EEB313 Final Report: Analyzing Fitness and Female Sex Ratio in Starling Populations

Abstract

This report analyzes the relationship between female sex ratio and fitness in a population from the study, Density Dependence and Egg to Fledgling Rates. Which tested for optimal life-history theory within spotless starling, *Sturnus unicolor,* populations. This report concluded that the female sex ratio and fitness have a positive linear relationship, however, it is not the sole influence on increased fitness in starling populations. It can be concluded that although the female sex ratio may cause more variation in fitness than density dependence, it cannot be concluded as the main contributor to fitness in this population.

Introduction

This analysis will build off of the Final Report done by Daniel Shiue which explored how the female sex ratio impacts survival rates in 846 Starlings, this analysis concluded that there was a statistically significant relationship between the number of females and eggs to fledgling survival. To build off this model, this analysis will aim to explore the relationship between fitness and female sex ratios in this population. The hypothesis is that there will be a relationship between the female sex ratio and fitness. Per the preliminary report, a positive relationship exists between survival rates and increased female sex ratio. It is expected that this positive relationship will also exist between fitness and increased female sex ratio, meaning reproductive rate and survival rate will increase with increased sex ratio. Since an increased female sex ratio is more likely to occur in high-density locations, we will likely see stronger selection for this trait in High-Density locations, due to the need for increased fitness.

Data Collection

The data in this study was collected by using nest boxes on a colony of starlings in Manzanares el Real, in Madrid Spain. The 48 nest boxes were scattered among trees in the flat pastureland. High-density locations used 4 groups of 6 nest-boxes within approx. 10 m of each other. Low-density locations spread the 24 boxes approx. 58 m apart from each other. The data collected in this study includes 11 columns: Mother ID (mother), treatment (low density vs high density), year, clutch order (1st vs 2nd clutch), hatching date, nest ID, number of eggs (eggs), number of hatched eggs (hatchlings), number of fledglings 16 days after hatching (fledglings), number of male hatchlings (males), numbers of female hatchlings (females). Mother and Treatment are given as character values. Year, Clutch, Date, Nest, Eggs, Hatchlings, Fledglings, Males, and Females are given numerically. There are 210 rows of collected data.

Methods

Data was analyzed using the statistical software R Studio to create models showing the significance of these relationships. First, we will look at the relationships between sex and survival rates to determine how to proceed. We will also look at the relationship between how these factors are impacted by density dependence, or by the treatment of Low Density (LD) and High Density (HD) to rule out any secondary influence. Fitness will be measured using the relative fitness formula which is the absolute fitness of the individual/average fitness. Therefore, the survival rate and reproductive rate must be calculated. Survival rate will be calculated by survival from eggs to fledgling in the study populations. The reproductive rate will be calculated by the average number of eggs each mother produces. Relative fitness will be calculated by dividing the reproductive rate multiplied by the survival rate by the peak values of these metrics seen in the population. From here we will be able to see how fitness changes in the population based on female sex ratio and density dependence.

Data Analysis

Upon initial visualization of the data, histograms showed that the females occur in larger numbers and at higher frequencies than males. Initial plots show a stronger linear negative relationship between the increased number of females and deaths than an increased number of males and deaths. A positive relationship is seen between the female ratio and survival rate, as the female ratio increases over 1 survival rates increases to above 0.50. As the female ratio decreases the number of deaths increases. Deaths will peak when the female ratio is < 0.50. When factoring in Treatment, meaning high-density or low-density locations, male deaths occur at a similar rate in HD and LD, whereas female deaths occur at higher numbers in HD locations than LD locations. When comparing the female ratio to survival rate, in HD female ratios are higher, and slightly increase as the survival rate increases. In LD female ratios are lower but increase, as the survival rate increases. In both treatments survival rate peaks when the female ratio is greater than 1. It was concluded through modelling that treatment does not have a more significant impact on survival rates than female ratio, but that female ratio was not the sole significant factor that alters survival rates in this population. When reviewing relative fitness, this analysis grouped the metrics based on each mother to summarize fitness per individual. Upon initial visualization, relative fitness and female ratio show a strong positive linear relationship per mother. Survival rate and female ratio show a strong linear relationship per mother. The number of births or Eggs produced, and the female ratio share a strong positive linear relationship per mother. When analyzing correlations between fitness and female ratio, the data produces a result of normality and shows heterogeneity of variation in the residuals vs fitted and scale-location plots. Therefore, meeting the assumptions of the model. When completing an ANOVA table, variation in fitness was mostly impacted by the female ratio and did not show any significant variation due to treatment, due to higher sum squared and F values for the female ratio of 0.325 and 2.6102 respectively. However, due to high P values, the null hypothesis failed to be rejected. Therefore, although the female ratio has a higher impact on fitness than treatment it does not provide a significant cause of variation of fitness in the population. Next a linear mixed model was conducted on fitness. When analyzing random effects in the population on fitness such as the individual (mother) it was concluded it did not account for the variance. For fixed effects, the female ratio, number of females, and number of births or eggs produced had the largest influence on the variation of fitness in this population. Although treatment shared similar standard error and t values to the other metrics, its p-value failed to reject the null hypothesis. Therefore, in the linear mixed model female ratio, number of females, and number of eggs account for the majority of the variation seen in fitness.

Results

Analysis shows that a relationship exists between fitness and the female sex ratio in this population. However, the female sex ratio is not the sole significant indicator of fitness in this population. Treatment did not reveal to greatly impact fitness and was not more significant than the female sex ratio, likely indicating that a higher female sex ratio will be beneficial in both treatments. This analysis shows that the female ratio does increase in high density populations over low-density and that male production is not greatly altered by density dependence.

Discussion

Further analysis must be done on this population to conclude the main contributor to fitness in these populations. There may be a more substantial relationship, as the results of this analysis show the relationship is less significant than previously thought. This analysis also indicates that the preliminary analysis showing a relationship between survival rates and female sex ratio is less significant than assumed. This previous study may require further exploration.

**Citation**

Rubalcaba, J.G. and Polo, V. (2022), Density dependence of clutch size and offspring sex ratio in starling colonies. J Avian Biol, 2022:  e02993.<https://doi.org/10.1111/jav.02993>

Dataset:<https://zenodo.org/record/6525052>