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FORUM

Are migratory monarchs really declining in eastern North America? Examining evidence from two fall census programs

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Abstract. 1. The status of the eastern North American monarch butterfly population is a highly sensitive issue, given that winter and breeding habitats are being lost at an alarming rate each year, and because of this, most believe the population to be declining, although there has been little empirical data to support this idea. In a recent forum article of this journal, Brower *et al*. (2011) report a statistically significant decline in winter colony size over a 17-year period and suggest that this is the first sign of impending collapse.

2. I conducted an analysis of numbers of migrating monarchs from two fall monitoring stations in the United States (Cape May, NJ and Peninsula Point, MI), which span 15 and 19 years, respectively, and at both locations there was no significant linear trend in average monarch numbers counted over time, which is in marked contrast to the conclusion drawn by Brower *et al*. (2011).

3. Although I identify several possible reasons for the discrepancy between the fall census counts and size of the overwintering areas, these differing patterns argue for a more balanced perspective regarding the status of this population, and certainly for considering more than one phase of the life cycle. Even though it is difficult to imagine how monarchs will fare in the future with so many threats to their population, the data presented here suggest that the population remains stable for now, probably because of the high fecundity of the species and its ability to rebound from small winter numbers.

Key words. *Danaus plexippus*, migration censuses, monarch butterflies, overwintering colonies, population status.

Introduction

The world-famous monarch butterfly (*Danaus plexippus*) population in eastern North America is perceived by many to be in trouble, a view that has been fuelled largely by studies documenting the many threats faced by breeding adults and larvae (Calvert, 1996; Sears *et al*., 2001; Oberhauser *et al*., 2006, 2007) and large-scale reductions in overwintering habitat (Brower *et al*., 2002). Collectively, these reports paint a dire picture for the future of this largest population of monarchs. However, thus far there have been few quantitative data demonstrating the negative effect on the population that many (scientists and laypersons) have long been anticipating. In a recent article of *Insect Conservation and Diversity*, Brower *et al*., (2011) appear to have identified the first tell-tale sign of the 'impending demise' of this population using data on the size of the overwintering generation in central Mexico as reported by World Wildlife Fund Mexico (Rendón-Salinas *et al*., 2010). The analyses of that 17-year data set clearly indicate a gradual and significant downward decline in the numbers of monarchs counted during this stage of their annual cycle. Although this observation does have important implications for the management and conservation of overwintering habitat, if one looks at another stage of the monarch cycle, its annual southward migration, the available data show an entirely different view of the monarch's population status.

There are two stations in the United States, where volunteers census the numbers of monarchs migrating each fall and that can provide this information: Peninsula Point, MI and Cape May, NJ (hereafter PP and CM). Both sites are located at geographic peninsulas adjacent to water bodies (Lake Michigan for PP, the Delaware Bay for CM), resulting in large concentrations of southward-migrating monarchs at both sites each fall.

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The procedures used at each monitoring station have been described elsewhere (Meitner *et al*., 2004; Walton *et al*., 2005). Briefly, for approximately 2 months (September and October), observers walk (PP) or drive (CM) a standardised transect and record the numbers of monarchs seen. There are three censuses per day at each site. Monitoring at PP was started in 1996, and at CM it began (in a rigorous manner) in 1992. As the same methodology has been employed at each station since its inception, the data from these programs are ideally suited for elucidating long-term trends in numbers of monarchs during this (migratory) phase of their annual cycle. Moreover, analyses of these data sets by the author revealed patterns not consistent with that found by Brower *et al*. (2011).

Data analyses

For the purposes of this article, I was interested in the abundance of migrating monarchs at either monitoring station per year (15 years for PP, 19 years for CM). I considered three ways of estimating annual abundance: (1) the overall average number of monarchs counted per census, per year, (2) the maximum census count per year, and (3) the total number of butterflies observed per year. These values were log-transformed to approximate normal distributions. To examine the means, I followed Brower *et al*. (2011), where I first tested for auto-correlation in both data sets using a Durbin–Watson test, and there was no evidence for this at either CM ($d = 2.08$, with critical $dU = 1.36$, $P > 0.05$) or at PP ($d = 2.94$, with critical $dU = 1.36$, $P > 0.05$). Then, I tested for an effect of time (year) on the annual monarch counts using linear regression (response variable = average number of monarchs, predictor = year). A similar analysis was performed using the maximum monarch numbers (i.e. linear regression with year). Finally, I examined the effect of year on the total number of monarchs per year at either station, not only using linear regression but also including the total number of censuses per year as a secondary continuous variable, to account for possible variation in sampling effort.

At CM, there was no significant linear relationship between the mean number of monarchs counted and year ($F_{1,17} = 0.35$, $P = 0.563$; whole model $r^2 = 0.02$). Nor was there a significant linear relationship between year and maximum annual monarch count at CM ($F_{1,17} = 1.09$, $P = 0.310$; whole model $r^2 = 0.06$). In addition, the analysis of total monarch numbers at this site revealed no effect of year ($F_{1,16} = 0.727$, $P = 0.406$) or number of censuses per year ($F_{1,16} = 0.258$, $P = 0.618$; whole model $r^2 = 0.04$). In other words, although there was certainly considerable year-to-year variation, the overall average number of monarchs seen at CM has not changed significantly over the 19-year monitoring period (Fig. 1).

Similar results were found with the PP data. The regression of average monarch numbers and year showed no significant linear relationship ($F_{1,13} = 0.42$, $P = 0.527$; whole model $r^2 = 0.03$). There was also no significant linear trend using the maximum monarch count per year ($F_{1,13} = 0.043$, $P = 0.838$; whole model $r^2 = 0.003$). Moreover, although there was a significant effect of sampling effort on the total monarchs counted per year at this site ($F_{1,12} = 5.27$, $P = 0.040$), there was still no linear relationship with year ($F_{1,12} = 0.509$, $P = 0.489$; whole model $r^2 = 0.31$). Collectively then, there was no evidence of a decline in the numbers of migrating monarchs seen at Peninsula Point, using any of the above metrics of abundance (Fig. 2).

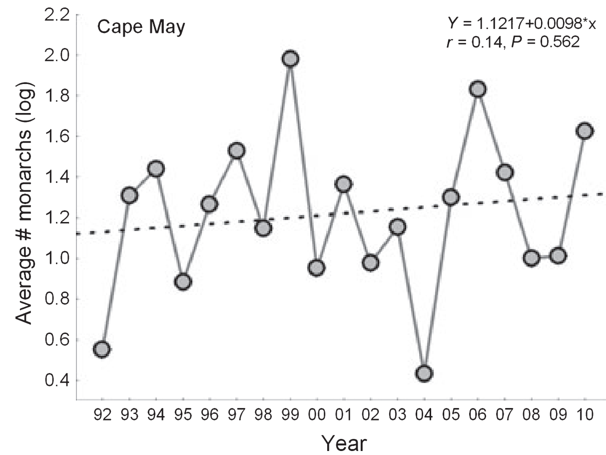

Fig. 1. Long-term trends in numbers of monarchs counted during fall driving censuses at Cape May, New Jersey. Each point is the log-transformed mean for the year. Dashed line indicates a linear trendline fitted to these data (equation indicated at top right).

Interpreting the data

Although there may be other possible interpretations to the results described above, given that the data from both stations [which sample monarchs from two geographically distinct areas (upper Midwest and northeastern US)] indicate the same pattern, one logical interpretation is that the number of monarchs

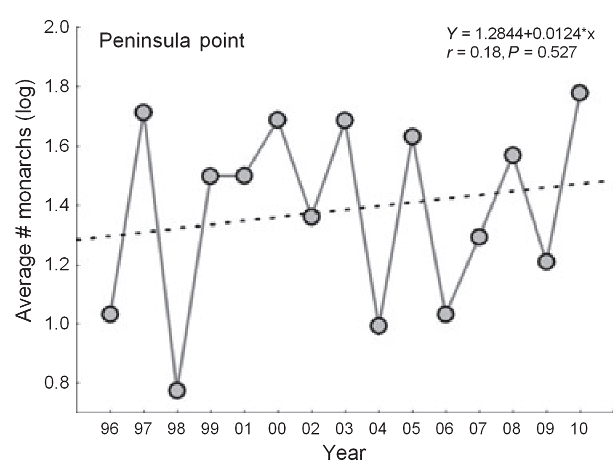

Fig. 2. Long-term trends in numbers of monarchs counted during fall walking censuses at Peninsula Point, Michigan. Each point is the log-transformed mean for the year. Dashed line indicates a linear trendline fitted to these data (equation indicated at top right).

migrating in the fall in eastern North America has not declined in the years since monitoring began (1996 for PP, 1992 for CM). Admittedly, this conclusion assumes that the numbers of monarchs counted at these two monitoring stations adequately reflects the size of the entire fall generation, which may or may not be true (see below). However, if one does believe this, then this conclusion would certainly be in marked contrast to that drawn by Brower *et al.* (2011), who suggest that the eastern monarch population is dwindling in size, based on annual estimates of colony sizes at overwintering sites. Given that the fall counts are estimates of the number of monarchs that will eventually (in theory) reach the Mexico colonies (i.e. the same generation of monarchs should be counted with both methods), it is therefore surprising that these three data sets are not more consistent. In other words, large numbers of fall migrants should lead to large wintering colonies and vice versa.

Why the discrepancy between fall and winter numbers?

There are several possible explanations for the differences between the data shown here and that from Brower *et al.* (2011). First, it may be that there is considerable mortality during migration that vastly reduces the population before it reaches Mexico. This may be the primary reason for the discrepancy between CM and the winter trends, as monarchs at this Atlantic coast site (and others like it) are known to have a much lower chance of reaching the Mexican colonies than those migrating inland (Garland & Davis, 2002; Brindza *et al.*, 2008; McCord & Davis, 2010). Thus, the numbers of monarch seen at CM may not necessarily reflect the overwintering colony size for this reason. However, at PP, which is situated at the northern edge of the primary ('central') flyway (Howard & Davis, 2009), this may be less of a factor. In any case, mortality during migration would be one reason why the fall and winter numbers are not consistent, and it remains an aspect of the monarch life cycle that is poorly understood.

Mortality during migration may not be the only factor causing southward-migrating monarchs to not reach the overwintering sites in central Mexico; although it may seem a radical idea, it is also possible that this is not the only winter destination of the eastern population of monarchs. This one site (which is actually a series of colonies on nearby mountains) in the neo-volcanic mountain range of central Mexico has only been known to science since 1976 (Urquhart, 1976), and there may be others that are not yet known. Moreover, as the numbers of overwintering monarchs at this one site seem to be diminishing (Brower *et al.*, 2011), it may be that the proportion of monarchs wintering elsewhere is increasing over time. Indeed, alternative wintering sites are not unheard of for this population, with known areas being in Cuba (Dockx *et al.*, 2004), southern Florida (Brower, 1995), and increasing reports of locations along the US Gulf coast (Howard *et al.*, 2010). None of these reports, however, are of monarch clusters hanging from trees, and numbering in the millions, as is true at the Mexican site. Thus, these locations probably would not account for the millions of 'missing monarchs' at the Mexican site.

Another possible factor would be the relative 'crudeness' of the monitoring data itself for picking up the true population trends on either end. It must be kept in mind that we are trying to estimate the number of individuals in a population that has a massive range and numbers in the millions. For the fall counts, we must make many assumptions when using the monitoring data to elucidate population trends, which may or may not be appropriate. For example, we must assume that the observers at either site can see all monarchs passing by, when in fact it is known that monarchs can fly so high during favourable weather conditions, as to be out of sight except by binoculars (Davis & Garland, 2002); thus, these migration counts, whether made while driving or walking, are surely biased towards those monarchs that fly low to the ground (or that are grounded). Furthermore, these unseen, high-flying, monarchs may make up such a substantial portion of the overall migratory population that their numbers could lead to major discrepancies between fall and winter counts. Regarding the winter estimates of 'population size', it must be remembered that these counts are estimates of surface area occupied by monarchs (i.e. total land area occupied by monarch trees), which may or may not accurately capture the true size of the winter population, especially because this method does not take into account tree density within the colonies. Thus, two wintering colonies that are of equivalent surface area could have large differences in numbers of trees that could support clusters of monarchs. By this same reasoning, one could also imagine how individual clustering density could go undetected using simple counts of colony surface area.

Are both estimates right?

If one assumes that both the overwintering population estimates and the fall migration counts do in fact provide (fairly) accurate assessments of the population size each year, then perhaps the lack of a decline in the fall counts can be explained simply by the incredible resiliency of the monarch (i.e. its high reproductive potential). In other words, even though the cohort in Mexico may be shrinking, there still could be enough monarchs each year that survive to re-colonize the breeding range in the United States and Canada. The population may be able to rebound during the summer even from very small wintering colonies. The exceptionally small colony size recorded in the 2009–2010 winter, which was pointed out by Brower *et al.* (2011), is an example of this. In that year (2010), the subsequent fall count of migrating monarchs at CM was the third highest in 19 years, and at PP it was the highest-ever in 15 years (Figs 1 and 2). This same phenomenon happened in a prior year as well, after the catastrophic winter storm of 2002 that dramatically reduced the wintering population size (Brower *et al.*, 2004). Again, the migration counts immediately following that winter showed average (i.e. not exceptionally low) census numbers. From this, it is logical to conclude that monarchs are able to 'bounce back' after exceptionally low wintering numbers. How long they will be able to do so, given losses in both breeding and wintering habitats, is not clear. Another worrisome issue is the recent discovery of a decline in females in the migratory generation (Davis & Rendon-Salinas, 2010), which, if it continues, could hinder the ability of the population to continue to rebound after such events.

A call for additional monitoring data

It is inevitable that when two sets of data that both are designed to count the same population do not match up, then the accuracy of one set will be called into question. Indeed, as I pointed out above, there are many problems when using migration monitoring data to infer population sizes. For the two monitoring stations used here, the biggest problem is their location – neither is located in an area that would sample the core of the migratory generation, which we know from isotopic studies to be in the Midwestern US (Wassenaar & Hobson, 1998). For that, we would need to have a monitoring station directly south of this area (i.e. in Kansas, Missouri, Arkansas or Oklahoma), or, ideally, in Texas, where monarchs would be concentrated and where the entire migratory generation would be required to pass through.

Conclusion

The data presented here argue that the number of migrating monarchs in eastern North America has not changed in the past 15+ years, which is an entirely different conclusion than that reached by Brower *et al.* (2011). This will surely lead some to ask which measure of monarch population size is most appropriate. I would argue that multiple measures must be employed to elucidate the big picture, and unfortunately, that picture seems more complicated than what is portrayed by Brower *et al.* (2011). Although there can be no doubt that the overwintering data show a statistical drop in colony size, the lack of a parallel drop in fall numbers shown here must also be considered. So even though the decline in suitable breeding and wintering habitat makes it a foregone conclusion that this unique and well-studied population of monarchs may someday collapse, I contend that it does not appear to be doing so just yet.

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