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Use of Spotted Knapweed/Star Thistle (Asterales: Asteraceae) as the Primary Source of Nectar by Early Migrating Monarch Butterflies (Lepidoptera: Nymphalidae) from Beaver Island, Michigan

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Cover Page Footnote

I would like to thank Brandy Van Zalen for her photography; Dr. Pamela Laureto of Grand Rapids Community College for her careful review; and the following for their observations and input into this paper: Dr. R. Haack and Dr. B. Leuck.

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ABSTRACT

Recent observations over the past decade suggest that the invasive star thistle (aka spotted knapweed (Asterales: Asteraceae *Centaurea stoebe* L.) provides much of the nectar that supports monarch butterflies (Lepidoptera: Nymphalidae *Danaus plexippus* L.) in their pre-migratory and early migratory flight from the Beaver Island archipelago, an isolated chain of islands located in northern Lake Michigan. With the advent and continuation of global climate change, the opportunistic evolutionary changes that may take place between migrating monarchs and their dependence on non-native nectariferous plants, prior to migration, is worth further documentation and examination.

Keywords: monarch migration, *Danaus plexippus,* star thistle, spotted knapweed, *Centaurea stoebe,* pre-migration nectar resources

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The eastern cohort of monarchs (*Danaus plexippus* L.)—residing largely east of the Rocky Mountains—exhibits an extended migratory period, somewhat variable in timing and success from year to year, but temporally wave-like in occurrence, and most pronounced between 15 August and 15 October (Brower 1995). The success of the migration is dependent upon viable nectar-bearing plants (Brower et al. 2006), as well as ambient temperatures above 10°C with enough radiant insolation, to warm the thorax to the minimal temperature required for the butterflies to conduct continuous, controlled flight (Douglas 1979).

One of the critical parameters ensuring successful migratory flight is the availability of nectar-bearing plants from which the adults feed, and from which they extract and convert sugars into fat reserves (Brower et al. 2006). Without sufficient food reserves, migratory monarchs often die in the overwintering roosts located in the state of Michoacan, Mexico. (Brower et al. 2012, Pleasants & Oberhauser 2012, Flockhart et al. 2013; Flockhart et al. 2015, personal observation February 2002). Thus, the ability to find nectar-bearing plants by sequential generations of late summer and fall butterflies migrating from southern Canada provinces and the northern tier states of the United States to Mexico is critical to their survival. The extraction of sugars from late summer and fall nectariferous plants is vital to their successful migration, survival in the overwintering roosts (located within oyamel/pine forest at 10,000 feet), and the *en masse* spring reproductive effort, which takes place prior to the spring remigration northward.

The natal origins of eastern North American migratory monarch butterflies that overwinter in Mexico have recently been identified, at least to general geographic areas. A full 38 percent migrate to Mexico from the "Midwest;" however, their origins are spread widely across a breeding range that extends across southern Canada and the northern tier states of the United States. University of Guelph scientists analyzed more than 1,000 samples from butterflies collected from the 1970's onward to determine their natal region. Approximately 17 percent originated from the north-central states, including Michigan and Ontario, which represented the greatest number of butterflies for any specific natal region (Flockhart et al. 2017).

This observational study should serve as a heuristic attempt to establish whether or not migratory monarchs from the northern tier states will ultimately switch to the invasive star thistle as a more reliable source of nectar during the early migratory season (Fig. 1).

Materials and Methods

Study Location and Period of Study. In previous years of observation, from 2010 through 2016, and especially during the late summer days of 2017, monarchs were

Figure 1: Central Michigan University Biological Station on Sandy Bay, Beaver Island. Star thistle is shown in foreground. The invasive star thistle has established extensive populations along the swales and parabolic dunes running the circumference of the island. Photo credit: Brandy Van Zalen.

observed nectaring almost exclusively on star thistle, also known vernacularly as spotted knapweed (*Centaurea stoebe* L.) that dominates the swales and parabolic dunes throughout Beaver Island, part of a small archipelago of nine islands located in Lake Michigan, about 45 km due west of Charlevoix, Michigan at latitude 45.67 N, and longitude 85.55 W. It measures 145 km^2 (about 60 square miles). Just north of Beaver Island resides Hog Island with a "natural state" flora of nearly 93 percent (Whately et al. 2005) and thus most of the flora is native and, in a few cases, endemic, leaving this isolated ecosystem of Lake Michigan islands relatively untouched by invasive species, save for the shoreline environments. This observational study has been conducted over a number of years at Sandy Bay, in front of the Central Michigan University Biological Station on Beaver Island. During mid-and late August of 2017, an unusually large population of monarch butterflies emerged and in the course of a week assumed typical migratory behavior (Fig. 2).

History of Star Thistle in Michigan. Star thistle, a Central European native with an estimated introduction in western North America in the 1890s, is an invasive plant that is currently the target of eradication in many states. In northern Michigan, however, many beekeepers are opposed to efforts directed at its eradication because a significant portion of their yearly revenue depends upon it, especially during late July and August, when it is one of the few extensively blooming plants in the northern Lower Peninsula of Michigan and along Lake Michigan lakeshore (honeytraveler.com). According to this source, star thistle honey has a light, transparent and thick viscous appearance with "an aroma of anise/almonds, slightly sharp or pungent with notes of sweet, spicy cinnamon, molasses and prune."

The star thistle first invaded the Beaver Island archipelago in the 1980's, became firmly established in the mid-1990's, and now can be found throughout the entire island, wherever there is appropriate habitat (B. Leuck personal communication 2018). There are approximately 476 populations comprising nearly 84 hectares (210 acres) of star thistle now on Beaver Island (GEI consultants 2017). Of 16 listed invasive species on Beaver Island, the invasion of star thistle is the largest, and except for Bladder Campion (*Silene vulgaris* (Moench) Garcke) at 70 hectares (175 acres), all other invasives can be measured at well under 16 hectares (40 acres), and typically fewer than 4 hectares

Figure 2: Star thistle population extending along the swales and parabolic dunes of Beaver Island. Newly emergent monarch butterflies spend over a week exclusively nectaring at the flowers, prior to the first ("early") wave of monarch migration from the island at the end of August. Monarch butterflies are now found on the island well into late October. Photo credit: Brandy Van Zalen.

(10 acres). Despite this recent and successful invasion, there has apparently not been any significant change in the *Solidago* L. (goldenrod) populations upon which migrants apparently used to rely (B. Leuck personal communication 2018).

Attractiveness of Star Thistle to Nectar-Seeking Butterflies. The star thistle is officially classified as an invasive herbaceous biennial or short-lived perennial. A highly branching species, it reaches heights during bloom between 0.3 and 1.2 meter. Star thistle is a beautiful and long-blooming plant (from June through October 2017), and a moderate nectar producer that attracts numerous butterflies during the mid- to late summer, including buckeye (*Junomia coenia* Hubner), red admiral (*Vanessa atalanta* (L.)), painted lady (*Vanessa cardui* (L.)), American lady (*Vanessa virginiensis* (Drury)), and viceroy (*Limenitis archippus* (Cramer)), which are numerous and fly in mixed species aggregations with pre-migratory monarchs. In fact, most species of butterflies on Beaver Island appear to avidly nectar at star thistle. [It is interesting to note that the buckeye, red admiral, and painted lady are also migratory species, whose orientation and flight behaviors are virtually unstudied, although they can be readily observed migrating southward down the western shore of Lake Michigan in August and September, along with migrating monarchs. (In contrast, the viceroy overwinters as first instar larvae in hibernacula created by rolling the leaves of willow that form extensive stands along the Beaver Island beaches.)]

Invasive Characteristics and Control Efforts of Star Thistle. The reproductive output of star thistle is considerable. A single plant can produce 1,000 to 10,000 seeds that are dispersed by animals and birds and through the feces of birds and small rodents that consume them. The seeds can remain dormant in the soil for over 5 years (DeVries and Laureto 2013). The species spreads rapidly by reseeding itself (North Dakota State University, publications circular, crops, 2013).

Because of its r-selected characteristics, star thistle has rapidly colonized much of North America, especially disturbed areas. Unfortunately, its taproot system provides a poor anchor for soils and thus monocultures of this plant along hill sides lead to elevated erosion (Lacey et al. 1995). Because of its ability to rapidly colonize a number of habitats, it has outcompeted many native species, and has proved difficult to control biologically (i.e., "biological control") even

Figure 3: Monarch adult foraging at one of the many blooms of a single star thistle plant, late August, 2017. Photo credit: Brandy Van Zalen.

with the introduction of numerous predatory arthropods that prey on various parts of the plant, including the moth *Metzneria paucipunctella* Zeller, the knapweed gall flies, *Urophora affinis* (Frauenfeld) and *U. quadrifasciata* (Meigen), the cochylid moth *Agapeta zoegana* L., and the beetle *Sphenoptera jugoslavica*.Obenberger (Lym et al. 1992, Clark et al. 2001). However, mechanical control, biological control, or chemical control or combinations thereof have not yielded significant results anywhere in North America, and the species continues its invasion eastward (Smithsonian.com 10.21.17).

In Michigan, Star thistle has adapted quickly to sandy, disturbed soils, such as the sandy beaches and dunes along the Great Lakes shoreline. The seeds may be brought to the beaches by hikers and kayakers, especially along the edges of the islands (Great Lakes Restoration Initiative 2011). Unfortunately, star thistle is not viewed as providing much in the way of benefits for any community it invades. Star thistle is a "wicked weed" according to Joe Alper: In fact, it is a "weed" that is massively destroying the rangeland of the western states such as Montana, where it costs ranchers more than $40 million annually in herbicide use and lost productivity (Alper 2004). Star thistle has invaded pastureland and rendered huge tracts commercially useless because cattle, horses, and most other animals will not eat it (Olson et al. 1997). Star thistle produces (-) catechin, which was formerly claimed to function in part as an allelopathic compound that destroys the roots of other competing plants (Rutledge and McLendon 1998). Star thistle-infected North American soils had two to three times more (-) catechin than soils from the plant's native habitat in Europe, where star thistle grows in apparent harmony with thousands of grasses and other perennials. However, the claim that (-) catechin is allelopathic is being re-investigated.

Clearly, in North America, star thistle does not have a stellar reputation. Star thistle was documented throughout the Beaver Island archipelago as an invasive species even on smaller islands, such as Hog Island (Whately et al. 2005)(Fig. 3).

Results

During the period from 10 to 17 August 2017, star thistle was virtually the only flowering/nectar-producing plant growing along the shoreline. [Several goldenrod species, tall goldenrod (*Solidago altissima* L.) and Canada goldenrod (*Solidago canadensis* L.) were just coming into bloom, and about 10

to 20 percent of common milkweed (*Asclepias syriaca* L.) and small patches of swamp milkweed (*A. incarnata* L.) were still in bloom in shaded areas with higher moisture content.] Previous personal observations over many years in the Upper Peninsula and at Beaver Island in mid-to late-August, show that major monarch emergences occur during this period, prior to the first advance of migration.

In mid-August 2017, many thousands of monarchs emerged to find very few foraging plants save for the abundant star thistle, which they visited continuously throughout the day from sunrise to sunset—even on completely overcast days. At times, 20 or more monarchs *per minute* could be seen flying up and down Sandy Bay beach (running North/South) along a stretch of beach about 100 meters long and about 20 meters deep, before the forest interface and the bordering forest of conifers and oaks. This was a common condition across the island. These newly emergent butterflies were not exhibiting migratory behavior at this point, which in northern Michigan and the Beaver Island archipelago ultimately forces them to cross Lake Michigan, typically in a S-SW direction. Their lake crossing can vary between 30 and 300 km in length depending on the direction of the winds at the onset of migration. Star thistles in the many thermal microhabitats available on Beaver Island could be found in early stages of bloom as well as late stages of senescence, suggesting that the nectar resource was available to several generations of monarchs on the island. (Star thistle begins to bloom in June across the northern part of the Lower Peninsula of Michigan and often continues through October, thus making its nectar available to all nectar-seeking insects, and especially late migratory monarchs and other butterflies leaving the island from the end of August until late October.)

At sunset, the "pre-migratory" butterflies would begin to form small roosts of 4-10 individuals about 50 meters from the shoreline, largely within coniferous trees (*Pinus strobus* L., *Abies balsamea* (L.) Miller, *Picea mariana* (Miller) BSP, and common juniper (*Juniperus communis* L.). It is worth noting that closely related smooth-bark Mexican pine (chamite/pacingo) *Pinus pseudostrobus* Lindlay and the oyamel "sacred" fir, (*Abies religiosa* (Kunth)) create mixed groves where massive roosts of overwintering monarchs form in the southwest-facing slopes of the Trans-Mexican Volcanic Belt, Sierra Madre del Sur, State of Michoacan, Mexico (Brower 1995, personal observation Sierra Chincua roost 2002).

The same scenario of monarch migration plays out on Drummond Island (R. Haack personal communication 2018), where star thistle is also widely prevalent. As star thistle continues its unabated invasion of the Great Lakes Region, moving towards the East Coast, it is likely to create an even more reliable source of nectariferous resources for migrating monarchs. This may be especially significant in dry areas where *Solidago* either does not dominate or blooms later in the season, which may not be useful for the first and typically largest wave of monarch butterflies leaving the region.

Discussion

The origins of monarch migration throughout the species distribution is not well understood, despite many decades of research as to the evolution and proximal causes that induce migration in the several species and subspecies of monarchs. Currently the populations of monarchs in eastern North America, western north America, and South America have an extended migratory period that relies on enough nectar-bearing plants from which migrating butterflies forage, converting sugars to fats, for the lengthy migrations, which may be either altitudinal or longitudinal. Survival in the overwintering roosts depends upon reserves of fat built up from foraging during the course of migration. Without sufficient nectariferous resources, monarchs may not complete the migration, may die in the overwintering roosts, or may fail in their reproductive efforts during the spring remigration.

Invasive plants such as the star thistle often disrupt intact ecosystems and as a result change all organismal players involved. However, invasive plants may also prove useful to many insects, particularly pollinator Hymenoptera and Lepidoptera, especially if the nectar they produced is available during critical times of their life cycles. At Beaver Island, star thistle has clearly become a vital resource utilized by the early migratory monarch population in the late summer and likely for earlier and later generations as well because the plants bloom from June through October. Whether or not star thistle has displaced other nectariferous plants such as goldenrod and common milkweed, is not known, but anecdotal observations suggest that it has not diminished their range or abundance, at least on the Beaver Island archipelago (Fig. 4).

In effect, star thistle has become an essential nectariferous plant of great value to the emerging early migratory populations on Beaver Island, and likely throughout the archipelago. What change and value this has for the monarchs under extensive pressure

Figure 4: Common milkweed *(Aesclepias syriaca)* forms dense monocultural stands along many areas of the Lake Michigan lakeshore on Beaver Island. Note the two newly emergent monarchs nectaring on the milkweed blooms in the front (second milkweed from the left) of the picture. Photo credit: Brandy Van Zalen.

during the migratory period from northern Michigan is not known, but it is likely that eradication efforts will demand a great deal of time and money, and the ultimate goal of eradication will prove extremely difficult if not impossible.

Future areas of investigation may involve the effects of star thistle success and the possible co-evolution of star thistle and monarchs during their migratory periods. With the advent and continuation of global climate change, the opportunistic evolutionary changes that may take place between migration of monarchs and their non-native nectariferous plants prior to migration would be worth examining.

Acknowledgments

I would like to thank Brandy Van Zalen for her photography; Dr. Pamela Laureto of Grand Rapids Community College for her careful review; and the following for their observations and input into this paper: Dr. R. Haack and Dr. B. Leuck.

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