The Effect of Monarch Butterfly Migration Patterns on Longevity from Host-Parasite Relationships

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April 6, 2022

BIOL 461

**Introduction**

Monarch butterflies were first introduced approximately 2 million years ago in the American Tropics (WWF, 2020). Since then, this species has made its way to the United States and areas outside of the continental United States. Each year, some monarchs show a migratory pattern from Canada, where they breed, to Mexico, where they spend the winter months (Center for Biological Diversity). Populations that have become geographically isolated, such as those who have made their way away from the continental United States, do not share the same migration tendencies (USDA) as those who are not geographically isolated. The environmental patterns are also different for those populations and allow for them to independently evolve from the interbreeding population that spans from Mexico to Canada.

Monarch butterflies are commonly infected by a parasite called *Ophryocystic elektroscirrha* during their larval stage when the parasitic spores make their way into the larvae and pupae. This occurs when the adult houses many of those spores and the larval stage monarchs consume them (Monarch Joint Venture, 2022). These parasites further affect the monarchs by not allowing their wings to properly expand and grow during their stages of development. The infections the parasites cause the monarchs range from unsuccessful departure from the pupal stage to difficulty flying. The life span of a monarch is typically between 2-6 weeks, or 14-42 days (Oberhauser, 2015). However, depending on the severity of the infection caused by the parasitic spores and the relationship the butterflies have with their migratory environment, their lifespan may be shorter or longer than expected.

Host-parasite relationships between the monarchs and parasites may also become different between geographically isolated populations. These relationships may vary based on the parasite and how its host may benefit it. In some species of animals, the parasite is detrimental to the health of its host, where others use the host for its resources without causing any harm. Ultimately, the fitness of both the host and the parasite may be impacted based on their local adaptations. These may include living conditions for each of them such as temperature, amount of available nutrients, amount of rainfall, and other factors that may influence the parasite or host’s ability to adequately survive. In populations that migrate, they may experience more risks compared to those who spend their whole life in one place, but still typically live longer lives (Oberhauser, 2015).

In this analysis, the longevity of monarch butterflies from three populations were compared to better understand the potential impact that the monarch’s migration pattern had on the longevity of monarchs infected by a parasite. The three populations show different migratory patterns with one of them being from Hawaii and staying there only to mate with one another. Another comes from an area of Florida that has the same migration pattern, and the other is the group that spans from Canada to Mexico. The article in which the data was drawn from groups the populations based on their migratory pattern rather than geographic location. Therefore, Hawaii was its own dataset, and monarchs that migrate over a long distance were placed in their own plot. Parasite prevalence in these areas varied, suggesting there are different levels of selection acting of the resistance and tolerance of the host (Sternberg et al 2013). To see the impact migration has on the monarchs, the longevity of each monarch sampled from each of the areas will be viewed to see if there is a trend that is dependent on the migration pattern used and the effect of host parasite evolution. Longer longevity for the monarchs may imply they are evolving quicker and are able to adequately live with the parasite, just as shorter longevity may indicate better evolution from the view of the parasite instead. This paper defined longevity as “a measure of host fitness” and was measured in the number of days the monarch lived after hatching.

The hypothesis of this experiment states those migrating over a long distance will adapt quicker to the parasites and live longer lives due to the variation it is seeing during its migration season, as opposed to those who stay in one place around the same group of butterflies year-round. From an evolutionary perspective, this hypothesis will look further into what the impact population isolation and migratory patterns have on the longevity of monarch butterflies who have already been infected by parasites. To test this hypothesis, X, Y scatter plots will be made to compare the lineages of monarchs that are and are not infected by the parasite. The groups of monarchs will also be separated based on whether they are in a migratory or nonmigratory population.

**Materials and Methods**

***Data Collection***

Data for this paper came from an article titled “Patterns of Host-Parasite Adaptation in Three Populations of Monarch Butterflies Infected with a Naturally Occurring Protozoan Disease: Virulence, Resistance, andTolerance” by Sternberg et al in 2013 that was found via Dryad. The analyses for this paper came from monarchs sampled from three areas of Hawaii (Oahu, Kauai, and Maui), St. Marks, Florida (Eastern North America), and Miami, Florida (Southern Florida). For the datasets used, areas in the continental United States were graphed in the same dataset. Monarchs and unhatched larvae from all areas were taken to a lab setting where they were brought into contact with a various number of parasitic spores by placing the butterflies on leaves containing the spores. The hatched larvae from each population were used as a source of parasite lineages for experimental tests. Each population continued to reproduce with only those they would have encountered in their natural habitat, and starvation resistance was also used to correlate with longevity patterns under natural conditions. Starvation resistance is defined as the amount of time the organism can continue to live while dealing with a severe lack of food (Jang et al 2014). *Danaus plexippus* was the species of monarch used and the parasite species was *Ophryocystic elektroscirrha.* Data collected was done so through observations from Sternberg et al in 2013.

***Data Analysis***

To see the relationship between longevity and migration pattern, X, Y scatter plots were constructed in RStudio 2021.09.1 Build 372. A plot was made for each population, using the plot() function, and was also a categorization based on the migration pattern and showed overall trends for butterflies that were and were not infected with the parasites. A plot of the whole population was also constructed to see trends in the area as one. All plots were used a visual representation of the relationships between samples. The data was initially separated into areas of monarchs that were and were not infected by the parasite to compare any changes seen there. The plot comparing nonmigratory and migratory populations altogether (Figures 5 and 6), were done to show the trend of all the monarchs together due to their mating patterns still allowing them to mate with those who may or may not be equally impacted by the parasite. Microsoft Excel Version 2203 was also used to find the average longevity for each sample and further analyze the data.

**Results**

For this analysis, the graphs with “Nonmigratory” in the title refer to those monarchs that stay in the same area year-round, while graphs with “Migratory” in the title refer to those who migrate from Canada to Mexico. Longevity is recorded in days and “Labeled Monarch” represents each monarch. Individual monarchs were numbered as it hatched making Monarch 1 the oldest and the higher numbers on the x-axis representing the latest ones to hatch.

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**Figures 1 and 2 (above) show the trend in monarch longevity in those that remain in one area year-round (left) and those that migrate from Canada to Mexico (right). All monarchs plotted were not infected with parasitic spores.**

Monarchs that remain in one area year-round and are uninfected seem to live longer lives compared to those that are also not infected but migrate from Canada to Mexico. Average longevity for the nonmigratory set was 18.725 days while the migratory set was 17.400 days. The first half of the uninfected nonmigratory population had an average longevity of 16.127 days while the second half had an average of 21.411 days. The first half of the uninfected migratory population had an average longevity of 21.846 days while the second half had an average of 13.262 days.

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**Figures 3 and 4 (above) show the trends in monarch longevity in those that remain in one area year-round (left) and those that migrate from Canada to Mexico (right). All monarchs plotted were infected with parasitic spores.**

Monarchs that were infected with parasitic spores and remained in one place show increased longevity as more butterflies emerge. However, those who have a more elaborate migration pattern do not show a difference in longevity as more butterflies emerge. Average longevity for the nonmigratory population was 16.911 days, while the migratory population was 8.883 days. The first half of the infected nonmigratory population had an average longevity of 13.970 days while the second half of that population had an average longevity of 20.506 days. The first half of the infected migratory population had an average longevity of 8.693 days while the second half had an average of 9.075 days.

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**Figures 5 and 6 (above) show all monarchs, both uninfected and infected, by parasitic spores. Those who remain in one place year-round are shown on the left and those that migrate over a farther distance are shown on the right.**

Monarchs from populations that stay in who place and interbreed with the same pool of mates show an increase in longevity as more monarchs emerge. Monarchs that do migrate over large areas tend to stay the same in terms of longevity. Average longevity for the nonmigratory population was 17.801 days, while the migratory population was 10.066 days. The first half of the population of nonmigratory monarchs had an average longevity of 14.531 days while the second half had an average of 21.306 days. The first half of the migratory population had an average longevity of 10.261 days while the second half had an average of 9.812 days.

**Access to Data Used to Construct Plots:**

<https://github.com/brittdye24/Tasks/tree/master/Project>

**Discussion**

Increased longevity occurred in populations of butterflies that remained in the same area for the duration of the whole year. This was shown specifically in the averages that were taken for the first and second halves of these populations. The uninfected monarchs averaged 16.127 days at in the first half but were living for an average of 21.411 days in the second half. A similar trend was shown in those that were infected, as those nonmigratory monarchs went from an average of 13.970 days to 20.506 days. This whole population, uninfected and infected, went from 14.531 days to 21.306 days. These patterns show that as more nonmigratory monarchs hatch, they begin to live longer lives, suggesting the hosts are in some way evolving to reduce the effects of the parasite or coevolve with the parasite so it is not detrimental to its fitness. Monarchs in this area may be better supported in terms of nutrition that may give them the chance to be more adequate in living while infected with parasites (USDA). There may also be other factors that lead to why those butterflies are able to evolve to live longer.

Monarchs that migrate over large areas of land did not show an increase in longevity as more butterflies emerged, and if there was an increase, it was slight. The infected migratory population was the only one to show an increase in longevity from the first to second half of the dataset. This population started with an average of 8.693 days and moved up to 9.076 days by the time those in the second half of the population had hatched. The uninfected migratory group on the other hand showed a much more drastic change, as its first half lived an average of 21.846 days while the second half lived 13.262 days. The original hypothesis stated that this group would live longer lives, however that hypothesis was not supported. This was surprising due to the previous research that stated that monarchs that migrate over large distances tend to live longer despite the increased chance of risk they encounter during migration. This may be due to the effective population size between the two populations, or effects of conducting the experiment in a lab setting. Monarchs that are moving from Canada to Mexico encounter butterflies from different areas as they migrate to and from each location. This may also be due to the ability the parasites in each area have to infect the butterflies. Parasites from Hawaii, the nonmigratory population, were said to be more infective than those from the migratory group, which may cause for selection to work in favor of the butterflies to evolve to better live with those parasites (Sternberg et al 2013). If the parasites are not as infective in the migratory category, there would be no reason for selection to be in favor of an issue that is not as immediately present as it is in the nonmigratory one. The smaller change in longevity in the migratory group may also be due to an evolutionary arms race between the host and parasite that allows for no change because neither is evolving to kill or rid of the other. If this was occurring, the two organisms would continue to evolve to try to counteract the other simultaneously, resulting in neither of them having a serious effect on the other. Previous research stating that monarchs that migrate over long distances and parasites in nonmigratory populations being more detrimental to their hosts led to the formation of the hypothesis of this experiment that was ultimately not supported.

To summarize, monarchs in populations that do not migrate over large areas tend to show patterns of longer longevity as more butterflies emerge. There are many different potential explanations that can lead to a reason as to why this is specifically. These may include factors from within the environment of the populations, such as food or weather conditions that may impact the monarchs. Moving forward with studies of this nature, more parasite and butterfly species may be useful in determining further relationships like this one, as well as considering what impacts the surroundings have on both the host and the parasite. It may also provide insight to compare these findings with those of other migratory organisms to see if this parasite has equal effects on others or if it is more detrimental to monarch butterflies.

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