**The Effects of Throat Area and Throat Intensity on Sexual Selection of Sticklebacks**

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ABSTRACT

Sticklebacks are among the most studied species for biologists. Their small body size, large geographic distribution, and high fecundity are just three of the many characteristics that make them a model organism (Reid et al., 2021). Several studies have looked at different factors that are believed to affect sexual selection in sticklebacks. For the purposes of this study, the effects of throat intensity and throat area on sexual selection of sticklebacks were analyzed. A logistic regression model analysis was performed. The results indicated that throat intensity and throat area do not directly affect the mating success of sticklebacks.

INTRODUCTION

Sticklebacks have recently experienced a burst of rapid diversification by migrating to freshwater habitats that became available at the end of the Last Glacial Maximum. Particularly looking at three-spine sticklebacks (*Gasterosteus aculeatus*), through their migrations to freshwater habitats from marine waters, it has become noticeable that a pool of genetic variation has provided a basis for the reproducibility of phenotypes over a short evolutionary timescale. Repeated derivation and local adaptation have created the possibility for a large set of replicate natural experiments (Reid et al., 2021). These factors make sticklebacks relatively easy to study, and as a result, there is a lot known about them.

An interesting area of research being studied is sexual selection and the factors that may affect it. Recently, stickleback coloration and its relationship with selection pressures, reproductive cycle, predation, courtship, and many other evolutionary concepts is being studied. These findings suggest that there is no significant variation in spine color across reproductive stages, but body color was redder during courtship and egg care. It was reported that pelvic spine coloration varied behaviorally, increasing during social interactions and in response to predators (Anderson and McKinnon, 2022).

Another study found that females of both benthic and limnetic three-spine sticklebacks prefer males with brighter red coloration. It is thought that ecological character displacement influences the red coloration through nesting and habitat use, as well as differences in diet (Albert et al., 2017).

A more specific area of study has been the throat area and throat intensity of sticklebacks. The throat intensity is a measurement of the range of red coloration. The throat area is a measurement of the size of the stickleback’s throat. To further investigate the effects of stickleback coloration the previous studies mentioned, the hypothesis is the larger the throat area and higher throat intensity, the higher the mating success.

MATERIALS AND METHODS

The stickleback throat area and throat intensity data used here came from the paper “Evidence for sex-specific selection in brain: a case study of the nine-spined stickleback” and “Phenotypic correlates of pelvic spine coloration in the Three-spine Stickleback (*Gasterosteus aculeatus*): Implications for function and evolution.” The sticklebacks were collected from two isolated ponds and two Baltic Sea marine sites in Sweden and Finland and Little Campbell River-Anadromous Site. For the purpose of this experiment, the data kept to run an analyses on contained whether the male nested or not, whether the female entered the male’s nest or not, the average of pre and post mate choice throat area, the average pre and post mate choice throat intensity, the average of pre and post mate choice throat area and throat intensity combined, throat area and throat intensity right after mate choice, and throat area and throat intensity right before mate choice. All data analysis were conducted using R version 4.1.3 (R. Core Team).

A multiple logistic regression was conducted in R, evaluating predictors of outcomes that either occurred or did not. For this study, this analysis presented whether the sticklebacks were successful in mating or not. This was carried out using the “glm()” function in R, resulting in a logistic regression model. This model made a comparison between mating success and throat intensity and throat area.

RESULTS

A correlation is the extent to which two variables are linearly related. The closer to zero, the weaker the correlation, and the closer to one, the stronger the correlation. Based off the data, the throat intensity and mating success had a weak positive correlation of 0.2089659, the throat area and mating success had a weak positive correlation of 0.1936837, and the throat combined, and mating success had a weak positive correlation of 0.2068537. All the correlations are positive, inferring those changes in one variable will relate to the same type of changes in the second variable.

The estimate, p-values, z value, and error were analyzed to compare mating success and throat intensity (Table 1), mating success and throat area (Table 2), mating success and throat combined (Table 3), mating success and throat area and intensity right after mate choice (Table 4), and mating success and throat area and intensity right before mate choice (Table 5). None of the p-values were less than 0.05, implying there is not a significant difference between the variables. Further, the p-values provided by the data analysis do not provide a lot of confidence with how statistically clear the differences between the variables are.

Logistic Regression Model Analysis

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Error | Z value | Pr (>|z|) |
| Intercept | -0.2785 | 0.3998 | -0.697 | 0.486 |
| X | 0.5628 | 0.3821 | 1.473 | 0.141 |

Table 1: Logistic regression model analysis results looking at mating success against throat intensity

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Error | Z value | Pr (>|z|) |
| Intercept | -0.2652 | 0.4100 | -0.647 | 0.518 |
| X | 0.2975 | 0.2154 | 1.381 | 0.167 |

Table 2: Logistic regression model analysis results looking at mating success against throat area

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Error | Z value | Pr (>|z|) |
| Intercept | -0.3022 | 0.4144 | -0.729 | 0.466 |
| X | 0.2092 | 0.1423 | 1.470 | 0.142 |

Table 3: Logistic regression model analysis results looking at mating success against throat combined

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Error | Z value | Pr (>|z|) |
| Intercept | 2.557e+01 | 5.387e+04 | 0 | 1 |
| X | -6.568e-07 | 2.313e+04 | 0 | 1 |

Table 4: Logistic regression model analysis results looking at mating success against throat area and intensity right after mate choice

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Estimate | Error | Z value | Pr (>|z|) |
| Intercept | 2.557e+01 | 5.908e+04 | 0 | 1 |
| X | -5.031e-08 | 2.371e+04 | 0 | 1 |

Table 5: Logistic regression model analysis results looking at mating success against throat area and intensity right before mate choice



Figure 1: Left to right: Mating Success (Y) vs. Throat Area (X), Mating Success (Y) vs. Throat Intensity (X), Mating Success (X) vs. Throat Combined (X)



Figure 2: Mating Success (Y) vs. PreThroatCombined\_a (X)



Figure 3: Mating Success (Y) vs. PreThroatCombined\_b (X)

DISCUSSION

As mentioned earlier, the hypothesis being tested was the bigger the throat area and higher throat intensity, the higher the mating success. Based on these results, there is no evidence that throat intensity or throat area directly effect the mating success of sticklebacks. A logistic regression model analysis models the probability of an event taking place or not while explaining the relationship between one dependent variable and one or more independent variables (*What Is Logistic Regression?* n.d.).

A bias that may have affected the data, resulting in little to no relationship between mating success and throat area and intensity, is small sample/population size. When performing this analysis on a small population size, the logistic regression overestimates odd ratios. The small sample size induces a systematic bias, where the regression coefficient estimates shift away from zero, and the odds ratios from one (Nemes et al., 2009). Without this bias, we may have seen a stronger correlation between throat intensity and area with mating success. A larger sample size and further analysis would be needed to better interpret the results of this study and determine the significance of the bias.

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