**Monarch Population Decline—Summary for Teachers**

As students make their way through the evidence presented by different authors, they should find conflicting claims based on different studies that use different methods and different kinds of evidence.

1. Flockhart et al. use a computer modeling approach to argue that loss of milkweed in the breeding grounds is driving the decline of monarch populations. They account for different factors that affect the monarchs life cycle in their model, and then they test for the effects of changing some of those factors, like the availability of milkweed or overwintering habitat. They find that monarch populations are most sensitive to the availability of milkweed, according to their model.
   1. One of the challenges with this research is the concept of using a computer model to combine evidence and make an argument may be challenging for many students. All of the estimates in the computer models come from data that may have varying degrees of certainty and validity.
2. Inamine et al. use citizen science data to compare estimated population sizes at different parts of the monarch life cycle, for example, in Mexico, and in different parts of the United States where they breed in the spring and summer. These data lead them to argue that milkweed cannot be limiting monarch populations, because when monarchs are abundant in Mexico, they are also abundant in the spring and summer breeding grounds in the US. Instead, they argue that monarch losses are most likely occurring during the fall migratory routes, perhaps due to insufficient nectar resources.
   1. The arguments in this research rely on scatterplots, which many students will find accessible. However, they should remember that correlation does not equal causation, and they should consider the quality of citizen science data.
3. Brower et al. simply report on the area occupied by overwintering monarchs in Mexico over a 17 year period for which data are available and they do a statistical analysis on the data. Most of the argument compiles evidence from the literature for three different hypotheses for the monarch decline: loss of milkweed breeding habitat in US, loss of overwintering forest habitat in Mexico, or climate-related losses. This is one of the earlier arguments about the monarch decline, and its value is in the broad hypotheses it sets out. The argument is more focused on demonstrating a decline than testing among hypotheses for it.
   1. This research is very conceptual, presenting just one figure but providing many important background ideas and synthesizing a lot of smaller pieces of evidence. Some students may find this more accessible; others may find it less compelling.
4. Pleasants and Oberhauser focus on gathering evidence related to one hypothesis for the monarch population decline: the loss of milkweed in the Midwest United States, associated with the introduction of Roundup Ready crops. Their evidence relies on estimates of milkweed density and the numbers of eggs laid per milkweed. They draw upon a variety of citizen science and other survey data to generate these estimates.
   1. These arguments rely on scatterplots and change over time. The calculations are more straightforward than the models of Flockhart. Students should be encouraged to consider the reliability of citizen science data.

Overall Notes: These articles present multiple hypotheses (at least 4) for the decline of the monarch butterfly populations, and disagreement about which is most important. If science is to guide conservation policy, such different recommendations pose a challenge. By looking at the reasons for their differences, we can start to identify gaps in reasoning or areas where more data would help us make better decisions.

One of the main differences is between the groups that cite milkweed as a primary cause of the decline (Flockhart et al and Pleasants and Oberhauser), and the group that argues milkweed is NOT the main cause of the decline. Authors that place a lot of stock on the decline of milkweed place a lot of emphasis on the egg and larval development stages in the breeding ground, as these are clearly reduced when milkweed is limited. Authors that are not convinced by the milkweed limitation hypothesis instead emphasize that adult monarch populations are not declining in the breeding grounds (Inamine et al). Many of these arguments are outlined in Zaya et al 2017 *Bioscience*.