Pooled Samples versus Accounting for Station

Analyses to account for the effect of station. The assessment of the effect of station was conducted by evaluating station as a random effect in a mixed effect framework. This was conducted using lme4 (Bates et al. 2015) for all analyses with the exception of the growth curve analysis where the nlme package (Pinheiro et al. 2020) was used. This was conducted for each respective analysis (e.g. maturity ratios, sex ratios, length at maturity, valve length to viscera weight relationship, growth curve analysis (von Bertalanffy)) and the result compared to the statistical modelling approach whereby all samples were pooled.

Maturity Ratios:

A comparison of the parameter estimates from incorporating station as a random effect (GLMM) and not (i.e. pooling stations; GLM) is shown in Figure S1. Both analyses support the conclusion that there has been a significant increase in the mature proportion of the population between 1998 and 2017 and there is no significant difference in the overall conclusion or parameter estimates between modelling approaches (Figure S1).

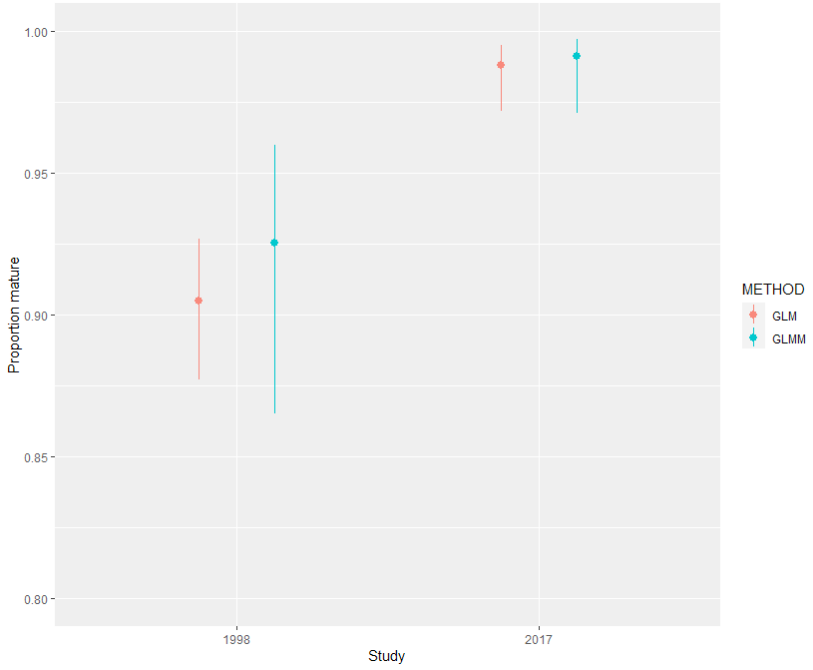

Figure S1. Modeled proportion of the mature population and 95% CIs with all samples pooled (GLM) and station as a random effect (GLMM).

Sex Ratios:

A comparison of the parameter estimates from incorporating station as a random effect (GLMM) and samples pooled (GLM) is shown in Figure S2. Both analyses support the conclusions that the sex ratio was not significantly different than 1:1 in 1998, that the sex ratio is significantly different than 1:1 in 2017, and that there has been a significant increase in the proportion of females (subsequent decrease in proportion male) in the population from 1998 to 2017. The parameter estimates are not significantly different between the two modelling approaches.

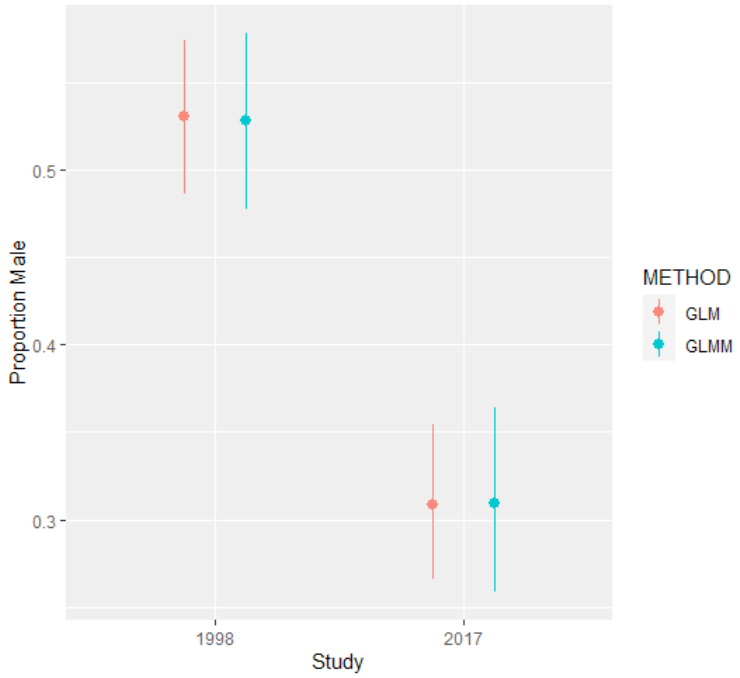

Figure S2. Modeled proportion male and 95% CIs with all samples pooled (GLM) and stations as a random effect (GLMM).

Length at maturity:

The overall conclusions for length at maturity are extremely similar irrespective of the incorporation of station as a random effect (GLMM) or via pooling the samples (GLM) as seen in Figure S3. Both analyses support the 50% length at maturity at ~ 40 mm valve length.

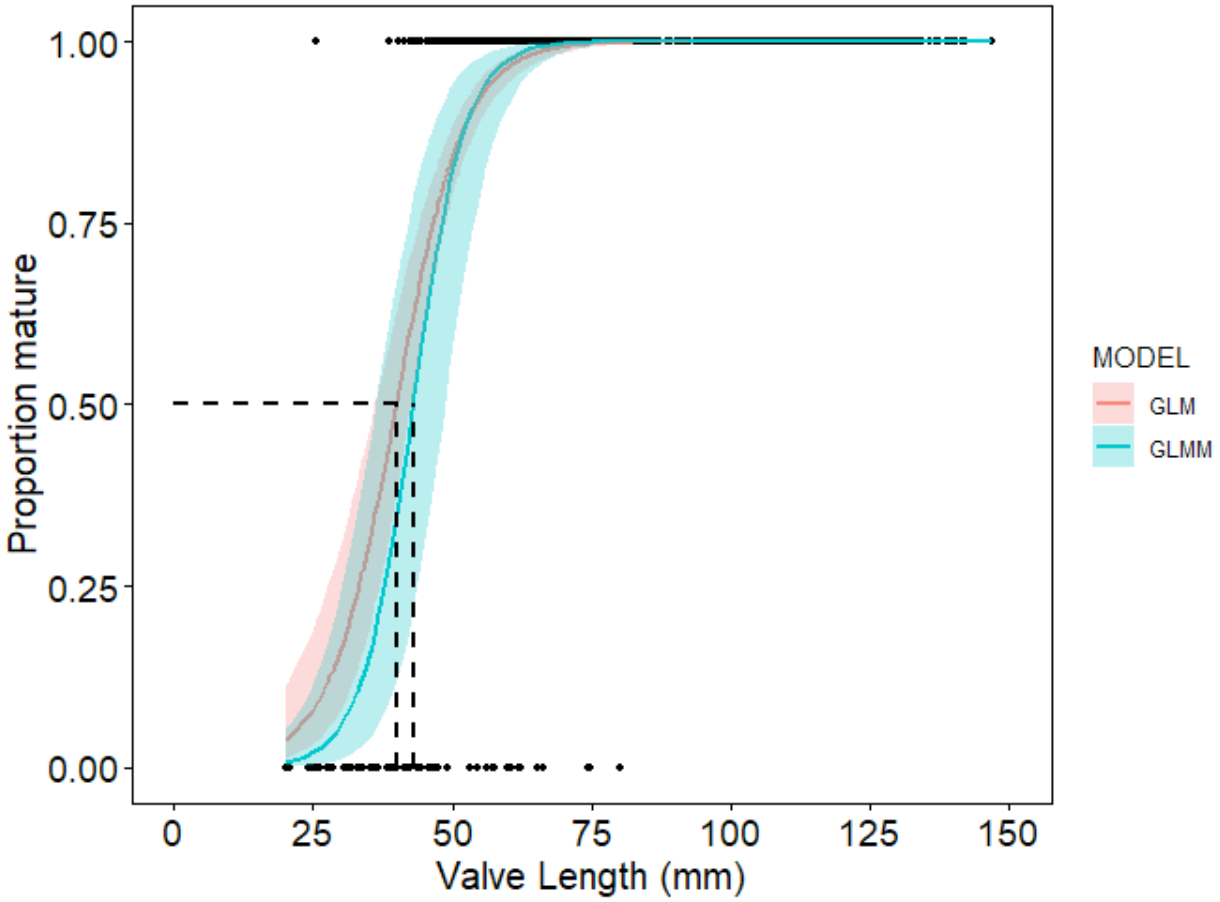

Figure S3. Length at maturity of live horse mussels collected from the Bay of Fundy in 1998 and 2017 pooling samples (GLM; pink) and incorporating station as a random effect from the random intercept model (GLMM; blue). The shaded areas indicate the 95% confidence interval, and dashed lines indicate size at 50% maturity (39.8 mm; 42.9 mm for the GLM and GLMM models, respectively).

Valve Length – viscera weight:

Side by side comparisons of the relationship in May and June of study period 1998 versus the September/October study period 2017 are shown below. A direct comparison of the pooled (GLM) versus accounting for station (mixed effect model; GLMM) for each study period for the viscera weight to valve length comparison can be seen in the overlapping models in Figure S4. The parameter estimates and conclusions are not significantly different between the two modelling approaches.

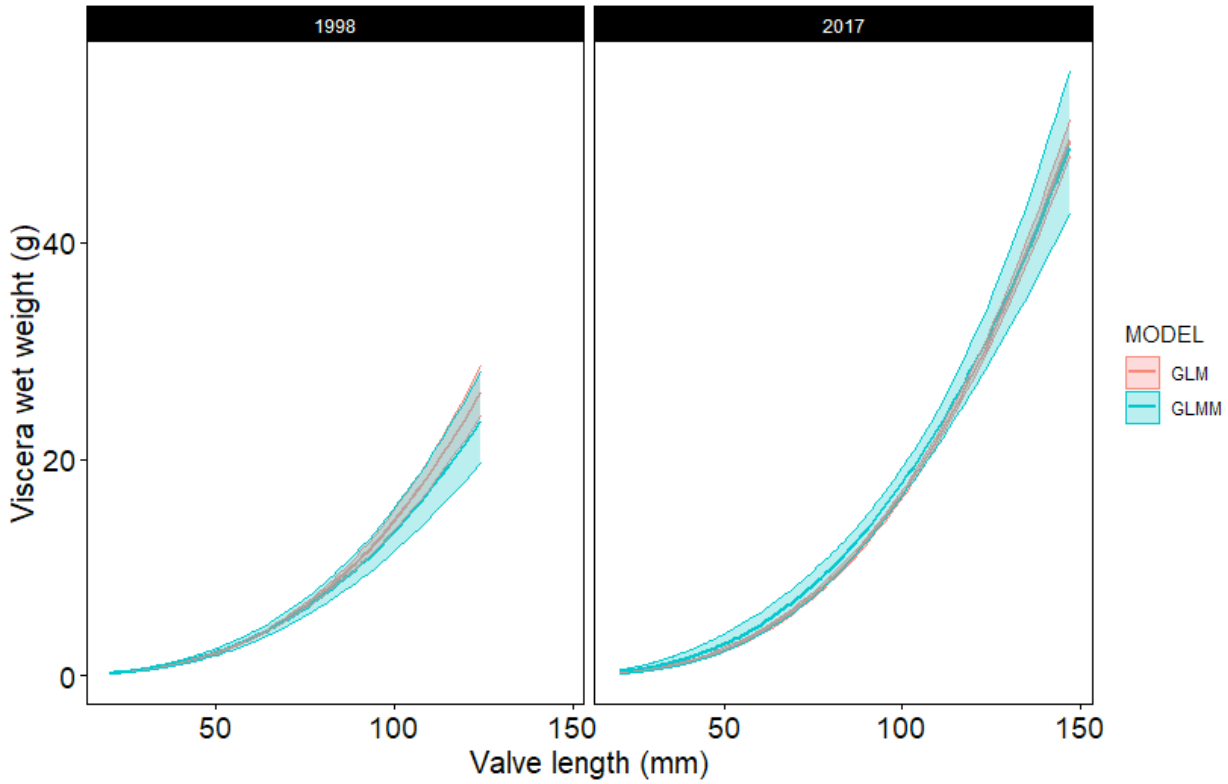

Figure S4. Valve length-to-viscera weight relationships modeled using a GLM (pink) and GLMM (blue) for horse mussels in the Bay of Fundy sampled in May and June in the study period 1998 (left) and sampled in September and October 2017 (right). The 95% CI is indicated by the shaded bounds around the predicted fit.

Growth/VonB:

Using the aging data from 2017, growth was examined and compared between the assumption of pooled samples (using nonlinear least squares and FSA package; Ogle et al. 2020) and a mixed effect modelling approach with station as the random effect (using the nlme package; Pinheiro et al. 2020). A comparison of the predicted fit and 95% CIs can be found in Figure S5. Overall there is general concurrence between these two approaches in the fixed effect and predictions by age. The 95% CIs are wider for the mixed effect modeling approach but this is not unexpected (Zuur et al. 2009).

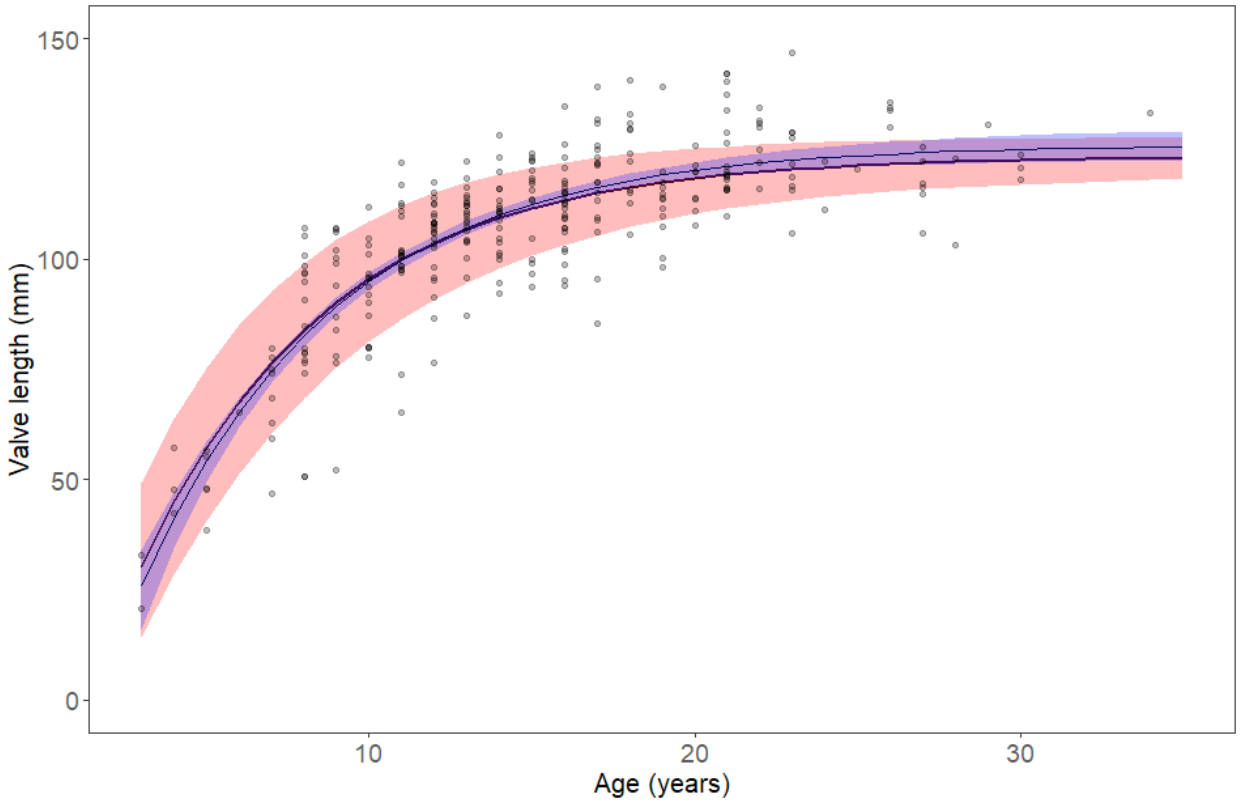

Figure S5. Von Bertalanffy growth model predicted for valve length-at-age for horse mussels in the Bay of Fundy for 2017 modeled using all samples pooled (nonlinear least squares, blue) and station as a random effect (nonlinear mixed effect model, red). 95% CIs are indicated by the shaded bounds around the predicted model fits.

References:

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Zuur AF, Ieno EN, Walker, NJ, Saveliev AA, Smith GM (2009) Mixed effects models and extensions in ecology with R. Springer, New York, NY