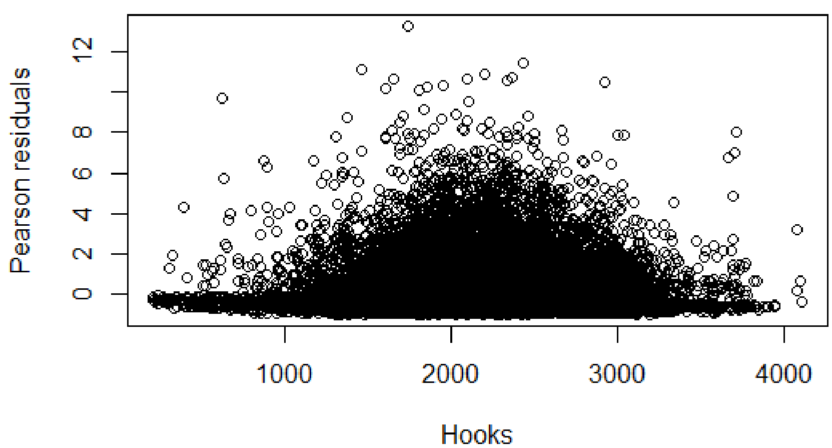

Pearson residuals
0
2
4
6
8
12
1995
1998
2001
2004
2007
2010
2013
Year

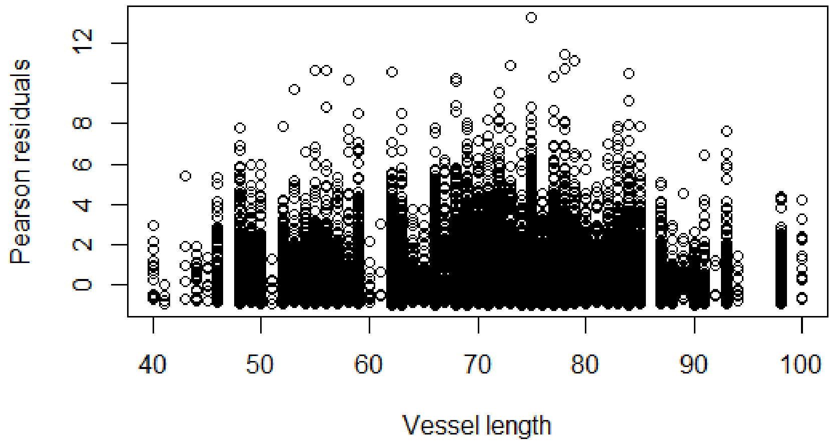

Pearson residuals
0
2
4
6
8
12
1
2
3
4
Quarter


Pearson residuals
0
2
4
6
8
12
1
2
3
4
5
6
7
8
Region


Pearson residuals
0
2
4
6
8
12
15
20
25
30
SST


Pearson residuals
0
2
4
6
8
12
10
20
30
40
50
Hooks per float


Pearson residuals
0
2
4
6
8
12
1000
2000
3000
4000
Hooks




```
> summary(ZNB_full_ds)

Call:
zeroinfl(formula = Striped_Marlin ~ Haulyr1 + Region1 + Quarter1 +
    Haulyr1:Quarter1 + Region1:Quarter1 + Hkpfl + Vesslen + SST +
    I(SST^2) + offset(log(Hooks)) | SST + I(SST^2), data = simp_obs_ds,
    dist = "negbin", link = "logit")

Pearson residuals:
    Min      1Q  Median      3Q     Max
-1.0101 -0.5971 -0.4282  0.2737 13.2759

Count model coefficients (negbin with log link):
                     Estimate Std. Error z value Pr(>|z|)
(Intercept)         -7.350e+00  5.431e-01 -13.533  < 2e-16 ***
Haulyr11996          5.881e-01  1.669e-01   3.524 0.000426 ***
Haulyr11997         -2.955e-01  1.907e-01  -1.550 0.121191
Haulyr11998         -3.300e-01  2.076e-01  -1.590 0.111946
```

Haulyr11999	-1.071e+00	2.148e-01	-4.985	6.19e-07	***
Haulyr12000	-1.026e+00	1.779e-01	-5.764	8.23e-09	***
Haulyr12001	-5.969e-01	1.300e-01	-4.590	4.43e-06	***
Haulyr12002	-8.483e-01	1.303e-01	-6.509	7.58e-11	***
Haulyr12003	-3.381e-01	1.293e-01	-2.614	0.008939	**
Haulyr12004	-3.907e-01	1.297e-01	-3.011	0.002602	**
Haulyr12005	-7.569e-01	1.311e-01	-5.771	7.88e-09	***
Haulyr12006	-1.294e+00	1.474e-01	-8.774	< 2e-16	***
Haulyr12007	-1.229e+00	1.485e-01	-8.271	< 2e-16	***
Haulyr12008	-1.863e+00	1.353e-01	-13.776	< 2e-16	***
Haulyr12009	-1.935e+00	1.379e-01	-14.030	< 2e-16	***
Haulyr12010	-2.839e+00	1.508e-01	-18.829	< 2e-16	***
Haulyr12011	-5.212e-01	1.289e-01	-4.042	5.30e-05	***
Haulyr12012	-1.212e+00	1.308e-01	-9.266	< 2e-16	***
Haulyr12013	-2.213e+00	1.367e-01	-16.187	< 2e-16	***
Region12	1.164e+00	5.397e-01	2.157	0.031036	*
Region13	1.965e+00	5.346e-01	3.675	0.000238	***
Region14	2.157e+00	5.346e-01	4.035	5.46e-05	***
Region15	2.023e+00	5.350e-01	3.780	0.000157	***
Region16	2.436e+00	5.351e-01	4.553	5.29e-06	***
Region17	3.538e-01	8.303e-01	0.426	0.669993	
Region18	-1.697e+00	1.146e+00	-1.480	0.138868	
Quarter12	9.369e-01	6.569e-01	1.426	0.153769	
Quarter13	7.910e-01	6.913e-01	1.144	0.252505	
Quarter14	1.176e+00	8.350e-01	1.408	0.159112	
Hkpfl	-5.253e-02	2.522e-03	-20.829	< 2e-16	***
Vesslen	-1.405e-03	7.191e-04	-1.954	0.050724	.

SST	2.609e-02	NA	NA	NA	
I(SST^2)	-6.282e-04	NA	NA	NA	
Haulyr11996:Quarter12	-1.454e+00	2.764e-01	-5.261	1.43e-07	***
Haulyr11997:Quarter12	-4.899e-01	3.182e-01	-1.540	0.123630	
Haulyr11998:Quarter12	-1.344e+00	4.836e-01	-2.779	0.005448	**
Haulyr11999:Quarter12	-5.185e-02	3.292e-01	-0.157	0.874867	
Haulyr12000:Quarter12	-9.129e-01	3.546e-01	-2.574	0.010045	*
Haulyr12001:Quarter12	-1.887e-01	2.350e-01	-0.803	0.422007	
Haulyr12002:Quarter12	-9.039e-01	2.338e-01	-3.866	0.000110	***
Haulyr12003:Quarter12	-7.025e-01	2.312e-01	-3.039	0.002376	**
Haulyr12004:Quarter12	-1.079e+00	2.307e-01	-4.678	2.90e-06	***
Haulyr12005:Quarter12	-4.233e-01	2.316e-01	-1.828	0.067598	.
Haulyr12006:Quarter12	8.242e-02	2.390e-01	0.345	0.730270	
Haulyr12007:Quarter12	-5.854e-01	2.452e-01	-2.387	0.016981	*
Haulyr12008:Quarter12	3.524e-01	2.315e-01	1.522	0.127972	
Haulyr12009:Quarter12	-1.804e-01	2.397e-01	-0.752	0.451771	
Haulyr12010:Quarter12	-2.561e-01	2.550e-01	-1.004	0.315161	
Haulyr12011:Quarter12	-1.421e+00	2.318e-01	-6.132	8.68e-10	***
Haulyr12012:Quarter12	-1.147e+00	2.343e-01	-4.895	9.83e-07	***
Haulyr12013:Quarter12	-8.829e-02	2.369e-01	-0.373	0.709383	
Haulyr11996:Quarter13	-2.357e-02	6.009e-01	-0.039	0.968704	
Haulyr11997:Quarter13	-9.594e+00	1.437e+02	-0.067	0.946782	
Haulyr11998:Quarter13	1.670e+00	4.654e-01	3.589	0.000332	***
Haulyr11999:Quarter13	1.778e+00	5.480e-01	3.245	0.001173	**
Haulyr12000:Quarter13	4.537e-01	5.314e-01	0.854	0.393214	
Haulyr12001:Quarter13	1.870e+00	4.018e-01	4.654	3.26e-06	***
Haulyr12002:Quarter13	6.128e-01	4.052e-01	1.512	0.130501	

Haulyr12003:Quarter13 1.195e+00 3.972e-01   3.008 0.002633 **

Haulyr12004:Quarter13 1.155e+00 3.991e-01   2.895 0.003796 **

Haulyr12005:Quarter13 8.990e-01 3.984e-01   2.257 0.024033 *

Haulyr12006:Quarter13 2.765e+00 4.022e-01   6.874 6.23e-12 ***

Haulyr12007:Quarter13 7.506e-01 4.109e-01   1.827 0.067735 .

Haulyr12008:Quarter13 1.774e+00 4.006e-01   4.430 9.43e-06 ***

Haulyr12009:Quarter13 1.583e+00 4.031e-01   3.927 8.62e-05 ***

Haulyr12010:Quarter13 2.105e+00 4.093e-01   5.142 2.72e-07 ***

Haulyr12011:Quarter13 -9.840e-02 4.008e-01 -0.246 0.806042

Haulyr12012:Quarter13 5.947e-01 4.017e-01   1.481 0.138720

Haulyr12013:Quarter13 2.114e+00 4.001e-01   5.283 1.27e-07 ***

Haulyr11996:Quarter14 -1.838e+00 2.758e-01 -6.666 2.63e-11 ***

Haulyr11997:Quarter14 -1.285e+00 2.926e-01 -4.391 1.13e-05 ***

Haulyr11998:Quarter14 -2.257e-01 2.553e-01 -0.884 0.376625

Haulyr11999:Quarter14 -9.705e-02 2.694e-01 -0.360 0.718674

Haulyr12000:Quarter14 -1.190e+00 2.192e-01 -5.429 5.68e-08 ***

Haulyr12001:Quarter14 -1.078e-01 1.726e-01 -0.624 0.532393

Haulyr12002:Quarter14 -1.057e+00 1.764e-01 -5.989 2.11e-09 ***

Haulyr12003:Quarter14 8.346e-02 1.715e-01   0.487 0.626545

Haulyr12004:Quarter14 -1.269e+00 1.735e-01 -7.317 2.54e-13 ***

Haulyr12005:Quarter14 -8.951e-01 1.762e-01 -5.080 3.78e-07 ***

Haulyr12006:Quarter14 2.254e-01 1.865e-01   1.209 0.226849

Haulyr12007:Quarter14 -1.873e+00 1.904e-01 -9.840 < 2e-16 ***

Haulyr12008:Quarter14 2.381e-01 1.787e-01   1.332 0.182792

Haulyr12009:Quarter14 -1.112e+00 1.864e-01 -5.968 2.40e-09 ***

Haulyr12010:Quarter14 -6.247e-01 2.008e-01 -3.111 0.001862 **

Haulyr12011:Quarter14 -1.248e+00 1.729e-01 -7.221 5.16e-13 ***

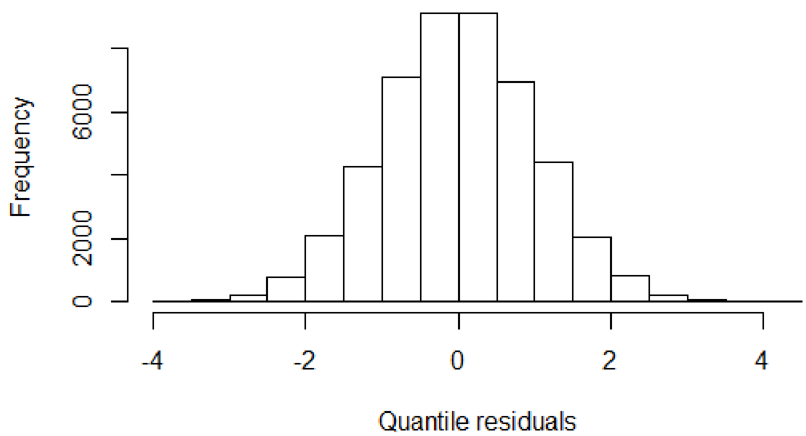
Haulyr12012:Quarter14	-1.439e+00	1.767e-01	-8.142	3.90e-16	***
Haulyr12013:Quarter14	7.465e-01	1.786e-01	4.180	2.92e-05	***
Region12:Quarter12	-9.901e-01	6.348e-01	-1.560	0.118823	
Region13:Quarter12	-8.920e-01	6.199e-01	-1.439	0.150164	
Region14:Quarter12	-6.789e-01	6.191e-01	-1.096	0.272861	
Region15:Quarter12	-8.014e-01	6.205e-01	-1.292	0.196513	
Region16:Quarter12	-2.750e-01	6.206e-01	-0.443	0.657666	
Region17:Quarter12	8.916e-01	8.989e-01	0.992	0.321210	
Region18:Quarter12	3.498e+00	1.195e+00	2.928	0.003412	**
Region12:Quarter13	-2.565e+00	5.917e-01	-4.334	1.46e-05	***
Region13:Quarter13	-3.609e+00	5.749e-01	-6.277	3.46e-10	***
Region14:Quarter13	-3.604e+00	5.726e-01	-6.294	3.10e-10	***
Region15:Quarter13	-2.963e+00	5.710e-01	-5.189	2.12e-07	***
Region16:Quarter13	-2.976e+00	5.744e-01	-5.181	2.20e-07	***
Region17:Quarter13	-1.257e+00	8.546e-01	-1.471	0.141295	
Region18:Quarter13	9.067e-01	1.166e+00	0.778	0.436645	
Region12:Quarter14	-5.685e-01	8.386e-01	-0.678	0.497836	
Region13:Quarter14	-8.791e-01	8.199e-01	-1.072	0.283654	
Region14:Quarter14	-9.063e-01	8.199e-01	-1.105	0.269033	
Region15:Quarter14	-4.802e-01	8.196e-01	-0.586	0.557932	
Region16:Quarter14	-5.571e-01	8.197e-01	-0.680	0.496790	
Region17:Quarter14	5.120e-01	1.059e+00	0.483	0.628916	
Region18:Quarter14	3.158e+00	1.316e+00	2.400	0.016391	*
Log(theta)	1.555e-01	6.234e-03	24.942	< 2e-16	***

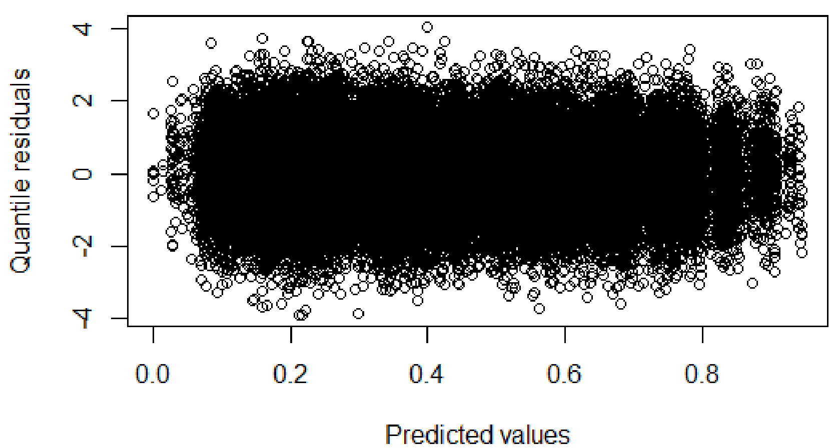
Zero-inflation model coefficients (binomial with logit link):

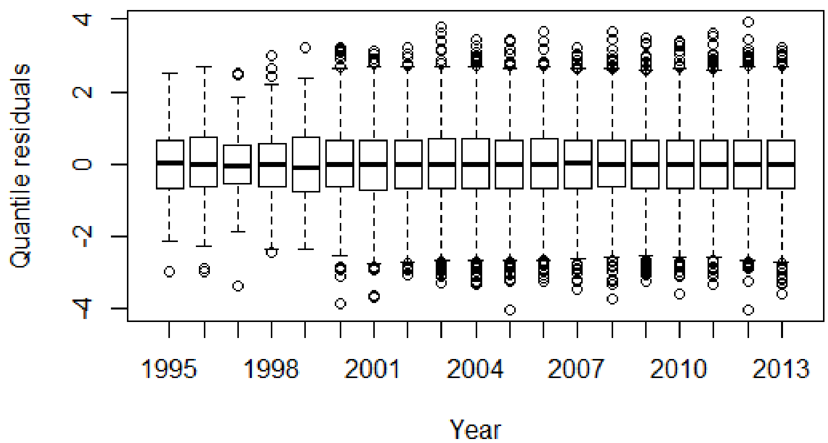
Estimate Std. Error z value Pr(>|z|)

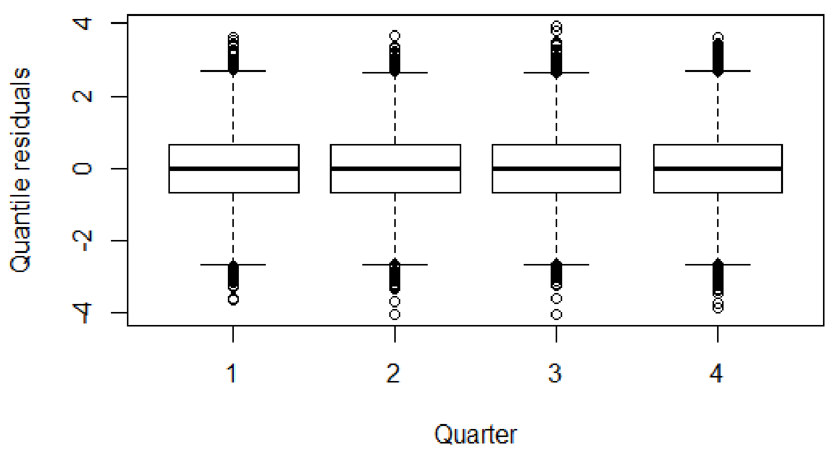
```
(Intercept) -515.7333     3.1343  -164.5   <2e-16 ***
SST           35.7325     0.1283   278.6   <2e-16 ***
I(SST^2)      -0.6191         NA      NA       NA
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Theta = 1.1682
Number of iterations in BFGS optimization: 142
Log-likelihood: -5.508e+04 on 112 Df
```

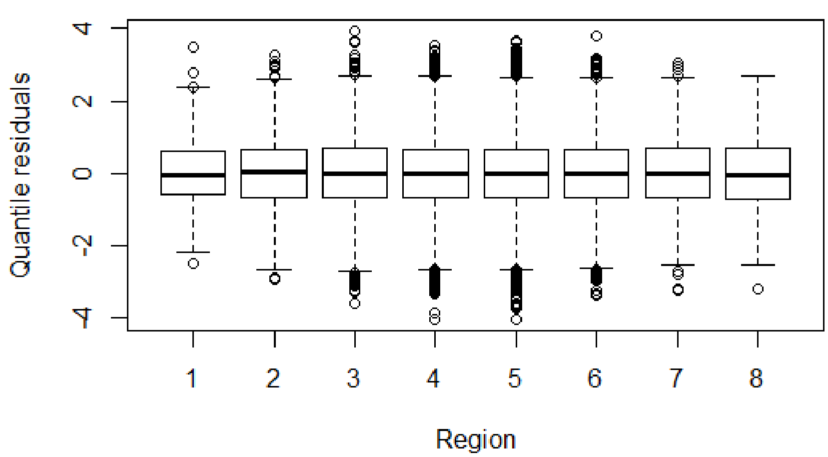
Appendix 6a: Quantile residual plots and R summary output for the zero process of the delta-lognormal distribution from the deep-set data only. Boxplots represent the median (line), the 1st and 3rd quartiles (box), data up to 1.5 times the interquartile range (IQR) from the quartiles (whiskers), and data beyond 1.5 times the IQR from the quartiles (open circles).

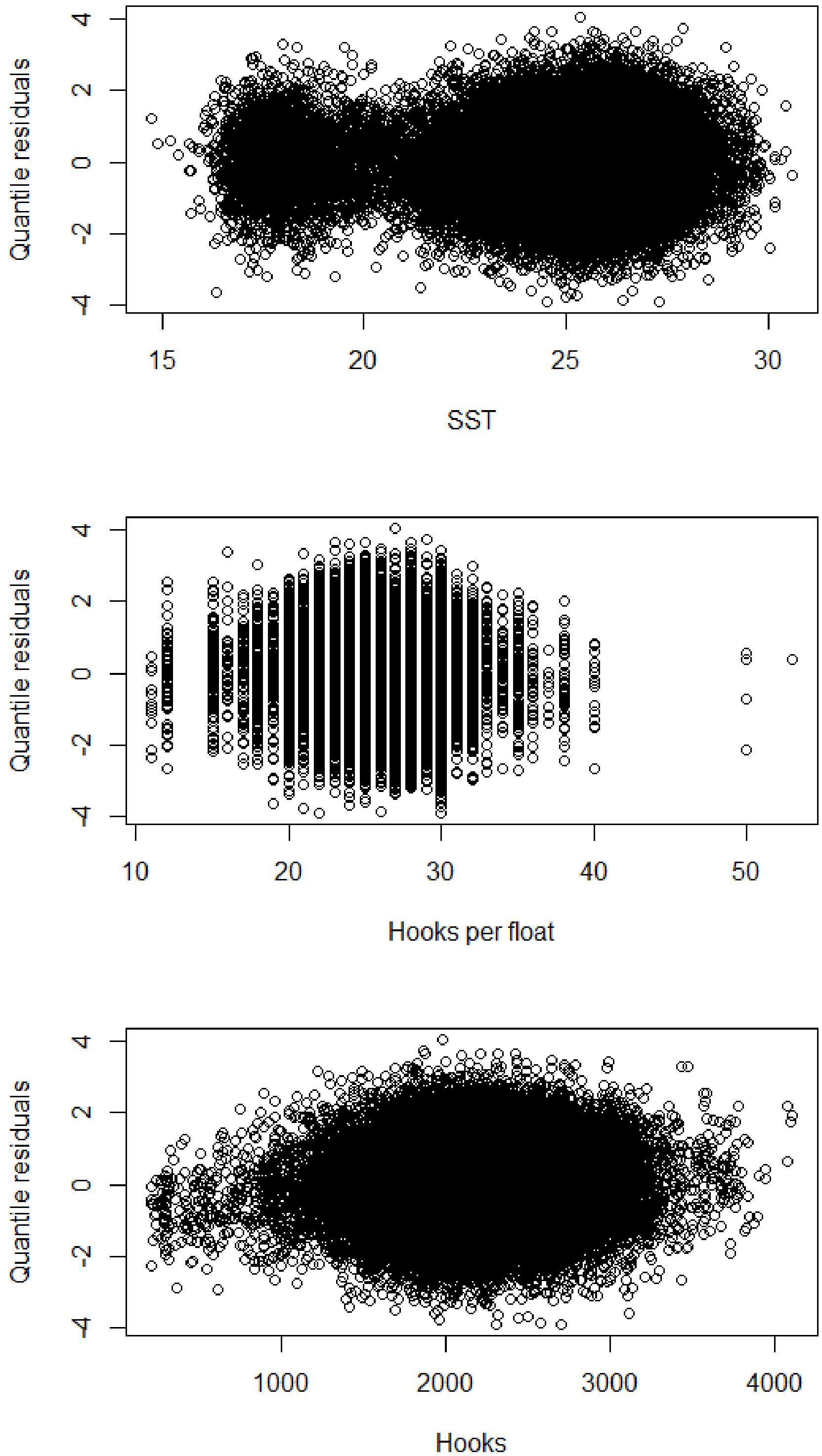


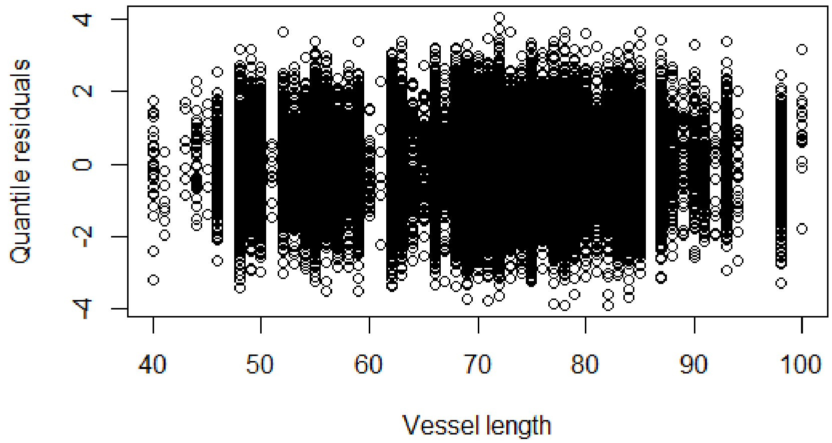



Quantile residuals
4
2
0
-2
-4
1995
1998
2001
2004
2007
2010
2013
Year


Quantile residuals
4
2
0
-2
-4
1
2
3
4
Quarter


Quantile residuals
4
2
0
-2
-4
1
2
3
4
5
6
7
8
Region


Quantile residuals
4
2
0
-2
-4
15
20
25
30
SST
Quantile residuals
4
2
0
-2
-4
10
20
30
40
50
Hooks per float
Quantile residuals
4
2
0
-2
-4
1000
2000
3000
4000
Hooks




```
> summary(LNBin_full_ds)
Call:
glm(formula = Z ~ Haulyr1 + Quarter1 + Region1 + SST + I(SST^2) +
    Haulyr1:Quarter1 + Region1:Quarter1, family = binomial(link = "logit"),
    data = simp_obs_ds)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.4116  -0.8997  -0.5862   1.0061   2.6676

Coefficients:
                      Estimate Std. Error z value Pr(>|z|)
(Intercept)          -4.960031   0.995755  -4.981 6.32e-07 ***
Haulyr11996           0.597940   0.526723   1.135 0.256289
Haulyr11997          -0.006063   0.510241  -0.012 0.990520
Haulyr11998          -0.933407   0.439000  -2.126 0.033486 *
Haulyr11999          -1.698261   0.403815  -4.206 2.60e-05 ***
Haulyr12000          -2.047213   0.364518  -5.616 1.95e-08 ***
```

Haulyr12001	-1.080826	0.321254	-3.364	0.000767	***
Haulyr12002	-1.489757	0.319250	-4.666	3.06e-06	***
Haulyr12003	-0.651096	0.322915	-2.016	0.043768	*
Haulyr12004	-1.099437	0.321281	-3.422	0.000622	***
Haulyr12005	-1.219944	0.321553	-3.794	0.000148	***
Haulyr12006	-1.773937	0.333304	-5.322	1.02e-07	***
Haulyr12007	-1.773196	0.335614	-5.283	1.27e-07	***
Haulyr12008	-2.471786	0.321087	-7.698	1.38e-14	***
Haulyr12009	-2.539357	0.322873	-7.865	3.69e-15	***
Haulyr12010	-3.231798	0.327446	-9.870	< 2e-16	***
Haulyr12011	-0.889136	0.322154	-2.760	0.005781	**
Haulyr12012	-1.485707	0.320133	-4.641	3.47e-06	***
Haulyr12013	-2.498561	0.320806	-7.788	6.79e-15	***
Quarter12	0.047174	0.783543	0.060	0.951991	
Quarter13	-0.467827	0.786346	-0.595	0.551885	
Quarter14	0.357545	0.903460	0.396	0.692289	
Region12	0.963378	0.543890	1.771	0.076516	.
Region13	1.982297	0.538837	3.679	0.000234	***
Region14	2.248551	0.538784	4.173	3.00e-05	***
Region15	1.787336	0.539333	3.314	0.000920	***
Region16	2.524319	0.540353	4.672	2.99e-06	***
Region17	-0.606905	1.165290	-0.521	0.602493	
Region18	-1.692273	1.148044	-1.474	0.140468	
SST	0.430440	0.069124	6.227	4.75e-10	***
I(SST^2)	-0.009808	0.001515	-6.476	9.41e-11	***
Haulyr11996:Quarter12	-1.635223	0.661847	-2.471	0.013485	*
Haulyr11997:Quarter12	-0.635192	0.684045	-0.929	0.353106	

Haulyr11998:Quarter12	-0.563385	0.726183	-0.776	0.437858	
Haulyr11999:Quarter12	0.851106	0.594837	1.431	0.152481	
Haulyr12000:Quarter12	0.620570	0.577249	1.075	0.282353	
Haulyr12001:Quarter12	0.560799	0.484272	1.158	0.246854	
Haulyr12002:Quarter12	-0.111859	0.476248	-0.235	0.814305	
Haulyr12003:Quarter12	-0.149715	0.480007	-0.312	0.755115	
Haulyr12004:Quarter12	-0.261787	0.475590	-0.550	0.582014	
Haulyr12005:Quarter12	0.327067	0.477810	0.685	0.493652	
Haulyr12006:Quarter12	0.830485	0.482634	1.721	0.085299	.
Haulyr12007:Quarter12	0.176072	0.488557	0.360	0.718555	
Haulyr12008:Quarter12	1.264500	0.474878	2.663	0.007750	**
Haulyr12009:Quarter12	0.671472	0.480296	1.398	0.162102	
Haulyr12010:Quarter12	0.489136	0.486726	1.005	0.314921	
Haulyr12011:Quarter12	-0.514645	0.478796	-1.075	0.282431	
Haulyr12012:Quarter12	-0.433135	0.477222	-0.908	0.364080	
Haulyr12013:Quarter12	0.536758	0.477919	1.123	0.261389	
Haulyr11996:Quarter13	-0.116114	0.830004	-0.140	0.888743	
Haulyr11997:Quarter13	-10.031336	73.102433	-0.137	0.890855	
Haulyr11998:Quarter13	1.010820	0.659206	1.533	0.125180	
Haulyr11999:Quarter13	2.123937	0.715603	2.968	0.002997	**
Haulyr12000:Quarter13	1.104031	0.639625	1.726	0.084337	.
Haulyr12001:Quarter13	1.743140	0.517684	3.367	0.000759	***
Haulyr12002:Quarter13	0.886380	0.516099	1.717	0.085895	.
Haulyr12003:Quarter13	1.095244	0.512258	2.138	0.032511	*
Haulyr12004:Quarter13	1.505242	0.511457	2.943	0.003250	**
Haulyr12005:Quarter13	1.127157	0.510384	2.208	0.027213	*
Haulyr12006:Quarter13	2.795469	0.517635	5.400	6.65e-08	***

Haulyr12007:Quarter13	1.074800	0.525544	2.045	0.040843	*
Haulyr12008:Quarter13	2.230028	0.511314	4.361	1.29e-05	***
Haulyr12009:Quarter13	2.012884	0.513398	3.921	8.83e-05	***
Haulyr12010:Quarter13	2.408029	0.517899	4.650	3.33e-06	***
Haulyr12011:Quarter13	0.234397	0.513819	0.456	0.648256	
Haulyr12012:Quarter13	0.854695	0.512995	1.666	0.095696	.
Haulyr12013:Quarter13	2.240266	0.510449	4.389	1.14e-05	***
Haulyr11996:Quarter14	-2.115611	0.644400	-3.283	0.001027	**
Haulyr11997:Quarter14	-1.184199	0.633086	-1.871	0.061412	.
Haulyr11998:Quarter14	1.190946	0.560042	2.127	0.033459	*
Haulyr11999:Quarter14	0.783922	0.521480	1.503	0.132771	
Haulyr12000:Quarter14	-0.209101	0.455050	-0.460	0.645866	
Haulyr12001:Quarter14	0.561358	0.418001	1.343	0.179285	
Haulyr12002:Quarter14	-0.585759	0.416291	-1.407	0.159401	
Haulyr12003:Quarter14	0.767603	0.420314	1.826	0.067811	.
Haulyr12004:Quarter14	-0.302512	0.415237	-0.729	0.466289	
Haulyr12005:Quarter14	-0.291903	0.417026	-0.700	0.483950	
Haulyr12006:Quarter14	0.962724	0.426446	2.258	0.023973	*
Haulyr12007:Quarter14	-1.107819	0.426925	-2.595	0.009462	**
Haulyr12008:Quarter14	1.050550	0.418209	2.512	0.012004	*
Haulyr12009:Quarter14	-0.277470	0.419775	-0.661	0.508615	
Haulyr12010:Quarter14	0.030787	0.425948	0.072	0.942380	
Haulyr12011:Quarter14	-0.392026	0.417483	-0.939	0.347718	
Haulyr12012:Quarter14	-0.768017	0.415909	-1.847	0.064805	.
Haulyr12013:Quarter14	1.591726	0.417230	3.815	0.000136	***
Quarter12:Region12	-1.094346	0.651992	-1.678	0.093256	.
Quarter13:Region12	-1.647291	0.632062	-2.606	0.009155	**

Quarter14:Region12	-1.141515	0.834160	-1.368	0.171168	
Quarter12:Region13	-0.845899	0.633017	-1.336	0.181452	
Quarter13:Region13	-2.874209	0.614406	-4.678	2.90e-06	***
Quarter14:Region13	-1.159665	0.810153	-1.431	0.152312	
Quarter12:Region14	-0.752386	0.632040	-1.190	0.233886	
Quarter13:Region14	-2.856633	0.611478	-4.672	2.99e-06	***
Quarter14:Region14	-1.059042	0.810146	-1.307	0.191137	
Quarter12:Region15	-0.595324	0.634255	-0.939	0.347926	
Quarter13:Region15	-1.987197	0.609440	-3.261	0.001111	**
Quarter14:Region15	-0.185366	0.809100	-0.229	0.818790	
Quarter12:Region16	-0.069559	0.636527	-0.109	0.912982	
Quarter13:Region16	-2.173760	0.615825	-3.530	0.000416	***
Quarter14:Region16	-0.472218	0.810502	-0.583	0.560146	
Quarter12:Region17	2.128248	1.224382	1.738	0.082172	.
Quarter13:Region17	0.586648	1.200229	0.489	0.624997	
Quarter14:Region17	1.393623	1.340346	1.040	0.298457	
Quarter12:Region18	3.658561	1.209472	3.025	0.002487	**
Quarter13:Region18	1.920183	1.185711	1.619	0.105354	
Quarter14:Region18	3.341509	1.322077	2.527	0.011489	*

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

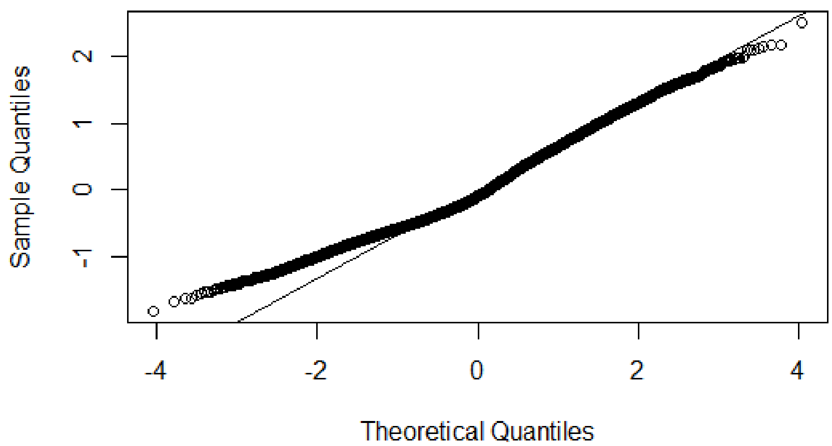
Null deviance: 63808 on 47321 degrees of freedom

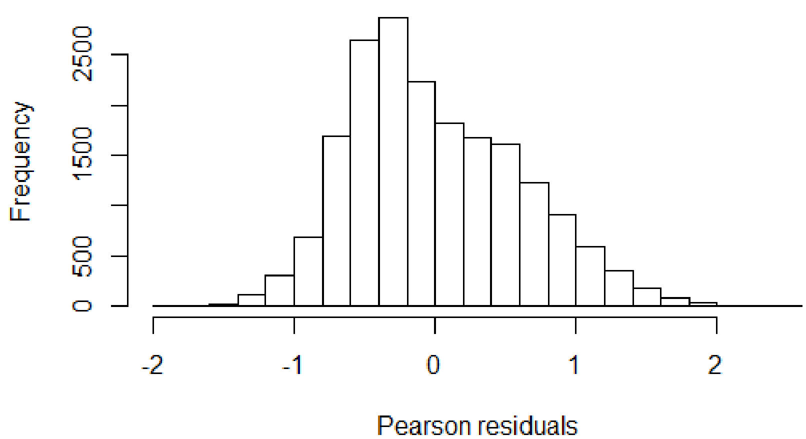
Residual deviance: 54582 on 47216 degrees of freedom

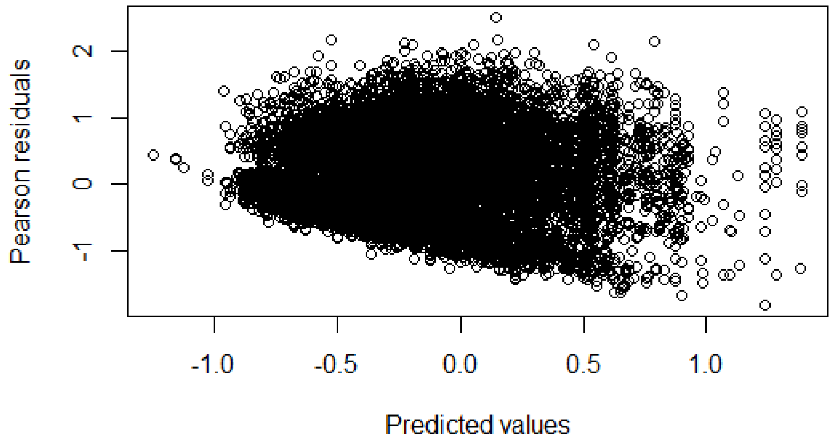
AIC: 54794

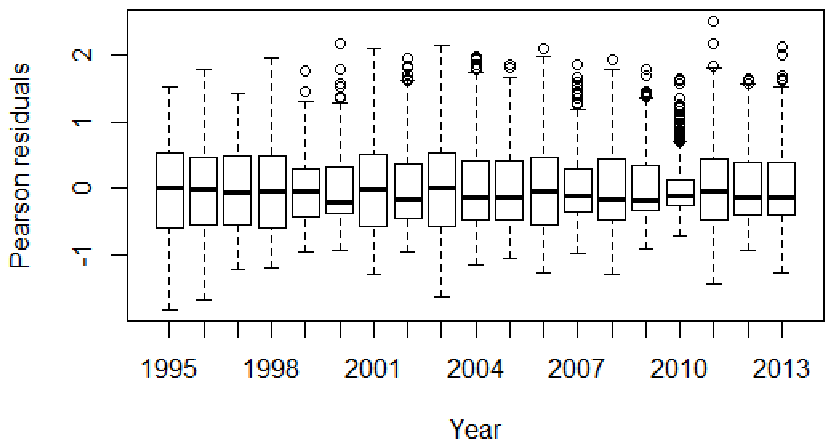
Number of Fisher Scoring iterations: 10

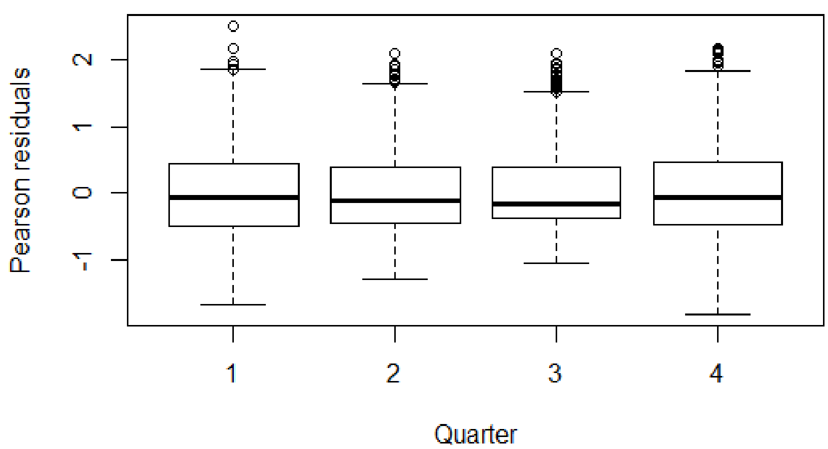
Appendix 6b: Pearson residual plots, quantile-quantile plot, and R summary output for the positive process of the delta-lognormal distribution from the deep-set data only. Boxplots represent the median (line), the 1st and 3rd quartiles (box), data up to 1.5 times the interquartile range (IQR) from the quartiles (whiskers), and data beyond 1.5 times the IQR from the quartiles (open circles).

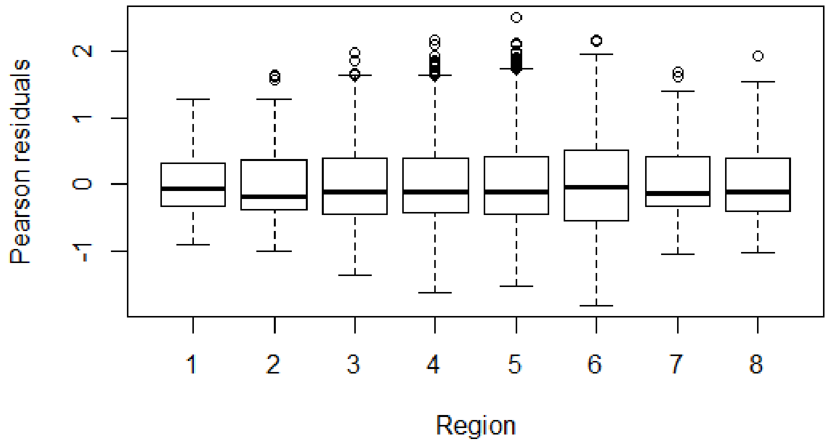


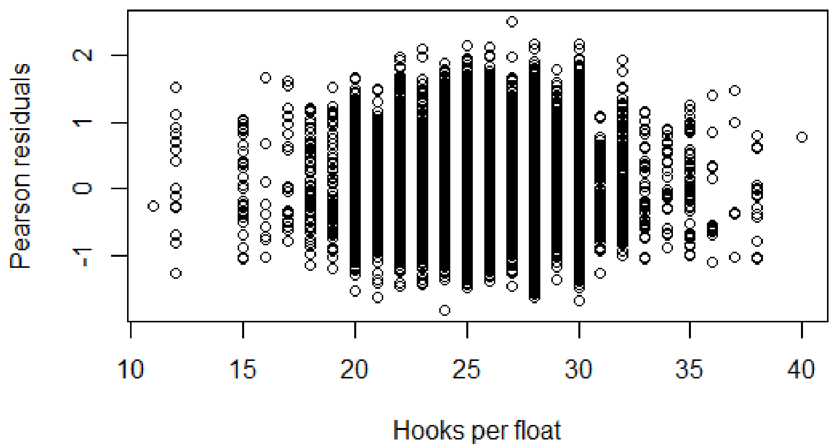


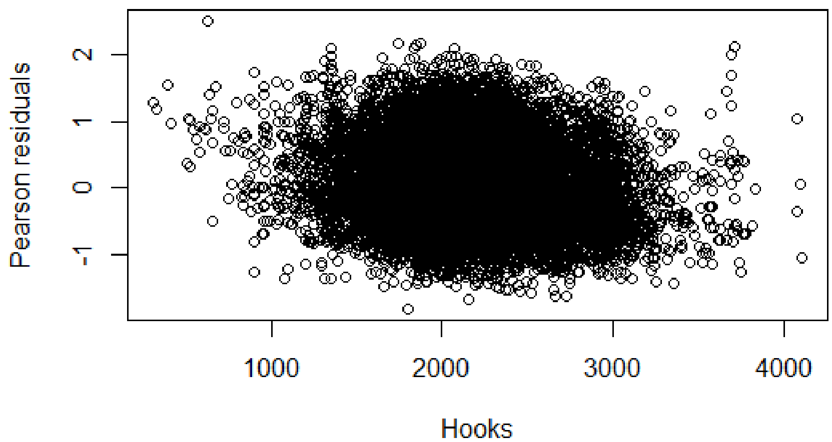

Pearson residuals
2
1
0
-1
-1.0
-0.5
0.0
0.5
1.0
Predicted values

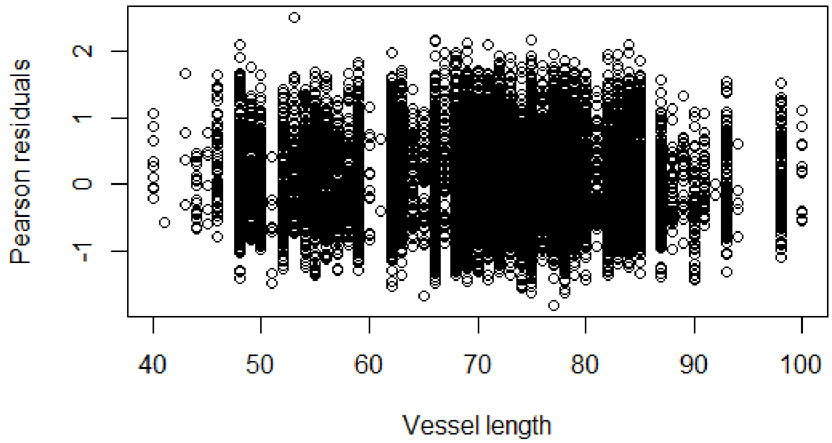

Pearson residuals
2
1
0
-1
1995
1998
2001
2004
2007
2010
2013
Year


Pearson residuals
2
1
0
-1
1
2
3
4
Quarter


Pearson residuals
-1
0
1
2
1
2
3
4
5
6
7
8
Region


Pearson residuals
-1
0
1
2
10
15
20
25
30
35
40
Hooks per float


Pearson residuals
-1
0
1
2
1000
2000
3000
4000
Hooks



> summary(LNPos_full_ds)

Call:

glm(formula = log(SM_cpue) ~ Haulyr1 + Quarter1 + Region1 + Hkpfl +
Vesslen + Haulyr1:Quarter1 + Region1:Quarter1, family = gaussian,
data = positives_ds)

Deviance Residuals:

Min	1Q	Median	3Q	Max
-1.82570	-0.45893	-0.09962	0.42460	2.51822

Coefficients: (1 not defined because of singularities)

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	0.9694017	0.3160161	3.068	0.002161	**
Haulyr11996	0.4770747	0.0979955	4.868	1.13e-06	***
Haulyr11997	-0.1939597	0.1088697	-1.782	0.074834	.
Haulyr11998	-0.2023642	0.1241141	-1.630	0.103019	
Haulyr11999	-0.5601158	0.1279781	-4.377	1.21e-05	***
Haulyr12000	-0.3309687	0.1105204	-2.995	0.002751	**

Haulyr12001	-0.3750544	0.0746985	-5.021	5.19e-07	***
Haulyr12002	-0.4720583	0.0751400	-6.282	3.41e-10	***
Haulyr12003	-0.2649918	0.0743129	-3.566	0.000364	***
Haulyr12004	-0.2681064	0.0748627	-3.581	0.000343	***
Haulyr12005	-0.4665291	0.0756578	-6.166	7.13e-10	***
Haulyr12006	-0.7135745	0.0855145	-8.344	< 2e-16	***
Haulyr12007	-0.6266355	0.0872772	-7.180	7.24e-13	***
Haulyr12008	-0.8654981	0.0787053	-10.997	< 2e-16	***
Haulyr12009	-0.8562669	0.0806034	-10.623	< 2e-16	***
Haulyr12010	-1.1266217	0.0874186	-12.888	< 2e-16	***
Haulyr12011	-0.3300486	0.0743458	-4.439	9.07e-06	***
Haulyr12012	-0.7656252	0.0753257	-10.164	< 2e-16	***
Haulyr12013	-1.1071145	0.0787361	-14.061	< 2e-16	***
Quarter12	0.3428886	0.3782806	0.906	0.364715	
Quarter13	0.0902028	0.4007615	0.225	0.821921	
Quarter14	0.5897558	0.4391456	1.343	0.179300	
Region12	0.1791203	0.3065578	0.584	0.559029	
Region13	0.4313015	0.3031890	1.423	0.154883	
Region14	0.5100756	0.3030586	1.683	0.092374	.
Region15	0.5559940	0.3033437	1.833	0.066835	.
Region16	0.6409979	0.3033720	2.113	0.034621	*
Region17	0.8951006	0.6754632	1.325	0.185132	
Region18	0.3894397	0.6755437	0.576	0.564295	
Hkpfl	-0.0317967	0.0015596	-20.387	< 2e-16	***
Vesslen	-0.0036042	0.0004441	-8.116	5.12e-16	***
Haulyr11996:Quarter12	-0.8008057	0.1677268	-4.774	1.82e-06	***
Haulyr11997:Quarter12	-0.2490266	0.1891779	-1.316	0.188068	

Haulyr11998:Quarter12	-0.6296121	0.2854870	-2.205	0.027438	*
Haulyr11999:Quarter12	-0.0702184	0.1977503	-0.355	0.722529	
Haulyr12000:Quarter12	-0.7121286	0.2079214	-3.425	0.000616	***
Haulyr12001:Quarter12	-0.0734862	0.1411325	-0.521	0.602589	
Haulyr12002:Quarter12	-0.3704323	0.1406792	-2.633	0.008466	**
Haulyr12003:Quarter12	-0.2722900	0.1388469	-1.961	0.049884	*
Haulyr12004:Quarter12	-0.4906880	0.1387372	-3.537	0.000406	***
Haulyr12005:Quarter12	-0.2186450	0.1392367	-1.570	0.116359	
Haulyr12006:Quarter12	0.0181472	0.1435211	0.126	0.899383	
Haulyr12007:Quarter12	-0.2901911	0.1480764	-1.960	0.050041	.
Haulyr12008:Quarter12	0.0640448	0.1396095	0.459	0.646424	
Haulyr12009:Quarter12	-0.1466321	0.1451679	-1.010	0.312467	
Haulyr12010:Quarter12	-0.1345564	0.1532611	-0.878	0.379979	
Haulyr12011:Quarter12	-0.7518669	0.1392451	-5.400	6.76e-08	***
Haulyr12012:Quarter12	-0.3829676	0.1408900	-2.718	0.006570	**
Haulyr12013:Quarter12	-0.0251902	0.1426083	-0.177	0.859794	
Haulyr11996:Quarter13	-0.4542566	0.3525258	-1.289	0.197561	
Haulyr11997:Quarter13	NA	NA	NA	NA	
Haulyr11998:Quarter13	0.9072768	0.2810625	3.228	0.001249	**
Haulyr11999:Quarter13	0.7305620	0.3207180	2.278	0.022744	*
Haulyr12000:Quarter13	0.2620639	0.3062678	0.856	0.392192	
Haulyr12001:Quarter13	0.7699731	0.2215436	3.475	0.000511	***
Haulyr12002:Quarter13	0.4769363	0.2241741	2.128	0.033389	*
Haulyr12003:Quarter13	0.5186052	0.2180689	2.378	0.017409	*
Haulyr12004:Quarter13	0.4502314	0.2191152	2.055	0.039915	*
Haulyr12005:Quarter13	0.4407533	0.2187980	2.014	0.043979	*
Haulyr12006:Quarter13	1.1547407	0.2211474	5.222	1.79e-07	***

Haulyr12007:Quarter13	0.4434237	0.2273538	1.950	0.051147	.
Haulyr12008:Quarter13	0.7535531	0.2207556	3.414	0.000643	***
Haulyr12009:Quarter13	0.7068182	0.2226459	3.175	0.001503	**
Haulyr12010:Quarter13	0.8572104	0.2258729	3.795	0.000148	***
Haulyr12011:Quarter13	0.0621988	0.2206088	0.282	0.777991	
Haulyr12012:Quarter13	0.4570502	0.2213081	2.065	0.038916	*
Haulyr12013:Quarter13	0.9585339	0.2203299	4.350	1.37e-05	***
Haulyr11996:Quarter14	-1.2221589	0.1720512	-7.103	1.26e-12	***
Haulyr11997:Quarter14	-1.0619338	0.1659110	-6.401	1.58e-10	***
Haulyr11998:Quarter14	-0.4646578	0.1537782	-3.022	0.002518	**
Haulyr11999:Quarter14	-0.3358040	0.1634838	-2.054	0.039984	*
Haulyr12000:Quarter14	-0.9877711	0.1372470	-7.197	6.38e-13	***
Haulyr12001:Quarter14	-0.3140080	0.1034766	-3.035	0.002412	**
Haulyr12002:Quarter14	-0.7085925	0.1069557	-6.625	3.56e-11	***
Haulyr12003:Quarter14	-0.1882960	0.1027135	-1.833	0.066786	.
Haulyr12004:Quarter14	-0.9917529	0.1041135	-9.526	< 2e-16	***
Haulyr12005:Quarter14	-0.7251871	0.1060666	-6.837	8.33e-12	***
Haulyr12006:Quarter14	-0.2410535	0.1118192	-2.156	0.031116	*
Haulyr12007:Quarter14	-1.0036085	0.1152788	-8.706	< 2e-16	***
Haulyr12008:Quarter14	-0.3510591	0.1083381	-3.240	0.001196	**
Haulyr12009:Quarter14	-0.8322100	0.1130234	-7.363	1.87e-13	***
Haulyr12010:Quarter14	-0.5850676	0.1214183	-4.819	1.46e-06	***
Haulyr12011:Quarter14	-1.0288641	0.1038922	-9.903	< 2e-16	***
Haulyr12012:Quarter14	-0.9239274	0.1062660	-8.694	< 2e-16	***
Haulyr12013:Quarter14	-0.1686085	0.1069359	-1.577	0.114876	
Quarter12:Region12	-0.0506468	0.3658598	-0.138	0.889900	
Quarter13:Region12	-0.7552013	0.3511327	-2.151	0.031508	*

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Quarter14:Region12     0.1293713  0.4438263   0.291 0.770679
Quarter12:Region13    -0.2346956  0.3551349  -0.661 0.508708
Quarter13:Region13    -0.9460882  0.3424386  -2.763 0.005736 **
Quarter14:Region13     0.0339423  0.4291254   0.079 0.936957
Quarter12:Region14    -0.1720821  0.3544526  -0.485 0.627337
Quarter13:Region14    -1.0494724  0.3404584  -3.083 0.002055 **
Quarter14:Region14    -0.0500782  0.4289977  -0.117 0.907073
Quarter12:Region15    -0.2928150  0.3555346  -0.824 0.410183
Quarter13:Region15    -0.9233103  0.3398175  -2.717 0.006592 **
Quarter14:Region15     0.0095479  0.4286681   0.022 0.982230
Quarter12:Region16    -0.0671229  0.3554375  -0.189 0.850216
Quarter13:Region16    -0.9980689  0.3419750  -2.919 0.003521 **
Quarter14:Region16     0.0784053  0.4288114   0.183 0.854923
Quarter12:Region17    -0.7650499  0.7052708  -1.085 0.278042
Quarter13:Region17    -1.3460484  0.6929120  -1.943 0.052080 .
Quarter14:Region17    -0.3954673  0.7520884  -0.526 0.599016
Quarter12:Region18     0.0073806  0.7043286   0.010 0.991639
Quarter13:Region18    -0.8711432  0.6937268  -1.256 0.209224
Quarter14:Region18     0.0761763  0.7480890   0.102 0.918894
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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
(Dispersion parameter for gaussian family taken to be 0.3646685)
    Null deviance: 9235.7  on 19068  degrees of freedom
Residual deviance: 6915.6  on 18964  degrees of freedom
AIC: 34986

Number of Fisher Scoring iterations: 2
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