Arabis drummondii

Drummond's Rockcress

Brassicaceae

Arabis drummondii by Peter M. Dziuk, 2017

Arabis drummondii Rare Plant Profile

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

501 E. State St.
PO Box 420
Trenton, NJ 08625-0420

Prepared by:
Jill S. Dodds
jsdodds@biostarassociates.com

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For:
New Jersey Department of Environmental Protection
Office of Natural Lands Management
New Jersey Natural Heritage Program
natlands@dep.nj.gov

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Life History

Arabis drummondii (Drummond's Rockcress) is an herbaceous member of the Brassicaceae with a distribution that extends from coast to coast in North America. Eastern plants have a biennial life cycle but the species is a short-lived perennial in the western part of its range (Hopkins 1937). The basal leaves are narrowly oblanceolate and 2–8 cm long: They may be entire or toothed. Mature plants usually produce a single stem from the center of the basal rosette. The stems are typically 3–9 dm high and the stem leaves are alternate, oblong, erect, clasping, and lobed at the base. The inflorescence is an unbranched raceme of 8–35+ flowers that are 7–10 mm long and are held on slender, erect pedicels. The four petals are normally white to lavender. Vaidya et al. (2018) found that about 80% of individual flowers were white but the remaining 20% were pink, lavender or dark purple and noted that the extent of pigmentation could vary within a plant. *A. drummondii* fruits are siliques (flattened narrow pods) that are 4–10 cm long, 1.5–2.5 mm wide, and have their seeds arranged in two rows. Like the flowers, the siliques are held erect on the pedicels. (See Britton and Brown 1913, Fernald 1903 and 1950, Hopkins 1937, Rollins 1941 and 1993, Gleason and Cronquist 1991, Al-Shehbaz and Windham 2020, Weakley et al. 2022).

Left: Britton and Brown 1913, courtesy USDA NRCS 2023a. Center and Right: Peter M. Dziuk, 2017.

Hough (1983) indicated that, in New Jersey, *Arabis drummondii* blooms from late May to late June and fruit may be found from May to late August. Notes from monitoring of New Jersey plants during the past 20 years indicate that flowering and fruiting have been starting in April (NJNHP 2022). Hopkins (1937) reported that the species is always in mature fruit by early June. Flowering time in *A. drummondii* is highly responsive to changes in environmental conditions including temperature, length of winter, soil microbes, and abiotic properties of soils (Anderson et al. 2010, Wagner et al. 2014).

In the eastern part of its range *Arabis drummondii* plants are often glabrous but western plants are likely to have short, stiff hairs on the basal leaves. However, pubescence in *A. drummondii*

and other *Arabis* species can vary considerably depending on the environment, the season, and the age of the plants (Rollins 1941). Drummond's Rockcress also exhibits notable chromosomal variability—the species contains diploid, triploid, and tetraploid races (Mulligan 1995). Al-Shehbaz and Windham (2020) described *A. drummondii* as promiscuous because it has been known to hybridize with at least fifteen other species.

Pollinator Dynamics

Blooming plants in the genus *Arabis* are visited by numerous bee species and an assortment of flies (Robertson 1929, Stubbs et al. 1992). The Mustard Miner Bee (*Andrena arabis*) is a pollen specialist that flies during spring and favors *Arabis* and *Cardamine* flowers (Fowler 2016). The solitary bee occurs in the northeastern, mid-Atlantic, and Great Lakes regions (NatureServe 2023).

Arabis drummondii is not reliant on insects for fertilization because it is primarily self-pollinated. The flowers typically deposit their own pollen on the stigmas as the buds open, and although outcrossing can also occur it is rare in the species (Roy 1995). Due to the paucity of cross-fertilization, genetic variation is limited in most populations of *A. drummondii* (Anderson et al. 2015, Colautti et al. 2017). Apomixis (asexual seed formation) has also been documented in the species (Rojek et al. 2018), and the plants that develop from unfertilized ovules are essentially maternal clones.

Seed Dispersal

Vegetative reproduction has not been reported for *Arabis drummondii* (USDA NRCS 2013b) so seeds are necessary for population maintenance. *A. drummondii* flowers have 110–216 ovules per ovary, and the plants are thus capable of producing numerous seeds (Al-Shehbaz and Windham 2020). Colautti et al. (2017) noted a lack of obvious adaptations for dispersal in the species, although wings are present on the small seeds. According to Rollins (1941), *A. drummondii* seeds are "prominently winged on distal end and on one side, narrowly winged or wingless on the other side." Wings on seeds can facilitate transport by wind (Howe and Smallwood 1982). Nevertheless, poor dispersal has been cited as one of the factors restricting gene flow between populations of Drummond's Rockcress (Anderson et al. 2015).

Dispersal in a related rockcress (*Arabis laevigata*) was studied by Bloom et al. (2002). In that species, distribution began immediately following seed maturation but continued as long as the dry culms remained erect, in some cases for up to 2.5 years. About half of the seeds from one growing season were dispersed by the third week of September and 92% had been released by early March of the following year. The majority of *A. laevigata* seeds fell within a half meter of the parent plants.

Seeds of *Arabis*, as well as those of many other genera in the Brassicaceae, require a period of drying in order to germinate (Deno 1993). Deno found that various species of *Arabis* germinated within 2–4 weeks after a period of three months in dry storage. *Arabis drummondii* seeds that

were planted outdoors in October germinated the following April and May (Johnson 2014). However, *A. drummondii* seeds can also remain viable for some time in the soil. The species emerged from seed bank samples taken in a number of western communities, in one instance originating at a site where the rockcress was not present in the extant vegetation (Clark 1991).

Habitat

Arabis drummondii has been reported from a variety of habitats. In the eastern part of its range typical sites are well-drained and have basic or circumneutral soils. Examples include rocky woodlands, thickets, dry ledges and cliffs, sandy or rocky river banks, open fields, and open dunes (Hopkins 1937, Fairbrothers and Hough 1973, Hough 1983, Weakley et al. 2022). In New Jersey, Drummond's Rockcress is known from back dune thickets dominated by Beach Plum (*Prunus maritima*) and Eastern Red Cedar (*Juniperus virginiana*) (NJNHP 2022).

In the west, *Arabis drummondii* is found at elevations up to 3900 meters on rocky or gravelly soils. Noted habitats include open conifer and hardwood forests, sagebrush and mountain shrub communities, and alpine meadows (Mitchell-Olds 2001, Al-Shehbaz and Windham 2020). Siemens et al. (2003) noted that *A. drummondii* frequently occurred in very dense grassy subalpine meadows. The rockcress appears to be tolerant of competition, as its growth was not affected by the presence of a graminoid species (*Bouteloua gracilis*) that was used to test its competitive responses (Jones et al. 2006). Rollins (1941) suggested that *A. drummondii* was more 'aggressive' in the western United States, indicating that the species was "quick to inhabit disturbed soils, where it becomes abnormally large and vigorous."

Clark (1991) identified some specific communities in Greater Yellowstone ecosystem that supported *Arabis drummondii* including *Pseudotsuga menziesii*/*Symphoricarpos albus*, *Artemisia tridentata/Festuca idahoensis*, and *Festuca ovina/Poa alpina* associations. Viable propagules were also retrieved from the seed bank of an *Abies lasiocarpa/Calamagrostis rubescens* community, although *A. drummondii* was not present in the vegetation at the site.

As a species, *Arabis drummondii* appears to be highly plastic in its response to varying environmental characteristics (Anderson et al. 2012, Wagner et al. 2014) which may explain its presence in diverse habitats. Once established, however, limited gene flow results in local populations that are well-adapted to a specific set of conditions (Anderson et al. 2015).

Wetland Indicator Status

Arabis drummondii is a facultative upland species, meaning that it usually occurs in nonwetlands but may occur in wetlands (U. S. Army Corps of Engineers 2020).

USDA Plants Code (USDA, NRCS 2023b)

ARDR

Coefficient of Conservatism (Walz et al. 2018)

CoC = 9. Criteria for a value of 9 to 10: Native with a narrow range of ecological tolerances, high fidelity to particular habitat conditions, and sensitive to anthropogenic disturbance (Faber-Langendoen 2018).

Distribution and Range

The global range of *Arabis drummondii* is restricted to Canada and the United States (POWO 2023). The map in Figure 1 depicts the extent of Drummond's Rockcress in the United States and Canada, although New Jersey has been omitted.

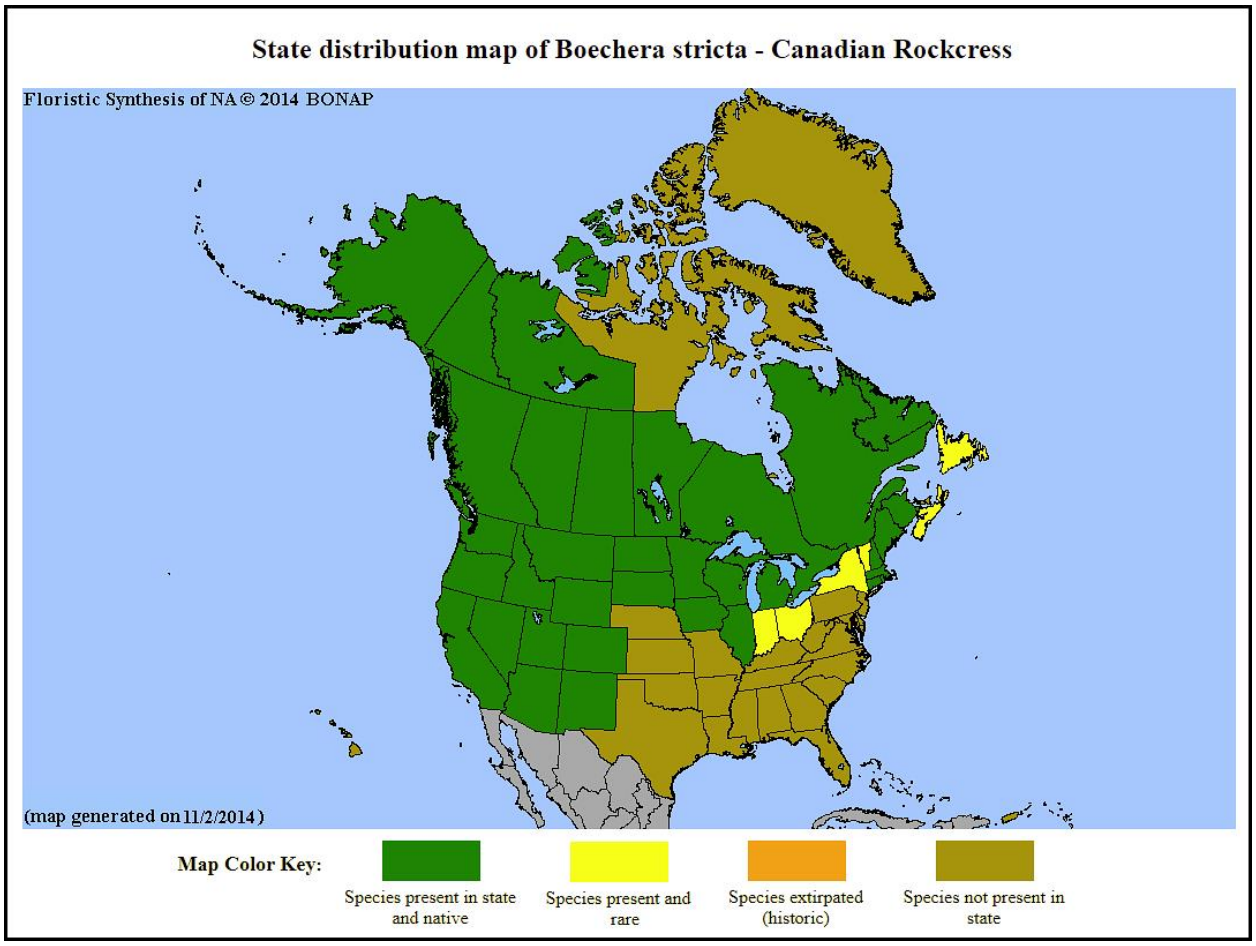

Figure 1. Distribution of A. drummondii in North America, adapted from BONAP (Kartesz 2015).

The USDA PLANTS Database (2023b) shows records of *Arabis drummondii* in one New Jersey county: Cape May (Figure 2 below). The record reflects the current known distribution of the species in the state.

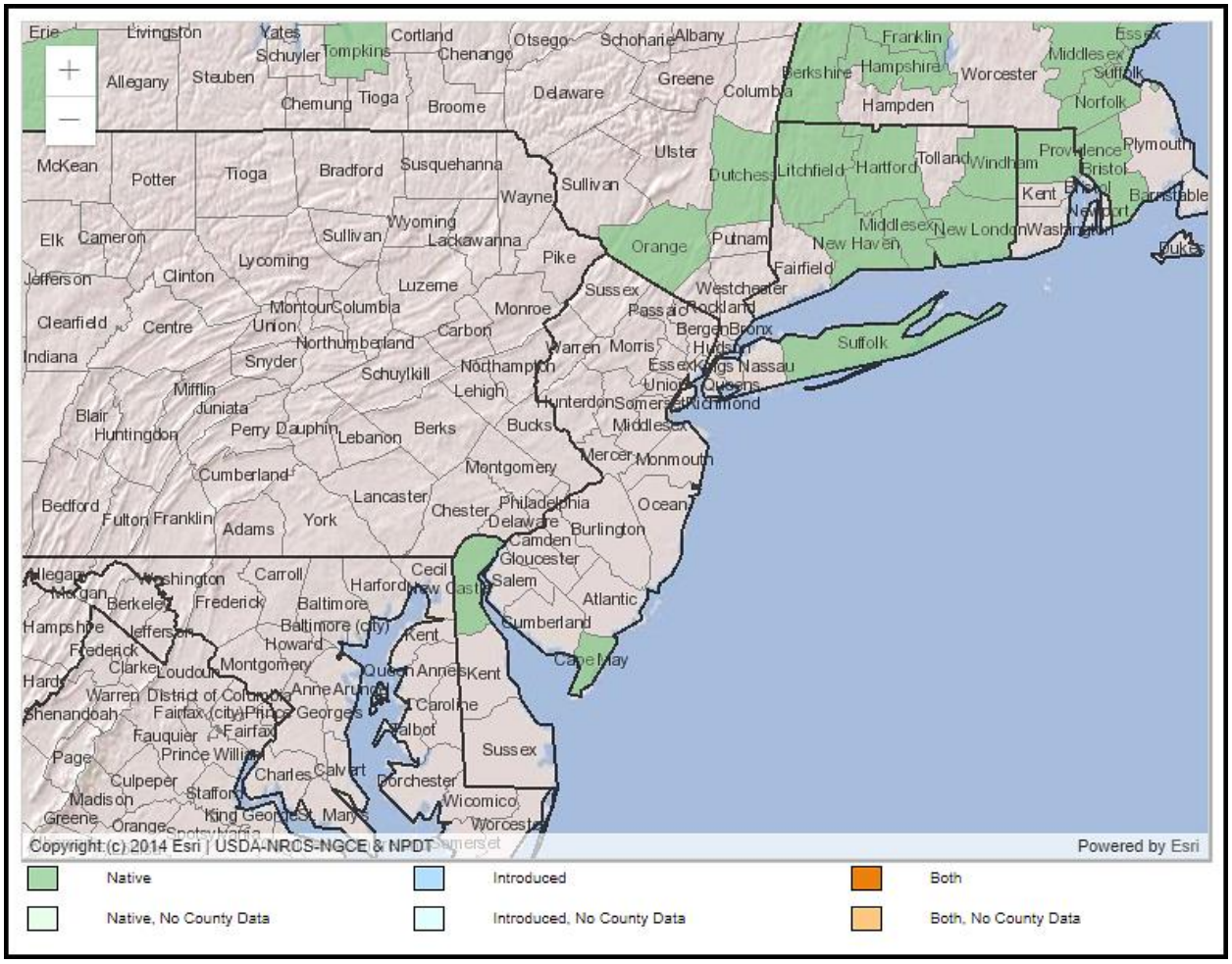

Figure 2. County records of A. drummondii in New Jersey and vicinity (USDA NRCS 2023b).

Conservation Status

Arabis drummondii is presently unranked globally (GNR) due to some outstanding taxonomic questions (NatureServe 2023, see Synonyms section). The map below (Figure 3) illustrates the conservation status of Drummond's Rockcress throughout its range. The species is shown as critically imperiled (very high risk of extinction) in three states, imperiled (high risk of extinction) in two states and two provinces, and vulnerable (moderate risk of extinction) in two provinces. The rockcress is secure, apparently secure, or unranked elsewhere in its range.

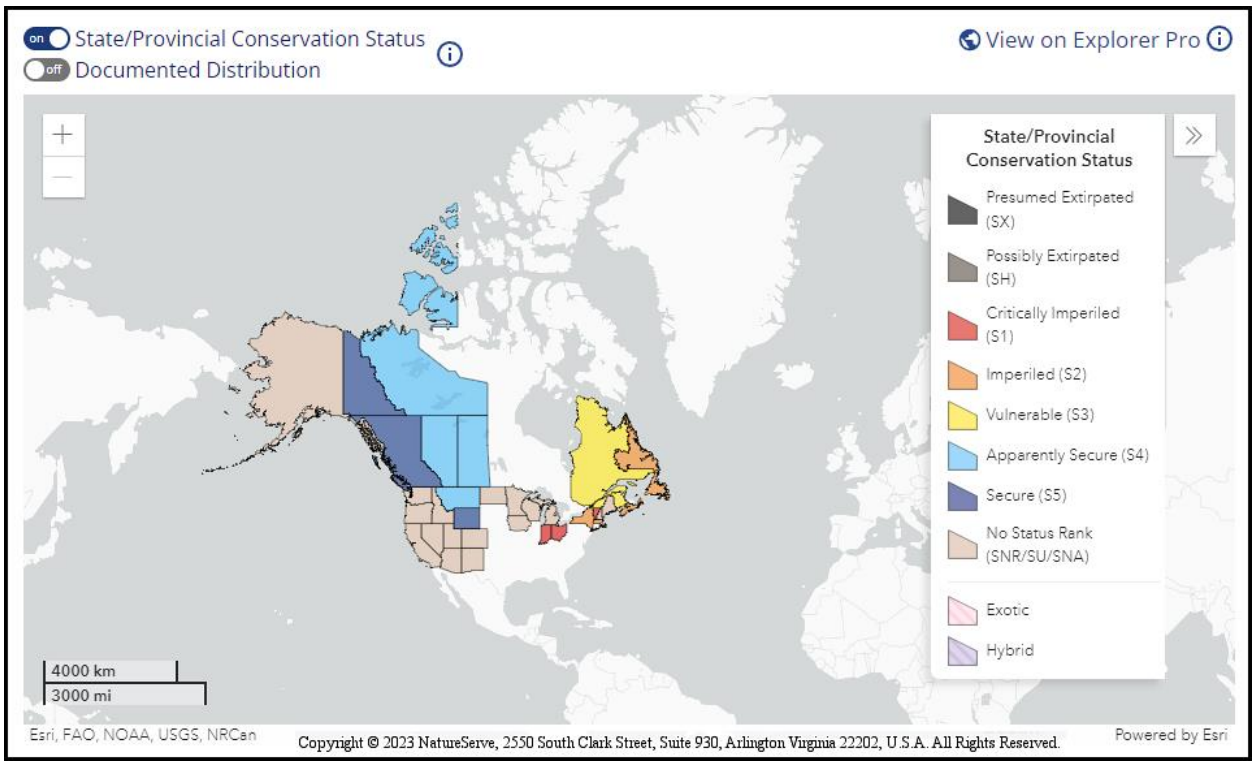

Figure 3. Conservation status of A. drummondii in North America (NatureServe 2023).

Although it is not included on the above map, *Arabis drummondii* is also critically imperiled in New Jersey. The state rank is S1.1 (NJNHP 2022), signifying that it is has only been documented at a single location in the state. *Arabis drummondii* is listed as an endangered species (E) in New Jersey, meaning that without intervention it has a high likelihood of extinction in the state. Although the presence of endangered flora may restrict development in certain communities, being listed does not currently provide broad statewide protection for plants. Additional regional status codes assigned to *A. drummondii* indicate that the species is eligible for protection under the jurisdictions of the Highlands Preservation Area (HL) and the New Jersey Pinelands (LP) (NJNHP 2010).

Arabis drummondii was collected from a single site in southern New Jersey several times between the 1880s and the 1920s, but after that it was not documented for nearly half a century (NJNHP 2022). The site was relocated by Vincent Abraitys in 1972 (Snyder 1984) and *A. drummondii* was cataloged as an endangered species in the state the following year (Fairbrothers and Hough 1973). Although that remains the only known occurrence of Drummond's Rockcress in New Jersey, more than 130 years after the population was first recorded the plants were still noted to be abundant at the site and flowering vigorously (NJNHP 2022).

Threats

Arabis drummondii is susceptible to a rust fungus that interferes with reproduction. *Puccinia monoica* inhibits flowering in its host plants (*Arabis* species), instead producing pseudoflowers that entice insects to spread its own spores. The primary fungal host of *P. monoica* is a grass: In

the case of *A. drummondii* the documented host graminoid is *Trisetum spicatum*. Wind-borne spores produced on the grass infect rockcress plants during the late summer, resulting in the development of pseudoflowers the following spring. Pseudoflowers on *Arabis* hosts mimic the flowers of unrelated plant species in shape, size, color and reward production, and those on *A. drummondii* strongly resemble the true flowers of *Ranunculus inamoenus* which often co-occurs with the rockcress (Roy 1993, 1994). To date the fungus has only been reported in western populations of Drummond's Rockcress, and Arthur (1920) indicated that Wisconsin and Ontario marked the eastern boundary of the range of *P. monoica*. Nevertheless, *Trisetum spicatum*—the alternate host—can be found in eastern North America (Kartesz 2015) so the fungus could spread farther. At least four additional graminoid genera are known to serve as intermediate hosts for *Puccinia monoica* and for some other closely related rust fungi that also infect *Arabis* species (Roy et al. 1998).

Plants in the Brassicaceae produce glucosinolates (mustard oils) which provide some protection from herbivores, although certain insects have developed mechanisms to break down the compounds (Bohinc et al. 2012). *Arabis drummondii* is one of the host plants for the larvae of the Olympia Marble (*Euchloe olympia*), and the rockcress also serves as a food plant for several other butterflies in the genus *Pieris* (Chew 1977, Parshall 2002). Chew (1975) observed that the larvae of *Pieris* species develop more slowly on *A. drummondii* than on some other plants in the mustard family. Both specialist (*Plutella xylostella*) and generalist (*Trichoplusia ni*) moths also feed on *A. drummondii*, and other insects known to eat *Arabis* foliage include grasshoppers, flea beetles, leaf beetles and weevils (Jones et al. 2006). Leaf herbivory alone is unlikely to threaten the species although it might be expected to contribute to a decrease in plant vigor, particularly in combination with other pressures. However, Siemens et al. (2003) found that *Arabis drummondii* plants which were growing in a competitive environment did not pay a higher price for resistance to herbivory. Drummond's Rockcress can increase the production of glucosinolates in response to both competition or herbivory (Jones et al. 2006). Vaida et al. (2018) found that drought-stressed *A. drummondii* plants developed a greater proportion of pigmented flowers, and that purple-flowered plants were less likely to experience leaf herbivory than those with white flowers. Thus the species may have a single systemic defensive response that limits the cumulative effect of multiple stresses.

New Jersey's coastal communities are already experiencing increasing rates of tidal flooding and sea levels are rising faster in the region than in other parts of the world (Hill et al. 2020). *Because Arabis drummondii* is intolerant of salinity (USDA NRCS 2023b), sea level rise poses a significant threat to the state's only occurrence of the rockcress. Although other potential effects of climate change have been extensively studied in western populations of *A. drummondii* the range-wide extent of the threat from shifting conditions is less clear. Drummond's Rockcress germinates earlier at warmer temperatures (Johnson 2014) and flowering time in the species advanced by 3.4 days per decade between 1973 and 2012 (Anderson et al. 2012). While synchronicity with pollinators is not a significant concern for the species due to the prevalence of self-fertilization, changes in developmental trajectory that result from elevated temperatures could reduce the viability of populations in other ways (Colautti et al. 2017). *Arabis drummondii* has demonstrated a great deal of plasticity in response to stresses ranging from herbivory to changes in local environmental conditions (Manzaneda et al. 2010, Anderson et al. 2012 and 2015, Wagner and Mitchell-Olds 2018) which indicates a good potential for adaptation to

climactic shifts at the species level. However, limited genetic variability has resulted in genotypes that are highly adapted to local conditions (Anderson et al. 2010, Johnson 2014, Bemmels et al. 2019, Hamaan et al. 2021) and that could result in greater vulnerability for individual populations if the plants' responses cannot keep up with the rate of climate change.

Management Summary and Recommendations

No specific short-term threats have been identified for the New Jersey population of *Arabis drummondii*, which has apparently remained stable at a single location for over a century (NJNHP 2022). However, database records indicate that the population was last monitored a decade ago. The occurrence is likely to be particularly vulnerable because it is isolated and it is situated at the extreme southeastern edge of the species' range. More frequent monitoring may be needed to update viability assessments and identify emerging threats. Longer-term planning is also required in order to maintain the presence of *A. drummondii* in New Jersey and to conserve the genotype of the state's isolated population. As the occurrence is increasingly threatened by rising tides, consideration should be given to establishing a new population at a more secure location using seeds from the extant plants.

Many studies of *Arabis drummondii* have taken place in the western United States where the species is apparently secure but information is lacking in the east where it is more vulnerable (see map in Figure 3). As there are still some unanswered questions regarding the boundaries between *A. drummondii* and other closely related species (see below), information obtained from research on western populations cannot be applied with absolute confidence to occurrences in other parts of North America. A closer look at *A. drummondii* populations in eastern parts of Canada and the United States may shed some light on why the species is more imperiled in that region.

Synonyms

The accepted botanical name of the species is *Arabis drummondii* A. Gray. Orthographic variants, synonyms, and common names are listed below (ITIS 2023, POWO 2023, USDA NRCS 2023b). Al-Shehbaz (2003) reclassified the species as *Boechera stricta* and a number of sources apply that name including Kartesz (2015), Al-Shehbaz and Windham (2020), Weakley et al. 2022, and ITIS (2023). However, a subsequent revision by Windham and Al-Shehbaz (2007) indicated that *Boechera stricta* only includes part of what used to be considered *Arabis drummondii*, so the two cannot be strictly equated (NatureServe 2023).

Botanical Synonyms	**Common Names**
Arabis albertina Greene	Drummond's Rockcress
Arabis brachycarpa (Torr. & A. Gray) Britton	Canadian Rockcress
Arabis connexa Greene	
Arabis confinis S. Watson	
Arabis drummondii var. *connexa* (Greene) Fernald	

Arabis drummondii var. *oxyphylla* (Greene) M. Hopkins
Arabis oxyphylla Greene
Boechera angustifolia (Nutt.) Dorn
Boechera brachycarpa (Torr. & A. Gray) Dorn
Boechera drummondii (A. Gray) Á. Löve & D. Löve
Boechera stricta (Graham) Al-Shehbaz
Erysimum drummondii (A. Gray) Kuntze
Streptanthus angustifolius Nutt.
Turritis drummondii (A. Gray) Lunell
Turritis spathulata Nutt.
Turritis stricta var. *brachycarpa* Alph. Wood

References

Al-Shehbaz, Ihsan A. 2003. Transfer of most North American species of *Arabis* to *Boechera* (Brassicaceae). Novon 13: 381–391.

Al-Shehbaz, Ihsan and Michael D. Windham. Page updated November 5, 2020. *Boechera stricta* (Graham) Al-Shehbaz. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico [Online]. 22+ vols. New York and Oxford. Accessed January 13, 2023 at http://floranorthamerica.org/Boechera_stricta

Anderson, Jill T., Cheng-Ruei Lee, and Thomas Mitchell-Olds. 2010. Life history QTLs and natural selection on flowering time in *Boechera stricta*, a perennial relative of *Arabidopsis*. Evolution 2011: 771–787.

Anderson, Jill T., David W. Inouye, Amy M. McKinney, Robert I. Colautti, and Tom Mitchell-Olds. 2012. Phenotypic plasticity and adaptive evolution contribute to advancing flowering phenology in response to climate change. Proceedings of the Royal Society B: doi:10.1098/rspb.2012.

Anderson, Jill T., Nadeesha Perera, Bashira Chowdhury, and Thomas Mitchell-Olds. 2015. Microgeographic patterns of genetic divergence and adaptation across environmental gradients in *Boechera stricta* (Brassicaceae). The American Naturalist 186(S1): https://doi.org/10.1086/682404

Arthur, Joseph Charles. 1920. North American Flora 7(4): 269–336.

Bemmels, Jordan B. and Jill T. Anderson. 2019. Climate change shifts natural selection and the adaptive potential of the perennial forb *Boechera stricta* in the Rocky Mountains. Evolution 73(11): 2247–2262.

Bloom, Thomas C., Jerry M. Baskin, and Carol C. Baskin. 2002. Ecological life history of the facultative woodland biennial *Arabis laevigata* variety *laevigata* (Brassicaceae): Seed dispersal. Journal of the Torrey Botanical Society 129(1): 21–28.

Bohinc, Tanja, Smiljana Goreta Ban, D. Ban, and S. Trdan. 2012. Glucosinolates in plant protection strategies: A review. Archives of Biological Sciences 64(3): 821–828.

Britton, N. L. and A. Brown. 1913. An Illustrated Flora of the Northern United States and Canada in three volumes: Volume II (Amaranth to Polypremum). Second Edition. Reissued (unabridged and unaltered) in 1970 by Dover Publications, New York, NY. 735 pp.

Chew, Frances S. 1975. Coevolution of Pierid butterflies and their cruciferous foodplants. I. The relative quality of available resources. Oecologia 20: 117–127.

Chew, Frances S. 1977. Coevolution of Pierid butterflies and their cruciferous foodplants. II. The distribution of eggs on potential foodplants. Evolution 31(3): 568–579.

Clark, David Lee. 1991. The effect of fire on Yellowstone ecosystem seed banks. Master's Thesis, Montana State University, Bozeman, MT. 115 pp.

Colautti, Robert I., Jon Ågren, and Jill T. Anderson. 2017. Phenological shifts of native and invasive species under climate change: Insights from the *Boechera–Lythrum* model. Philosophical Transactions of the Royal Society B 372: 20160032. http://dx.doi.org/10.1098/rstb.2016.0032

Deno, Norman C. 1993. Seed Germination Theory and Practice. Second Edition. Pennsylvania State University, State College, PA. 242 pp.

Dziuk, Peter M. 2017. Three photos of *Boechera stricta*. Images courtesy of Minnesota Wildflowers, https://www.minnesotawildflowers.info/flower/drummonds-rock-cress, licensed by https://creativecommons.org/licenses/by-nc-nd/3.0/.

Faber-Langendoen, D. 2018. Northeast Regional Floristic Quality Assessment Tools for Wetland Assessments. NatureServe, Arlington, VA. 52 pp.

Fairbrothers, David E. and Mary Y. Hough. 1973. Rare or Endangered Vascular Plants of New Jersey. Science Notes No. 14, New Jersey State Museum, Trenton, NJ. 53 pp.

Fernald, M. L. 1903. *Arabis drummondi* and its eastern relatives. Rhodora 5: 225–231.

Fernald, M. L. 1950. Gray's Manual of Botany. Dioscorides Press, Portland, OR. 1632 pp.

Fowler, Jarrod. 2016. Specialist bees of the Mid-Atlantic: Host plants and habitat conservation. The Maryland Entomologist 6(4): 2–40.

Gleason, H. A. and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. Second Edition. The New York Botanical Garden, Bronx, NY. 910 pp.

Hamann, Elena, Susana M. Wadgymar, and Jill T. Anderson. 2021. Costs of reproduction under experimental climate change across elevations in the perennial forb *Boechera stricta*. Proceedings of the Royal Society B 288: https://doi.org/10.1098/rspb.2020.3134

Hill, Rebecca, Megan M. Rutkowski, Lori A. Lester, Heather Genievich, and Nicholas A. Procopio (eds.). 2020. New Jersey Scientific Report on Climate Change, Version 1.0. New Jersey Department of Environmental Protection, Trenton, NJ. 184 pp.

Hopkins, M. 1937. *Arabis* in eastern and central North America. Rhodora 39: 63–98, 106–148, and 155–186.

Hough, Mary Y. 1983. New Jersey Wild Plants. Harmony Press, Harmony, NJ. 414 pp.

Howe, Henry F. and Judith Smallwood. 1982. Ecology of seed dispersal. Annual Review of Ecology, Evolution, and Systematics 13: 201–228.

ITIS (Integrated Taxonomic Information System). Accessed January 13, 2023 at http://www.itis.gov

Johnson, Samuel. 2014. Climate-induced changes in the germination phenology of *Boechera stricta*. Master's Thesis, University of South Carolina, Columbia, SC. 63 pp.

Jones, Tessa, Shannon Kulseth, Karl Mechtenberg, Charles Jorgenson, Michael Zehfus, Paul Brown, and David H. Siemens. 2006. Simultaneous evolution of competitiveness and defense: Induced switching in *Arabis drummondii*. Plant Ecology 184(2): 245–257.

Kartesz, J. T. 2015. The Biota of North America Program (BONAP). Taxonomic Data Center. (http://www.bonap.net/tdc). Chapel Hill, NC. [Maps generated from Kartesz, J. T. 2015. Floristic Synthesis of North America, Version 1.0. Biota of North America Program (BONAP) (in press)].

Manzaneda, Antonio J., Kasavajhala V. S. K. Prasad, and Thomas Mitchell-Olds. 2010. Variation and fitness costs for tolerance to different types of herbivore damage in *Boechera stricta* genotypes with contrasting glucosinolate structures. New Phytologist 188: 464–477.

Mitchell-Olds, Thomas. 2001. *Arabidopsis thaliana* and its wild relatives: A model system for ecology and evolution. Trends in Ecology and Evolution 16(12): 693–700.

Mulligan, Gerald A. 1995. Synopsis of the genus *Arabis* (Brassicaceae) in Canada, Alaska, and Greenland. Rhodora 97(890): 109–163.

NatureServe. 2023. NatureServe Explorer [web application]. NatureServe, Arlington, VA. Accessed January 13, 2023 at https://explorer.natureserve.org/

NJNHP (New Jersey Natural Heritage Program). 2010. Special Plants of NJ - Appendix I - Categories & Definitions. Site updated March 22, 2010. Available at https://nj.gov/dep/parksandforests/natural/docs/nhpcodes_2010.pdf

NJNHP (New Jersey Natural Heritage Program). 2022. Biotics 5 Database. NatureServe, Arlington, VA. Accessed February 1, 2022.

Parshall, David K. 2002. Conservation Assessment for Olympia Marble Butterfly (*Euchloe olympia*). Prepared for USDA Forest Service, Eastern Region, Milwaukee, WI. 16 pp.

POWO. 2023. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Accessed January 13, 2023 at http://www.plantsoftheworldonline.org/

Robertson, Charles. 1929. Flowers and Insects: Lists of Visitors of Four Hundred and Fifty-three Flowers. Science Press Printing Company, Lancaster, PA. 221 pp.

Rojek, Joanna, Małgorzata Kapusta, Małgorzata Kozieradzka-Kiszkurno, Daria Majcher, Marcin Górniak, Elwira Sliwinska, Timothy F. Sharbel and Jerzy Bohdanowicz. 2018. Establishing the cell biology of apomictic reproduction in diploid *Boechera stricta* (Brassicaceae). Annals of Botany 122: 513–539.

Rollins, Reed C. 1941. A monographic study of *Arabis* in western North America. Rhodora 43: 289–325, 348–411, and 425–481.

Rollins, Reed C. 1993. The Cruciferae of Continental North America: Systematics of the Mustard Family from the Arctic to Panama. Stanford University Press, Stanford, CA. 976 pp.

Roy, B. A. 1993. Floral mimicry by a plant pathogen. Nature 362: 56–58.

Roy, B. A. 1994. The effects of pathogen-induced pseudoflowers and buttercups on each other's insect visitation. Ecology 75(2): 352–358.

Roy, B. A. 1995. The breeding systems of six species of *Arabis*. American Journal of Botany 82(7): 869–877.

Roy, Barbara A., Detlev R. Vogler, Thomas D. Bruns, and Timothy M. Szaro. 1998. Cryptic species in the *Puccinia monoica* complex. Mycologia 90(5): 846–853.

Siemens, David H., Heike Lischke, Nicole Maggiulli, Stéphanie Schürch, and Bitty A. Roy. 2003. Cost of resistance and tolerance under competition: The defense-stress benefit hypothesis. Evolutionary Ecology 17: 247–263.

Snyder, David B. 1984. Botanical discoveries of Vincent Abraitys. Bartonia 50: 54–56.

Stubbs, C. S., H. A. Jacobson, E. A. Osgood, and F. A. Drummond. 1992. Alternative forage plants for native (wild) bees associated with lowbush blueberry, *Vaccinium* spp., in Maine.

Maine Agricultural Experiment Station, Technical Bulletin 148, University of Maine, Orono, ME. 54 pp.

U. S. Army Corps of Engineers. 2020. National Wetland Plant List, version 3.5. https://cwbi-app.sec.usace.army.mil/nwpl_static/v34/home/home.html U. S. Army Corps of Engineers Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH.

USDA, NRCS (U. S. Dept. of Agriculture, Natural Resources Conservation Service). 2023a. *Arabis drummondii* illustration from Britton, N. L. and A. Brown, 1913, An illustrated flora of the northern United States, Canada and the British Possessions, 3 vols., Kentucky Native Plant Society, New York, Scanned By Omnitek Inc. Image courtesy of The PLANTS Database (http://plants.usda.gov). National Plant Data Team, Greensboro, NC.

USDA, NRCS (U. S. Dept. of Agriculture, Natural Resources Conservation Service). 2023b. PLANTS profile for *Arabis drummondii* (Drummond's Rockcress). The PLANTS Database, National Plant Data Team, Greensboro, NC. Accessed January 13, 2023 at http://plants.usda.gov

Vaidya, Priya, Ansley McDurmon, Emily Mattoon, Michaela Keefe, Lauren Carley, Cheng-Ruei Lee, Robin Bingham, and Jill T. Anderson. 2018. Ecological causes and consequences of flower color polymorphism in a self-pollinating plant (*Boechera stricta*). New Phytologist 218: 380–392.

Wagner, Maggie R., Derek S. Lundberg, Devin Coleman-Derr, Susannah G. Tringe, Jeffery L. Dangl, and Thomas Mitchell-Olds. 2014. Natural soil microbes alter flowering phenology and the intensity of selection on flowering time in a wild Arabidopsis relative. Ecology Letters 17(6): 717–726. [Used with Corrigendum to Wagner et al.: Natural soil microbes alter flowering phenology and the intensity of selection on flowering time in a wild Arabidopsis relative. Maggie R. Wagner, Derek S. Lundberg, Devin Coleman-Derr, Susannah Green Tringe, Jeffery L. Dangl, Thomas Mitchell-Olds. Volume 18 Issue 2 Ecology Letters pages: 218–220; published online December 10, 2014].

Wagner, Maggie R. and Thomas Mitchell-Olds. 2018. Plasticity of plant defense and its evolutionary implications in wild populations of *Boechera stricta*. Evolution 72(5): 1034–1049.

Walz, Kathleen S., Linda Kelly, Karl Anderson and Jason L. Hafstad. 2018. Floristic Quality Assessment Index for Vascular Plants of New Jersey: Coefficient of Conservativism (CoC) Values for Species and Genera. New Jersey Department of Environmental Protection, New Jersey Forest Service, Office of Natural Lands Management, Trenton, NJ. Submitted to United States Environmental Protection Agency, Region 2, for State Wetlands Protection Development Grant, Section 104(B)(3); CFDA No. 66.461, CD97225809.

Weakley, A. S. and Southeastern Flora Team. 2022. Flora of the Southeastern United States. University of North Carolina Herbarium, North Carolina Botanical Garden, Chapel Hill, NC. 2022 pp.

Windham, Michael D., and Ihsan A. Al-Shehbaz. 2007. New and noteworthy species of *Boechera* (Brassicaceae) III: Additional sexual diploids and apomictic hybrids. Harvard Papers in Botany 12(1): 235–257.