2017, 26(3): 181-183
http://www.jbscn.org

DOI: 10.3969/j.issn.2095-1787.2017.03.001

Thoughts of a travelling ecologist 12.

The plight of the monarch butterfly

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Nature conservation needs people who care about nature, and the efforts to convince people to care about the fate of nature has extensively relied on selected charismatic species, the "conservation icons". One famous example is the great panda, *Ailuropoda melanoleuca*, well known as the World Wide Fund for Nature (WWF) logo. When it comes to invertebrates, the possible candidates are few. Most of them are not considered colourful, intriguing, or charismatic enough [but read the late, great Thomas Eisner's wonderful book (Eisner, 2003) and your views could change]. Perhaps the butterflies come closest, and among them, one species is a good candidate: the North American monarch butterfly, *Danaus plexippus*.

This butterfly is unique, because it is not only colourful, but has a peculiar behaviour: it is migratory. Virtually the whole population that emerges in the summer season on their North American breeding grounds will migrate to spend the winter in a small area in Mexico (Brower, 1995). The summer breeding grounds extend to more than 2.5 million km^2 (Malcolm *et al.*, 1993) but they overwinter in an area of not more than 20 ha (Stenoien *et al.*, 2017), seeking out individuals of the oyamel fir, *Abies religiosa*. Here they can reach densities of up to 60 million individuals/ha (Calvert, 2004); the butterfly-clad trees are among the most wonderful spectacles of nature. In the spring, the butterflies migrate north, and produce another generation in the Gulf Coast states of the US, which then repopulate the breeding grounds further north. On these areas, which include the maize- and soybean-growing regions of the American mid-west, they produce three or four generations before autumn arrives and the migration starts again.

This unique phenomenon, a regular migration of an insect species, generated a justified interest, and the monarch butterfly became a conservation icon, especially in North America. We have long-term population counts, which is easier to do on the wintering grounds than elsewhere, and due to falling numbers, there is considerable alarm among entomologists and conservation biologists, leading to a petition to declare the species as threatened (Stenoien *et al.*, 2017). What could have caused this serious decline is an intriguing question.

Any migratory organism will depend on a number of different habitats: the breeding grounds are obviously important, because this is where reproduction takes place. Traditionally, it was thought that the fate of migrating populations was decided there. However, conditions on the overwintering grounds, and even on stopover areas are of importance, because they are all needed in order to complete the cycle. The strength of a chain is only the strength of its weakest link. It is not enough that the breeding and the wintering grounds are safe and of good quality. If the migrating individuals

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cannot reach either because of the lack of suitable resting places during migration, the species is at risk. The monarch, like any migrating organism, has a lot of obstacles to overcome, and if we want to understand what caused the recent, drastic declines, we have several factors to consider. A recent review (Stenoien *et al.*,2017) has done just that, and a picture of understanding starts to emerge.

The species is obviously vulnerable on its wintering grounds, because of the concentrations of vast number of butterflies: whatever happens there, even a local storm, or illegal logging, can have huge impacts on the species. The recent shrinking of the wintering area increases the risk that a stochastic local event throws the whole population into crisis (Semmens *et al.*,2016). However, it seems that the area is now effectively protected, and storms are not frequent enough to explain the decline. Migrating insects also need nectar and suitable habitats to use on their journey, as well as to build up sufficient fat reserves for a successful overwintering. Autumn-migrating individuals do not arrive to the wintering grounds with lower fat reserves than in earlier times, so poor migration conditions are also unlikely to be the cause. Conditions on the breeding ground have to be scrutinised.

The host plant of the monarch is the milkweed, *Asclepias syriaca*. Larvae not only obtain food from this plant – they also accumulate the alkaloids, making them chemically protected (Eisner,2003). Both the monarch larvae and the adults are brightly patterned and coloured, advertising this fact. Milkweeds are relatively common members of the North American flora, and probably were widespread but historically not of very high density. This likely changed with the start of large-scale maize growing – because milkweed proved to be a weed of maize and soybean. Weed control has traditionally been a major task of farmers; in the temperate region, weeds are the main plant protection problem, and a recurring one. Even with herbicides, weed control was rarely efficient and never complete. With the formation of the huge monocultures of maize and soybean in the North American mid-west, a considerable increase in the amount of available food plants must have occurred. Until... until things changed. And this seems to hold the key to the varying fortunes of this colourful butterfly.

Concerns about the effect of agriculture on the monarch butterfly surfaced almost two decades ago. That was only one element of the Great Biotechnology Debate, which is about the benefits and risks and the overall impact of transgenic crops on agricultural practice, environment, and many other things besides. The "environmental pages" of this ongoing debate have been written with much passion but less knowledge.

The finding that pollen from transgenic maize that expresses the toxin from the insect pathogenic bacterium *Bacillus thuringiensis* (*Bt*-maize) can kill the larvae of the monarch butterfly (Losey *et al.*,1999) generated much attention, and spawned a widened interest in the non-target effects of transgenic crops. Several commentators criticised different aspects of the work, often missing its main point: the identification of a risk factor that has not, in spite of the 'no new information' claim (Pimentel & Raven,2000), been much thought about before.

Maize has rarely been treated against insects, but herbicide applications were routine. However, herbicides are not very selective, and kill all vegetation (Benbrook,2016), so the timing and the dosage are both crucial; a mistake in either could kill off the crop itself. It is thus not surprising that herbicide-tolerant GM crops, when became available, were quickly taken up, especially by large-scale producers. There are many such farmers in the US mid-west, where both maize and soybean are major crops. With their crop no longer sensitive, farmers started to use herbicides more and more frequently, and at increasing doses. In the USA, the use of the major herbicide, glyphosate, has increased 15-fold between 1996 and 2014 (Benbrook,2016). This, unsurprisingly, practically eliminated milkweed (and other weeds) from vast areas, decimating the food plant base of the butterfly (Pleasants,2015).

To assess the consequences, spatially explicit modelling would help, but no such models exist yet. Stenoien *et al.*(2017) review what knowledge is available about the movement of egg-laying butterflies and larval development success, and conclude that "the

matrix of North American agricultural landscapes is now effectively empty of resources that once supported... monarch butterflies". They also point out that butterflies now probably concentrate on remnant high-density milkweed patches in old fields and conservation areas.

A recent paper (Inamine *et al.*, 2016) using citizen science data about the autumn migration of the monarch butterfly claims that the numbers of autumn migrants did not decrease in the USA, thus the cause of the decline is not to be sought on the (largely weed-free) transgenic maize and soybean fields of the American mid-west. However, Stenoien *et al.* (2017) argue that the monarch butterfly-monitoring "citizen scientists" seek out milkweed patches to count butterflies, so their findings are not representative of the population trends over the whole landscape. Further, they correctly point out that the location of the migratory autumn counts is important, and these are north of the major maize- and soybean-growing regions. Numbers counted there say nothing about the population trends in the core breeding areas.

So, another controversy is about to break out and this is also heavily shaded by aspects of the Great Biotechnology Debate: there still are participants who seem to wish to lessen or negate the profound effects transgenic crops have on agricultural habitats and their inhabitants. Yet no matter how sophisticated our technology will become, and no matter how fervently some may believe in techno-solutions, the final conclusion is already clear to ecologists: there is no escape from the "ecological theatre and the evolutionary play" (Hutchinson, 1965). Humans are also risking to become the stupid villains in the play. Villains, because they seem to decimate many or most other living beings. Stupid, because they do not realise that they themselves cannot survive without them. The monarch butterfly as a species may not be at risk because it has migrated to many other parts of the world. The plight of the North American monarchs, nonetheless, is best answered with conservation action, in order to save this wonderful natural phenomenon.

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