A Comparison in Migration Behavior between the Monarch Butterfly *Danaus plexippus* and the Painted Lady *Vanessa cardui*

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Abstract

Two Lepidopteran species, the monarch butterfly, *Danaus plexippus* and the painted lady butterfly, *Vanessa cardui* make incredible migrations in different parts of the world (Guerra 2015). The monarch migrates from its native range of southern Canada and the United States, south to overwinter in Michoacán, Mexico, a small location in the mountains of central Mexico. (Guerra 2014 and Reppert 2010). Monarchs can travel up to 4,000 kilometers during migration (Reppert 2010). The painted lady overwinters in northern Africa and migrates to northern Europe (Nesbit 2009). Painted lady butterflies have been documented to travel up to 15,000 kilometers during migration (Stefanescu 2012).

According to R.L Nesbit, “behavior plays a central role in migration strategies because it directly influences migration outcomes and is acted upon almost immediately by natural selection,” (Nesbit 2009, p. 1119). For both species, migration is not a learned behavior because there are several generations in between the migrating generation (Reppert 2010). A variety of internal behaviors and external environmental factors play a role in helping both species migrate to its destination (Guerra 2015). Internal behaviors include the sun compass and related circadian clock and the magnetic compass. External environmental factors include temperature, wind and altitude. Multiple navigation behaviors and multiple environmental cues can increase the likelihood of them arriving to their destination (Guerra 2015). This review will show commonalities and differences between the two species and their migration behaviors. Understanding all aspects of migrations will help develop conservation strategies and overall survival of the species (Brower 1991). This review will also suggest ideas on how to apply knowledge and research from one species to learn more about the other species. This could help direct long term conservation efforts for all migrating Lepidopteran species.
**Introduction**

Two Lepidopteran species, the monarch butterfly, *Danaus plexippus* and the painted lady butterfly, *Vanessa cardui* make incredible migrations in different parts of the world (Guerra 2015). The monarch migrates from its native range of southern Canada and the United States, south to overwinter in Michoacán, Mexico, a small location in the mountains of central Mexico (Guerra 2014 and Reppert 2010). Monarchs can travel up to 4,000 kilometers during migration (Reppert 2010). The painted lady overwinters in northern Africa and migrates to northern Europe (Nesbit 2009). The breeding areas and migration routes for the painted lady are not as well defined or documented as the monarch for a few reasons. The painted lady is more widely-distributed, and they also can breed many times a year (Stefanescu 2012). Painted lady populations fluctuate most likely due to precipitation levels in the winter breeding areas. The breeding locations could also vary from year to year (Nesbit 2009). Painted lady butterflies have been documented to travel up to 15,000 kilometers during migration (Stefanescu 2012).

According to R.L Nesbit, “behavior plays a central role in migration strategies because it directly influences migration outcomes and is acted upon almost immediately by natural selection,” (Nesbit 2009, pg. 1119). For both species, migration is not a learned behavior because there are several generations in between the migrating generation (Reppert 2010). This literature review will examine the life history of the two different species and their migration patterns. A variety of internal behaviors and external environmental factors play a role in helping both species migrate to its destination (Guerra 2015). Internal behaviors include the sun compass and related circadian clock, and the magnetic compass. External environmental factors include temperature, wind and altitude. Multiple navigation behaviors and multiple environmental cues can increase the likelihood of them arriving to their destination (Guerra 2015). This review will show commonalities and differences between the two species and their migration behaviors.
Monarch Butterfly Life History

The monarch migrates from its native range of southern Canada and the United States, south to overwinter in Michoacán, Mexico, a small location in the mountains of central Mexico. (Guerra 2014 and Reppert 2010). The high-altitude, overwintering grounds are approximately 800 square kilometers and are covered in Oyamel fir trees *Abies religiosa* (Brower 1996). When they are not overwintering, much of the population is located east of the Rocky Mountains. A smaller population exists west of the Rocky Mountains (Brower 1991). Monarchs can travel up to 4,000 kilometers during migration (Reppert 2010).

Unlike many other migratory species, monarch butterflies do not learn to migrate from previous generations. There are usually at least three and five generations in between the migrant generations (Brower 1996). All generations of monarchs breed, except the migrating generation will go into a reproductive diapause while they overwinter. The will begin to breed on the return journey in the spring when milkweed begins to grow (Brower 1996).

Milkweed is the sole food source for monarch butterfly larvae and the plant relies on similar environmental cues as the monarchs. Increasing photoperiod and warmer temperatures are cues for milkweed to sprout, which coincides with the same cues that monarchs use to recalibrate and migrate back to the United States and Canada. Milkweed relies on cold temperatures prior to sprouting (Guerra 2015). The migrating generation of monarchs lays eggs on the newly sprouted milkweed as it travels northward (Guerra 2015).

Monarch Migration Internal Navigation

Early research indicated that monarchs have an internal navigation system that keeps them on course through migration while using wind as a resource to push them along (Brower 1996 and Gibo 1981). Recently, new research has shown the complexity of the monarch’s internal navigation system.
**Sun Compass**

The antennae, brain and compound eyes play a role in the monarch’s sun compass. The antennae are light-sensitive, which allows them to process information on time and the sun’s location (Guerra 2015). This time-compensation throughout the sun’s movement during the day is known as the circadian clock (Merlin 2009). Experiments have shown when the monarch antennae are removed or painted black, the monarchs become disoriented proving that the antennae play a role in receiving light, and navigating with a clock (Merlin 2009).

The brain and eyes also process light, but in different ways. The brain can sense when the days become shorter, which informs the butterfly when to migrate (Guerra 2015). The main retina in the eyes processes the skylight cues, or horizontal position of the sun, and the dorsal rim area of the eye can process polarization patterns (Guerra 2015). The information processed in the antennae, brain and eyes is all transferred to the motor system of the butterfly, and indicates when, where and how the butterfly navigate (Guerra 2015).

Monarch butterflies rely on their sun compass during both legs of the migration, but it is environmental cues that will recalibrate the compass for the migration northward (Guerra 2015).

**Magnetic Compass**

The antennae also provides the monarch with a magnetic compass (Guerra 2014). The magnetic compass could be a backup navigation system for when daylight cues are unavailable for the monarch’s sun compass. Overcasts days are an example of when the daylight cues may not be as prominent. The magnetic compass could also help to calibrate the sun compass, ensuring accuracy in navigation (Guerra 2014 and Guerra 2015).
Painted Lady Life History

The painted lady butterfly overwinters in northern Africa and migrates northern Europe each year most likely because of hot, dry conditions in northern Africa in the summer time (Nesbit 2009). The breeding areas and migration routes for the painted lady are not as well defined or documented as the monarch for a few reasons. The painted lady is more widely-distributed, and they also can breed many times a year (Stefanescu 2012). Painted lady populations fluctuate most likely due to precipitation levels in the winter breeding areas. In the past 20 years, there have been documentations of large populations every three to four years. Those years include 1996, 2000, 2003, 2006, and 2009 (Nesbit 2009). Populations were the highest on record in 2009 (Stefanescu 2012). The breeding locations could also vary from year to year (Nesbit 2009). Painted lady butterflies have been documented to travel up to 15,000 kilometers during migration (Stefanescu 2012).

Painted lady butterflies usually have six generations in a year of migration (Stefanescu 2012). Painted lady butterflies have been documented migrating northward, but there is not nearly as much research or records on the butterfly’s migration south. Experiments completed by R.L Nesbit and a team of researchers discovered that autumn butterflies reared in a laboratory had the instincts to fly southward (Nesbit 2009). Since other species of Lepidoptera, such as Vanessa atalanta, the red admiral butterfly, have been documented on both the north and south migrations, it is likely that painted lady butterflies do make the southward migration but they may migrate in wind currents at higher altitudes (Mikkola 2003, Nesbit 2009, Stefanescu 2007).

Painted lady butterflies have a variety of host plants that are available throughout their migration range including thistles and common mallow (Stefanescu 2012).
Painted Lady Migration Internal Navigation

Sun Compass

Painted lady butterflies also use a sun compass to help them navigate in the correct direction (Nesbit 2009). Their sun compass relies on daylight cues, but not the time compensation behavior seen in the monarch (Guerra 2015 and Nesbit 2009). There has been no research to indicate that painted lady butterflies use a magnetic compass to navigate, but more research could be done in this area (Nesbit 2009).

Environmental Components in Migration for Monarch and Painted Lady Butterflies

Butterflies also rely on environmental factors to help them migrate to including wind, altitude and temperature. (Guerra 2015 and Wehner 1998).

Wind and Altitude

Both species utilize high altitude winds and the flight boundary layer. This boundary layer refers to the air close to the ground. Butterflies can generally fly faster than the wind close to the ground and therefore have more control of their flight (Taylor 1974). More research need to be done to determine how butterflies decide whether to use high altitude winds or the lower flight boundary layer (Nesbit 2009).

Monarchs can fly as high as 1,250 meters (Gibo 1981). They select their altitude based on wind speed and direction (Guerra 2015). Monarchs travel in warm air thermals, which will help them conserve energy during migration (Reppert 2010). Using the sun compass and magnetic compass, they stay on course even if the wind blows them in a difference direction (Guerra 2015). Studies suggest that while migrating, the decision whether monarchs will search for food, or continue flying depends on the weather and wind (Brower 1996). Monarchs can choose to avoid wind or soar in wind currents going in the correct direction (Gibo 1979). When winds are blowing from the south, southwest or west, monarchs can fly low, approximately one meter above the
ground to avoid going off course (Gibo 1979). The opposite wind directions, north, northeast and east will generally keep the butterflies on track (Gibo 1979). Through Brower’s research, he observed that, “soaring in combination with the ability to exploit tailwinds, increases ground speed, conserves lipid reserves and reduces wing wear” (Brower 1996, p. 96).

Brower and other researchers also made many observations that monarchs will travel specifically after a cold front passes. In fact, they determined about 100 million butterflies passed through a Texas location in one day in 1994 after a cold front (Brower 1996).

Wind cues are received by the Johnston’s organ found in the antennae, which can help monarchs determine wind direction (Guerra 2015).

Stefanescu and a team of researchers studied the painted lady butterfly population in 2009 when the population was one of the highest on record. The used radar to determine high altitude flight and ground observations to determine if butterflies used the flight boundary layer. They estimated approximately 11.1 million butterflies on the radar between May and June 2009 traveling north through the southern United Kingdom. Only about 65% were traveling directly north. Radar detected approximately 25.9 million butterflies traveling south during August through October 2009. Only about 55% actually traveled south. The butterflies that were not directly going north or south were displaced by winds blowing in other directions (Stefanescu 2012).

Painted lady butterflies were also well-documented traveling in the flight boundary layer in 2009 and in other years (Stefanescu 2007 and 2012). They traveled in the boundary layer more often in the spring (Stefanescu 2012). Painted ladies use both strategies to migration, but it is not clear how painted lady butterflies make the decision fly at high altitudes or low to the ground (Stefanescu 2007 and 2012).
**Temperatures**

Research has shown that temperatures will trigger the monarchs on when to migrate. They need cold temperatures to know when to migrate back north (Guerra 2013). It is unknown how the monarchs receive temperature information. One theory is that there are temperature receptors in the antennae, which is similar to other species such as *Drosophila* (Guerra 2015). A combination of the cold temperatures and changing amounts of daylight recalibrates the internal compass for monarchs, which triggers them to migration northward (Guerra 2015). The same triggers that recalibrate the compass are the same triggers that milkweed need to begin growing (Guerra 2015). As the monarch migrates north, it has new milkweed plants for egg laying (Guerra 2015).

More research needs to be done to determine the exact environmental cues that trigger painted lady butterflies to migrate. Environmental cues could include photoperiods, temperatures and host plant availability, similar to the monarch butterfly (Stefanescu 2012).

**Other Factors That May Play a Role in Migration**

There are other aspects that may help both monarchs and painted lady butterflies navigate during migration that were not considered in the review. Most generations of monarchs are solitary, but the migrating generation tends to gather in roosts along the migration route, usually in Texas and further south. This could help the overall success of migration (Reppert 2010).

Another consideration in migration is the presence of juvenile hormone. Migrating monarchs do not have juvenile hormone, which increases the lifespan and induces reproductive diapause (Reppert 2010). Juvenile hormone does not impact navigation mechanisms such as the sun compass, but monarchs could not migrate with the juvenile hormone (Reppert 2010).

Topographic landmarks can also play a role in butterfly migration patterns. Monarchs will avoid traveling across the Gulf of Mexico (Urquhart 1978). It has also
been documented with *Vanessa atalanta*, the red admiral butterfly that they will take the shortest path across the sea from Sweden to Demark (Brattström 2008). The two North American populations of monarch butterflies are separated by the Rocky Mountains (Brower 1996).

Searching for food and oviposition sites on host plants are an important aspect in the path and direction of migration (Nesbit 2009). Milkweed, the food source for monarch larvae responds to the same environmental cues as monarchs use to trigger migration (Guerra 2015). Painted lady butterfly larvae can feed on many plant species which can increase their range and habitat possibilities (Stefanescu 2012).

Defense against predators can also ensure a successful migration. The milkweed that monarch butterflies consume as larvae contain cardenolides, which can be poisonous against predators. The cardenolides stays with the insect throughout metamorphosis (Brower 1991). The bright colors on the monarch butterfly is an indicator to predators that they may be poisonous.

**Areas for Future Research**

Monarchs are declining because of the milkweed habitat loss in the United States. This is primarily due to land-use changes and genetically modified crops. Milkweed is the only host plant for monarchs, so if the milkweed habitat declines, the population will decrease. Deforestation in Mexico was thought to be the primary reason for population decline, but recent research has shown that it is not as significant as the loss of milkweed habitat (Flockhart 2015).

Having a variety of mechanisms to navigate during migration will increase the likelihood of surviving and adapting to diverse conditions. However, climate change could have a significant impact on migrating butterflies (Guerra 2015). Temperature changes could alter when monarchs receive temperatures cues, triggering their migration (Guerra 2013). Changing winds, stronger or weaker could also make it more challenging for butterflies to reach their destination (Guerra 2015).
Conservation Strategies

Research can help guide current and future conservation strategies for both species of butterfly. Based on research presented in this paper, the following are possible considerations for future conservation ideas:

- Look at other species of migrating Lepidoptera research to provide insights into conservation. For example, painted lady butterflies have a wider migration range due to food source availability (Stefanescu 2012). When developing plans to preserve monarch habitat, perhaps the painted lady could be looked at to determine patterns of how their host plants are spatially arranged.

- Most evidence indicates that painted ladies rely on wind and a very basic sun compass to navigate during migration (Stefanescu 2012). Recent research has shown the complexity of the monarch’s internal navigation system (Guerra 2015). Perhaps similar experiments can be replicated to better understand the painted ladies sun compass and other possible internal mechanisms.

- Tagging butterflies has proven to be a very successful research tool (Brower 1996 and Urquhart 1941). Urquhart and his team tagged monarchs to learn more about their specific migration path (Urquhart 1941). Stefanescu and his team utilized the public’s help to record butterfly sightings when the population was at one of the highest on record (Stefanescu 2012). Projects such as these can not only help with migrating butterfly population research, but also increase public support for conservation.

Conclusion

The percentages of butterflies that were veered of the direct migration path when flying at high altitude was very high in 2009 (Stefanescu 2012). Since painted lady butterflies are more widely distributed and adaptable with breeding locations, wind may be the most beneficial way to migrate. It is a fast way to migrate, while not conserving energy (Stefanescu 2007). Since monarchs have a specific migration destination, they
cannot afford to veer off the migration path. High altitude winds may not be the most beneficial strategy for monarchs to migrate. This could explain why monarchs have a more complex internal navigation behaviors including the time compensated sun compass and magnetic compass. A more complex compass system can ensure they will arrive to Mexico. Painted ladies navigate using the sun, but without time compensation. There is no research indicating they have a magnetic compass.

Since migration is not a learned behavior, and there are many generations in between the migrating generation, both species rely on internal behaviors such as a sun compass and a magnetic compass (Reppert 2010). Both species also rely on environmental cues to assist with migration. They can rely on wind to help them soar to their destination (Gibo 1979). They also rely on temperatures as triggers. Cold temperatures will recalibrate the monarch’s sun compass, indicating to migrate northward (Guerra 2015).

There are many aspects that contribute to the long migrations of monarch and painted lady butterflies. Other factors include social behavior, the presence of juvenile hormone, topographic landmarks, host plant habitat and defense mechanisms.

With declining habitats, human impacts and climate change, populations for migrating butterflies will be more at risk for decline. Applying current research, looking at other examples of migrating Lepidopteran, and utilizing public support to assist with tracking and monitoring are considerations for developing conservation strategies. Understanding all aspects of migrations will help guide conservation strategies and ensure the survival of the species (Brower 1991).

References


