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COMMENT/DEBATE

Response to Davis: choosing relevant evidence to assess monarch population trends

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Abstract. 1. We recently reported in this journal that the abundance of the migratory population of monarch butterflies is declining (Brower *et al.*, 2011). Davis (Davis, 2011) subsequently challenged our conclusion.

2. Here, we provide further information about the increasing loss of larval habitat and how it may be contributing to the decline.

3. We also point out that Davis's census data were obtained from peripheral monarch populations minimally influenced by the changes in agriculture and development that have affected the larger Midwestern monarch population. Therefore, the data cited by Davis are not representative of the overall monarch population.

Key words. Conservation, habitat, Lepidoptera, migration, monitoring.

Monarch butterflies are iconic insects, as reflected in their being the official insect/butterfly in seven different US states. Recently, we published the first quantitative analysis of the abundance of migratory monarch butterflies in eastern North America, based on the combined size of overwintering colonies from all known sites (Rendon-Salinas *et al.*, 2011). Our analysis showed a statistically significant decline over the past 17 years (Brower *et al.*, 2011). Subsequently, Davis (2011) challenged our conclusion, claiming that census data from Michigan and New Jersey suggest that overall abundance has not changed during the same time period. We argue that the evidence presented by Davis is not appropriate for assessing the size of the migratory population.

Recolonisation of the breeding grounds in the United States and Canada is a two-generation process (Malcolm *et al.*, 1993). The reproductive success of the returning migrants from Mexico depends on variable climatic and biotic factors, including predators, parasitoids and the quality and availability of milkweed host plants. Offspring (the first generation) of the butterflies returning from Mexico migrate north in May and June and colonise the northern breeding area from which most of the fall migrants originate one or two generations later. This second stage of recolonisation is also a variable process, and subsequent population growth depends on the same variable climatic and biotic factors.

The lack of change in census results presented by Davis for Cape May, NJ, and Peninsula Point, MI, suggests two things: that recolonisation of the areas that produce monarchs for these sites has not changed, and that the abundance of milkweeds there has not been significantly reduced by development or agriculture. Indeed, current evidence indicates that the pattern of recolonisation of the northern breeding areas has not changed across the entire range (Journey North 2011). Although the pattern of recolonisation has not changed, the overwintering population in Mexico has declined, likely due to the extensive loss of habitat (> 100 million acres) in the Midwestern corn belt, as we argued previously (Brower *et al.*, 2011). Additional evidence comes from monarch tagging. The number of monarchs tagged by Monarch Watch volunteers peaked in 2001–2003 (mean = 93 231/year) followed by a 22.7% decline for 2004–2010 (mean = 72 047/year) (Monarch Watch 2011) coincident with the rapid rate of adoption of herbicide tolerant (HT) maize and soya (from 46.9%, 28.8 million hectares, in 2003 to 80.9%, 54.1 million hectares, by 2010 (U.S.D.A. 2011; Fig. 1). There has been no decline in the number of taggers over the 2004–2010 period. These maize and soya row crop fields contained milkweeds before the adoption of HT varieties and were shown to be the most productive monarch habitat in year 2000 surveys (Oberhauser *et al.*, 2001). So far, the rates of breeding season recolonisation in the North have been largely independent of the size of the overwintering population (Davis & Howard, 2005; Howard & Davis, 2011; Journey North data). However, recolonisation is likely to be affected if the overwintering population continues to decline. Furthermore, small overwintering populations, of which there have been four in the last 11 years, are extremely vulnerable to catastrophic winter mortality, such as in January, 2002, when nearly 75% of the overwintering monarchs were killed (Brower *et al.*, 2004).

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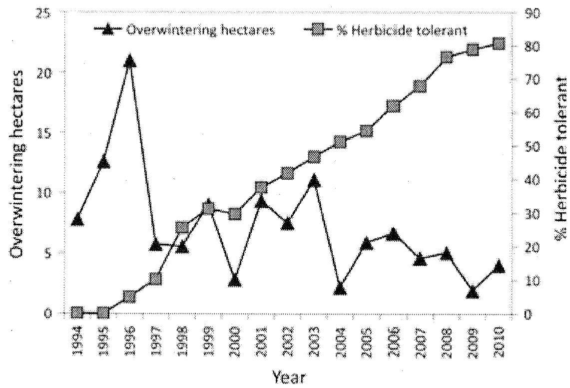

Fig. 1. Annual per cent adoption of herbicide tolerant maize and soya planted in the U.S. over the past 17 years compared to the combined area of the overwintering colonies of monarch butterflies. Crop data from USDA (2011); colony data from Rendon-Salinas *et al.* (2011)

So what can we say about monarch abundance? The combined area of the overwintering colonies is the best indicator of abundance because it is a direct measure of the entire migratory population. Censuses of adults, or of eggs and larvae (MLMP, 2010), at critical periods in the breeding season, along with estimates of milkweed abundance, in the main monarch breeding areas would be more likely to correlate with overwintering abundance. Such an analysis is currently underway (J. Pleasants & K. Oberhauser, unpubl. data). On the other hand, one would not expect censuses from northern Michigan or coastal New Jersey to be so correlated because these areas represent peripheral source populations (Wassenaar & Hobson, 1998; Brindza *et al.*, 2008) from regions little affected by the conditions that are negatively impacting the growth of the populations in the main monarch production areas.

When evaluating trends in population abundance, there is no substitute for (i) considering the overall biology of the organisms being studied and (ii) choosing evidence that is directly pertinent to the questions being asked. As a result of these considerations, we find that Davis's interpretation is not supported and does not challenge our earlier conclusion of monarch butterfly decline.

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Note added in proof

Maps of maize and soya production are available at: www.usda.gov/oce/weather/pubs/Other/MWCACP/Graphs/USA/soybeans.pdf and www.usda.gov/oce/weather/pubs/Other/MWCACP/Graphs/USA/corn.pdf

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