Factors Influencing Conservation of the Threatened Migratory Phenomenon in North American Monarch Butterflies

Abstract:

The monarch butterfly, *Danaus plexipus* is a tropical insect which has developed the unique life history trait of long distance migration in order to exploit its food plant milkweed (*Asclepias sp*.) throughout North America. Although this life history trait supports a large population, it also leaves the species venerable to human environmental impacts, putting the migratory phenomenon in danger. Without overlapping generations is it hard to model the population using a Leslie Matrix, but looking at models for discrete time population growth we find that survivorship and carrying capacity are the biggest threats to the perpetuation of this phenomenon. This means that maintaining habitat throughout the monarchs range and limiting mortality due to human influenced factors such as climate change are the most important factors to conserve this species and its unique life history strategy.

Introduction:

Monarch butterflies (*Danaus plexipus*) are a well known and loved lepidopteran species found throughout North America during the summer months. Although this tropical butterfly cannot overwinter in freezing habitats, the species has evolved a unique life history trait allowing it to utilize its host plant, milkweed (*Asclepias sp*.) throughout its range. The North American monarch populations have developed an annual life cycle where adults of the species overwinter in reproductive diapause in a cool temperate climate during the winter months before migrating to use milkweed as it emerges in more inhospitable climates during the spring and summer. (Slolensky, 2004)

Monarch populations living east of the Rocky Mountains overwinter in temperate high-altitude fir forests in the Sierra Madre Mountain range in Mexico, gathering by the millions each winter to wait for the return of spring in the north. In March, responding to cues indicating the return of spring, the butterflies sexually mature, mate and fly north, arriving in the southern United States just as the first milkweed of the season begins to sprout. These adults lay their eggs (300-500 per female) and then die, never to return to Mexico. Their first generation of offspring eat, grow, and transform into adults which continue north, arriving in the upper Midwest in late May just as milkweed there begins to emerge from the recently snow-covered ground. This generation of monarchs never enters reproductive diapause, but use their reproductive resources quickly and die, leaving their offspring to perpetuate the species. These offspring, often emerging as adults in June and July, lay the final generation of eggs during a season. As the final generation of monarch grow and approach pupation, they respond to cues announcing the end of summer which announce it is time for them to leave the cooling climate to return to the overwintering grounds in Mexico (Figure 1). (Slolensky, 2004)

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This migratory phenomenon is unique the world over for its size, both in distance and in and numbers. The overwintering refuge in Mexico provides support for a population size many times what would be possible in tropical habitats, and the insect elicits a great deal of enthusiasm and support from citizens throughout North America. However, human development is having an adverse influence on this happening, which is currently listed as a “threatened phenomenon” in the United States. Loss of habitat and changing climate are the biggest stressors to the population. In Mexico the oyamel fir forests which provide the cool temperate climate and physical substrate to keep the monarchs protected are under pressure from logging. (Malcolm, 1993) The fragmentation of these forests not only reduces the amount of habitat available to the insects, but also makes what forest is left less protective. Removal of forest canopy allows more penetration of precipitation, which makes the insects more susceptible to freezing. (Anderson and Brower, 1996) Significant freezing events have already taken their toll on these populations, with over 80% of the overwintering population dying during a sever storm in 2002. (Brower et. al, 2004) Not limited to the Mexican overwintering sites, monarch habitat is also under pressure in the monarchs’ summer range. The widespread planning of Roundup ready crops mean that pesticides are being sprayed later in agricultural fields, effectively eliminating a large percentage of the milkweed available to monarchs in the Midwest during the summers. (Oberhauser and Solensky, 2002)

Additionally, and perhaps more difficultly, the migrating monarch populations are anticipated to be adversely affected by impending climate change. Climate change models show that projected shifts in temperature and precipitation will threaten monarch survival, both in their Mexican overwintering grounds and in their seasonal habitats throughout North America. Climate in the overwintering grounds is expected to become cooler and wetter, which could potentially cause irreparable damage to the monarch populations. With the currently reduced forest cover there will be little protection from the increasing precipitation and cool temperatures and it is likely that large die-offs may occur with more regularity as climate change becomes more pronounced (Oberhauser and Peterson, 2003; Batalden, Oberhauser, and Peterson, 2007)

Method and Results:

The life history of monarch butterflies is rather simple, with no overlap of generations, large clutch size but relatively low survival, and no parental care. (Table 1) In fact the monarch is a characteristically R-selected organism – spreading its offspring far and wide in hopes that a few if the organisms will survive to perpetuate the species. This implies that the organism will do well in variable habitats. However, there is a limit to this adaptability, and a conservationist must also keep the overwintering strategy in mind, which although it allows monarch to exploit a large amount of breeding territory it concentrates them I in a small area every year which can quickly turn into a genetic bottleneck if mortality rates there are high.

When analyzing monarch population dynamics it is difficult to use a Leslie Matrix, because there is no functional overlapping of reproduction between generations, meaning

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we do not learn useful information by looking at the age distribution of individuals in the population. Here, the size of subsequent generations is dependant only on the size of the previous generation, its fecundity and the survival rate of the offspring. Therefore, we can return to a more simple equation to model population dynamics. Because each generation can be separated, and depends on the number of offspring in the previous generation we will use a discrete continuous model for reproduction: $N_{t+1} = N_t e^{r(1-\frac{N_t}{K})}$
This means that the population of the next generation (Nt+1) will equal the number of individuals in the current population N_t multiplied by *e* raised to the sum of the growth rate, r and 1- the current number of individuals (N_t) divided by the carrying capacity, K. Looking at this equation we can see that the size of subsequent generations will depend heavily on the size of the previous population, the growth rate (which will be a function of the fecundity and survival rate of the eggs laid) and the carrying capacity of the environment. Within monarch populations survival is low - about 1% in wild populations with the rest of the offspring falling prey to predators (Prysby, 2004 The generation (cohort) sizes can are monitored in many different ways (from estimating numbers from overwintering area occupied, to monitoring patches of breeding habitat in the breeding grounds to counting migrating butterflies as they pass certain geographical locations.) An average size overwintering population might be 50,000,000 individuals. (Oberhauser, 2002) Monarch breeding populations vary along the same order of magnitude, varying from year to year with climatic and other variables.

Applying this information to what we know of the monarch life history strategy we can see that monarchs are most venerable to reductions in their reproductive rate and to reductions in their carrying capacity. This means that increased mortality due to parasites, pesticides or predation at any life cycle stage or a reduction in habitat at any stage would greatly affect the population size of one generation, and thus the number of individuals in subsequent generations.

One of the greatest threats to monarch populations is reduction of suitable habitat, which significantly reduces carrying capacity (K) for the organism. Throughout the breeding range it is unlikely that the carrying capacity is currently being reached because not all milkweed is being consumed throughout North America. However, habitat size in the overwintering sites is extremely important and limiting, and reductions in suitable habitat there can significantly affect the overwintering population. In addition, increased mortality in the overwintering sites can greatly affect the fecundity and survivorship of the generation. (Oberhauser and Peterson, 2003) This generation is also especially venerable to mortality because the butterflies are concentrated within a small area, and any mortality events are concentrated within the population.

In addition to venerability in the overwintering zones, climate change modeling has shown that the optimal breeding range will become much more elongated, and monarchs will have to fly much farter distances north to reach suitable habitats to breed. (Batalden, Oberhauser, and Peterson, 2007) This may also contribute to reductions in survival rates if monarchs cannot adapt to make longer journeys. In addition, another important influencing factor to survival of monarch butterflies is the incidence of pathogens in the

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populations. One important pathogen, *Ophryocystis elektroscirrha* can be passed though populations, reducing population fitness. (Altizer and Oberhauser, 1999)

Discussion:

Overall, the most important methods of monarch conservation are those that protect monarch habitat and prevent monarch mortality. Because monarch populations are so venerable in their overwintering habitat in Mexico it is extremely important to protect these forests from logging, and to mitigate the effects of climate change to prevent increasing storm events in the future. It is also important to protect monarch habitat in their breeding range, both by providing suitable habitat for their host plant milkweed, and by again mitigating the effects of climate change to reduce the challenges of a significantly longer migration path for the species.

In addition, because each generation relies completely on previous generations in various parts of the habitat it is important to monitor all of these populations to catch any downturns in populations which will effect subsequent populations. Currently all aspects of the monarch life cycle are monitored, from estimating the size of the overwintering populations by area, to counting eggs and larvae in sites throughout north America during the breeding season. By monitoring these variables and keeping a finger on the pulse of monarch population dynamics while maintaining an understanding of the factors influencing monarch survival monarch conservation will have a chance to be successful.

Figure 1: Life cycle of the monarch butterfly. Survival rates of 0.01 shown.

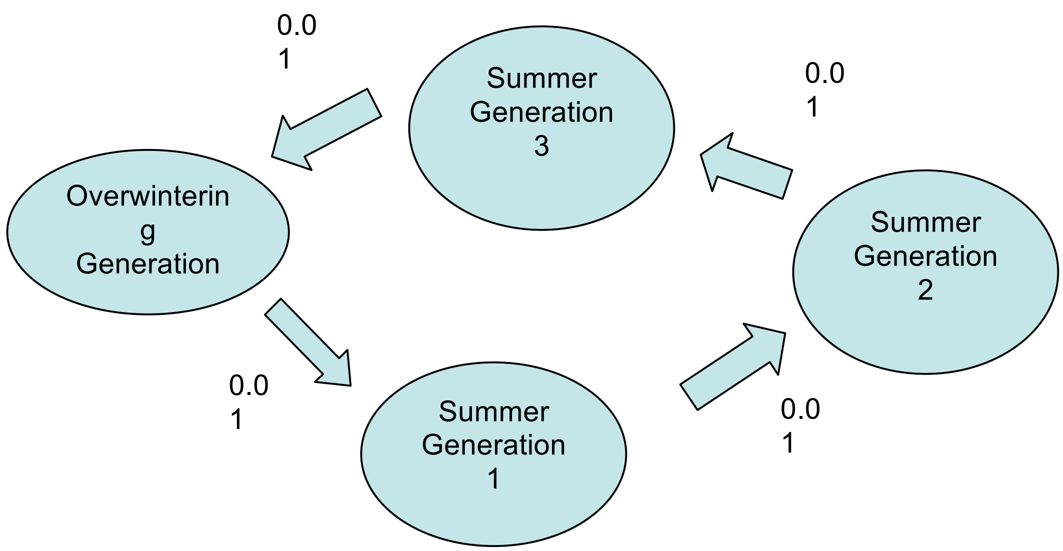

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Table 1. Life history characteristics of the monarch butterfly.

Longevity	2-3 months during breeding season, up to 9 months during overwintering season.
Age at first reproduction	1 month for summer individuals, 7-8 months for overwintering generation.
Fecundity (clutch size)	300-500 eggs
Survival rate	~1%
Period for parental care	None, only egg laying on host plant.
Habitat	Oyamel fir forests, milkweed in grassland, agricultural and wetland systems.
Potential threats	Destruction of overwintering b\habitat, loss of habitat in breeding range, climate change.
r- or K- strategy	R-selected.

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