

Monarch Butterfly (Lepidoptera: Nymphalidae) Migration Monitoring at Chincoteague, Virginia and Cape May, New Jersey: A Comparison of Long-term Trends

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ABSTRACT: The recent increase in illegal logging of the eastern North American monarch butterfly population's overwintering site in central Mexico has emphasized the need for accurate long-term population monitoring tools, especially for this population. One way to obtain indices of annual population size is to record the numbers of monarchs passing by fixed points along the migration route each year, using standardized censusing methods. This methodology has been employed at several sites in eastern North America; however, long-term trends obtained from these sites have never been compared. From 1997 through 2004, the numbers of migrating monarchs were censused daily at the Chincoteague National Wildlife Refuge, VA, and 100 km directly north at Cape May, NJ, each fall using similar methodologies. We compared the daily census counts from these sites to determine if each site recorded similar daily and yearly numbers of monarchs, and if the year-to-year trends obtained from each site reflected the same patterns over the eight year period (1997–2004). From comparisons of 210 days during which both sites were operated simultaneously, we found that consistently more monarchs were counted at the Cape May than at the Chincoteague site. This may indicate a greater preference for Cape May as a stopover site or its proximity to the tip of the peninsula where monarchs accumulate in unfavorable weather. However, the year-to-year trends were the same at both sites, with each site showing fluctuating numbers of monarchs from year to year with the lowest numbers in 2004. These results indicate the strengths of migration monitoring as a population monitoring tool, and suggest that future monitoring sites be widely separated to minimize redundancy in data collection.

KEY WORDS: Monarch butterfly, *Danaus plexippus*, migration monitoring, census, Cape May, Chincoteague

The monarch butterfly (*Danaus plexippus* (L), Lepidoptera; Nymphalidae) migration phenomenon in eastern North America has received considerable attention in recent years (Davis and Garland, 2002; Borland *et al.*, 2004; Howard and Davis, 2004), owing in part to the rapidly depleting overwintering habitat in Mexico (Brower *et al.*, 2002). Each fall, the final breeding generation undertakes a spectacular migration from parts of northern US and Canada to overwintering sites in the mountains of central Mexico (Brower, 1995). Illegal logging of the Oyamel trees threatens to destroy these sites (Honey-Roses and Galindo, 2004; Brower *et al.*, 2005) placing the future of this monarch population in jeopardy. It is therefore important that steps be taken to obtain annual estimates of the size of this population so that long-term population trends can be detected.

One way to estimate the size of this population is to record the numbers of monarchs that migrate south each year at key locations along their migration routes. Migrating monarchs often become concentrated at specific geographic locations, such as peninsulas (Meitner *et al.*, 2004), and may use these areas as stopover sites for one to two days (Davis and Garland,

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2004). Thus, if standardized censuses are made each year at such sites, then annual estimates of population size can be obtained and a long-term database eventually established which can be compared with other censuses such as those obtained by counts of breeding individuals in the summer (Walton and Brower, 1996), as for example the 4th of July butterfly counts (Swengel, 1995) or the Monarch Larva Monitoring Project (Prysby and Oberhauser, 2004).

Indices from migration censuses at monitoring locations thus far have shown that local monarch populations fluctuate annually. At Peninsula Point, MI, daily one hour walking censuses made each fall produced average census counts between 6 to 52 monarchs per census from 1996 to 2002, with a 7-year average of 29 (Meitner *et al.*, 2004). Meanwhile, standardized driving censuses along an 8 km route at Cape May, NJ showed annual indices between 3 and 96 monarchs per census run from 1992 to 2004, with a 13-year average of 21 (Walton *et al.*, 2005). Although fluctuations such as these are common in monarch butterfly populations (Swengel, 1995), they also mean that detecting long-term population trends requires many years of monitoring (Walton *et al.*, 2005).

One complication that could arise with counts made of monarchs during migration is that monarchs may choose to stop, or visit, some locations but not others, depending on the resources available to them at each location. It is well-known among ornithologists that the suitability of stopover sites influences the migrating bird's decision to stop and for how long (Hutto, 1998; Davis, 2001). If the same were true for monarchs, then observers at some locations along the migration route may see fewer monarchs in general than those at other sites simply because of differences in the characteristics and monarch preferences for each site. However, regardless of this issue, the year-to-year trends in monarch migration counts (i.e., annual population indices) should reflect similar patterns between sites, especially if the same methods to census monarchs are used each year. However this idea has never been tested using data from long-term monarch monitoring sites.

Since 1997, migrating monarchs have been surveyed each fall at the Chincoteague National Wildlife Refuge (hereafter 'Chincoteague'), on the Virginia coast, using a similar road census method as done in Cape May, NJ, which is 117 km directly to the north. Because the same census method was used at both sites, a unique opportunity exists now to compare the long-term censusing data from each site. In this paper we compared the daily and yearly driving census data from Chincoteague and Cape May from 1997 to 2004. We address two important questions that will help to guide future monitoring efforts: 1) do the year-to-year trends observed at one site correspond to that of the other? and 2) after standardizing for sampling effort, is the same number of monarchs counted at Chincoteague as at Cape May? Knowing this will inform as to which site is utilized more as a stopover area for monarchs. This will help to direct future studies that would then ask how the characteristics of these two sites compare.

Study Site and Methods

Study sites

The Chincoteague site (37.95 N, 75.35 W) was the Chincoteague National Wildlife Refuge, located on Assateague Island, a barrier island on the coast of the Delmarva Peninsula (Fig. 1). The refuge includes more than 14,000 acres of beach, dunes, marsh, and maritime forest, although the censusing took place only in the southern Virginia portion of the refuge. The Cape May site (38.94 N, 74.91 W) was the immediate area around the Cape May Bird Observatory, located on the southern tip of the Cape May Peninsula on the coast of New Jersey (Fig. 1).

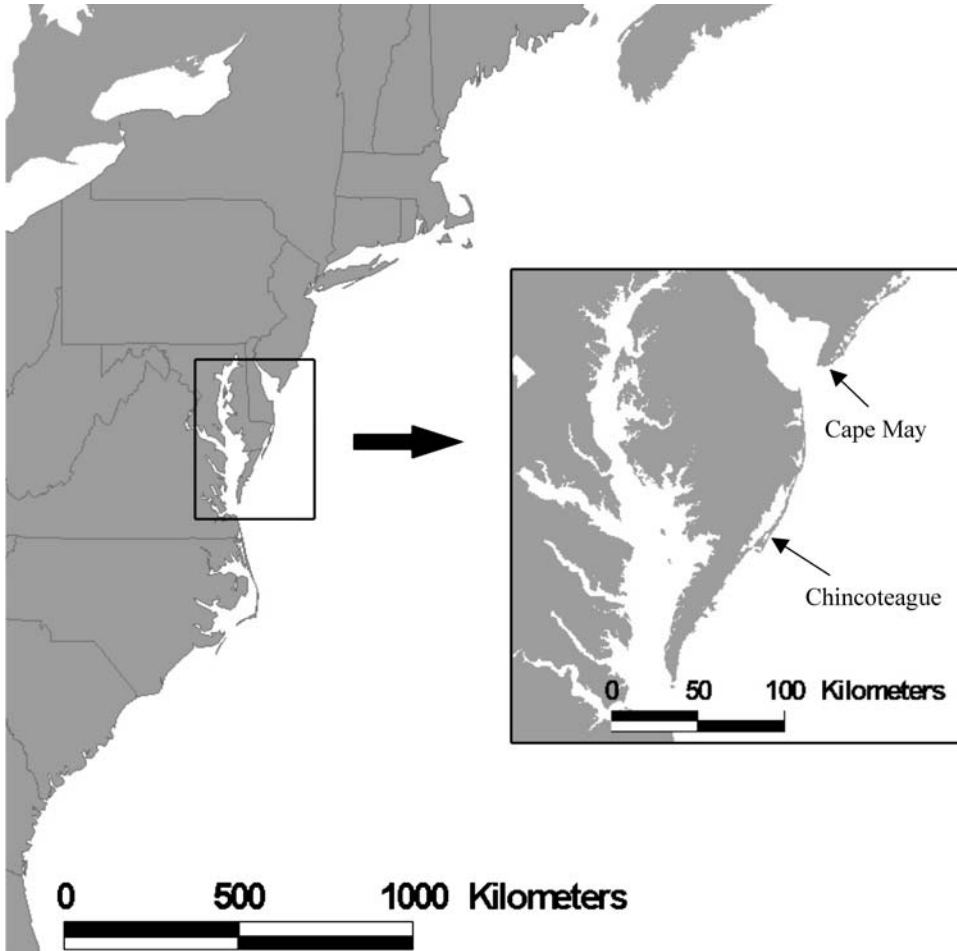


Fig. 1. Map of the Atlantic coast states with locations of the Cape May, NJ and Chincoteague, VA study sites shown (inset).

Cape May censuses

Details of the Cape May data collection were described previously in Walton and Brower (1996). In brief, since 1992, from 1 September to 31 October, assistants and volunteers conducted three daily driving censuses, recording all monarchs seen while driving a standardized 8 km transect at a set speed (32 km per hour). The transect route encompassed several different habitats, including beach dunes, agricultural fields, and residential neighborhoods at the south end of the Cape May peninsula. Censuses began every day at 9 A.M. 11 A.M. and 3 P.M. (AST) on all days until October 15, when counts were reduced to 11 A.M. and 2 P.M. (AST) for the remainder of the season.

Chincoteague censuses

Beginning in 1997, three daily driving censuses were conducted each fall around an 8 km route that encompassed most areas of Assateague Island. The route passed through a variety of habitats including: salt marsh, wet meadow, tidal canals, mixed deciduous

forest, maritime forest, inter-dune areas, and primary dune and beach along the Atlantic Ocean. Censuses were conducted from mid-September through mid-October in most years, but for logistical reasons, did not begin and end at the same time each year. Because of this, we only used census data from the Cape May data set that corresponded to that of the Chincoteague data, i.e., only data from 1997 onward, and only those days for which Chincoteague censuses were also conducted.

Data analyses

At Cape May, censuses lasted approximately 17 minutes on average (D. Walton, unpubl. data), while at Chincoteague, they lasted 16 minutes on average (D. Gibbs, unpubl. data). Since in the present study we were interested in comparing the abundance of monarchs counted at each site, we derived an index of monarch abundance for each census at each site that takes into account the length of time spent per census at each site. Thus, for each census we extrapolated the data to the total number of monarchs seen per hour (number of monarchs counted/duration of census in minutes \times 60). Because there were some days at both sites where less than three censuses were conducted, for logistic reasons or inclement weather, we then calculated the average of all censuses per day (in monarchs/hr). This “daily monarch count” became the test variable for both sites in the present study. Further, we only included the daily monarch counts from each site for days when both sites collected data congruently. Thus over 8 years there were 210 days where both sites collected data on the same days.

To test for differences in the year-to-year trends at each site, and for differences in overall abundance between sites, we performed a univariate ANOVA, with the daily monarch count as the test variable, and year, site, and their interaction as independent variables. In this test, the categorical site variable addressed the variation in abundance between Cape May and Chincoteague, the year variable examined variation between years, and the year by site interaction term examined variation in the annual trends (i.e., population indices) between both sites. Daily monarch counts were log-transformed (+1) to meet assumptions of normality. Tests were performed using SPSS software (SPSS 2004), and patterns were considered significant when $P < 0.05$.

Results

Data overview

Over the entire eight years at Chincoteague, a total of 14,122 monarchs was counted during 616 censuses. There was a total of 210 days on which both the Cape May and Chincoteague censuses were conducted, with 3 censuses conducted per day in most cases at each site. Averages of all daily censuses from Chincoteague are presented in the Appendix. The average daily census counts at Chincoteague ranged from 0 to 932 monarchs per hour or up to 233 monarchs per standard 15 minute driving census. The 8-year average census count was 23 monarchs per census run. The full 13 years of Cape May data are published elsewhere (Walton *et al.*, 2005), however, a total of 33,523 monarchs was counted from 1997–2004 at Cape May, with an eight-year average census count of 25 monarchs per census run.

Annual variation and site comparisons

We found significant variation in monarch abundance between years ($P < 0.001$; Table 1). Post-hoc tests indicated that the highest census counts (at both sites) were obtained in the

Table 1. Summary of ANOVA results. The dependent variable was the log-transformed daily monarch counts from the Chincoteague and Cape May sites. A total of 210 days over 8 years was used in the analysis.

| Variable | d.f. | Mean square | <i>F</i> | <i>P</i> |
|-------------|------|-------------|----------|----------|
| Year | 7 | 6.421 | 12.155 | 0.000 |
| Site | 1 | 6.236 | 11.805 | 0.001 |
| Year * Site | 7 | 0.214 | 0.405 | 0.899 |
| Error | 404 | 0.528 | | |

1997, 1999 and 2001 seasons, while the lowest was the 2004 season (Fig. 2). Furthermore, there was a significant difference in monarch abundance (after standardizing for effort) between sites ($P=0.001$; Table 1). Direct comparison of census data from both sites showed that more monarchs were counted overall at Cape May than at Chincoteague (2-sample *t*-test, d.f. = 418, $t=3.22$, $P=0.001$; Fig. 3). At Cape May, the overall average number of monarchs/hr was 127, while at Chincoteague it was 88 monarchs/hr. For a 15 minute census, these numbers translate into 32 monarchs versus 22 monarchs per census at Cape May and Chincoteague, respectively. Finally, and most importantly, there was no significant difference in the year-to-year trends in monarch abundance between sites (i.e., the year * site interaction term was non-significant: $P=0.899$; Table 1). Furthermore, plotting the log-transformed daily census counts of each site against each other resulted in a significantly positive linear relationship (Pearson correlation, $n=210$, $r=0.51$, $P<0.001$; Fig. 4).

Discussion

Our comparisons of monarch abundance between sites showed clear and consistent differences; each year, more monarchs were counted at Cape May than at Chincoteague.

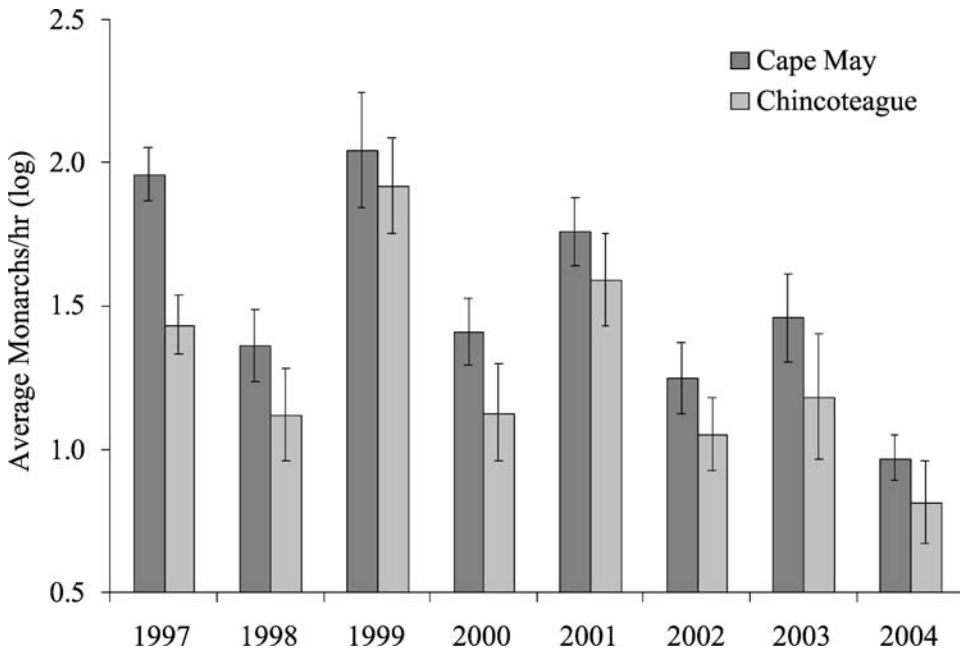


Fig. 2. Average annual monarch counts at each site. Error bars represent standard errors.

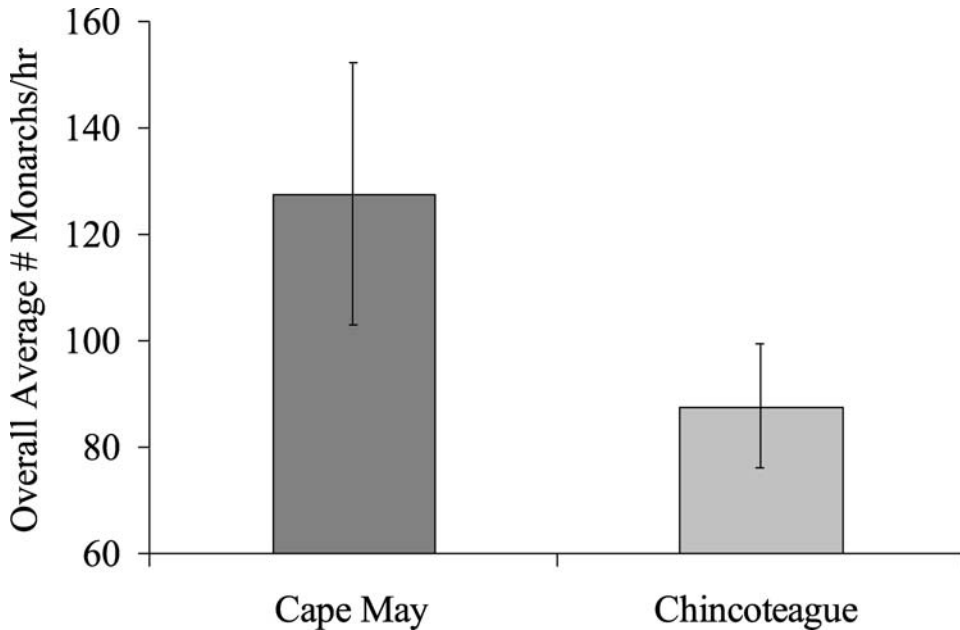


Fig. 3. Overall average numbers of monarchs counted at each site for 8 years (1997–2004, $n = 210$ days for both sites). Error bars represent standard errors.

This result is interesting, given that the sites are located only 117 km apart, along the same line of travel for monarchs (Garland and Davis, 2002), and that the same methods were used to count them. It could be assumed that both sites should have recorded similar numbers, since the same waves of monarchs should be passing through each site every year, as migrating monarchs follow the coastline southward. One possible explanation for this result may be the differential usage of these sites as stopover points. For example, the ecological characteristics of the Cape May site (i.e., habitat, nectar resources, etc.) may make it a more preferred site for landing or temporary stopovers and the larger buildup of monarchs on the ground would lead to more monarchs seen during driving censuses (Davis and Garland, 2002). A second possibility is that monarchs could have built-up at our site on Cape May simply because it was located on the bottom tip of a peninsula and the census route passed by the area where monarchs were accumulating at the tip. Monarchs are known to accumulate at such places because of their reluctance to cross large water bodies (Schmidt-Koenig, 1985; Brower, 1995). These accumulations can last for several days (Davis and Garland, 2004), or until the right wind conditions for overwater flight occur. The Chincoteague road census was approximately 6 km from the southernmost land on Assateague Island, where monarchs accumulate and roost (Fig. 1, Gibbs, unpubl. data). Thus, the fact that the Chincoteague census route did not pass by an accumulation area, but the Cape May census did, may be the reason for the higher census numbers at Cape May.

Regardless of the differences in abundance between sites, we found that there was no difference in the long-term population trends obtained from each site. Thus the data from each site showed the same general patterns of population size fluctuations from year to year. This result has important implications for the use of migration monitoring as a tool for assessing the size of monarch populations. For example, the data from both sites

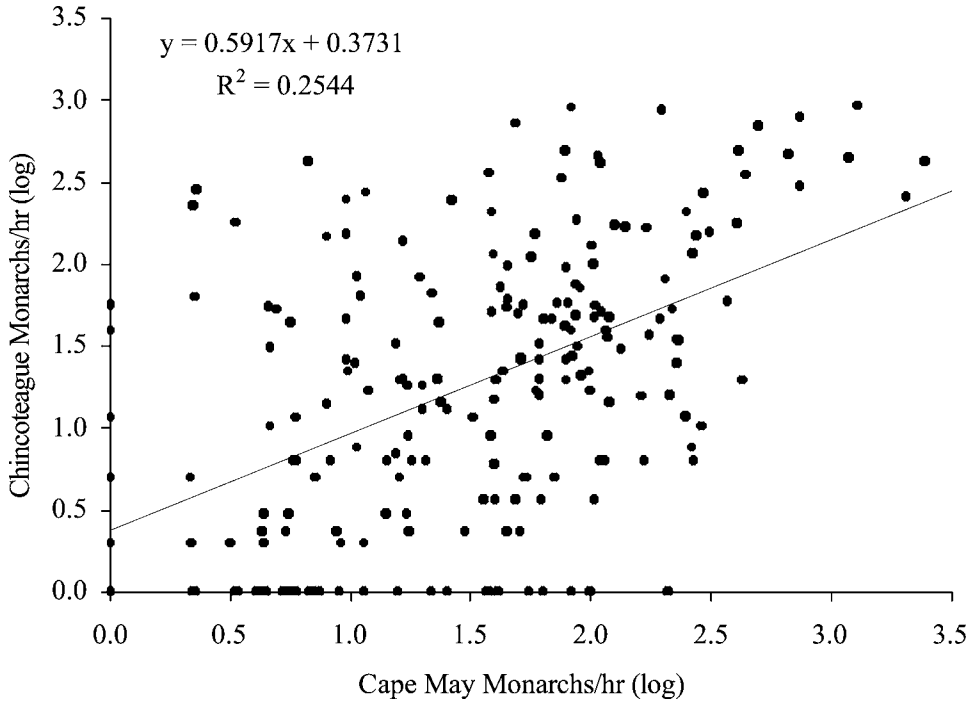


Fig. 4. Comparison of daily monarch counts over 8 years (1997–2004, $n = 210$ days) from both sites.

suggest that the migrant population in 2004 was the smallest since censusing began. Walton *et al.* (2005) also showed that the 2004 season at Cape May was the lowest of 14 years of monitoring and suggested that this could be at least in part the result of recently increased degradation of the overwintering habitat in central Mexico (Honey-Roses and Galindo, 2004; Brower *et al.*, 2005). Regardless of the reason, the fact that the Chincoteague data show a similar overall pattern in population decline indicates the usefulness of this method of monitoring and estimating the eastern North American monarch population's size.

The similarities between the data collected from the two sites confirm general patterns in monarch population size during the fall, and also suggest guidelines for establishing additional monitoring sites in the future. Monitoring sites should be separated far enough apart to avoid redundancy in data collection. Walton and Brower (1996) demonstrated that the Cape May migration counts reflect the number of monarchs breeding in the geographic area to the north and northwest of Cape May, NJ. Since the Chincoteague data correspond to the Cape May data in most years, it would appear that the same populations of monarchs are sampled at both sites. These data also point to advantages and disadvantages of establishing sites at the end of peninsulas. The higher abundance at Cape May suggests that peninsula tips provide sites for monitoring the greatest numbers of migrating monarchs. However numbers could be inflated by the presence of individuals that pause migration at these locations. Either way, the data presented here point to the importance of obtaining long-term data sets on the size of migrating monarch populations because the trends they depict can provide the information needed for conservation measures to be implemented.

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Appendix. Average daily census data from Chincoteague. Shown are the averages of the three daily census counts (monarchs/hr). Dates where no censuses conducted are left blank.

| Date | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | Total |
|-------|------|------|------|------|------|------|------|------|-------|
| 9/13 | | 0 | | | | | | | 0 |
| 9/14 | | 0 | | | | 21 | | | 11 |
| 9/15 | 11 | 0 | | | 3 | 60 | | | 19 |
| 9/16 | 9 | 0 | | | 19 | 12 | | | 10 |
| 9/17 | 15 | 0 | | 5 | 48 | 52 | | | 24 |
| 9/18 | 5 | 0 | | 3 | 47 | 51 | | | 21 |
| 9/19 | 19 | 0 | | 3 | 71 | 65 | | 0 | 28 |
| 9/20 | 8 | 2 | | 3 | 5 | 84 | | 0 | 17 |
| 9/21 | 208 | 0 | | 0 | 45 | 82 | 0 | 1 | 47 |
| 9/22 | 24 | 1 | | 5 | 25 | | 0 | 5 | 10 |
| 9/23 | 5 | 19 | 472 | 1 | 5 | | 11 | 4 | 54 |
| 9/24 | 0 | 100 | 696 | 0 | 0 | 15 | 1 | 2 | 102 |
| 9/25 | 33 | 153 | 932 | 3 | 0 | 0 | 0 | 1 | 140 |
| 9/26 | 301 | 55 | 45 | 0 | 47 | 0 | 1 | 1 | 56 |
| 9/27 | 51 | 57 | 56 | 284 | 5 | 5 | 1 | 1 | 58 |
| 9/28 | 11 | 116 | 45 | 149 | 351 | 32 | 8 | 0 | 89 |
| 9/29 | 52 | 34 | 21 | 59 | 880 | 17 | 129 | 0 | 149 |
| 9/30 | 13 | 15 | 45 | 8 | 39 | 9 | 491 | 1 | 78 |
| 10/1 | 459 | 43 | 449 | 1 | 147 | 4 | 416 | 2 | 190 |
| 10/2 | 25 | 167 | 472 | 0 | 493 | 4 | 333 | 2 | 187 |
| 10/3 | 20 | 173 | 424 | 0 | 176 | 5 | 208 | 0 | 127 |
| 10/4 | 29 | 30 | | 41 | 80 | 1 | 137 | 6 | 46 |
| 10/5 | 31 | 94 | | 39 | 39 | 16 | 168 | 16 | 57 |
| 10/6 | 97 | 49 | 795 | 11 | 0 | 5 | 72 | 13 | 130 |
| 10/7 | 21 | 26 | 157 | 1 | 904 | 7 | 16 | 43 | 147 |
| 10/8 | 36 | 12 | 269 | 360 | 729 | 111 | 13 | 32 | 195 |
| 10/9 | 27 | 19 | | 115 | 185 | 4 | 7 | 19 | 54 |
| 10/10 | 75 | 54 | 227 | 424 | 25 | 0 | 0 | 14 | 107 |
| 10/11 | 19 | | 257 | 56 | 25 | 0 | 0 | 246 | 86 |
| 10/12 | 57 | | 35 | 248 | 53 | | | 274 | 133 |
| 10/13 | | | 17 | 153 | | | | 180 | 117 |
| 10/14 | | | 63 | 24 | | | | 63 | 50 |
| 10/15 | | | 19 | | | | | 4 | 11 |
| 10/16 | | | 4 | | | | | 0 | 2 |
| 10/17 | | | 4 | | | | | | 4 |
| 10/18 | | | 0 | | | | | | 0 |
| Total | 60 | 44 | 243 | 71 | 159 | 24 | 96 | 34 | 88 |