Mimulus moschatus var. *moschatus*

Muskflower

Scrophulariaceae

Mimulus moschatus var. *moschatus* by Chris Buelow, 2020

Mimulus moschatus var. *moschatus* Rare Plant Profile

New Jersey Department of Environmental Protection
State Parks, Forests & Historic Sites
Forests & Natural Lands
Office of Natural Lands Management
New Jersey Natural Heritage Program

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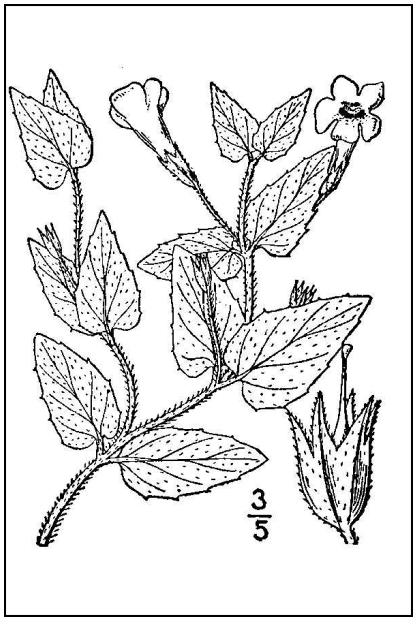
Life History

Mimulus moschatus var. *moschatus* is a rhizomatous perennial herb. *Mimulus* was traditionally included in the Scrophulariaceae but changes to the figwort family based on the outcomes of genetic analyses resulted in its transfer to Phrymaceae (APG II 2003). Due to a recent re-evaluation of the genus *Mimulus*, *M. moschatus* var. *moschatus* is currently known by several different scientific names (see Synonyms and Taxonomy section). The common name, Muskflower, was originally based on a characteristic musky odor produced by the plants (Ward 1904) but early in the 1900s people began to notice that the species had become scentless, an inexplicable phenomenon that was reported in naturalized and cultivated plants on multiple continents (Hardy 1934, Nature 1934). Native North American muskflowers have apparently retained their scent, which can be produced by all parts of the plants (Gleason and Cronquist 1991, PFAF 2024).



Left: Britton and Brown 1913, courtesy USDA NRCS 2024a. Right: Chris Buelow, 2020.

The rootstocks of *Mimulus moschatus* var. *moschatus* are constricted at regular intervals. The species reproduces clonally, rooting at the nodes. Macoun (1898) noted that a particular population of *M. moschatus* was growing "luxuriously and in great abundance" and other observers have described colonies of Muskflower plants as forming dense tangles (Ward 1904, Fernald 1911). The stems are short, usually under 2 dm in height, and they habitually creep at the base and ascend at the tips. The short-petioled leaves are ovate-triangular in shape, 1.5–4 cm long, 0.5–2.5 cm wide, and coarsely toothed. Sticky, glandular hairs are frequently present on the stems and leaves, and Nestler (1896) observed that their secretions often trapped small insects. The axillary flowers of *M. moschatus* var. *moschatus* are funnel-shaped tubes 11–16 mm in length that end in five flaring lobes which are 2–4 mm long and approximately equal in size. The flowers are bright yellow and have red or brown markings in the throat and a cluster of short hairs on the lower lip. Two pairs of unequally-sized anthers are present and the single style ends in a two-lobed stigma. The fruits are ovate capsules 6–8 mm in length. (See Britton and Brown 1913, Grant 1924, Fernald 1950, Gleason and Cronquist 1991, Nesom 2012, Nesom and

Fraga 2020). Throughout its range *Mimulus moschatus* var. *moschatus* flowers from May to August but in New Jersey and Pennsylvania July to August is typical, with fruits developing during August and September (Hough 1983, Rhoads and Block 2007, Nesom 2012).

M. moschatus var. *moschatus* is not closely related to other *Mimulus* species that occur in New Jersey, which have taller, smoother stems and pink, violet, or bluish flowers (Nesom and Fraga 2020, Weakley et al. 2022). In the western United States *Mimulus moschatus* has been known to hybridize with an annual species, *M. floribundus*, producing offspring that are vigorous but sterile (Mukherjee and Vickery 1961).

Pollinator Dynamics

The structure of *Mimulus moschatus* flowers encourages cross-pollination by insects but facilitates self-fertilization in the absence of pollinators. The stigmatic lobes are sensitive and close in response to touch. A pollen-laden insect entering a Muskflower seeking nectar may brush against the stigma and cause it to close so that when it exits carrying pollen from that flower none will be deposited (Kitchener 1873). The stigmas typically reopen after a few minutes (Newcombe 1922).

With the exception of hummingbird-favored species, *Mimulus* flowers are primarily pollinated by bees. Bees known to visit the yellow-flowered species include bumblebees (*Bombus* spp.), mining bees (Andrenidae), sweat bees (Halictidae), mason bees and allies (Megachilidae), and *Apis mellifera*, the honeybee (Kiang 1972, Meineke 1992, Sutherland and Vickery 1993, Roels and Kelly 2011). Both bumblebees and smaller bees have been documented on *Mimulus moschatus* (Carlson 2002, Yoder 2011). Small bees may be the more effective pollinators because they can better access the narrow corolla tubes, and bumblebees have been noted to spend very little time at *Mimulus* flowers (Meinke 1992, Carlson 2002). Toxic alkaloids have been detected in the nectar of *Mimulus moschatus* but their function is not clear: Suggestions by Adler (2000) included inhibition of microbial activity, deterrence of nectar robbers, or manipulation of pollinator behavior.

Mimulus species are generally self-compatible and capable of seed set without the aid of insects (Grant 1924, Carlson 2002). In some instances, the proximity of the anthers and stigma could allow some pollen to be transferred as the flowers move in the wind (Grant 1924). A number of species, including *M. moschatus*, have a deciduous corolla. When a corolla is released from an unpollinated flower the stigma may come into contact with the anthers, which are attached to the floral tube, or with pollen that has become trapped in the hairs that line the tube (Dole 1990, Meinke 1992).

Seed Dispersal and Establishment

The capsules of *Mimulus moschatus* var. *moschatus* contain numerous tiny seeds that are smooth and flat but not winged. The capsules split incompletely along the seams at maturity (Thiselton-Dyer 1899, Grant 1924, Nesom and Fraga 2020). The seeds of similar *Mimulus* species are

released slowly over a long period of time as the wind shakes them free from the partially open capsules. *M. moschatus* has a particularly high seed retention rate because the long, twisting tips of the sepals obstruct the opening in the capsules to some extent and the fruits are often rather sheltered from the wind by the creeping habit of the plants (Meinke 1990).

Farnsworth and Ogurcak (2008) categorized *Mimulus moschatus* as a plant with widely dispersed seeds. Pennell (1920) and Grant (1924) agreed that the broad ranges of the wetland-inhabiting *Mimulus* species were likely due to the transport of seeds that adhered to the muddy feet of birds. Observed dispersal mechanisms for *M. moschatus* seeds have included gravity, wind, and water (Meinke 1990). Studies of *Mimulus guttatus*, which has similar seeds and habitat requirements, found that the seeds were dispersed locally by wind but could be carried for longer distances by flowing water, and that post-consumption dispersal by deer was also an effective means of long-distance distribution (Waser et al. 1982, Vickery et al. 1986).

Mimulus moschatus seeds have no dormancy requirement and are capable of germination upon release (Meinke 1990, Carlson 2002). Experimental work yielded high rates of germination for *M. moschatus* seeds, most of which sprouted within 3–4 weeks of planting. Only a small percentage of the seeds did not germinate until the following spring (Meinke 1990). Although it is not clear how long the propagules can remain viable in the soil, *M. moschatus* seedlings have emerged from litter collected in a mixed conifer forest (Strickler and Edgerton 1976) and from soil samples collected on a gravel bar where no mature plants were present (Harmon and Franklin 1991). *M. moschatus* seeds have been tested for their tolerance of extreme temperature conditions: They remained viable after exposure to intense cold by submersion in liquid hydrogen (Thiselton-Dyer 1899) and at temperatures up to 105ºC (Dixon 1902).

Mimulus moschatus can also be dispersed vegetatively via plant fragments or dislodged rhizomes that are transported to new locations by water (Meinke 1990). The process has also been observed in *M. guttatus*—a study of that species found that the plants fragmented readily when water flow rates were high and even small pieces had a high regenerative capacity (Truscott et al. 2006).

Habitat

Mimulus moschatus var. *moschatus* typically grows in swampy, wet soil at elevations of 300–3100 meters above sea level. Characteristic habitats include seeps, springs, wet swales, gravel bars, and the banks of brooks, streams, or rivers (Hay et al.1884, Macoun 1898, Eames 1909, Pennell 1919, Ferguson 1924, Fernald 1935, Muenscher 1938, Montgomery 1948, Henry 1953, Hough 1983, Rhoads and Block 2007, Nesom and Fraga 2020, Weakley et al. 2022). Most occurrences of *M. moschatus* var. *moschatus* in New Jersey have been found on limestone ledges or cobbled shores in the Delaware River floodplain (NJNHP 2024).

Some sites where the species occurs may dry out during the summer months but others remain wet all year (Meinke 1990). *M. moschatus* is shade-tolerant and it can occur in coniferous or deciduous forests but it has also been found in more open sites such as meadows and grasslands (Fernald 1935, Nesom 2012, Schuller et al. 2021, Tarbill 2022, Orozco 2023). Muskflower has

sometimes been known to colonize disturbed sites including moist trail edges, roadsides, and ditches (Arsène 1947, Bouchard and Hay 1976, Ewing 2001).

Wetland Indicator Status

Mimulus moschatus is an obligate wetland species, meaning that it almost always occurs in wetlands (U. S. Army Corps of Engineers 2020).

USDA Plants Code (USDA, NRCS 2024b)

MIMOM2

Coefficient of Conservancy (Walz et al. 2020)

CoC = 6. Criteria for a value of 6 to 8: Native with a narrow range of ecological tolerances and typically associated with a stable community (Faber-Langendoen 2018).

Distribution and Range

Mimulus moschatus is native to North America but it has been introduced on other continents including parts of South America, Europe, Africa, and Australia (Nesom 2012, POWO 2024). The map in Figure 1 depicts the extent of *M. moschatus* in the United States and Canada. Muskflower was widely cultivated globally during the 1800s (McDonald 1895, Hardy 1934, Nature 1934). The species' discontinuous distribution on the North American continent, along with its popularity as a garden plant, led to the assumption that eastern populations had been introduced from the west where *M. moschatus* was more abundant (eg. Ward 1904). Farwell (1915) put forth the alternate hypothesis that Muskflower was once more widespread but populations in the central part of the continent had been destroyed during the last glacial period. A number of botanists concluded that at least some eastern occurrences were indigenous based on the locations where the plants were growing (Macoun 1898, Pennell 1919, Fernald 1935) but other populations were evidently introduced (Arsène 1947, Montgomery 1948, Brumback and Mehrhoff 1996). The status of eastern *M. moschatus* populations remains unresolved and the likelihood that a given occurrence is native is often evaluated based on where it is found (Ewing 2001, Weakley et al. 2022).

The USDA PLANTS Database (2024b) shows records of *Mimulus moschatus* var. *moschatus* in three New Jersey counties: Hunterdon, Sussex, and Warren (Figure 2). The data include historic observations and do not reflect the current distribution of the species.

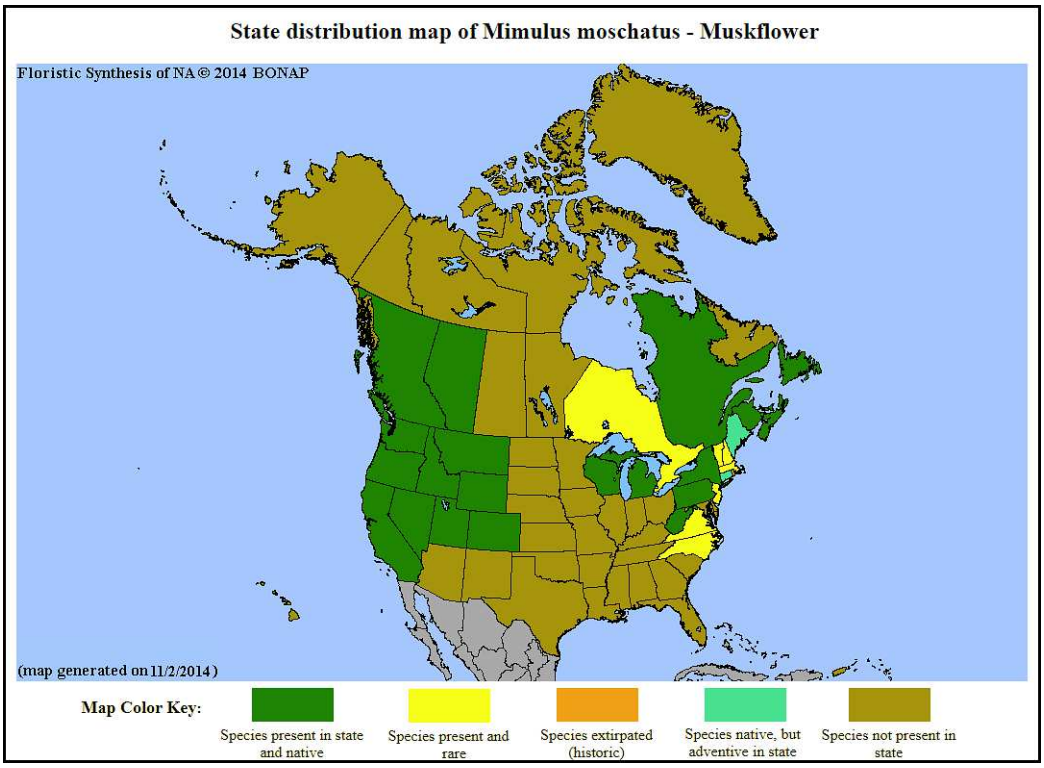


Figure 1. Distribution of M. moschatus in North America, adapted from BONAP (Kartesz 2015).

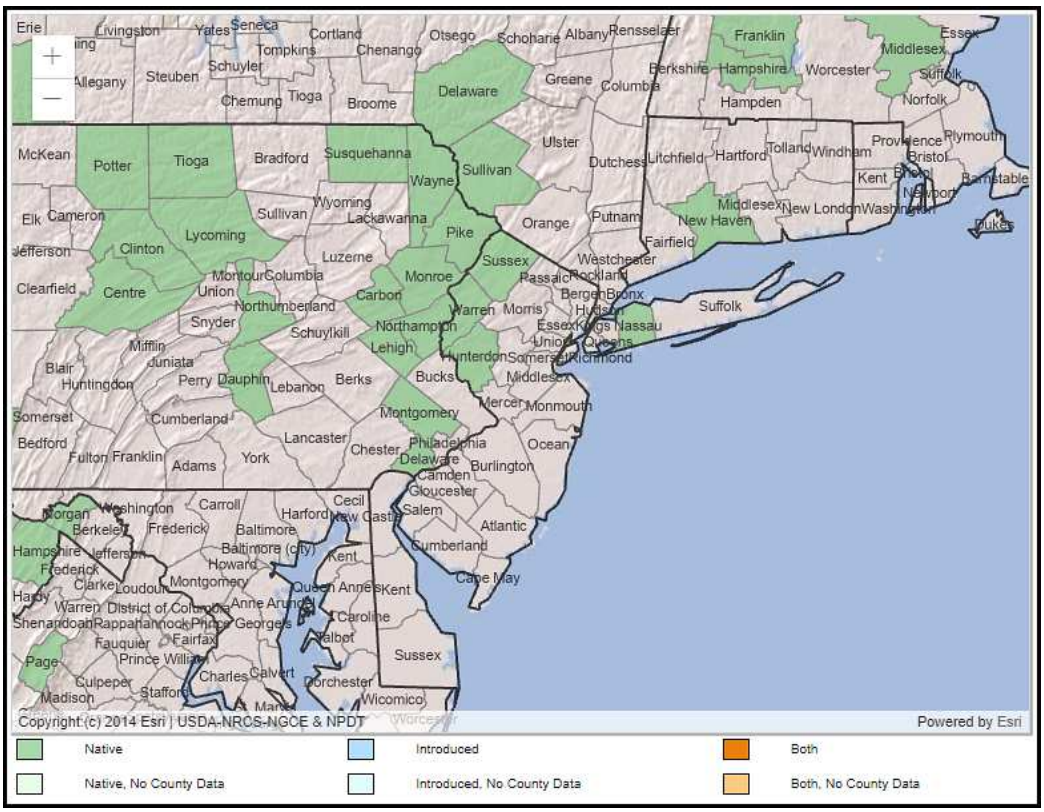


Figure 2. County records of M. moschatus var. moschatus in New Jersey and vicinity (USDA NRCS 2024b).

Conservation Status

NatureServe (2024) recognizes Muskflower as *Erythranthe moschata* (see Synonyms and Taxonomy section). *E. moschata* is considered globally secure. The G5 rank means the species has a very low risk of extinction or collapse due to a very extensive range, abundant populations or occurrences, and little to no concern from declines or threats. The map below (Figure 3) illustrates the conservation status of *E. moschata* in the United States and Canada, showing it as secure in British Columbia, vulnerable (moderate risk of extinction) in Vermont and Wyoming, critically imperiled (very high risk of extinction) in Ontario, possibly extirpated in Virginia, and exotic in provinces east of Ontario. The absence of information for many districts where *E. moschata* is known to occur is likely due to the species being listed under a different name in those provinces or states. In the North Atlantic region, which includes four Canadian provinces and twelve U. S. states, *Mimulus moschatus* was classified as likely to be high conservation priority but currently unrankable (Frances 2017).

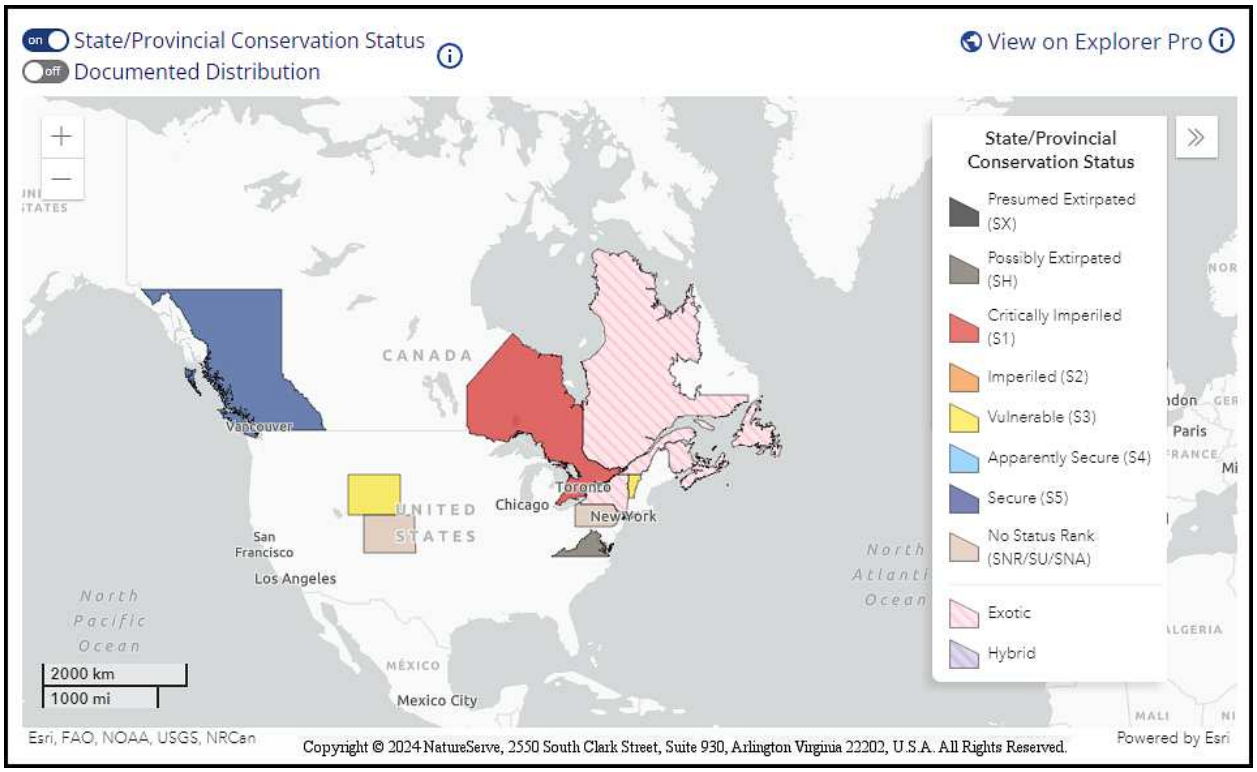


Figure 3. Conservation status of M. moschatus var. moschatus in North America (NatureServe 2024). See text regarding gaps in data.

Mimulus moschatus var. *moschatus* is critically imperiled (S1) in New Jersey (NJNHP 2024). The rank signifies five or fewer occurrences in the state. A species with an S1 rank is typically either restricted to specialized habitats, geographically limited to a small area of the state, or significantly reduced in number from its previous status. Muskflower has also been assigned a regional status code of HL, signifying that the species is eligible for protection under the jurisdiction of the Highlands Preservation Area (NJNHP 2010).

Mimulus moschatus was not included in any of New Jersey's early floras and the first collections in the state were made during the 1950s. The three populations documented during that period are now ranked as historical. Hough (1983) reported relatively recent records from three counties, but the majority of known sites were discovered after the publication of her book. Although nine occurrences are tracked as potentially extant by the Natural Heritage Program, four of those were tiny (2–4 plants) when last seen and have not been revisited in over 30 years. The monitoring of three other populations during 2021 and 2022 produced discouraging results, with a single Muskflower plant remaining at one site and no plants found at two other locations—including one that had been noted as the most vigorous colony in the state a decade earlier (NJNHP 2024).

Threats

Invasive, non-native plants pose a significant threat to *Mimulus moschatus* var. *moschatus* in New Jersey and their overabundance may have already eliminated some occurrences (NJNHP 2024). Ewing (2001) reported both invasive plants and natural succession as threats to the species in New England, noting that *M. moschatus* was not a strong competitor. Data collected by Tarbill (2022) during an evaluation of the impact of fire on pollinator communities showed that *Mimulus moschatus* was particularly abundant in meadow and upland sites that had experienced severe fires during the previous few years but scarce in comparable habitats that were unburned. Proliferation of the Muskflower following the fires was probably due to the removal of more competitive plant species.

Purple Loosestrife (*Lythrum salicaria*) was first noted as a concern at a number of New Jersey's *Mimulus moschatus* var. *moschatus* sites 25–35 years ago (NJNHP 2024). In some locations along the Delaware River, biological controls have been an effective means of keeping the loosestrife in check (USNPS 2022). However, recent records indicate that *L. salicaria* is still present in a number of communities where *M. moschatus* var. *moschatus* has been found. Other equally aggressive exotic species that have become troublesome at multiple Muskflower sites include *Artemisia vulgaris*, *Reynoutria japonica*, and *Rosa multiflora*. Vines such as *Celastrus orbiculatus* and *Lonicera japonica* have also contributed to the problem and at one location an introduced stonecrop (*Sedum sarmentosum*) has become dominant on the limestone ledges. In some instances, the dense growth of invasive plants has made shoreline habitats nearly impenetrable (NJNHP 2024). Other non-indigenous species that were identified as threats to *M. moschatus* populations in New England included *Berberis thunbergii* and *Tussilago farfara* (Ewing 2001, Farnsworth 2004).

A secondary threat to *Mimulus moschatus* var. *moschatus* noted at two New Jersey sites was the potential for inadvertent destruction of the plants during the course of recreational activities along the river, particularly as a result of foot traffic or canoe transport (NJNHP 2024). There are a number of additional factors that may sometimes take a toll on plant vigor or reproduction, especially in small or otherwise vulnerable populations. *Mimulus moschatus* is susceptible to an assortment of widespread phytoviruses including tobacco necrosis virus, tobacco ringspot virus, tomato ringspot virus, cucumber mosaic virus, and alfalfa mosaic virus (Price 1940). *M. moschatus* is also utilized as a food plant by the larvae of *Annaphila miona*, an owlet moth

(Henne 1967), and while *A. miona* is a western species there could be a related moth in the east that also feeds on the plants. However, the glandular hairs of *M. moschata* can help to protect the plants from some invertebrate herbivores: The small insects that become trapped in the plant's sticky hairs attract insectivorous predators that subsequently remain nearby and reduce damage to the plants (LoPresti et al. 2015).

A new area for concern was reported following a recent study using a similar species, *Erythranthe lutea (*aka *Mimulus luteus*), in South America. Microplastics transported on the bodies of bees can adhere to floral stigmas, and the synthetic materials have the potential to decrease the reproductive success of plants by limiting pollen adhesion or impeding the development of pollen tubes (Carvallo and Muñoz-Michea 2023).

Climate Change Vulnerability

Information from the references cited in this profile was used to evaluate the vulnerability of New Jersey's *Mimulus moschatus* var. *moschatus* populations to climate change. The species was assigned a rank from NatureServe's Climate Change Vulnerability Index using the associated tool (Version 3.02) to estimate its exposure, sensitivity, and adaptive capacity to changing climactic conditions in accordance with the guidelines described by Young et al. (2016) and state climactic computations by Ring et al. (2013). Based on available data *M. moschatus* was assessed as Moderately Vulnerable, meaning that it is likely to show some decrease in abundance or range extent in New Jersey by 2050.

As a result of global warming, New Jersey is experiencing higher temperatures and shifting precipitation patterns which are increasing the frequency and intensity of both droughts and floods in the region (Hill et al. 2020). *Mimulus moschatus* var. *moschatus* may be able to adapt to higher temperatures during the growing season by modifying its phenology: A study in Massachusetts indicated that the species has recently been blooming about two weeks earlier than it did prior to 1980 (Bertin et al. 2017). However, winter temperatures are rising even more rapidly in the region (Hill et al. 2020) and that is having a significant effect on the habitats utilized by *M. moschatus* in New Jersey. Limestone ledge communities along the Delaware River have historically been maintained by ice scour. As large chunks of ice were transported down the river by spring snowmelt, most woody species would be scraped off of the rocks but herbaceous plants growing in the crevices could rapidly regenerate from buried rootstocks and seeds (Gawler 2006, Sneddon 2010, USNPS 2022). Much of the snowmelt and ice originated upstream in New York, where the winters are now warming three times faster than the summers (NYDEC 2023). As scouring events have decreased in frequency, both native and invasive species that previously could not become well-established in the communities have been able to gain a foothold (USNPS 2022).

Although winter floods and ice scour are decreasing, floods during the summer and fall months are becoming more frequent. Over a decade ago it was predicted that flooding events in the Delaware Basin could increase in both frequency and magnitude as a result of climate warming (Schopp and Firda 2008, UDS 2008). Some of the *Mimulus moschatus* var. *moschatus* occurrences in New Jersey were submerged during a part the growing season for several

consecutive years (NJNHP 2024). Depending on when they take place, floods may dislodge plants or interfere with reproduction. Extended droughts could be equally harmful: *M. moschatus* is often found in seepage areas and long-term changes in hydrology might threaten the populations (NJNHP 2024). Muskflower is particularly susceptible to drought stress during the seedling stage (Meinke 1990).

Management Summary and Recommendations

Ewing (2001) suggested that the native status of eastern Muskflower populations should be clarified prior to the implementation of costly conservation plans. However, the river scour communities utilized by *Mimulus moschatus* var. *moschatus* in New Jersey are relatively rare and have been known to support other species of concern in the state (Sneddon 2010, NJNHP 2024). Some management activities have already been initiated in order to protect the sites. For example, biological controls were employed to reduce the spread of *Lythrum salicaria* and invasive shrub species were removed from selected sites by hand (USNPS 2022).

Roughly two thirds of the potentially extant populations of *Mimulus moschatus* in New Jersey are in need of updated assessments to evaluate both population status and habitat conditions. It seems likely that some site-specific management plans will be needed in order to preserve remaining occurrences and invasive species control will probably be the focus at most locations. Suitable habitat may still be present in the vicinity of the three historical occurrences so searches of those sites could contribute to a more comprehensive understanding of Muskflower's present status in the state.

Synonyms and Taxonomy

The accepted botanical name of the species is *Mimulus moschatus* Douglas ex Lindl. var. *moschatus*. Orthographic variants, synonyms, and common names are listed below (ITIS 2024, POWO 2024, USDA NRCS 2024b). Historically *Mimulus* was a large genus and numerous proposals were put forth to move some of the species into other genera or to establish subsections based on different morphological features, but efforts to achieve a satisfactory system were hampered by overlapping characteristics and species that appeared to be polymorphic (Grant 1924). Over the years, *Mimulus moschatus* has been treated as a single species with multiple varieties or viewed as a species complex. More recently, genetic investigations revealed that neither the genus *Mimulus* nor the *M. moschatus* complex were monophyletic, necessitating significant revisions (Beardsley and Olmstead 2002, Whittall et al. 2006). The work was undertaken by Nesom (2012) and resulted in the transfer of some former *Mimulus* species, including *M. moschatus*, to *Erythranthe*. *Erythranthe* was further divided into sections, with *M. moschatus* assigned to section *Mimulosma*. Two other species that occur in New Jersey, *M. alatus* and *M. ringens*, remained in *Mimulus*. Under Nesom's system, *Mimulus moschatus* var. *moschatus* was recognized as *Erythranthe moschata*, and the remaining varieties were listed as synonyms of other *Erythranthe* species (Nesom 2012 & 2017; Barker et al. 2012). Names in current use for the subject of this profile are *Mimulus moschatus* (Kartesz 2015),

Mimulus moschatus var. *moschatus* (ITIS 2024, USDA NRCS 2024b), and *Erythranthe moschata* (Weakley et al. 2022, NatureServe 2024, POWO 2024).

Botanical Synonyms	**Common Names**
Erythranthe moschata (Douglas ex Lindl.) G. L. Nesom	Muskflower
Erythranthe inodora (Greene) G. L. Nesom	Musky Monkey-flower
Erythranthe moniliformis (Greene) G. L. Nesom	
Mimulus crinitus A. L. Grant	
Mimulus dentatus var. *gracilis* A. Gray	
Mimulus guttatus var. *moschatus* (Douglas ex Lindl.) Prov.	
Mimulus inodorus Greene	
Mimulus leibergii A. L. Grant	
Mimulus macranthus Pennell	
Mimulus moniliformis Greene	
Mimulus moschatus var. *longiflorus* A. Gray	
Mimulus moschatus var. *moniliformis* (Greene) Munz	
Mimulus moschatus var. *pallidiflorus* Suksd.	

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