Annals of the Entomological Society of America Advance Access published February 4, 2016

Annals of the Entomological Society of America, 2016, 1–3
doi: 10.1093/aesa/sav115
Letter to the Editor

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Conclusion of No Decline in Summer Monarch Population Not Supported

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Received 12 October 2015; Accepted 29 October 2015

Seven research papers and a cover article recently appeared in the *Annals of the Entomological Society of America* (online, 5 August 2015) that examined several long-term monarch butterfly monitoring programs. In their cover summary, Davis and Dyer (2015) focused on three studies that concluded there had been no decline over the past two decades in summer breeding numbers for the eastern North American population. This purported lack of decline is at odds with both the observed decline in the size of the population at the Mexican overwintering site (Brower et al. 2012a) and the decline in estimates of monarch egg production during the summer (Pleasants and Oberhauser 2013). To reconcile their conclusion of no summer population decline with the decline observed at the overwintering sites, Davis and Dyer hypothesized that there must be some unknown mortality factor that reduces the population during its fall migration to Mexico. This would ignore the evidence that the key driver of population decline is the massive loss of milkweeds, the larval host plant, in agricultural fields due to the use of glyphosate herbicide in conjunction with the widespread adoption of glyphosate-tolerant corn and soybeans that began in 1996 (Pleasants and Oberhauser 2013). Current conservation efforts in the United States for eastern migratory monarch butterflies are focused on restoration of milkweeds in the summer breeding range. Badgett and Davis (2015) suggested that conservation efforts should be shifted from breeding habitat restoration to focus instead on protecting monarchs during their fall migration. This would be a major change in current conservation efforts, so the support for their contention must be critically examined. Here we address the three papers and show that the purported conclusion of no decline is not supported.

A. Response to Ries et al. (2015)

Ries et al. used surveys of adult butterflies made during July 19 to August 15 by NABA (North American Butterfly Association) and IBMN (Illinois Butterfly Monitoring Network) to estimate end-of-summer population size. The most serious problem with their analysis is with the assumption that the habitats where these surveys were made provide an accurate measure of population size. These counts are made in a variety of nonagricultural habitats. But in the late 1990s, corn and soybean fields accounted for >80% of monarch egg production (Oberhauser et al. 2001). Counts in nonagricultural habitats would reflect the size of the general population of monarchs if the proportion of the population occupying those habitats remained constant over the years. However, over the past decade and a half, milkweeds were virtually eliminated from agricultural fields, resulting in progressively less monarch activity in agricultural fields (Pleasants and Oberhauser 2013) and proportionately more in nonagricultural areas. Therefore, yearly butterfly counts in nonagricultural areas would progressively overestimate the actual size of the population. In fact, if the population remained constant, as Ries et al. (2015) argue, we would have actually expected to see an increase in butterfly counts over the years because of the increasing proportion of the population occupying nonagricultural habitats. Ries et al. found no such increase, which we argue indicates that the overall population was in fact declining.

Pleasants and Oberhauser (2013) were aware of this issue in calculating mid to late summer egg production to estimate the size of the migratory population. They used MLMP (Monarch Larva Monitoring Project: mlmp.org (accessed 20 September 2015)) data on eggs per milkweed stem from nonagricultural habitats. But to calculate total egg production, it is necessary to multiply eggs per stem by the number of available stems over the entire landscape. Although eggs per stem data came from nonagricultural habitats, several years of monitoring agricultural fields for monarchs and information on the decline in the density of milkweeds in agricultural fields over the years allowed them to incorporate both agricultural and nonagricultural habitats in their egg production calculations. Ries et al. (2105) did not have data from agricultural fields, so they were not able to obtain a representative picture of population size over the years. Ries et al. were aware of this deficiency and posed this as a possible explanation for their results, but Davis and Dyer (2015) interpreted their results as proof of the null hypothesis of no decline.

Apart from the primary problem with the analysis, features of the NABA and IBMN data sets introduce variability and inaccuracy, thereby further reducing their ability to estimate the final fall migratory population size. Data on eggs per stem provide a better estimate of monarch activity.

1. Summer butterfly surveys, as well as eggs per stem, seek to capture information about a population that is in the process of growing. Nail et al. (2015) Fig. 5 shows that the eggs that produce the migratory population begin to increase on milkweed stems in early July and build to a peak in the last two weeks of July, with a decline through the end of August. To accurately gauge the population size, monitoring must be done frequently and at regular intervals throughout this period and follow a similar schedule from one year to the next. The NABA data (North American Butterfly Count Reports 1994–2015) are based on one survey done at each site per year, and the number of sites sampled per year was very small (range 12–29, mean = 19.6), hardly adequate to characterize the entire breeding range and breeding season. Also, the distribution of dates of the NABA surveys are skewed heavily toward earlier (July) dates that are before the egg production peak (Fig. 1). In addition, the timing of sampling was not the same in every year; the yearly median sampling date ranged from July 19 to July 29. The IBMN survey provides higher quality data because three or more surveys were conducted at each site, and the number of sample points (dates by sites) was greater (40–60 in the early years and 100–200 in the past 15 yr, Ries et al. (2015) Table 1). However, the sampling was focused on one geographic area (vicinity of Chicago) and not the entire monarch range. Data on eggs per stem are based on weekly surveys in multiple locations throughout the Midwest summer breeding range. Pleasants and Oberhauser (2013) used the peak value of eggs per stem as an index of population size, which provides a more standardized comparison of population size over the years.
2. Surveys of adult butterflies are snapshot samples based on a few hours on a single day whereas eggs per stem are long exposures based on the eggs that have accumulated over the previous week. This is equivalent to having watched the patch for adult butterflies every day for an entire week and is therefore far more comprehensive than adult surveys that record only part of a single day at each location.
3. The butterfly counts are one generation removed from the migratory population; it is the eggs from the butterflies counted that produce the migratory population. While we would expect the size of the penultimate generation to be correlated with the ultimate generation, the correlation with the size of the overwintering population would be weaker than it would be with the last generation. The egg production data used by Pleasants and Oberhauser (2013) is based on counting eggs that will become the migratory population.

B. Response to Howard and Davis (2015)

Davis and Dyer (2015) also cite Howard and Davis (2015) as evidence for lack of a declining population; this paper used 18 yr of data from Journey North (journeynorth.org) on the timing and distribution of observers' first yearly sightings of adult monarchs. Howard and Davis (2015) found that first sightings of each year were occurring later in more recent years, but that the range over which they occurred had not contracted. They acknowledged that the later sightings could be because the "population is smaller and it takes longer for the first one [butterfly] to be sighted." As for the range, they hypothesized that a smaller population should be manifested by a more restricted range. Since they found no range restriction, they inferred that the population is capable of bouncing back every summer to a large population size.

We take issue with this range-restriction hypothesis. Monarchs are excellent long-distance fliers, and even a sparse population could reach the entire typical range. Also, Howard and Davis (2015) note that the number of observers participating in Journey North has increased and this increased sampling effort would increase the chances that monarch individuals will be observed throughout their typical range even if the population is smaller. Additionally, first

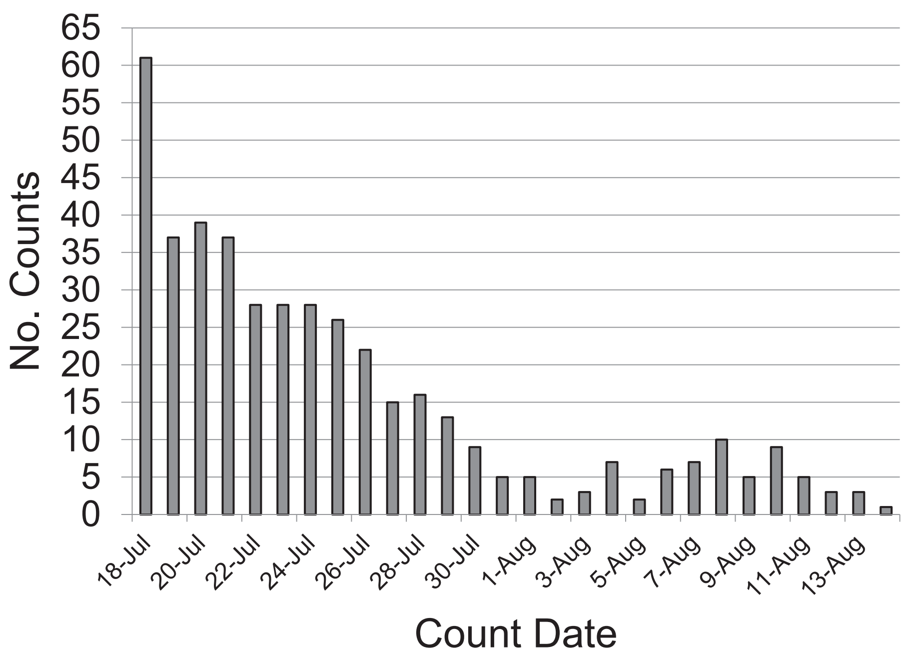

Fig.1. Distribution of NABA sampling dates from the north-central U.S. region from July 19 through August 15 for the years 1993–2014.

sightings capture only the leading edge of the recolonization wave but say nothing about the size of that wave because there are no subsequent observations.

C. Response to Badgett and Davis (2015)

Finally, Davis and Dyer (2015) cite Badgett and Davis (2015) as evidence for lack of a declining summer population. Badgett and Davis used counts made from 1996 to 2014 during the fall migration at Peninsula Point, Michigan, to gauge the size of the end-of-summer population. They found no significant trend over the years nor did they find a correlation between the yearly counts and the size of the overwintering population. This contrasts with the results of another paper in this Annals series; Crewe and McCracken (2015) found a downward trend in the counts of monarchs migrating through Ontario. Badgett and Davis (2015) did not reference this paper nor did the covering article by Davis and Dyer (2015) address the discrepancy between the results of the Ontario and Peninsula Point studies.

One explanation for the lack of a trend observed at Peninsula Point is that censuses were conducted at three different times during the day. It is highly likely that individuals counted at one census were recounted at one or more later censuses. The Ontario data came instead from a single daily census. Crewe and McCracken (2015) describe how the power to detect population trends is eroded when there is a significant amount of recounting. Davis (2012) discussed other difficulties associated with accurately counting monarchs at stopover sites that add to the variance among years. Also, Brower et al. (2012b) in response to Davis (2012) pointed out that the source areas for the butterflies passing through Peninsula Point are the Upper Peninsula of Michigan and south central Ontario, neither of which are heavy agricultural areas and would not have experienced milkweed loss and local population decline. The Ontario data, on the other hand, come from Long Point peninsula in Lake Erie whose butterfly source area in southeast Ontario is heavily agricultural (Statistics Canada 2015), and would have experienced a loss of milkweeds and a correlated local population decline.

In summary, problems with the three papers cited by Davis and Dyer undercut their conclusion of no decline in the summer monarch population. Ries et al. (2015) did not account for an increasing proportion of the population using the butterfly survey habitats as milkweeds disappeared from agricultural fields. Howard and Davis (2015) made an invalid assumption that a population decline should be manifested by a range restriction. For Badgett and Davis (2015), the recounting, coupled with the inherent variability in the proportion of the population that stops over in any year, results in a highly variable data set lacking in statistical power. Finally, Davis and Dyer (2015) ignore the results of another long-term study at a migratory stopover in Ontario (Crewe and McCracken 2015) that draws butterflies from an agricultural landscape and does show a decline in population size. While Davis and Dyer (2015) would have conservation efforts focus on protecting the migratory pathway, we submit that a shift in conservation focus away from milkweed restoration in the breeding zone is completely unwarranted and is not supported by the data presented in the Annals papers.

Finally, we want to be clear that this critique should not be construed as impugning the value of citizen science. The many citizen science efforts associated with monarch butterflies have been and will continue to be of great value in unraveling questions about their biology. We simply point out that that data from any monitoring effort have to be analyzed and interpreted appropriately.

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