Tradeoff Between Natural and Sexual Selection Underlies Evolutionary Divergence of a Conspicuous Sexual Signal in Bahamas Mosquitofish (Gambusia hubbsi)

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Abstract

Understanding the evolution of sexual signals in plants and animals, such as colorful traits, represents an important goal of evolutionary biology. By studying a species in different habitats at the same time, we will be able to get a better idea of what factors are causing evolution of a characteristic. Bahamas mosquitofish (Gambusia hubbsi) have occupied blue holes for thousands of years after colonizing the areas around 15,000 years ago. The species has evolved stronger orange coloration in their dorsal fin in the absence of fish predators. We will be traveling to Andros Island to conduct experiments in roughly five blue holes; some blue holes will have predators while others will not. We will be using models of the Bahamas mosquitofish with different shades of orange on their dorsal fins, and we will observe how the predatory fish respond. Our hypothesis is that predation has a great effect on the evolution of this characteristic. We will test this by deploying models of the mosquitofish in the blue holes and observing the activity with underwater video equipment. There will also be a complimentary experiment testing whether the females prefer males with a bright orange dorsal fin or not, and we will be able to pull the results from each experiment to help us determine if there are other environmental effects, besides predation and/or sexual preference, on the evolution of the fish, and if so, what the causes of fin color variance may be.

Introduction
Within different species, there is a vast diversity of different sexual signals and signaling behaviors, as well as how these signals are received (Endler 1992). There are many factors that influence the origin and reception of these sexual signals in a species. This makes studying the evolution of these traits fairly complicated. It is important for us to recognize and comprehend how these characteristics change over time, and why they change the way they do (Martin et. al 2013). In an attempt to understand sexual signal evolution, we must observe a species in various different environments at the same point in time. From there, we will be able to see which factors most greatly affect the evolution of this trait.

An individual’s sexual signal(s) is sent through the environment in hopes that another individual in the population will see the signal and react in a way that favors reproduction (Martin et. al 2013). When this sexual signal undergoes evolution, there must be a need for an adaptation. Since signals, reception of these signals (whether by the opposite sex or by predators), and signaling behavior are all able to change the direction of evolution, we can see that they are linked together to affect the diversity of a population (Endler 1992).

For nearly 15,000 years, the Bahamas mosquitofish have inhabited blue holes on Andros Island, along with other aquatic habitats. Blue holes are essentially vertical caves that were filled with water roughly 15,000 years ago. Since the mosquitofish is a smaller, livebearing fish, it is easier for them to colonize and disperse than it is for larger predatory fish; they have a much larger presence among blue holes than some of the other larger, predatory fish (Langerhans et al. 2007). On Andros Island, the only flowing water can be found in tidal creeks. This means that, for the most part, blue holes are isolated; mosquitofish have colonized these blue holes showing great applicability to population structure studies (Schug et al. 1998). Since predatory fish are seen in less abundance than mosquitofish in blue holes, there are blue holes with populations of mosquitofish that have no threat from predators (Langerhans et al. 2007). On the topic of evolutionary ecology, it is important to
look at deviations of some specific traits, and how natural and/or sexual selection affect these traits within different environments. It is an ultimate goal of evolutionary ecology to be able to recognize the ecological causes of phenotypic variation (Heinen *et al.* 2012).

Differences in these sexual characteristics, like bright orange dorsal fins of Bahamas mosquitofish, between sexes can upset the common rates of selection in a species. Because males are usually the ones who have the traits meant to signal the females for mating, predators are often times more attracted to the males of a species because these traits are sometimes visible to a predator. When changes are made to these signaling characteristics within a species, it shows how the species has adapted to escape predation. Different changes have occurred including a species using a different signal, loss of the signal, and a change in the signal characteristics (Zuk *et al.* 1998). For example, the Bahamas mosquitofish has a bright orange fin. It has been noticed that the color of this fin has been evolving and fading over time, so now some of the fish have a very pale orange dorsal fin, as opposed to the original bright orange color. This incidence leads to the expectation that natural selection will occur in contrast to sexual selection (Zuk *et al.* 1998).

With this study, we are going to be examining the theories of natural selection and sexual selection by studying the ecological divergence in a conspicuous trait (bright orange fin color) among the Bahamas mosquito fish in hopes to understand how this species has developed this diversification. We have hypothesized that natural selection has a greater effect on the evolution of the Bahamas mosquito fish than sexual preference does; predation affects the color of the males’ dorsal fin more than the preference of the females. We will use the presence and absence of natural predators, as well as variance of fin color intensity on model fish, throughout approximately five blue holes to help us come to a conclusion about what type of influence natural selection has on the changing fin color.
Methods

Participants

Four group members were assigned to this study via student selection from a group of students who voluntarily signed up for this research opportunity. This study involves students from diverse majors all enrolled at North Carolina State University ranging from 18-22 years old.

Procedure

The study will begin July 6, 2013 when we reach Andros Island, the location of our study. During this study period, our group will observe Bahamas mosquitofish in their natural environment of blue holes and study the populations and how the changing color of the orange dorsal fins may be affected by natural selection from predation or by sexual selection from the females. Once observation is complete, we will deploy models of the mosquitofish in 5 blue holes and use underwater monitoring and videos to determine whether predators notice and attack the models with a brighter orange dorsal fin more often than the duller-colored models. A simultaneous study will also be conducted by the mentor of our group testing whether females prefer males with more orange dorsal fins to round out our study to provide a strong test of the balance between natural and sexual selection.

Measures

For our study we are going to observe the five blue holes and see if we find some type of pattern in the selection of predation on the Bahamas mosquitofish. We will use empirical data to test the hypothesis of whether predators attack the mosquitofish with brightly colored dorsal fins more often than not. We will use models of Bahamas mosquitofish and place them in five blue holes. Each set of models will have one model
mosquitofish with a bright orange dorsal fin and another model with a dull colored dorsal fin. We will observe the actions of the predators and see which model gets attacked more. We will be using underwater film equipment to watch the actions of the predators on the model mosquitofish for approximately seven days. After the seven days, we will analyze the damage done to each set of mosquitofish and record the attacks on each of the film recordings. This will provide us with quantitative data that we can compare between each set of models to see if there is any statistical difference between the treatments. This information will be used to see if our hypothesis corresponds with the data or not.

Data analysis

We plan to collect data from all five blue holes on the impact that the sexual signal of the orange dorsal fin has on natural selection. We will conclude if there is statistical significance between the data across all of the five blue holes to see whether natural selection is determined by the preference of predation on specific sexual signals; in our study we’re looking at the bright orange dorsal fins. A conclusion will then be made either proving or refuting our hypothesis of predation having an influence on natural selection due to the specific sexual signals of the Bahamas mosquitofish.

Potential Results

There are multiple possible outcomes to this study. The first would be if the coloring of the model with the brighter orange dorsal fin was attacked significantly more often. This would be consistent with a study done on guppies that found that in an area with less predation the male colors increased within 20 generations (Labonne et al. 2010). Meaning that the predators typically attacked the guppies with more color. Although this study will not be able to attain information on the change in a species over generations based on which
coloring is attacked more, a prediction could be made on what color changes may occur overtime. This would mean that the sexual signal of the animal would also be a trait that made them more attractive to predators. This mismatch has been seen in the house finch as well. The females prefer bright and large patches but the male plumage is actually driven by environmental pressures rather than the females’ preferences (Panhuis et al. 2001). The opposite outcome could also be found, that the model with the brighter colored fin were attached significantly less.

It may also be found that there is no statistical difference between the amount of times the two different models were attacked. In this case the study would not be able to conclude whether or not the fish’s dorsal fin color has an effect on their attractiveness to predators. It may also mean that it does not have an effect.

The experiment is going to be conducted in five different blue holes therefore it is also possible that there will be different results in different blue holes. A previous study found that there were different levels of predation in Bahamas’ blue holes. It was found that the different levels of predation affected the body shape of Gambusia hubbsi (Langerhans et al. 2007). In a study related to the predation and sexual selection of Amazonian frog species with complex calls it was also determined that the sexual selection against complex calls was stronger in one of the tested locations then the other (Trillo et al. 2013).

**Implication of Findings**

Results from this study could show how environmental factors can influence the fin color of the Bahamian mosquito fish. Predators can be found in some of the blue holes, but not all of them. As a result, the presence of predators can be isolated for the mosquito fish. Looking at what color the predators prefer shows how this impacts the distribution of
fin color in the mosquitofish. The extent of the predators’ influence reveals details about the evolution of mosquitofish. The impact of the orange fin in males is more noticeable to predators, but preferred by females. Mosquitofish with faster burst of speed and body shape have evolved as a result of predation (Langerhans et al. 2004). A predator preference of orange fins would mean that predators could influence evolution of fin color in mosquitofish. The Australian skinks, Carlia, in open habitats have different breeding colors and sexual signals than in covered habitats (Dolman et al. 2010).

No preference in the fin color by the predators is another possible result. Another environmental factor could be the cause of the orange fin differentiation in mosquitofish. Other factors in each of the blue holes could be tested to find what else could be affecting this evolving characteristic. Sexual selection paired with ecological speciation can be the cause of speciation. The orange fin color may be preferred over a lighter color variation by females in the population (Dobeli et al. 2000; Panhuis et al. 2001).

Each blue hole could produce different results for fin preference in predators. A difference in the individual environmental factors of each of the blue holes could cause this difference. Environmental factors have been shown to influence communication signaling in species (Endler 1992). For example, complex frog calls are used in low predation areas, while simple calls are used in high predation areas. The complex call is easily identifiable to predators and caused geological divergence has occurred in the species (Trillo et al. 2013). Research on the divergence of fin color in mosquitofish would identify what environmental factor is causing the distribution of the orange fin color. Differences in each of the blue holes would be shown throughout this research.
References


