

Parental Effects on Development and Behavior in Threespine Stickleback *Gasterosteus* *aculeatus* of Lake Mývatn, Iceland

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Introduction

Development and early life history are two of the most important time periods for an organism. Consequentially, the traits gained by an organism from its parents during this time are key to its success as an individual. It is not suprising then, that parental effects, both maternal and paternal, have a major impact on the an organism from before it is born (???). Parental effects, defined as a change in an Offspring's phenotype due to the genotype and/or environment of one or more of its parents, were for a long time considered a nuicance, a deviation from pure heritable traits. Now however we have seen a researgence of interest in these effects (?). While much research has been done concerning the impact of parental effects on development (?) and behavior of invertabrates (particularly beetles), comparitivley less is known about parental effects on vertabrates. Work on teleosts has revealed strong links between parental effects on the co-evolution of behavior and cellular function (?). The connection between parental affects influencing behavior and gene expression has serious implications for evolutionary ecology, because rapid environmental could act as a mechanism for rapid evolution via parental programming of offspring phenotypes, effectively providing their offspring with a "jumpstart" of sorts (??). From the standpoint of quantitative genetics, the phenotype (P) is equal to the influence of genes (G) and environment (E) such that

$$P = G \times E$$

However, genetic effects from parents can be further broken down into inheritance from genes directly (I_G) and inheritance from the parental environment (I_E) such that

$$P = (I_G \times I_E) \times E$$

Here in Iceland, work on various populations of *Gasterosteus aculeatus* has focused on phenotypic diversity, including phenotypic plasticity (Kristjánsson et al., 2002; Millet et al., 2013). However, the extent to which parental effects shape the morphology and behavior of lake Mývatn stickleback has yet to be investigated. Previous work on different stickleback populations have discovered a range of parental effects, both maternal and paternal. Bell et al. (2018) investigated the heritability of parental behavior (Specifically, fanning of eggs) by male stickleback and found strong heritability of the trait. Furthermore, they concluded that a strong amount of genetic variation could lead the evolvability of the fanning trait. Offspring of male stickleback that experience predation risk have shown to grow smaller and spend less time in the open (Bell et al., 2016; Stein and Bell, 2014) Female stickleback have also been shown to pass on phenotypic information to their eggs. An RNAseq study analyzing female stickleback found that eggs from mothers exposed to predators had faster development times, as well as major epigenetic changes and alterations to non-coding genes during development (Mommer and Bell, 2014; Bell et al., 2016).

Major questions I want to address:

- To what extent are the phenotypes of lake Mývatn stickleback shaped by maternal and paternal (parental) effects?
- Specifically, how much variation in stickleback phenotypes are driven by genetic inheritance vs environmental inheritance?
- Do Mývatn stickleback

Methods

I will use a half-sibling common garden experiment to assess TGP in Mývatn stickleback. Stickleback will be collected from separate basins of the lake, the North, or cold shore, and the South, or warm shore. Sticklebacks from both shores will then be crossed using standard methods laid out by Schluter.

Half-sibling split clutch designs have been used previously to examine the effects of indirect fitness in parasite resistance, as well as transgenerational plasticity in response to temperature in marine stickleback (Barber et al., 2001; Ramler et al., 2014). One of the major problems when considering historical work on parental effects is disentangling genetic and environmental effects (?). Using a Linear Mixed Model (LMM) approach to decompile the effects should be effective. 15 males and 15 breeding females will be collected from the shore of the hot basin (hereon: hot shore) and a nearby cool region called Grimstaðir. Sperm from each male will be split and used to fertilize two females, and eggs from each female will be fertilized by two males. Each family will be split between two tanks to account for tank effects on individuals. Fish will be

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