The Importance and Consequences of Maternal Characteristics on Larval Growth and Survival in Two Atlantic Coast Striped Bass Populations

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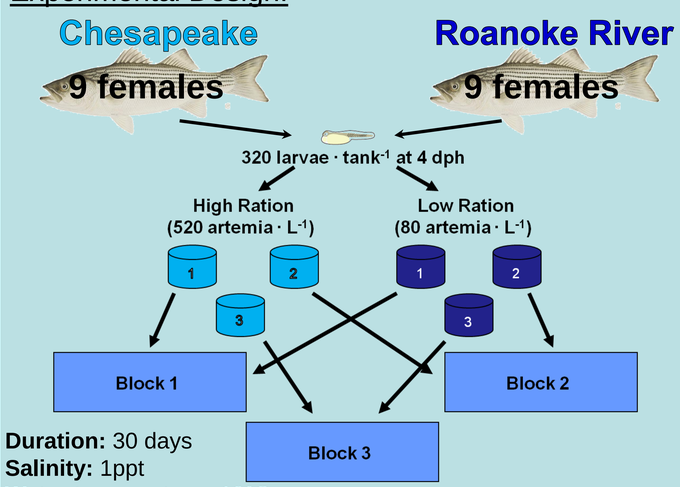
Introduction

Understanding the relationship between the abundance of spawners and the number of new recruits they produce is central to ensuring the sustainability of fish populations. Traditional approaches have principally related recruitment to stock biomass only. However, factors such as the size and age of spawners are known to influence survival of their eggs and offspring through a variety of mechanisms. Less understood is the role of female nutritional condition on reproductive potential. To investigate the role of striped bass maternal condition on reproductive potential, 9 females each, were collected from the Chesapeake Bay (CB) and Roanoke River, NC (RO) and spawned to assess egg quality, larval growth and survival. Mixed models and multivariate analyses were used to explore which maternal characteristics influence progeny phenotype.

Methods

Experimental Design:



Duration: 30 days
Salinity: 1ppt
Water temperature: 19°C

Maternal lines:
Females were wild caught in the Ronaoke River, NC and Chesapeake Bay by electrofishing, and tank spawned to produce eggs & larvae.

Maternal Characteristics Measured:
Weight (**Wt**)
Age
Hepatosomatic index (**HSI**)
Total liver energy (kJ, **TLE**)
Relative liver energy (kJ g^{-1} female weight, **RLE**)
Liver energy per gram (kJ g^{-1} liver dry weight, **LEG**)
Total length (**TL**)
Fulton's K (**K**)

Estimating Growth and Oil Globule Resorption:
To estimate oil globule size (amount still available) and resorption (amount utilized) and instantaneous growth in weight and length, 5-10 larvae were removed at 5, 7, 12, 17, 22, 27, and 30 days post hatch (dph).

Estimating Mortality:
To estimate mortality, dead larvae were removed and counted every 2 days.

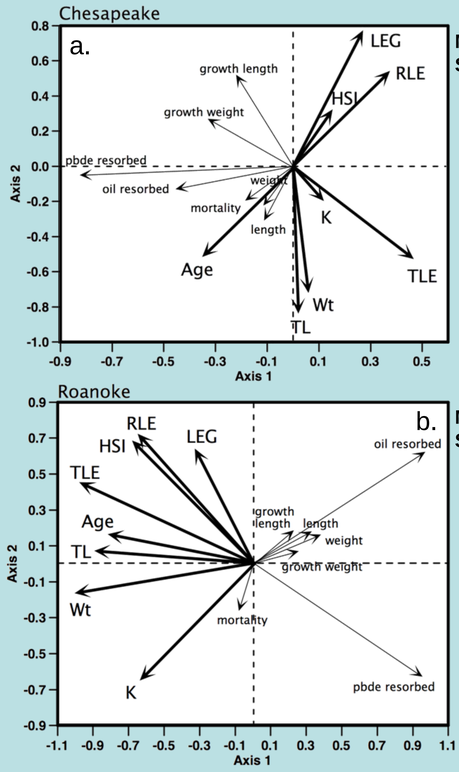
PBDE Resorption:
Polybrominated diphenyl ethers were measured in eggs. Because PBDEs are lipophilic and because striped bass oil globlules are nearly 100% extractable lipids and >95% of egg lipids are in oil, we estimated PBDE resorption in larvae by assuming it was proportional to oil resorption.

Methods continued

Statistical Analyses:
Redundancy analyses (RDA) was conducted to determine which maternal phenotypes are most strongly related to larval phenotypes for each individual stock and to determine stock effects with both stocks combined. RDA can be described as a series of multiple regressions followed by a principal component analysis that takes into account correlation structure among independent variables.
Repeated measures linear mixed models were used to separately evaluate maternal influences on each phenotype measured. To account for maternal dependence among tanks from each maternal line, tank ID was nested in maternal ID and included as a random factor.
Principal components analysis (PCA) was used to determine whether initial stock differences existed in the egg characteristics prior to the initiation of the experiment.

Results

Fig. 1. *RDA biplots* for Chesapeake (a) and Roanoke (b) lines. The length of a dependent variable vector reflects the proportion of variance explained by the independent variables and the length of the independent variable vectors reflects the relative proportion of variance in the dependent variables explained by the independent variable. Further, the angle between dependent variables, independent variables and dependent and independent variables reflects the correlation between variables.



Monte-Carlo Permutation: Significant ordination (P < 0.005)

Independent variables = bold line
Dependent variables = fine line

Table 1. Repeated measures mixed models results. Dependent variable: Mortality

Chesapeake Bay

Effect	*F*	*P*
Female age	$27.017_{1,44}$	< 0.0001
Ration	$38.39_{1,44.3}$	< 0.0001
Larval age	$142.27_{10,111}$	< 0.0001
Female age × larval age	$14.15_{10,115}$	< 0.0001
HSI × larval age	$4.81_{11,119}$	< 0.0001
Ration × larval age	$14.96_{10,111}$	< 0.0001

Roanoke River

Effect	*F*	*P*
Female weight	$20.58_{1,35.4}$	< 0.0001
Ration	$75.71_{1,35.3}$	< 0.0001
Larval age	$222.73_{10,102}$	< 0.0001
Female weight × larval age	$5.44_{10,102}$	< 0.0001
RLE ×larval age	$5.37_{11,105}$	< 0.0001
Ration ×larval age	$31.34_{10,102}$	< 0.0001
Female weight × HSI	$21.06_{1,28.1}$	< 0.0001

Table 2. Repeated measures mixed models results. Dependent variable: Growth in weight

Chesapeake Bay

Effect	*F*	*P*
Female weight	$9.02_{1,87.2}$	0.0035
Ration	$120.54_{1,79.9}$	< 0.0001
Larval age	$37.26_{5,82.4}$	< 0.0001
Female weight × larval age	$3.94_{5,83.8}$	0.003
Ration × larval age	$9.65_{5,82.4}$	< 0.0001

Roanoke River

Effect	*F*	*P*
Ration	$89.77_{1,53.9}$	< 0.0001
Larval age	$21.82_{4,56.4}$	< 0.0001
TLE × ration	$14.54_{2,35.9}$	< 0.0001
Ration × larval age	$10.14_{4,56.3}$	< 0.0001
HSI × larval age	$6.69_{5,66.1}$	< 0.0001

Fig 2. PCA biplot of egg variables. Arrows = eigenvector loadings, Points = axis scores (inset).

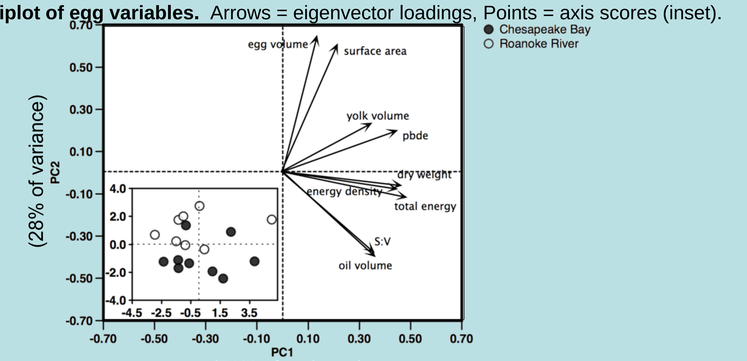
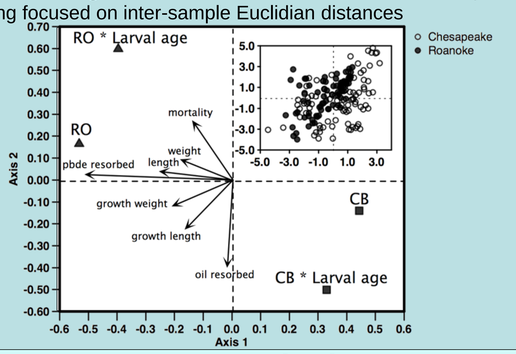


Fig 3. RDA biplot showing stock effects. Inset shows shows scatter plot of sample scores with scaling focused on inter-sample Euclidian distances



Conclusions

- For the first time in striped bass, maternal influences on larval mortality were demonstrated – showing somewhat unexpectedly that maternal age and size were positively related to mortality in CB and RO, respectively (Table 1). In CB, this relationship is possibly due to faster oil resorption or faster resorption of PBDEs. However, in RO the positive relation with maternal size may be due to smaller oil globules in larvae from larger females.
- Although indices of maternal condition did explain some of the variation in larval mortality (primarily early in development) as shown by RDA and mixed models (MM) (Fig 1, Table 1, 2), MM showed that traditional measures of size and age explained a larger component of variance in each larval phenotype over the duration of the experiment for both stocks.
- PCA showed that females from RO tend to produce eggs with smaller oil globules, but larger egg volumes and surface area (Fig 2). The smaller oil in RO larvae likely evolved to enhance egg survival in high energy systems like RO (Bergey et al. 2003), but likely leads to higher mortality in RO larvae compared to CB, as shown by Fig 3.

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Bergey et al. 2003. Variability of Atlantic coast striped bass egg characteristics. North American Journal of Fisheries Management, 23: 558-572.