Aquaculture Reports 4 (2016) 150–155

Contents lists available at ScienceDirect

Aquaculture Reports

journal homepage: www.elsevier.com/locate/aqrep

Analysis of transaction records of live freshwater finfish in China: A case study of customers' claims of fish mortality using cross-classified modeling

Beibei Jia[a], Sophie St-Hilaire[a], Henrik Stryhn[a], Jenny Yu[a], David B. Groman[b], Ian A. Gardner[a,*]

[a] *Department of Health Management, Atlantic Veterinary College, University of Prince Edward Island, Charlottetown, PE C1A4P3, Canada*
[b] *Aquatic Diagnostic Services, Atlantic Veterinary College, University of Prince Edward Island, Charlottetown, PE C1A4P3, Canada*

ARTICLE INFO

Article history:
Received 7 April 2016
Received in revised form 11 October 2016
Accepted 11 October 2016

Keywords:
Live fish transportation
Fish mortality claims
Customers
Cross-classified model
China

ABSTRACT

Customers of finfish in China place a high priority on healthy fish at the point of sale but factors that increase the risk of morbidity and mortality during transportation have had limited study. We designed a case study to investigate variation of mortalities claimed by customers receiving fish at markets with above-normal mortalities. We used daily transaction records of the 3 species transported from a company located in Guangdong province to its destination markets in Beijing between April and July 2013: largemouth bass (*Micropterus salmoides*), Chinese perch (*Siniperca chuatsi*), and longsnout catfish (*Leiocassis longirostris*). We quantified magnitudes and patterns of weekly mortalities of transported fish, and used cross-classified random-effect modeling to explore variation and clustering of fish mortality claims at wholesale destinations. Random effects for customer and market-week were interpreted by variance partition coefficients (VPC) and intraclass correlation coefficients (ICC). A significant fixed effect of market was found in the model of mortality claims for longsnout catfish ($p < 0.05$), and changing patterns of VPC and ICC suggested that customers ordering longsnout catfish had more variation in claims than those ordering the other 2 species. Our findings indicate a need for better customer communication for live fish transportation and a need for detailed measurements during the process including physiological factors and transportation conditions, to better understand their role in reported mortalities.

1. Introduction

Freshwater finfish farmed in China are mostly targeted for domestic markets (UN Comtrade, 2015), where marketing of live fish is the most important form of retail. Most freshwater fish transportation companies in China are located in Guangdong Province because the temperate climate allows fish harvest all year round. Farmed fish, especially high-value species, are transported on a daily basis from this region to wholesale markets in provincial capitals throughout the country. The supply chain of live fish is, therefore, a critical component of the nation-wide provision of freshwater aquatic products to meet high market demands, and ensure profitability for local fish farmers.

Mortality of transported live fish is one of the most important concerns of fish transportation companies. Annual mortality of transported fish averages 1.48 million tons in China, about 7% of the total production (Nie et al., 2014; Bureau of Fisheries of Ministry of Agriculture of China, 2013). Maintaining healthy live fish during prolonged transport can be problematic and is a key factor affecting the operational performance of the supply chain (De Silva, 2011). One of the decision-supporting processes is management of customer claims of fish mortality (Stefanovic, 2014). Due to the lack of empirical information on biological, physical, and environmental conditions of transported fish, fish transportation companies have the challenge of how to quantify the relative occurrence of fish mortalities and identify whether fish mortalities claims by customers are spurious or real. There are no protocols for documenting mortality or morbidity during the delivery process and on arrival, thus judgments made by wholesale customers about dead fish may involve ambiguity about recording of fish mortality measurements at delivery (Fang and Tan, 2010; Wang, 2014). Clarification of the validity of these claims is still a major bottleneck for fish transportation companies in China.

---

* Corresponding author.
E-mail address: iagardner@upei.ca (I.A. Gardner).

http://dx.doi.org/10.1016/j.aqrep.2016.10.003
2352-5134/

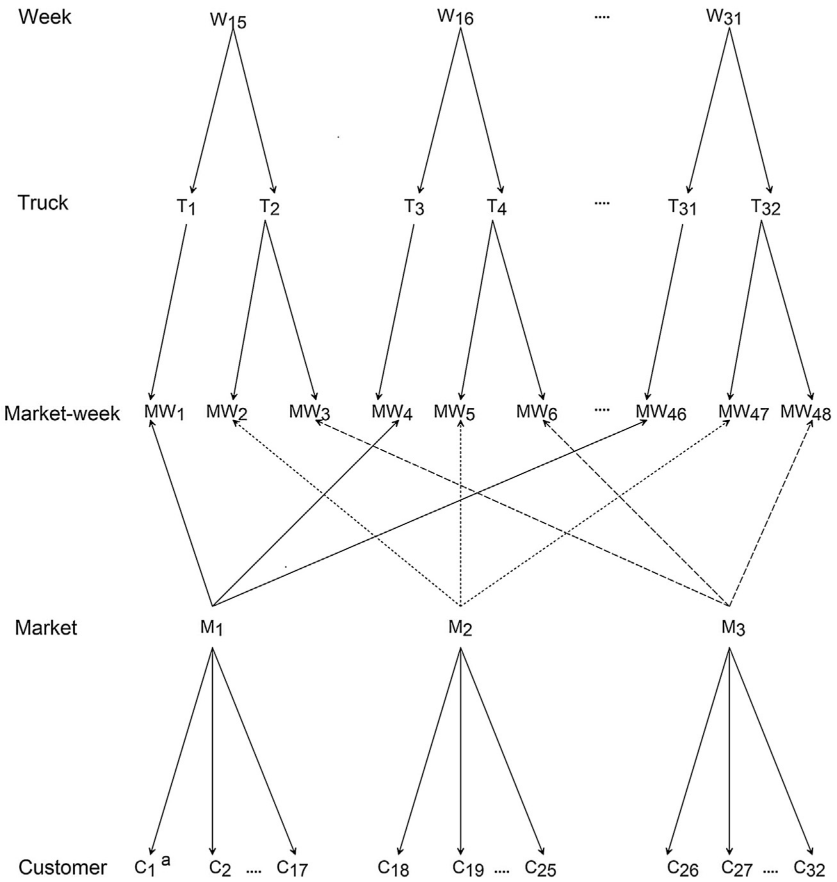

Fig. 1. Data structure of week, market-week, market, customer, for largemouth bass between mid April (week 15) and the end of July (week 31).
Note: [a] C_1 here denotes the first customer sequentially counted in the markets, but not the customer ID, i.e., 17 customers in Market 1 ordered largemouth bass during the study period. (All 3 species have the same data structure, and largemouth bass is used here for illustration purposes.).

In this study, we explored how fish transportation companies can benefit from analyses of their transaction records. According to anecdotal information from a leading live fish logistics company in China, Beijing markets receive the highest volume of fish among all of its transportation routes, with single-species orders of up to 5000 kg per day. However, mortalities claimed from Beijing markets were higher than the other destination markets with similar transportation durations, which causes ongoing financial losses to the company. We designed a case study, based on transaction records, to analyze the variation of fish mortality claims from customers. The specific purpose of the study was to assess whether there was clustering of fish mortality claims among customers over time and among markets.

2. Materials and methods

2.1. Data source and data preparation

The company in this study, located in Guangdong province in China, purchases farmed freshwater fish, and packages and transports about 40 thousand metric tons (TMT) of live fish to more than 40 cities across the country. Fish processing from farm to market is detailed in supplemental information (S1).

Among all destination markets in China, Beijing markets accounted for the largest volume of fish transportation routes for this company, and fish mortality claims by customers in Beijing markets resulted in the highest financial losses for the company. We retrieved the company's daily transaction records for the following 3 species in 5 wholesale markets in Beijing, from mid-April to the end of July 2013: largemouth bass (*Micropterus salmoides*), Chinese perch (*Siniperca chuatsi*), and longsnout catfish (*Leiocassis longirostris*). Information in the daily records included customer identification (ID), market name, dates of the corresponding transaction records, daily ordered weight of each fish species, and total daily received weight of live and dead fish.

We excluded one customer in Market 5, which was the company's own store, from the analysis but we included them in the descriptive analysis as a separate customer for comparison. We aggregated markets 2, 4, and 5 into a single market, and re-named this as Market 2. We applied the same procedures of data preparation and modeling for each of the 3 species. All data preparation was done in Stata 13 (Stata Corp., College Station, TX, USA) as detailed in S2.

2.2. Conceptual introduction of statistical modeling

For each customer within a market, the claims across weeks constituted repeated measures, and customers' claims at a specific market in a given week shared the same source and market-week of fish. This resulted in another (and cross-classified) hierarchical structure, involving market-week combinations representing deliveries to customers (Fig. 1). This data structure necessitated a mixed-model for data analysis that accounted for repeated measures for customers, random effects, and cross-classification structure. We, therefore, constructed a cross-classified random-effect model (CCREM) for the weekly mortality claimed by each customer to explore the variance structures and determine how influential factors (market, market-week, and customer) were associated with variation of mortality claims. Market was regarded as a fixed effect, and random-effect terms included customer and market-week. After square-root transformation of mortality claims, the random effects and error terms were assumed normally distributed with equal variance (Eq. (1)).

$$\mathrm{sqrt}(\mathrm{mort}_{ijk}) = \mu + \alpha_i + u_j + \nu_{ik} + \varepsilon_{ijk} \qquad (1)$$

where *i—market, j—customer, and k—week.* That is: mort_{ijk} is the k-th week mortality claimed by customer j at market i. μ is a parameter representing the mean of all observations. α_i, u_j, and ν_{ik} are the mean deviations from μ of the mortality claims in market, customer and market-week respectively. ε_{ijk}, the error term, is the deviation of mortality claims of the j-th customer at market i in week k from the weekly mean of mortality claims reported from market i in week k.

$$u_j \sim N\left(0, \sigma^2_{customer}\right)$$

$$\nu_{ik} \sim N\left(0, \sigma^2_{market-week}\right)$$

$$\varepsilon_{ijk} \sim N\left(0, \sigma^2_k\right)$$

For the withing-customer errors $(\varepsilon_{ijk})_k$, we explored different covariance structures: compound symmetry, first-order autoregressive, first-order autoregressive moving average, Toeplitz, as well as heterogeneous autoregressive and heterogeneous Toeplitz, of which the latter two allowed for unequal variance (σ^2_k) across weeks.

2.3. *Data analysis: descriptive analysis and CCREM modeling*

Weekly mortalities reported were summarized for each customer and for each market. After testing overall market effects by a multiple Wald test, pairwise comparisons were also done to compare means between markets.

CCREM modeling was performed separately for each species using PROC MIXED in SAS 9.1.2 (SAS Institute Inc., Cary, NC, USA). In general, the analysis followed the principles described in Pinheiro and Bates (2000). Maximum likelihood estimation was used, and the best-fitting covariance structure was determined by Akaike's information criterion (AIC).

In order to facilitate interpretation of variance parameters, we calculated variance partition coefficient (VPC) and intraclass correlation coefficient (ICC) to examine how the variation of mortality claims could be attributable to customers, market-week, or other unexplained factors. The VPC expressed the percentage of variance across customers out of the total variance (Eq. (2)), and the unexplained variance during specific weeks (σ^2_k), might be potentially related to factors not included in the model, i.e. transportation conditions (e.g. driver, packaging conditions).

$$VPC\,(week_k) = \frac{\sigma^2_{customer}}{\sigma^2_{customer} + \sigma^2_{market-week} + \sigma^2_k} \qquad (2)$$

where,

$\sigma^2_{customer}$	, overall variance among customers
$\sigma^2_{market-week}$	,variance attributed to the market deliveries during a specific week
σ^2_k	, unexplained variance among customers at specific week

ICC indicates the homogeneity of observations sharing the same units of hierarchical structure (Goldstein et al., 2002), and represents the percentage of variance explained by the customer when the market effect is removed from the total variance (Eq. (3)).

$$ICC\,(week_k) = \frac{\sigma^2_{customer}}{\sigma^2_{customer} + \sigma^2_k} \qquad (3)$$

Table 1
Number of weekly transaction records of each of the 3 species in each destination market in Beijing.

Markets	Largemouth bass (*Micropterus salmoides*)	Chinese perch (*Siniperca chuatsi*)	Longsnout catfish (*Leiocassis longirostris*)
1	239	248	156
2	76	80	59
3	100	108	68
Overall	415	436	283

Table 2
Number of weekly transaction records of all 3 species in destination markets in Beijing during the 16-week time frame (weeks 15–31 with week 17 excluded).

Months	Week	First day of week	Number of weekly transactions aggregated
April	15	4/7/2013	79
	16	4/14/2013	75
	18	4/28/2013	74
May	19	5/5/2013	73
	20	5/12/2013	74
	21	5/19/2013	75
	22	5/26/2013	72
June	23	6/2/2013	70
	24	6/9/2013	70
	25	6/16/2013	72
	26	6/23/2013	76
July	27	6/30/2013	67
	28	7/7/2013	60
	29	7/14/2013	64
	30	7/21/2013	66
	31	7/28/2013	67

To identify customers with extremely high claims of fish mortalities, we computed best linear unbiased predictors (BLUP), and ranked customers based on these BLUP estimates as detailed in Supplementary materials (S3).

Diagnostics in the mixed model were based on BLUPs and Studentized marginal residuals, using plots of residuals versus predicted values and Q–Q plots, and identifying the highest and lowest residual values. Square-root transformation of the weekly mortality claims ensured that model assumptions of normality were met.

3. Results

3.1. *Descriptive statistics*

3.1.1. *Unbalanced data structure*

We aggregated 8094 daily records from 3 aggregated markets to generate 415, 436, and 283 weekly data points for the 3 species (Tables 1 and 2). An unbalanced structure existed because different numbers of customers were distributed within each market and the numbers of orders were different among markets and among customers across weeks.

The total transportation of live fish weight also varied across weeks. Mean daily orders for different weeks pooled across markets, ranged from 177 kg to 4700 kg, 424 kg to 3097 kg, and 509 kg to 1836 kg for largemouth bass, Chinese perch and longsnout catfish, respectively. There was an apparent decrease in orders of largemouth bass in the first week of July 2013.

3.1.2. *Weekly biomass claimed as mortality summarized across customers and weeks*

We found customers claimed differently for mortality in the 3 species (Fig. 2). Patterns in mortality claims indicated that some weeks had more variation in claims than others and these patterns

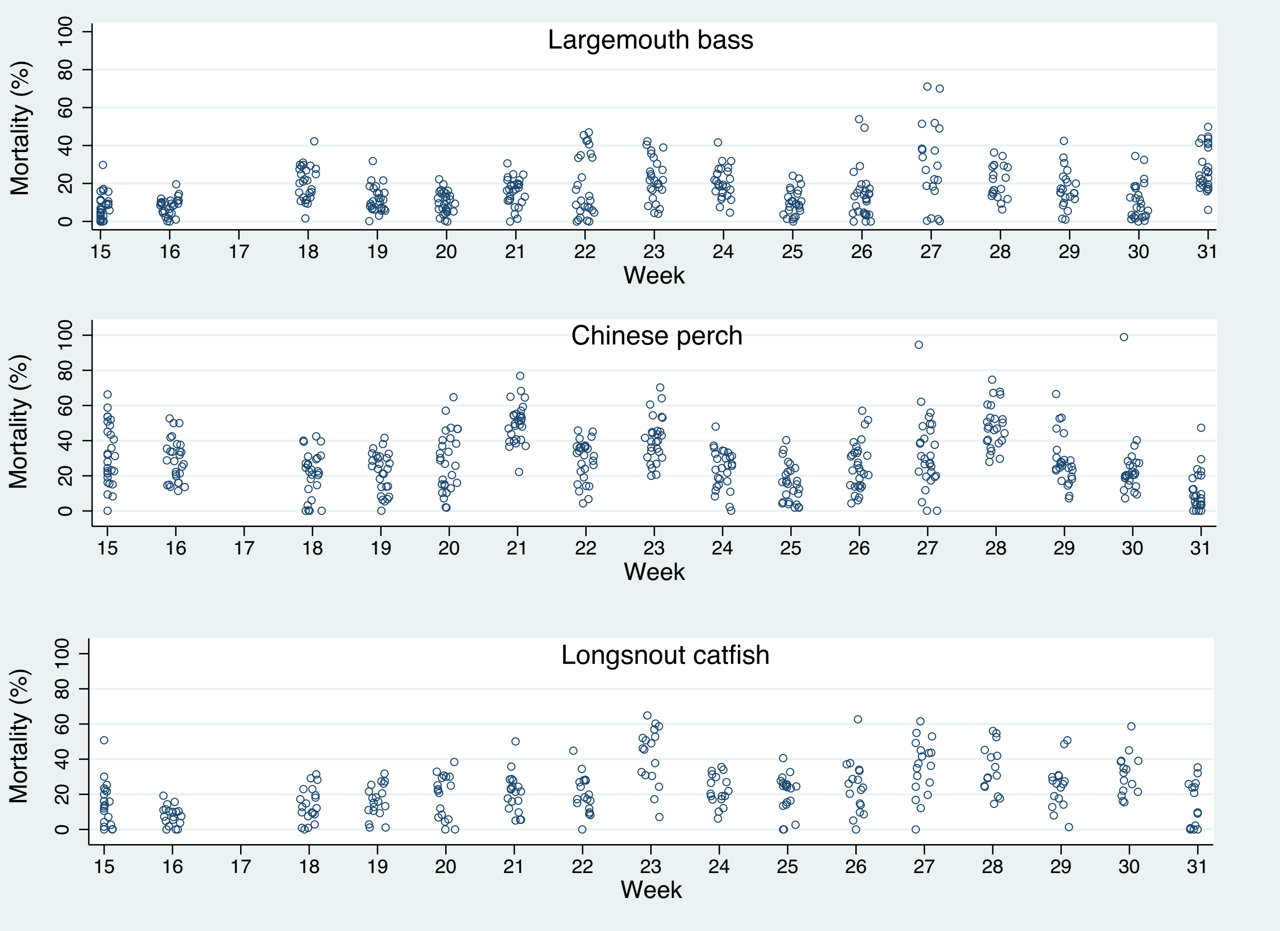

Fig. 2. Patterns of weekly mortality claimed by customers for 3 fish species between mid April (week 15) and the end of July (week 31).

differed among the 3 species (Fig. 2). The species with the overall highest number of claims was Chinese perch (Fig. 2).

Among customers, the highest weekly mortality reported from Market 1 was 69% for largemouth bass, 100% for Chinese perch, and 64.5% for longsnout catfish. The highest individual customer claims for the 3 species occurred in weeks of 27, 31, and 26, respectively, for largemouth bass, Chinese perch and longsnout catfish. The highest means of weekly claims across all customers occurred during weeks 27, 21, and 28, respectively, for largemouth bass (29.6%), Chinese perch (49.7%) and longsnout catfish (34.6%), in which the Chinese perch had the highest average weekly mortality claims. The species with the lowest average mortality claims was largemouth bass (16.1%). The highest weekly variance of mortality claims, based on the square-root scale, occurred in weeks 27, 18 and 31, respectively, for largemouth bass (0.074), Chinese perch (0.045) and longsnout catfish (0.054).

3.2. *Cross-classified random-effect modeling*

3.2.1. *Model selection*

Based on the AIC model selection criterion, we chose the same heterogeneous autoregressive structure for all species in order to facilitate the interpretation of our modeling results across the 3 species.

3.2.2. *CCREM using candidate models*

3.2.2.1. *Estimation of fixed effects.* The market effect was only significant for longsnout catfish (Table 3). Markets 2 and 3 were significantly different from Market 1, but were not different from each other (Table 3).

3.2.2.2. *Estimation of random effects.*

(1) Overall customers and market-week. We found similar random effects of customer and market-week for largemouth bass and Chinese perch (Table 3). However, for longsnout catfish, the customer random effect was much greater (Table 3), indicating that claims for longsnout catfish were more likely to vary among customers and different deliveries within the same destination market.
(2) Week variation. There was variation across weeks in the unexplained variance for the different species (Table 3), with the reported model estimates ranging from 0.004–0.066 for largemouth bass, 0.005–0.039 for Chinese perch, and 0.002–0.031 for longsnout catfish. There was only moderate auto-correlation among weeks between fish mortality claims, however, the mortality claims for Chinese perch were more likely to be influenced by the previous week than were claims for other 2 species (Table 3).
(3) Variance partition coefficients (VPC). We found that customer VPC and ICC estimates calculated from the longsnout catfish model were generally higher than those from the largemouth bass and Chinese perch models. For example, the highest VPC for each species was 0.206 for largemouth bass, 0.198 for Chinese perch, and 0.607 for longsnout catfish. The VPC calculated per week in the longsnout catfish model was always higher than 0.315 (Table 3). The variability of claims of longsnout catfish

Table 3
Fixed effects and random effects estimated by modeling with heterogeneous autoregressive covariance structure for data of the 3 fish species.

Fixed effects	**Largemouth bass** (*Micropterus salmoides*)		**Chinese perch** (*Siniperca chuatsi*)		**Longsnout catfish** (*Leiocassis longirostris*)	
	Estimate	**95% CI**[a]	**Estimate**	**95% CI**	**Estimate**	**95% CI**
Intercept	0.341	0.278–0.404	0.505	0.438–0.572	0.498	0.406–0.590
market2	0.040	−0.058–0.138	0.023	−0.081–0.127	−0.222	−0.370–−0.069
market3	0.024	−0.074–0.122	−0.017	−0.119–0.085	−0.273	−0.430–−0.118

Random effects	**Estimate**	**SE**	**VPC**[b]	**ICC**[c]	**Estimate**	**SE**	**VPC**	**ICC**	**Estimate**	**SE**	**VPC**	**ICC**
$\sigma^2_{customer}$	0.004	0.002			0.004	0.002			0.019	0.007		
$\sigma^2_{market-week}$	0.011	0.003			0.013	0.003			0.010	0.003		
Week (15) σ^2_{k15}	0.020	0.006	0.113	0.168	0.026	0.008	0.093	0.121	0.029	0.011	0.327	0.400
Week (16) σ^2_{k16}	0.004	0.001	0.209	0.503	0.006	0.002	0.172	0.363	0.014	0.006	0.441	0.579
Week (18)σ^2_{k18}	0.007	0.002	0.182	0.374	0.030	0.009	0.084	0.106	0.006	0.002	0.549	0.776
Week (19)σ^2_{k19}	0.011	0.003	0.156	0.281	0.013	0.004	0.132	0.213	0.008	0.003	0.52	0.721
Week (20)σ^2_{k20}	0.011	0.003	0.155	0.278	0.007	0.003	0.168	0.346	0.004	0.002	0.582	0.843
Week (21)σ^2_{k21}	0.007	0.003	0.182	0.373	0.005	0.002	0.179	0.404	0.013	0.005	0.458	0.608
Week (22)σ^2_{k22}	0.010	0.003	0.161	0.298	0.016	0.006	0.121	0.182	0.008	0.003	0.508	0.698
Week (23)σ^2_{k23}	0.006	0.002	0.187	0.392	0.003	0.001	0.198	0.532	0.007	0.003	0.531	0.740
Week (24)σ^2_{k24}	0.007	0.002	0.179	0.361	0.011	0.003	0.145	0.254	0.002	0.001	0.607	0.893
Week (25)σ^2_{k25}	0.014	0.004	0.138	0.228	0.015	0.005	0.124	0.191	0.024	0.009	0.356	0.443
Week (26)σ^2_{k26}	0.021	0.006	0.110	0.163	0.009	0.003	0.156	0.295	0.010	0.004	0.489	0.663
Week (27)σ^2_{k27}	0.066	0.022	0.049	0.059	0.035	0.01	0.078	0.094	0.012	0.005	0.461	0.614
Week (28)σ^2_{k28}	0.008	0.003	0.174	0.340	0.004	0.002	0.195	0.506	0.015	0.007	0.430	0.561
Week (29)σ^2_{k29}	0.012	0.004	0.148	0.256	0.010	0.004	0.146	0.257	0.007	0.003	0.531	0.742
Week (30)σ^2_{k30}	0.035	0.011	0.079	0.105	0.021	0.006	0.107	0.149	0.009	0.004	0.498	0.679
Week (31)σ^2_{k31}	0.004	0.002	0.206	0.482	0.039	0.012	0.071	0.084	0.031	0.013	0.315	0.383
autocorrelation	0.192	0.068			0.338	0.131			0.245	0.094		

Note: [a]CI, Confidence interval. [b]VPC, Variance partition coefficient. [c]ICC, Intraclass correlation coefficient.

in the low-VPC weeks has a different pattern than the general variability of this species.

The models for the 3 species largely met the normality assumption, except for a few outliers. Sensitivity analyses were done respectively for outliers and Box-Cox scales, and the results confirmed that both outliers and Box-Cox transformation (Box and Cox, 1964) had minimal impact on general conclusions and other detailed model results.

4. Discussion

We found high mortality claims for all 3 species across markets, and patterns of mortality claims varied by customer and market-week (delivery). In addition, significant among-market differences were found for longsnout catfish. The highest claims for longsnout catfish were from customers in Market 1. The high VPC during most weeks indicated that customer consistently explained most of the variation. In other words, the unexplained variation was low relative to among-customer variation. This high customer effect was mainly attributable to a few customers always claiming higher mortalities. The weeks with low VPC for this species suggested that there was relatively more unexplained variance, indicating that some customers comparatively claim quite differently to how they generally do. Higher variation of claims of longsnout catfish occurred in some weeks when mortalities of 1 or 2 deliveries were extremely high compared to others deliveries in the same weeks.

For largemouth bass, customers inconsistently claimed high or low mortalities, suggesting customers only explained minor variations in mortality claims. Weekly variation in mortality claims for this species indicated that either some customers over- or under-claimed mortality, or some customers frequently claimed fish mortality differently, but high or low claims were not from the same individual customers (i.e. overall low customer effect).

For the species with the highest claims, Chinese perch, there were several high ICC weeks when most of the customers claimed high mortalities across the markets. There were also a few low ICC weeks that also coincided with high mortality. During these weeks it is possible that the majority of claims were made by only a few customers. Although we were unable to assess whether mortality clustered at the level of truck deliveries or box containers, the fact that so many customers were claiming on the same weeks suggested mortality claims of Chinese perch were likely valid. In addition, the value of Chinese perch apparently decreases when loss of pigmentation occurs after transport. Customers may have claimed mortality based on pigmentation reduction if the fish had been transported long distances.

We examined whether specific customers purchasing multiple species complained more than others. Of the 10 customers with the highest predicted parameter estimates for Chinese perch, 4 were also on the top-10 list for the other 2 species, and 6 were on the top-10 list for largemouth bass, suggesting that these 10 customers may complain more than others. It was interesting to note that the tertiary markets did not have higher claims than Market 1, which was the first delivery point. We assessed whether specific weeks were worse for claims than others. The summer weeks, defined as the period between June 2 and the end of July, had higher mortality claims across all species. Higher claims were evident in all 3 species in week 27. Interestingly, a few weeks with high claims for specific species were those that had the smaller deliveries. During week 27, only some deliveries had high mortality claims and these were consistent across markets and all customers suggesting “real” mortality problems with these deliveries.

5. Conclusions

Our analysis indicated that customers were associated with variation in fish mortality claims but not as the only factor. To our knowledge, this study is the first in warm-water aquatic animals to use cross-classified modeling to explore how to partition the variability in mortality, specifically mortality claims, across different logistics factors along the transportation chain. The usefulness of this exploratory study can be improved with future investigation of likely causes of transportation mortalities on arrival at destination markets. Future research is necessary to evaluate how variation in measurements of water quality and fish physiological factors are associated with mortality of transported live fish and assess whether sub-standard conditions of transportation are consistent with the customers' claims identified in this study.

Acknowledgements

The study was funded by the Canadian Excellence Research Chair (CERC) Program in Aquatic Epidemiology at University of Prince Edward Island Canada. We thank staff working at Guangdong Heshi Co. Ltd for providing and explaining the data used in the study, and William Chalmers for editorial assistance in preparation of the manuscript. We thank an anonymous reviewer for their insightful comments which improved the manuscript.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.aqrep.2016.10.003.

References

Box, G.E.P., Cox, D.R., 1964. An analysis of transformations. J. R. Stat. Soc. Ser. B 26, 211–252.

Bureau of Fisheries of Ministry of Agriculture of China, 2013. China Fisheries Year Book 2013. [in Chinese]. p. 30.

De Silva, D.A.M., 2011. Value Chain of Fish and Fishery Products: Origin, Functions and Application in Developed and Developing Country Markets. Value Chain Project, Food and Agriculture Organisation, Rome, pp. 1–53.

Fang, W., Tan, Y.Y., 2010. The wholesale market as the core of aquatic products supply chain management model. In: Proceedings of the 3rd International Conference on Logistics and Supply Chain Management, Hunan, China, pp. 411–417.

Goldstein, H., Browne, W., Rasbash, J., 2002. Partitioning variation in multilevel models. Underst. Stat. 1 (4), 223–231.

Nie, X., Zhang, Y., Sun, X., Huang, B., Zhang, C., 2014. Process and key technologies of transportation of live fish. Fish. Mod 41, 34–39.

Pinheiro, J.C., Bates, D.M., 2000. Theory and computational methods for linear mixed-effects models. In: Mixed-Effects Models in S and S-PLUS. Springer, New York, pp. 57–96.

Stefanovic, N., 2014. Proactive supply chain performance management with predictive analysis. Sci. World J. 12, 911–930.

UN Comtrade (United Nations Commodity Trade Statistics Database), 2015. Available at http://comtrade.un.org/db/ce/ceSearch.aspx (accessed 31 March 2016).

Wang, H.B., 2014. Aquatic logistics model based on supply chain management. Adv. Mater. Res., 1576–1579.