THE EFFECTIVENESS OF HIGH MIMIC TO MODEL RATIOS IN A BATESIAN COMPLEX

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ABSTRACT

This study was conducted to observe the effectiveness, in a Batesian mimicry complex, of model to mimic frequencies in a natural environment. The purpose of this study is to observe differential selection based on the frequency of model to mimic. There are several different questions this study examined. For example, will prey types with a high mimic to model ratio be predated more than prey types with a low model to mimic ratio? Is there a difference in the consumption of prey with a high model to mimic ratio from week one to week two? Is there a difference in the consumption of prey with a high mimic to model ratio from week 1 to week two? This study consisted of three different sites with a mesh feeding tray at each site. Trays were set out two times a day and consisted of three different ratio types of prey. Each ratio was dyed either blue, green, and purple depending on the proportion of palatable to unpalatable prey. Blue died prey was entirely palatable, green prey is ¾ palatable (3:1 palatable to unpalatable ratio), and purple prey is ¼ palatable (1:3 palatable to unpalatable). The number and treatment of prey removed was recorded each visit. Results from the chi-squared analysis indicated that predators changed their eating habits to include ratios with high mimic to model frequencies. The H_A was supported.

INTRODUCTION

Many prey species have evolved unique defense mechanisms to provide protection from predation. These mechanisms include several strategies to avoid capture, detection and predation. Avoidance mechanisms include the use of venom, defecation and vomiting. Turkey vultures, for example, defend themselves by defecating on predators. If this initial behavior does not deter the predator, then the turkey vulture will vomit, and bite its attacker (F. Ammer per.comm). Other predator avoidance mechanisms include sliming frogs and oozing snails use. Another adaptation used as a defense mechanism that many insects and plants use is the ability to mimic another organism. Mimicry can be defined as the superficial resemblance of one organism to another (britannica.com).

Mimicry is important in many predator/prey relationships because it has the potential to reduce predation pressure(Charlesworth 1994). Mimicry has arisen in natural populations because of adaptations brought about by selective pressures. Most adaptations evolve as a result of selection for any feature of an organism that substantially improves a species ability to survive and leave offspring (F. Ammer per.comm). Darwin's theory of natural selection holds that variation within species occurs randomly and that survival or extinction of each organism is determined by that organism's ability to adapt to present and future environmental changes (Turner 1988).

There are three main components to most mimicry complexes: the model, the mimic and the predator. The model is a noxious, or sometimes dangerous prey species that the mimic copies. Mimics are normally a palatable or non-harmful prey species that closely resembles the model. The predator is the signal receiver which may not be able to distinguish between the mimic and the model. In different types of mimicry, two of three of these components can actually be the same organism. For example in aggressive mimicry the predator is also the mimic. The model, mimic, and predator can then vary in the way they are presented throughout the various types of mimicry (Williams 1991).

There are many types of mimicry that have been described in nature; however, each type is defined in a slightly different manner. Müllerian mimicry is described as one noxious or dangerous species mimicking another noxious or dangerous model. A common example of this type of mimicry is the monarch and viceroy butterflies. Both the monarch and viceroy are very similar in phenotype and are both highly unpalatable. In this form of mimicry, each species serves as both the model and the mimic (Pinheiro 2003). Another example of mimicry, speed mimicry, is when a slow, easy-to-capture species resembles a faster, hard-to-capture species. If a predator sees a species that it believes to be fast, it is not likely to invest time or energy to chase after it. Wasmannian mimicry is when the mimic resembles the model in order to live in the same nest or structure. Even though these varieties of mimicry are different, they are all effective avoidance mechanisms for the organisms that use them (Pasteur 1982).

The main focus of this study is Batesian mimicry. This is when a palatable, mimic species resembles a noxious, unpalatable or harmful model. After only a few encounters with an unpalatable model, the predator may learn to avoid organisms with similar phenotypes. Prey species may have evolved similar colors and patterns to model species because they are either unpalatable or able to defend themselves. For example, Pfennig et al. (2001) predicted that in areas inhabited by both the harmless king snake and the highly venomous coral snake, predators normally do not approach either species. To examine this prediction, he placed clay models of both snake species in an area where both naturally occur and most of the clay models were left alone. In areas where only the coral snake occurs and the king snake clay replicas were introduced, predators did not bother the replicas. On the other hand, in areas where the king snake resided and coral snake clay replicas were introduced, many of the replicas were predated (Pfennig et al. 2001).

Mimicry is a predator-driven process meaning that if there were no predators in a specific area, then prey species have no reason to seek protection. If a species occurs in a region with high predation pressures, it may evolve adaptations to increase survival. The process of mimicry is ultimately an evolutionary chase where the mimic only benefits if it continues to share specific traits or characteristics with the model. The predator also plays an important role in this relationship and must be able to identify potential prey species.

The effectiveness of most of these mimicry adaptations depends on three factors that include the degree of distastefulness, the ratio of models to mimics, and the similarity of phenotypes between mimic and model. The degree of distastefulness normally describes how unpalatable the model tastes. If the model is not very distasteful, then predators are likely to consume the organism. Therefore, it would not benefit an organism to mimic this species it would have a higher probability of being predated. The ratio of models to mimics is also very important in mimicry effectiveness. If there is a larger number of mimic species compared to a model species, mimicry does not benefit either species because predators may not be able to distinguish among them and will predate both species. The final factor is the similarity of a mimic's phenotype and/or physical features to those of the model. When a mimic's appearance is not close to the model, the predators may not recognize the resemblance, and the mimic may be consumed. However, if the mimic closely resembles the model species, most predators are not able to differentiate between the two species, and fewer of the mimics are consumed (Williams 1991).

The purpose of our study is to observe the differential selection based on the frequency of mimics to models. Specific aims and goals include determining whether predators will adjust feeding patterns during the course of this study, focusing on the effectiveness of model to mimic frequencies in a natural environment and frequency dependent selection based on treatment. We hypothesized that prey types with high mimic to model ratios will be more predated then types with high model to mimic ratios. We also hypothesized that there would be a difference in consumption of prey types with high model to mimic ratios from week one to week two.

METHODS

STUDY SITES

Three study sites were located on the Frostburg State University campus in Frostburg, Maryland. The first array was located in the FSU arboretum in a wooded area that contained a partially closed canopy. This array was located near a man-made wetland and a walking path. The second array in the arboretum was located at a riparian edge with an open-meadow. The third array was located at a forest edge between a woodland and developed area behind Sand Spring Hall at FSU. Each of the arrays was located 250 m apart to ensure independent observations.

Test sites were located in different habitats to attract a diverse predator base. Experimental variables were kept at a minimum number in order to reduce error and to keep the experiment from becoming too complex for the allotted time. Methodology used was modified from a study developed by Williams (1991).

ARRAY CONSTRUCTION

Arrays measured 60.96 cm x 91.44 cm and were constructed from a wooden frame with a wire mesh tray. Each array was divided into 90 equally spaced blocks used for prey arrangement during testing. Feeding trays were positioned approximately 1.2 m from the ground. To randomize where the prey was placed on the arrays, a random number table was used to create a total of 42 array design sheets.

PREY PREPARATION

Prey were created to resemble insect larvae from a recipe of flour and vegetable shortening. A ratio of (1.6 to 1) 1360 grams of flour to 850 grams of vegetable shortening was used to craft the prey. Water was added to make the dough easier to knead. Once the dough was mixed completely, a top loading balance was used to equally divide the dough into three portions. Food coloring was added to each portion of dough to establish treatments (blue, green, and purple). One fourth of the green dough and three fourths of the purple dough was made unpalatable by adding 0.75% quinine sulfate by weight. The treatments were: blue, which were all mimics; green, which had a high mimic to model ratio; and purple, which had a high model to mimic ratio (Table 1).

Table 1 – This table shows the 5 treatments and the actual number of prey made for each treatment.

	palatable	**unpalatable**
Blue (all mimic)	100% (1260)	0%
Green (high mimic: model)	75% (882)	25% (378)
Purple (high model :mimic)	25% (378)	75% (882)

The dough was then rolled 3 mm in width and cut into 15 mm pieces. A total of 3780 prey were made. After the prey was made, it was stored in the refrigerator at 4°C for preservation.

The experiment was conducted from July 12 to July 14 and from July 19 to July 22, 2004. Different groups of students were assigned to arrange the prey on the feeding trays in the morning at 0745 and pick them up at 1045, then in the afternoon again place the prey on the feeding tray at 1245 and picked them up at 1545. Each day sites were visited, 30 of each prey type were arranged on each array, blue all mimics, green high mimic to model and purple high model to mimic. Giving a ratio of 2/3: 1/3 for the high mimic to model vs. the high model to mimic prey types. The students collected data based on the number of treatments removed from each tray. They recorded the amount of mimics and models that were removed from each array on a chart, which was on the back of the array sheet. The students removed the prey from the arrays after the morning and afternoon treatments.

Statistical Analysis

The chi-square analysis was used for statistical analysis because it is a robust test designed for numerical data. Two equations were used to calculate the chi-square (see below).

$$\text{Equation 1: } \chi^2 = \sum \frac{(O-E)^2}{E}$$

Equation 2: *E = (Total Prey Predated) (Ratio for Prey Treatment)*

For the first hypothesis, we used chi-square to determine if the prey types with high mimic to model ratios will be predated more than prey types with high model to mimic ratios. It was also used to determine whether or not there was a difference in the consumption of prey types with a high model to mimic ratio from week one to week two. Differences were considered significant at an α value of 0.05.

RESULTS

A total of 83 out of 3780 prey placed were removed or misplaced during the experiment, of these, the number of prey with high mimic to model ratios was 71 and the number of prey with a high model to mimic ratio consumed was 12 (Fig. 1) There were 17 prey recorded for week one and 66 prey recorded for week two (Fig. 2). The total number of prey varied between the treatments (Fig. 3)

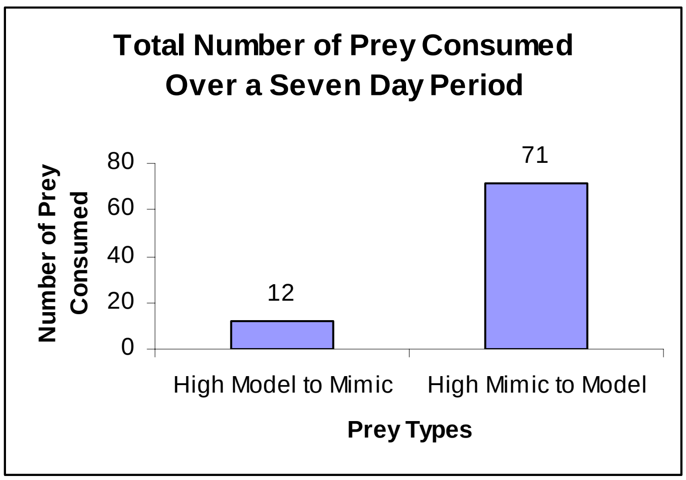

Fig.1.- This figure shows the number of prey consumed based on mimic frequencies.

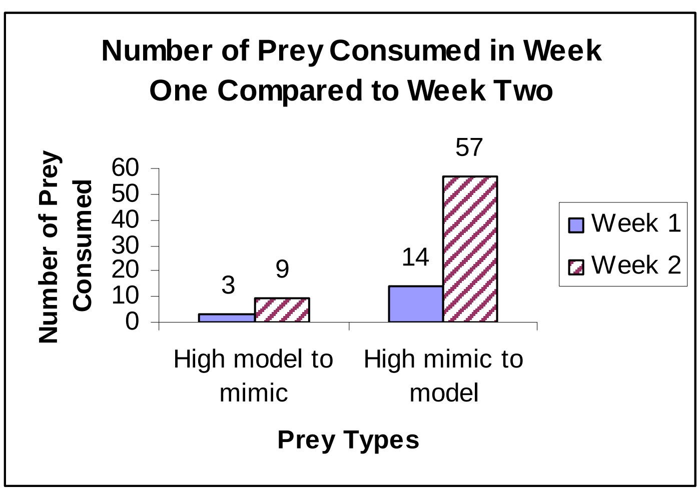

Fig.2.- This figure shows the comparison of week one to week two using the treatment ratios.

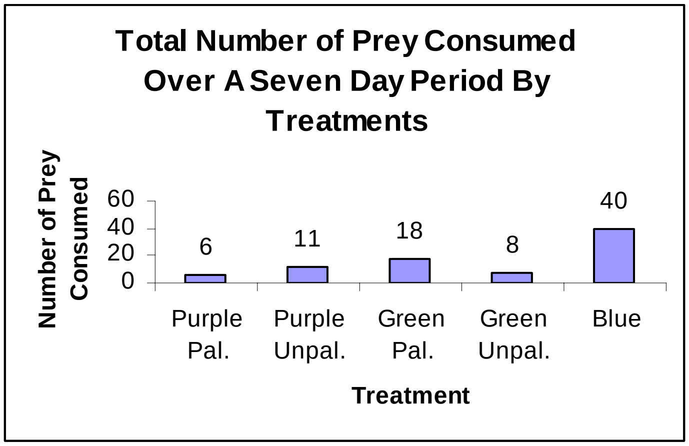

Fig.3.- This figure shows the amount of prey consumed for each treatment.

The ratio for high model to mimic prey types to the high mimic to model prey types misplaced or removed was expected to be 26 to 57 however, the ratio observed was 12 to 71 (Fig.1), this was significantly different (χ_1^2=6.169, p<0.05). There was no significant difference in comparing the expected ratio (5.66 to 11.340) to the observed ratio (3 to 14 Fig. 2) during week one (χ_1^2=1.874, p>0.05). When comparing the expected ratio (22 to 44) to the observed ratio (9 to 57 Fig. 2) for week two, there was significant difference (χ_1^2=11.87, p<0.05).

Potential predators that were observed near our arrays included blue jays, American song sparrow, grey catbird and American crow. There were also several small mammals sighted near the trays, such as gray squirrels and raccoons.

DISCUSSION AND CONCLUSION

The purpose of this study is to examine differential selection based on mimic to model frequencies in a Batesian complex.

The ratio of prey consumed with respect to mimic frequencies was significantly higher then the amount of prey consumed with a high model to mimic complex. It was hypothesized that prey types with large mimic to model ratios will be more predated than prey types with high model to mimic ratios. Data from Fig.1. shows there were more mimic to model prey types removed than high model to mimic. The ratio of predated prey was expected to be one thirds to two thirds. However, the observed was significantly different from the expected value. We expected there would be significant difference between the expected and observed because more prey was set out with a higher ratio of mimic to model rather than model to mimic. The total number of prey consumed over the course of the experiment is displayed in Fig. 3. Previous studies such as, Nonacs (1985), suggested that the larger numbers of mimics present in one region, the greater chance of predation. The alternative hypothesis was accepted however, the null hypothesis states that prey types with large mimic to model ratios will not be predated more than prey types with high model to mimic ratios and was rejected.

The number of prey consumed during the first week of experimentation differed significantly from week two. In week two, a larger number of prey representing a high mimic to model complex was consumed (Fig. 2.). The results from the chi square analysis suggested that predators changed their feeding habits throughout the experiment. It was expected the predators would consume the prey in a two thirds ratio during both weeks, however, using the chi square, it shows the predators LEARNED from week one to week to not to consume the prey with a high model to mimic compex. It was hypothesized that there is a difference in consumption of prey types with high model to mimic ratio from week one to week two. Pfennig et al. (2001) tested a similar Batesian mimic to model complex in three different regions where the king snake and coral snake distributions differed. This experiment showed different predation pressures based on model to mimic frequencies. Our ALTERNATIVE OR NULL hypothesis was accepted due to the fact that more prey were consumed with a higher mimic to model complex. (Fig.2). It was examined to test if predators learned not to predate the prey treatments with increased model to mimic ratios, demonstrated in figure three. Based on our results there is a differential selection. The predators prefer the prey with a higher mimic to model ratio.

The null hypothesis states that there is no difference in consumption of prey types with high model to mimic ratios from week one to week two. Nonacs stated that the model to mimic ratios may be important in deterring predation. As models increase in number predators may be less willing to attack a mimicry complex. Brower et al. (1960) looked at the relations of relative abundance of mimics and the efficiency in the complex -of discouraging predators. She found 30% of the prey were models and that a significant amount of protection from predation would occur. It is demonstrated in Fig.2? that the null hypothesis was rejected.

There were several potential limiting and confounding factors that could have affected the outcome of this study. These factors included the dates of the experiment, weather conditions, possible predators, and color of prey. It was assumed predators were not initially biased to the color. However, this assumption may not hold true. For example, predators may learn not to eat a particular color preference depending on the model to mimic ratio. The weather has a large impact of feeding time for many predators. Our prey may not have been predated due to the fact that it rained the first several days of our testing. Also, the small length of time the prey was allotted to set out each day could have affected the results of the experiment.

For future experiments, many improvements could be made. Leaving the prey out for a longer duration of time each day could potentially improve this study. Also, the experiment could have been preformed over a longer time frame to increase the accuracy of our data. … Dr. Ammer do you have any other suggestions as top what we could use for improvements?

New questions have arisen from this experiment. Could the color and shape of the prey affect the amount prey consumed? Would we have received different results in a different location? Did the distance between each prey on the tray affect our results? Also, if the experiment would have been conducted over a longer period, would there be a change in predator feeding habits?

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