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Notes and Discussion

An Examination of Monarch Butterfly (Danaus plexippus) Autumn Migration in Coastal Virginia

ABSTRACT.—Although it is known that monarch butterflies (*Danaus plexippus*) in North America east of the Rocky Mountains migrate each fall to overwintering sites in central Mexico, the migratory routes monarchs take have only been indirectly studied. Over three fall migration periods (1998–2000) we captured monarchs on the eastern shore of Virginia in an attempt to recover monarchs initially tagged farther north. Of 2190 monarch captures, 6 were previously tagged in other locations, allowing possible migration routes and rates of travel in varying wind conditions to be inferred. Monarchs reached our site fastest when they migrated with strong northerly winds. Only one monarch tagged at our study site was recovered at the overwintering site in Mexico. Compared to recovery rates from monarchs tagged in other locations in North America, this suggests that monarchs at our site are less likely to reach the Mexican overwintering site in certain years. We also report discovery of an annual monarch accumulation area on the extreme southern tip of the eastern shore of Virginia on the Delmarva Peninsula.

INTRODUCTION

Monarch butterfly (*Danaus plexippus*) migration has been classified as ''an endangered biological phenomenon'' in eastern North America because of deforestation of overwintering habitat in Mexico (*e.g.*, Brower and Malcolm, 1991). Monarch migration has received much attention during the past two decades (Brower, 1995, 1996; Rogg *et al.*, 1997; Knight *et al.*, 1999) and these studies have documented much of the general migration of this insect in North America. For example, it is well known that monarchs east of the Rocky Mountains migrate each fall to a select few overwintering sites in Mexico (*e.g.*, Brower, 1995, 1996; Hobson *et al.*, 1998). How monarchs navigate during migration has also been addressed (*e.g.*, Perez *et al.*; 1997, Oliveira *et al.*, 1998).

Although the overwintering destination of the eastern population of monarchs is known, the specific migration routes used in eastern North America are still debated. Urquhart (1987) maintained that monarchs found along the Atlantic coast were individuals that had become disoriented and that these monarchs did not make it to the overwintering destination in Mexico. However, Brower (1995) suggested that monarchs did use the eastern coast of North America as an annual fall migration route to central Mexico. Walton and Brower (1996) provided the first evidence in support of this. By establishing a monarch monitoring program whereby monarchs were censused and captured in a standardized fashion each year, Walton and Brower showed that large numbers of monarchs consistently moved through their coastal study site in New Jersey each fall, and that the timing of arrival of the main peaks of migration was consistent each year. Furthermore, these authors showed that fall migration counts of monarch on the Atlantic coast are correlated with counts of breeding monarchs in the summer.

Aside from Walton and Brower's site at Cape May, New Jersey, many other monarch tagging programs are carried out each fall on the Atlantic coast by various agencies and concerned citizens. In recent years, this tagging information, as well as recoveries at the overwintering site in Mexico, has been summarized by Monarch Watch (MonarchWatch, 2001). However, despite the thousands of monarchs tagged each fall in eastern North America, the migration routes of monarchs are still not clearly understood, especially on the east coast of North America. A possible reason for this is that compared to recovery rates of tagged monarchs at the overwintering site in Mexico, which was 1 in 130 in 1999 (MonarchWatch, 2000), the number of monarchs that are recaptured along the migration route in the same season is less than 1 in 1000. However, such recaptures can provide important information on flight speeds and migration routes. Knowing specific migration routes can also help to determine where important monarch staging areas are located.

In the fall of 1998, 1999 and 2000 we captured migrating monarch butterflies on the southern tip of the Delmarva Penninsula, a known bird concentration area in the fall, in an attempt to capture previously tagged monarchs from northern tagging sites, and to determine if monarchs become concentrated in this area similar to birds.

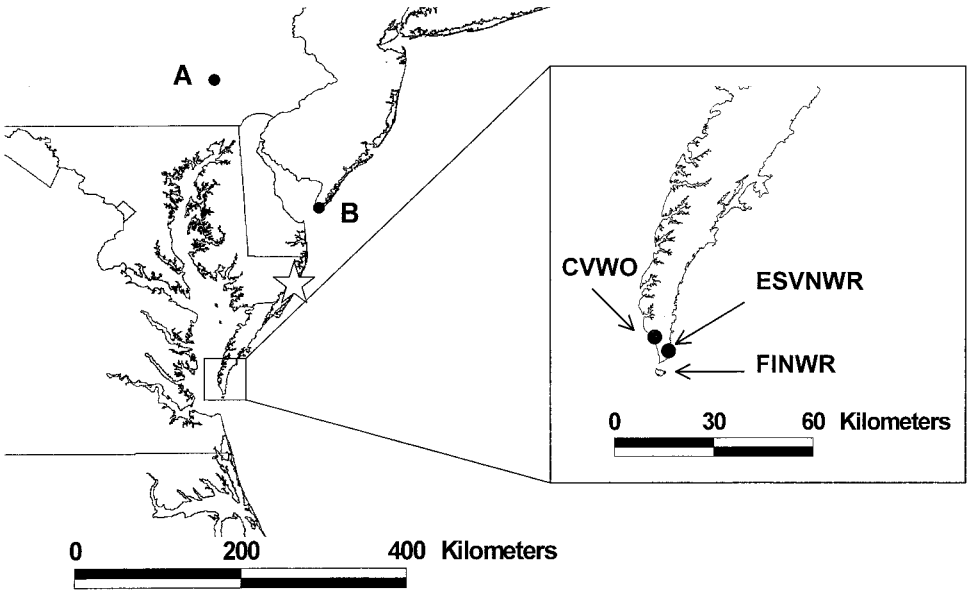

FIG. 1.—Map showing location of study sites (CVWO: Coastal Virginia Wildlife Observatory; ESVNWR: Eastern Shore of Virginia National Wildlife Refuge; FINWR: Fisherman's Island National Wildlife Refuge) in coastal Virginia and points of origin (A, B) of monarch butterflies recaptured in the study site. Site where wind data was obtained also shown (star)

METHODS

Study sites.—Our study sites were located at the southern tip of the eastern shore of Virginia on the Delmarva Penninsula, which forms the outer barrier to the Delaware Bay (Fig. 1). Specifically, we captured monarchs at the Coastal Virginia Wildlife Observatory (CVWO), located at Kiptopeke State Park, VA, approximately 5 km from the southernmost end of the penninsula; the Eastern Shore of Virginia National Wildlife Refuge (ESVNWR), approximately 1 km from the southernmost point of the penninsula; Fisherman's Island National Wildlife Refuge, VA, located 2 km off the southern tip of the penninsula; as well as the surrounding areas within an approximate 5 km radius.

Field methods.—Monarchs were captured between 24 Sept. and 30 Oct. in 1998, 6 Sept. and 31 Oct. in 1999 and between 7 Sept. and 28 Oct. in 2000. The capture effort varied throughout the study, due to weather, the number of people capturing or tagging, or other logistic reasons. Monarchs were captured using standard 15-inch butterfly nets, usually while the insects were nectaring or flying low to the ground. Due to the variable nature of butterfly netting, and because of the unequal capture effort throughout the study, no standardized procedure for catching monarchs was adopted. Furthermore, since the capture effort varied throughout the study, we did not attempt to map the seasonal distribution of monarchs using this data. Our goal was to capture as many monarchs as possible. At CVWO, in Kiptopeke State Park, many monarchs were captured when they descended to the CVWO butterfly Garden, which attracts many species of butterflies.

All captured monarchs (except those already tagged) were given a small numbered sticker, applied to its right or left hindwing, supplied by project Monarch Watch at the University of Kansas. The identification number of all previously tagged butterflies was recorded, as well as the time and location of capture.

RESULTS AND DISCUSSION

Capture results.—A total of 2190 monarchs were captured and tagged over the three migration seasons. In 1998, 547 monarchs were captured during 19 d of tagging, 955 were captured in 23 d in 1999

and 688 were captured in 36 d in 2000. We captured 6 monarchs that were previously tagged in sites north of ours (Table 1). Four of the 6 recovered monarchs were captured in 1998 on 13 and 14 October. Two recoveries occurred in 1999 on 5 and 7 October, while no monarchs were recovered in 2000. Interestingly, due to better financial and logistic support in the 2000 season, we were able to increase our capture effort greatly over the previous two seasons, but captured fewer monarchs and failed to recover any previously tagged monarchs.

Migration routes.—Five of the six recovered monarchs were originally captured and tagged at Cape May, NJ (Fig. 1C), whereas the remaining monarch was originally tagged in Reinholds, PA (Fig. 1B). The fact that we recaptured five monarchs that were originally captured in Cape May, NJ is consistent with Walton and Brower (1996). These monarchs appeared to be following the coastline south. This directional movement is inconsistent with Urquhart (1987), who suggested that coastal monarchs were abberant individuals. Although only one monarch was recovered which originated from an inland location (Reinholds, PA), it suggests that the Delmarva Peninsula funnels and concentrates monarchs from northern locales toward the southern end of the peninsula.

Wind effects.—Monarchs are known to take advantage of tailwinds during migration by soaring to reduce energy expenditure (Gibo and Pallett, 1979). However, until now, it has not been possible to demonstrate the effects of tailwinds on flight speeds except under laboratory conditions (Gibo and Pallett, 1979). By comparing the transit times of the six recaptured monarchs between the tag location and our site to the wind directions at the time of tagging, we addressed this issue. We obtained wind data from an automated weather station located at Wallops Island, VA, which is located on the Delmarva Peninsula, approximately halfway between Cape May and our study site (Fig. 1). The wind directions and speeds were measured at noon and at varying heights. We averaged the measurements from all heights below 1000 m to obtain the directions and speeds for the days presented in Table 1.

As expected, the two monarchs that travelled from Cape May the fastest (# 118633 and 182240) both did so when the wind was over 27 km/h and had a northerly component. In one case, monarch #182240 was tagged at Cape May on 6 Oct. 1999 at 13:00, and subsequently recovered at 17:00 the next day on Fisherman's Island, approximately 16 daylight hours later. This indicates an average flight speed of approximately 14 km/h. The wind on the date of tagging was over 35 km/h and directly from the north (*i.e.*, tailwind). During these wind conditions then, this monarch only needed 1 d to travel 226 km, while those migrating during other wind conditions needed 7 d or more to travel the same distance.

Roost formation.—Walton and Brower (1996) in New Jersey described how monarchs aggregated during the day in specific sites and subsequently formed overnight roosts, which would disperse the next day. While catching and searching for monarchs for this study we too found an area on the end of the peninsula where monarchs accumulated during the day and formed roosts at night. Often these roosts contained thousands of monarchs. On 5 Oct. 1999, we estimated that a roost on Fisherman's Island contained over 50,000 monarchs. Furthermore, roosts were found in the same group of trees in successive years. Annual use of the same area for overnight roosts has also been found in the northern limit of monarchs' breeding range in Canada (Urquhart and Urquhart, 1979) and on the Atlantic coast (Walton and Brower, 1996).

Recovery rates.—Only one monarch tagged during our study has been recovered at the overwintering site in Mexico (MonarchWatch, 2001). A monarch we tagged on 3 Oct. 2000 on Fisherman's Island was recovered on 26 January 2001 at the overwintering site. That one of our monarchs was found at the overwintering site is not surprising. What was surprising, however, was the lack of recoveries of our 1998 and 1999 tagged monarchs. On average, approximately 1 out of every 200 (0.5%) tagged monarchs in the eastern population were recovered at the overwintering site in 1998, and 1 out of every 130 (0.77%) in 1999 (MonarchWatch, 2001). This means that at least 2 of the 547 monarchs we tagged in 1998 should have been recovered, plus 7 of the 955 in 1999. A goodness of fit test between the recovery rate of monarchs at our site versus those at all other sites shows that this difference in 1999 is significant ($P < 0.05$). The difference in 1998 was not statistically significant ($P = 0.09$) but suggests a weak difference. Recovery rates of the 2000 season were not yet published at the time of this writing but were estimated to be 1 in 425 (O. R. Taylor, pers. comm.). This rate was not significantly different than our recovery rate of 1 in 688 tagged monarchs in 2000 ($P = 0.73$). Thus, the lack of recoveries

TABLE 1.—Summary of foreign monarch butterflies recovered at the southern end of the Delmarva Penninsula

Tag #	Original tag site	Original tag date	Recovery date	Distance travelled (km)	Wind direction on tag date*	Wind speed (km/h)**	Transit time (d)
132340	Cape May, NJ	5 Oct. 1998	13 Oct. 1998	226	WNW	17.6	7
118633	Cape May, NJ	11 Oct. 1998	13 Oct. 1998	226	NNW	35.7	2
132452	Cape May, NJ	6 Oct. 1998	14 Oct. 1998	226	E	19.1	8
132455	Cape May, NJ	6 Oct. 1998	14 Oct. 1998	226	E	19.1	8
588JQ	Reinholds, PA	26 Sept. 1999	5 Oct. 1999	333	SSW	7.8	9
182240	Cape May, NJ	6 Oct. 1999	7 Oct. 1999	226	N	27.4	1

* The direction the wind was coming from, averaged from 6 height intervals from 13 m to 1000 m

** Averaged from 6 height intervals from 13 m to 1000 m

of monarchs tagged by us in the first 2 y of this study suggests on one hand that monarchs on the east coast are less likely to arrive at the overwintering site in Mexico than inland migrants. However, the fact that our recovery rate for 2000 was similar to that of all other monarchs tagged in that year suggests that this is only true on certain years. Only with further research and greater tagging efforts will we be able to fully understand this, and other aspects of the migration of this species.

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