Sagittaria teres

Slender Arrowhead

Alismataceae

Sagittaria teres by Bob Cunningham, 2016

***Sagittaria teres* 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

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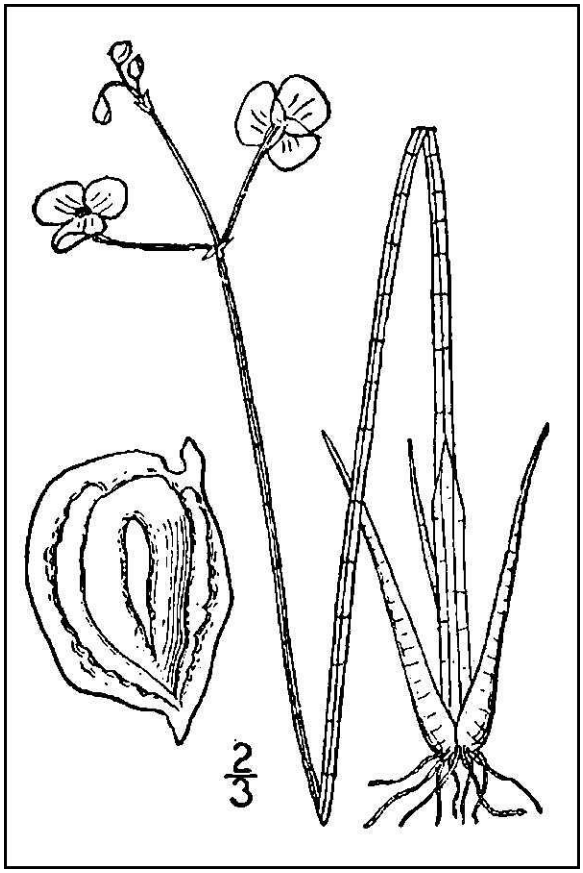
Life History

Sagittaria teres (Slender Arrowhead) is a perennial herb in the water-plantain family that can grow as a submerged or emergent aquatic. *S. teres* reproduces vegetatively via thin stolons 1–30 cm in length that develop minute, tuberous storage organs from which new plants arise. The connections between clones do not persist (Edwards and Sharitz 2000, Les 2020). Plants that were cultivated in a greenhouse produced 1–20 new ramets during the course of a year (Edwards and Sharitz 2003). Each ramet has a small cluster of whitish roots that are noticeably partitioned (Harvey and Haines 2003). The leaves of *S. teres* are basal and nearly round in cross-section, thickest at the bases and tapering to the tips (Fassett 1957). Submersed and emergent leaves are similar in form, but those that develop below the water are usually 3.5–8.5 cm long while those of shoreline plants may be up to 60 cm in length (Sinnott 1912, Hellquist and Crow 1981, Haynes and Hellquist 2020).



Left: Britton and Brown 1913, courtesy USDA NRCS 2023a. Right: Doug McGrady, 2022.

Sagittaria teres can flower from July through September. In habitats where the water levels fluctuate the flowering of *S. teres* is governed by hydrologic conditions (Fairbrothers and Hough 1973, Cavileer and Gallegos 1982, Harvey and Haines 2003) and some populations rarely flower (Sorrie 1987). When the plants do bloom, the flowers are held above the water. The erect scapes are 10–80 cm high and bear 1–4 whorls of flowers with three reflexed sepals and three showy white petals. The flowers are generally unisexual, although perfect flowers may occasionally be produced. The female flowers, with long stalks and numerous pistils, are

positioned in the lowest whorl. The male flowers have about a dozen stamens with anthers that are longer than the dilated, hairy filaments. The fruiting heads of *S. teres* are typically 6–10 mm in diameter and have numerous achenes that are arranged spirally on a dome-shaped receptacle. The achenes are obovoid, 2–3 mm long by 1.2–1.5 mm wide, and have an erect or horizontal beak less than half a millimeter in length near the tip. Several distinct, irregularly scalloped keels are present on the faces of the achenes. (See Smith 1895, Britton and Brown 1913, Eyles et al. 1944, Fernald 1950, Bogin 1955, Wooten 1973, Haynes and Hellquist 2020, Gleason and Cronquist 1991, Weakley et al. 2022).

S. teres in flower and fruit by Doug McGrady, 2022.

Sagittaria teres can utilize different photosynthetic mechanisms depending on whether the plants are growing above or below water. Emergent plants use the normal C_3 photosynthetic pathway but submerged plants can shift to CAM photosynthesis (Edwards and Sharitz 2000). CAM (Crassulacean Acid Metabolism) is a way of concentrating CO_2 in carbon-limited environments. The process was originally studied in plants that grow in arid habitats but it has since been documented in some aquatic species, particularly in shallow, temporary pools where CO_2 levels are considerably higher at night (Keeley 1998). The use of CAM photosynthesis has also been observed in *S. isoetiformis*, a species that shares many life history characteristics with *S. teres* but has a more southern distribution (Edwards and Sharitz 2000, 2003). Otherwise the process is quite uncommon in *Sagittaria* (Haynes and Hellquist 2020).

Pollinator Dynamics

Sagittaria flowers are visited by an array of insects but the primary pollinators are short-tongued bees and flies (Rogers 1983). Robertson (1929) observed that an assortment of long and short-tongued bees, flies, and butterflies visited both staminate and pistillate flowers of *S. latifolia*. Generalist bees have been observed on other *Sagittaria* species, including various types of *Augochlora*, *Augochlorella*, *Bombus*, *Ceratina*, *Dialictus*, *Halictus*, *Hylaeus*, and *Lasioglossum* (Stubbs et al. 1992, Muenchow and Delesalle 1994, Hilty 2020). Edwards and Sharitz (2000, 2003) indicated that *Sagittaria teres* was insect pollinated but the specific pollinators were not noted.

When *Sagittaria teres* blooms the lower (pistillate) flowers on a stalk open first, which could promote outcrossing. However, the pollinators tend to visit nearby blooms and since the species reproduces vegetatively the pollen deposited on a female flower may originate from a clone. Since *S. teres* is self-compatible, fertilization with related pollen would not reduce fruit set but it does contribute to limited genetic diversity in populations. Studies of *Sagittaria teres* have documented significant levels of inbreeding in the species. Nevertheless, the researchers noted that *S. teres* has fairly high genetic diversity relative to many other clonal plants and concluded that sexual reproduction is likely to play an important role in maintaining populations (Edwards and Sharitz 2000, 2003).

Seed Dispersal

Fruit set in *Sagittaria teres* is generally high (Hellquist and Crow 1981, Edwards and Sharitz 2003). The achenes of most species in the Alismataceae are well-adapted for aquatic dispersal, and the basic structure of *Sagittaria* achenes might facilitate transport by air or water while the protruding beaks and keels could aid in their attachment to birds or animals (Arber 1920, Rogers 1983). However, the majority of *Sagittaria teres* seeds are dispersed by gravity and do not travel far from the parent plants before sinking through the water column and settling into the substrate (Edwards and Sharitz 2000). *S. teres* seeds are occasionally consumed by ducks (McAtee 1918, Mabbott 1920, Fassett 1957), which could result in some dispersal over greater distances. Some vegetative dispersal may also occur when plants become detached from the substrate and float to new locations (Rogers 1983, Harvey and Haines 2003).

Sagittaria teres seeds can germinate in wet soil or under a few centimeters of water (Edwards and Sharitz 2003). *Sagittaria* seeds have a hard inner coat that delays germination until the protective layer becomes cracked or decayed (Crocker 1907, Arber 1920). Moist seeds of various *Sagittaria* species can remain viable for over a year and seed banking has been documented in the genus (Rogers 1983, Leck and Simpson 1993). Some of the genetic diversity observed by Edwards and Sharitz (2003) in *S. teres* populations was attributed to recruitment from persistent seed banks.

Habitat

Most populations of *Sagittaria teres* occur on the Atlantic coastal plain at elevations from 0–100 meters above sea level (Haynes and Hellquist 2020). Typical habitats are intermittent ponds or the shorelines of lakes and ponds where the substrate is alternately inundated and exposed by seasonal fluctuations in water levels. The canopy is generally open and the substrate is sandy, nutrient-poor, and acidic with a pH ranging from 4.5–6.7 (Eyles et al. 1944, Bogin 1955, Fables 1958, Fairbrothers and Hough 1973, Coddington and Field 1978, Angelo and Boufford 2000, Edwards and Sharitz 2000, Les 2020). Inland populations of *S. teres* are rare but they occur in similar habitat (Hellquist and Crow 1981, Zebryk 2004).

Sagittaria teres can be found growing on moist, exposed substrate or under water (Hough 1983). The water is usually shallow but the submerged plants have been observed at depths up to a meter (Sorrie 1987, Harvey and Haines 2003). At some locations Slender Arrowhead is submersed early in the season and the plants become exposed later in the year as water levels decline (Harvey and Haines 2003) but at other sites the water depth may vary from one year to the next (Cavileer and Gallegos 1982). The water levels of intermittent ponds on the coastal plain are closely tied to groundwater levels, which in turn are driven by long-term trends in regional rainfall (Zaremba and Lamont 1993).

S. teres growing in emergent (left) and submerged (right) sites by Doug McGrady (2012, 2022).

Most New Jersey populations of *Sagittaria teres* occur in coastal plain intermittent ponds, although one is situated along the shoreline of a large lake (Johnson and Walz 2013, NJNHP 2022). A number of the occurrences are in man-made wetlands that were created by activities such as gravel or sand mining but now function like natural intermittent ponds. One population was found in another highly altered site where an earlier disturbance had created an unusually flat, sandy streambed (NJNHP 2022).

Coastal plain pondshores often develop distinct vegetation bands in response to hydrologic conditions, with a gradient that ranges from the permanently flooded pond bottom to an upper wetland shrub thicket (Zaremba and Lamont 1993). Periodic exposure of the substrate in the section favored by *Sagittaria teres* may facilitate the establishment of young arrowhead plants (Enser and Caljouw 1989). Competition in that zone is limited because many plant species are either strictly aquatic or strictly terrestrial and cannot persist when the water levels shift (Coddington and Field 1978).

Young (2012) noted that *Sagittaria teres* often co-occurs with larger emergent plants. Typical associates of the species in coastal plain ponds usually include a variety of sedges, rushes, and grasses. White Water-lily (*Nymphaea odorata*), yellow-eyed grasses (*Xyris* spp.) and bladderworts (*Utricularia* spp.) are also likely to be present (Snyder 1996, Young 2012). Seven-angle Pipewort (*Eriocaulon aquaticum*) and Golden Hedge-hyssop (*Gratiola aurea*) have been known to share habitat with *S. teres* at both the northern and southern ends of the arrowhead's range (Harvey and Haines 2003, MANHESP 2015, NJNHP 2022). Several other globally rare species that occur in the region also favor coastal plain ponds including *Coreopsis rosea*, *Hypericum adpressum*, and *Uvularia puberula* var. *nitida* (Tiner 2003).

Wetland Indicator Status

Sagittaria teres 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 2023b)

SATE2

Coefficient of Conservatism (Walz et al. 2018)

CoC = 10. 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 *Sagittaria teres* is restricted to a few states in the northeastern United States (POWO 2023). The map in Figure 1 depicts the worldwide extent of Slender Arrowhead.

The USDA PLANTS Database (2023b) shows records of *Sagittaria teres* in five New Jersey counties: Atlantic, Burlington, Camden, Cape May, and Morris (Figure 2). Hough (1983) noted that the Morris County record was an isolated occurrence. *S. teres* has also been found in Ocean County (NJNHP 2022). The data include historic observations and do not reflect the current distribution of the species.

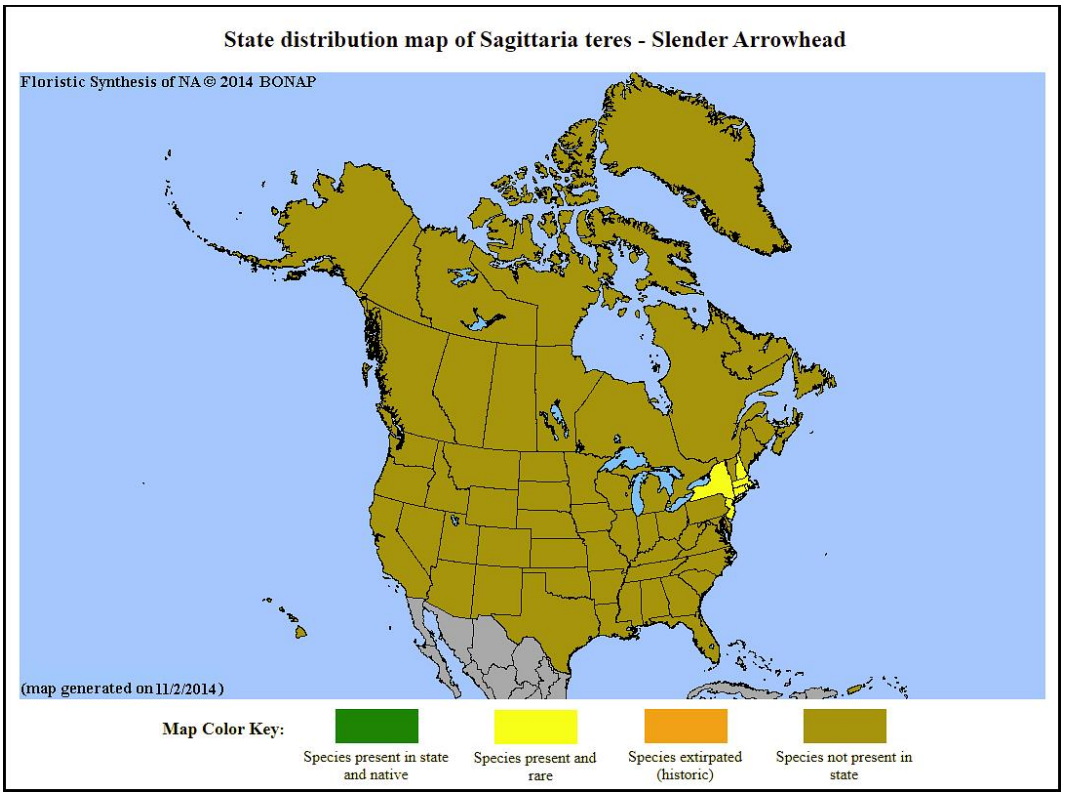


Figure 1. Distribution of S. teres in North America, adapted from BONAP (Kartesz 2015).

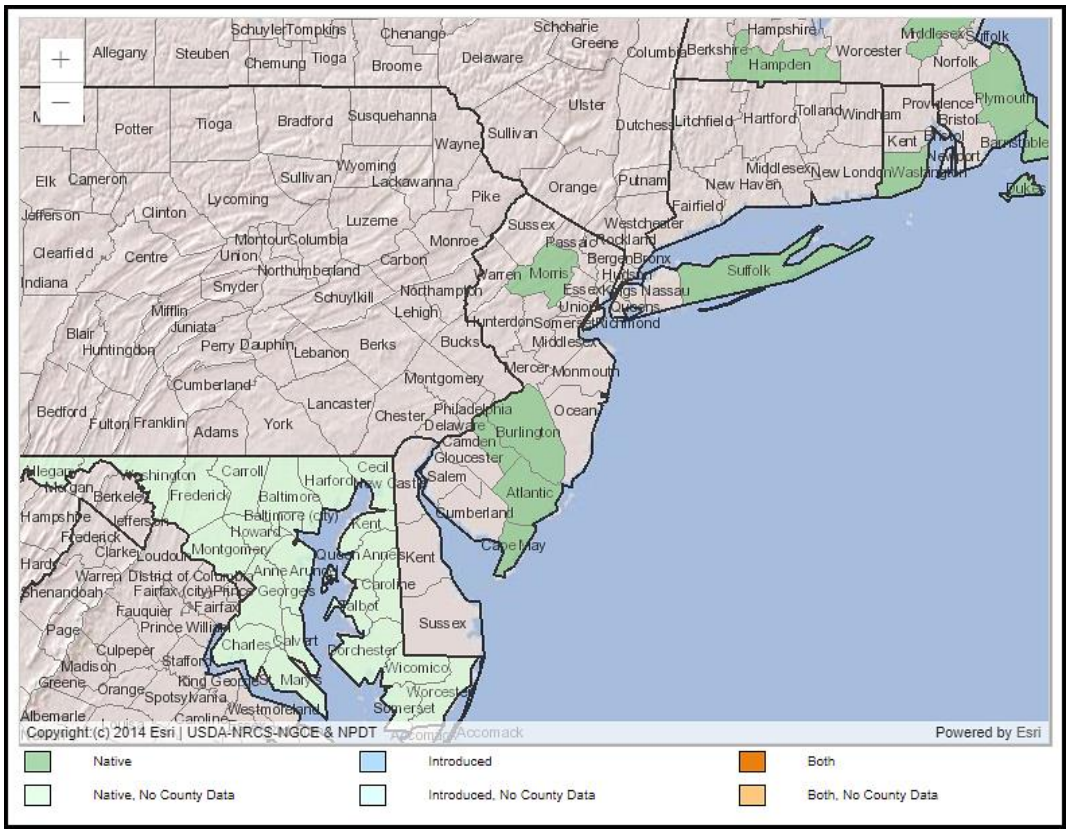


Figure 2. County records of S. teres in New Jersey and vicinity (USDA NRCS 2023b).

Conservation Status

Sagittaria teres is globally vulnerable. The G3 rank means the species has a moderate risk of extinction or collapse due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors (NatureServe 2023). The map below (Figure 3) illustrates the conservation status of *S. teres* throughout its range. The species is not considered secure anywhere: It is vulnerable (moderate risk of extinction) in one state, imperiled (high risk of extinction) in one state, and critically imperiled (very high risk of extinction) in four states. *Sagittaria teres* has also been identified as a plant species of highest conservation priority for the North Atlantic region, which includes four Canadian provinces and twelve U. S. states. The species has a regional rank of R3 (vulnerable), signifying a moderate risk of regional extinction (Frances 2017).

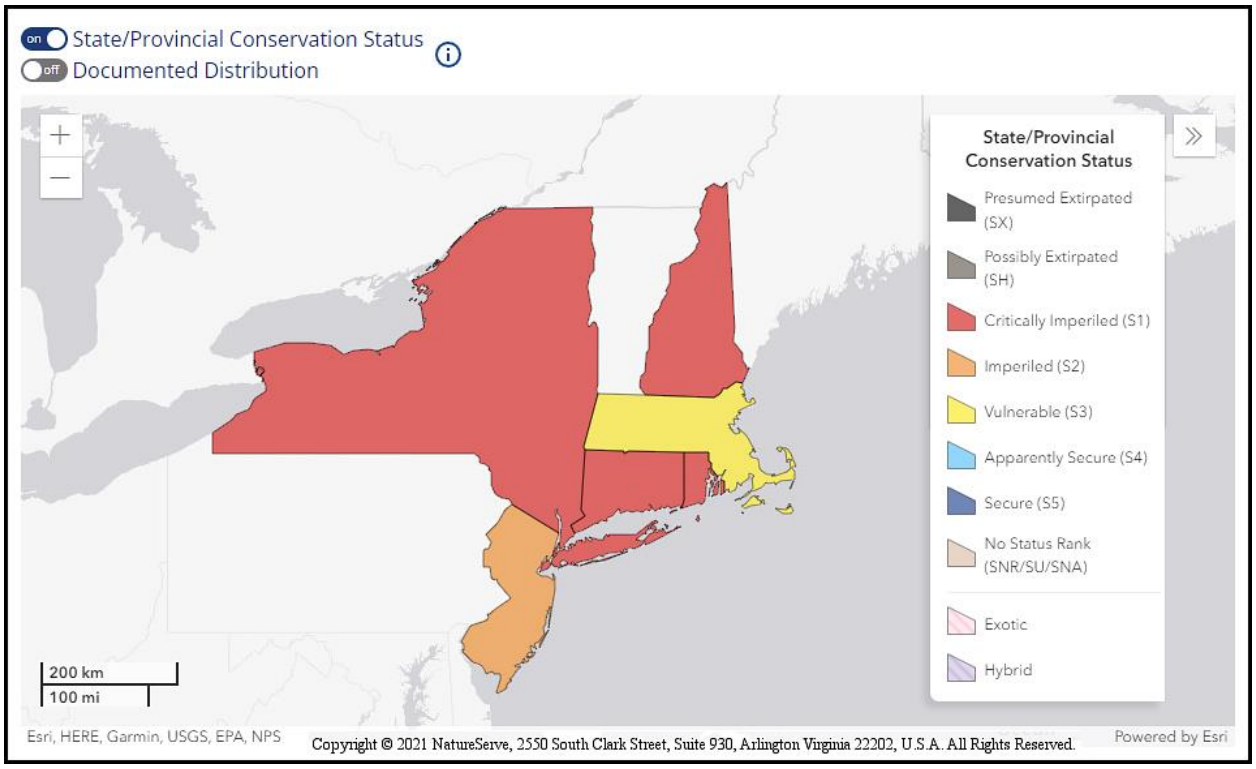


Figure 3. Conservation status of S. teres in North America (NatureServe 2023).

Sagittaria teres is imperiled (S2) in New Jersey (NJNHP 2022). The rank indicates that the species is very rare in the state, with 6 to 20 occurrences. Species with an S2 rank may have once been more abundant in the state but now persist in only a few of their former locations. Slender Arrowhead is also 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 such as wetlands or coastal habitats, being listed does not currently provide broad statewide protection for the plants. Additional regional status codes assigned to *S. teres* signify that the species is eligible for protection under the jurisdictions of the Highlands Preservation Area (HL) and the New Jersey Pinelands (LP) (NJNHP 2010).

Sagittaria teres was first reported in New Jersey by Smith (1895), who examined a specimen that had been collected in the Pine Barrens by John Torrey in 1833. Stone (1911) questioned the identification since *S. teres* was not known to occur in New Jersey at that time, although shortly after that an Atlantic County record was cited by Taylor (1915). The first verified collection of *S. teres* in the state was made in 1916 in Cape May County but the species was not observed at that site after 1921 (NJNHP 2022). The number of known occurrences of *Sagittaria teres* has slowly increased with the passage of time. Fables (1958) reported three populations in Atlantic and Burlington Counties and Breden et al. (2006) indicated that five extant populations were located in Atlantic and Camden counties. Additional discoveries in recent years have shifted the state status of Slender Arrowhead from critically imperiled (S1) to imperiled (S2), and the species is currently considered extant at nine sites in three counties (NJNHP 2016, 2022).

Threats

The most frequently reported threat to *Sagittaria teres* populations in New Jersey is off-road vehicle (ORV) traffic (NJNHP 2022). ORV damage to exposed shorelines and pond bottoms has been identified as a concern throughout the range of *S. teres* (Zaremba and Lamont 1993, Tiner 2003, Young 2012, MANHESP 2015). In addition to causing direct damage to rare plants, seed banks, and microtopography, heavy ORV traffic often leads to secondary impacts such as the deposition of trash (Tiner 2003, NJNHP 2022) or the introduction of invasive plants via seeds that adhere to muddy tires (personal observation). Despite longstanding efforts to curb the illegal use of ORVs on public lands in New Jersey (NJDEP 2018), the availability of resources for enforcement of regulations has been limited so the destruction of sensitive natural areas continues to be a significant problem in the state (Rodas 2022).

ORV damage at site of *S. teres* occurrence in a New Jersey coastal plain pond (Google 2023).

In places where *S. teres* occurs along the shoreline of larger ponds and lakes, habitat damage can result from other recreational uses such as boating, swimming, horseback riding, or camping (MANHESP 2015). Both heavy recreational usage and urbanization of the surrounding landscape were cited as factors that eliminated critical habitat for *Sagittaria teres* in Rhode Island (Enser and Caljouw 1989). One of the reasons that *S. teres* is so rare is the scarcity of suitable habitat throughout its range (Coddington and Field 1978). In the past, some coastal plain ponds were lost when they were converted for use as road runoff catchment basins, cranberry bogs, or mines (Zaremba and Lamont 1993, Johnson and Walz 2013), but even sites that were protected have been affected by activities that occurred offsite. Runoff from adjacent agricultural, commercial, or residential properties has resulted in the eutrophication of some ponds, while watershed-wide development has caused water table drawdowns that altered the natural hydrological patterns at other sites (Zaremba and Lamont 1993, Tiner 2002, Green and Gauver 2010, Johnson and Walz 2013, MANHESP 2015). The challenge of dispersing propagules across a fragmented landscape to limited number of suitable sites is probably the greatest threat to the long-term persistence of *Sagittaria teres* (Edwards and Sharitz 2003).

Although no invasive plant species have been identified as threats to extant populations of *Sagittaria teres* in New Jersey some have been noted as problematic in other states. In aquatic settings, *S. teres* may be impacted by the dense growth of exotic species like *Cabomba caroliniana* (Greene and Grauver 2010) or by the unintended consequences of efforts to control invasives like *Myriophyllum heterophyllum* (Harvey and Haines 2003). Young (2012) noted that several Slender Arrowhead populations in New York had been jeopardized by the establishment of *Phragmites australis* ssp. *australis*.

As the global climate continues to warm, rising temperatures and altered precipitation patterns are increasing the frequency and intensity of both floods and droughts in New Jersey (Hill et al. 2020). The hydrologic regimes of intermittent coastal plain ponds are directly governed by the climate. Local rainfall and seepage from groundwater, which is also influenced by regional precipitation trends, are the primary water sources for a typical coastal plain pond in southern New Jersey. Following any initial overflow runoff via temporary streams the pools slowly lose water through evaporation and percolation, becoming fairly dry by mid-summer during a normal year (Snyder 1996). Extended deviations from the pattern can be harmful to *Sagittaria teres*: Prolonged inundation can deter flowering in the species (Cavileer and Gallegos 1982, Harvey and Haines 2003) and successive years of drought can facilitate the establishment of more competitive upland plants (Zaremba and Lamont 1993). A regional species-level assessment by Ring et al. (2013) determined that *Sagittaria teres* is extremely vulnerable to climate change. The threat level signifies that Slender Arrowhead is extremely likely to substantially decrease in abundance or disappear from New Jersey by 2050. Because the fate of individual ponds is tied to local conditions the impact of climate change may vary between sites. However, the loss of even a small number of populations could have an outsized impact on the globally rare species due to the limited availability of alternate sites, wide separations between patches of suitable habitat, and a limited capacity for dispersal over long distances.

Management Summary and Recommendations

Although *Sagittaria teres* may sometimes become locally abundant when circumstances are favorable, the global range of the species is small and its habitat requirements are narrow. Conservation of the acidic, sandy, intermittent ponds and shorelines utilized by *S. teres* will help the arrowhead to persist and will also benefit a number of other rare species with similar habitat preferences. In places where *S. teres* is extant, site-specific management planning is needed to protect natural hydrological regimes and water quality, minimize direct human disturbance, and prevent or control the establishment of invasive plants.

Although the number of known occurrences of *Sagittaria teres* has increased in New Jersey, some of the populations are small and a number of them face ongoing threats from disturbance. The challenge of managing illegal ORV use on public lands is not unique to New Jersey (eg. Sierra Forest Legacy 2008, MIDNR 2016) and PEER (2023) has called for a national strategy to address the issue, noting that it is "fast becoming the number one law enforcement problem on our public lands." Ongoing cooperation and communication between land managers in multiple states may advance the identification of a workable solution.

During a recent visit to one New Jersey population of *Sagittaria teres* it was noted that numerous plants had been uprooted by waterfowl and were floating in the water or washed up along the shoreline (NJNHP 2022). More frequent monitoring of that site is recommended in order to determine the extent of the problem and whether it is having any long-term effects on the vigor or viability of the *S. teres* population.

Synonyms

The accepted botanical name of the species is *Sagittaria teres* S. Watson. Orthographic variants, synonyms, and common names are listed below (ITIS 2021, POWO 2023, USDA NRCS 2023b).

Botanical Synonyms	Common Names
Sagittaria graminea var. *teres* (S. Watson) Bogin	Slender Arrowhead Quill-leaved Arrowhead Terete Arrowhead

References

Angelo, Ray and David E. Boufford. 2000. Atlas of the flora of New England monocots except Poaceae and Cyperaceae. Rhodora 102(909): 1–119.

Arber, Agnes. 1920. Water Plants: A Study of Aquatic Angiosperms. Cambridge University Press, Cambridge, United Kingdom. 436 pp.

Bogin, Clifford. 1955. Revision of the genus *Sagittaria* (Alismataceae). Memoirs of the New York Botanical Garden 9(2): 179–233.

Breden, T. F., J. M. Hartman, M. Anzelone and J. F. Kelly. 2006. Endangered Plant Species Populations in New Jersey: Health and Threats. New Jersey Department of Environmental Protection, Division of Parks and Forestry, Office of Natural Lands Management, Natural Heritage Program, Trenton, NJ. 198 pp.

Britton, N. L. and A. Brown. 1913. An Illustrated Flora of the Northern United States and Canada in three volumes: Volume I (Ferns to Buckwheat). Second Edition. Reissued (unabridged and unaltered) in 1970 by Dover Publications, New York, NY. 680 pp.

Cavileer, G. and J. Gallegos. 1982. The influence of fluctuating water levels upon the incidence of rare plant species of southern New Jersey. In William J. Cromartie (ed.). New Jersey's Endangered Plants and Animals. Stockton State College Center for Environmental Research, Pomona, NJ.

Coddington, Jonathan and Katharine G. Field. 1978. Rare and endangered vascular plant species in Massachusetts. Report prepared by the New England Botanical Club, Cambridge, MA. 67 pp.

Crocker, William. 1907. Germination of seeds of water plants. Botanical Gazette 44(5): 375–380.

Cunningham, Bob. 2016. Cover photo of *Sagittaria teres*. Used with permission.

Edwards, Adrienne L. and Rebecca R. Sharitz. 2000. Population genetics of two rare perennials in isolated wetlands: *Sagittaria isoetiformis* and *S. teres*. American Journal of Botany 87(8): 1147–1158.

Edwards, Adrienne L. and Rebecca R. Sharitz. 2003. Clonal diversity in two rare perennial plants: *Sagittaria isoetiformis* and *Sagittaria teres* (Alismataceae). International Journal of Plant Sciences 164(1): 181–188.

Enser, Richard W. and Caren A. Caljouw. 1989. Plant conservation concerns in Rhode Island—A reappraisal. Rhodora 91(865): 121–130.

Eyles, Don E., J. Lynne Robertson, Jr., and Garnet W. Jex. 1944. A Guide and Key to the Aquatic Plants of the Southeastern United States. U. S. Health Service, Public Health Bulletin No. 286.

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

Fables, David Jr. 1958. Caesarian flora and fauna, Number 4. Published posthumously in Bartonia 32(1961-62): 11–13.

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.

Fassett, Norman C. 1957. A Manual of Aquatic Plants. Second Edition. University of Wisconsin Press, Madison, WI. 405 pp.

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

Frances, Anne (Principal Investigator). 2017. Prioritization and Conservation Status of Rare Plants in the North Atlantic - Final Report. Report prepared for NatureServe by the North Atlantic Landscape Conservation Cooperative, Hadley, MA. Available at https://www.natureserve.org/publications/prioritization-and-conservation-status-rare-plants-north-atlantic-final-report

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.

Google. 2023. ORV damage to intermittent pond. 2023 imagery by Maxar Technologies. Accessed February 9, 2023 at https://www.google.com/maps/

Greene, L. and K. Grauver. 2010. *Sagittaria teres* conservation status factors. NatureServe, Arlington, VA. Accessed February 6, 2023 at https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.149826/Sagittaria_teres

Harvey, Liz and Arthur Haines. 2003. *Sagittaria teres* (Alismataceae) in New Hampshire. Rhodora 105(923): 282–285.

Haynes, Robert R. and C. Barre Hellquist. Page updated November 5, 2020. *Sagittaria teres* S. Watson. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico [Online]. 22+ vols. New York and Oxford. Accessed February 6, 2023 at http://floranorthamerica.org/Sagittaria_teres

Hellquist, C. B. and G. E. Crow. 1981. Aquatic Vascular Plants of New England: Part 3. Alismataceae. New Hampshire Agricultural Experiment Station, Durham, NH. 42 pp.

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.

Hilty, John. 2020. Insect Visitors of Illinois Wildflowers. Accessed January 8, 2023 at https://www.illinoiswildflowers.info/flower_insects/index.htm

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

ITIS (Integrated Taxonomic Information System). Accessed November 13, 2021 at http://www.itis.gov

Johnson, Elizabeth A. and Kathleen Strakosch Walz. 2013. Integrated Management Guidelines for Four Habitats and Associated State Endangered Plants and Wildlife Species of Greatest Conservation Need in the Skylands and Pinelands Landscape Conservation Zones of the New Jersey State Wildlife Action Plan. Report prepared for NatureServe #DDCF-0F-001a, Arlington, VA. 140 pp.

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)].

Keeley, Jon E. 1998. CAM photosynthesis in aquatic plants. The Botanical Review 64(2): 121–175.

Leck, Mary A. and Robert L. Simpson. 1993. Seeds and seedlings of the Hamilton Marshes, a Delaware River tidal freshwater wetland. Proceedings of the Academy of Natural Sciences of Philadelphia 144: 267–281.

Les, Donald H. 2020. Aquatic Monocotyledons of North America: Ecology, Life History and Systematics. CRC Press, Boca Raton, FL. 568 pp.

Mabbott, Douglas C. 1920. Food Habits of Seven Species of American Shoal-water Ducks. United States Department of Agriculture Bulletin No. 862. 67 pp.

MANHESP (Massachusetts Natural Heritage and Endangered Species Program). 2015. *Sagittaria teres*. Species profile available at https://www.mass.gov/doc/terete-arrowhead/download

McAtee, W. L. 1918. Food Habits of the Mallard Ducks of the United States. United States Department of Agriculture Bulletin No. 70. 36 pp.

McGrady, Doug. 2012. Photo of *Sagittaria teres* from Massachusetts. Shared via Flicker at https://www.flickr.com/photos/douglas_mcgrady/34647342265/in/photolist-Ty7ME8-UMEFL6-PJkCVS-UMEFez/, licensed by https://creativecommons.org/licenses/by/2.0/

McGrady, Doug. 2022. Four photos of *Sagittaria teres* from Massachusetts. Shared via iNaturalist at https://www.inaturalist.org/observations/145098597 and at https://www.inaturalist.org /observations/145015483, licensed by https://creativecommons.org/licenses/by-nc/4.0/

MIDNR (Michigan Department of Natural Resources). 2016. Managing Illegal Off-Road Vehicle Use Action Plan. Available at https://www2.dnr.state.mi.us/publications/pdfs/ForestsLandWater/ORV/2008/DraftPlan/D--ORVActionPlanOct12.2006FINAL.pdf

Muenchow, Gayle and Veronique Delesalle. 1994. Pollinator response to male floral display size in two *Sagittaria* (Alismataceae) species. American Journal of Botany 81(5): 568–573.

NatureServe. 2023. NatureServe Explorer [web application]. NatureServe, Arlington, VA. Accessed February 6, 2023 at https://explorer.natureserve.org/

NJDEP (New Jersey Department of Environmental Protection). Page updated July 3, 2018. Policy Directive 2002-001, Off-Road Vehicle Use. Accessed February 9, 2023 at https://www.nj.gov/dep/commissioner/policy/orvpolicy.htm

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). 2016. List of Endangered Plant Species and Plant Species of Concern. Biotics Database. NatureServe, Arlington, Virginia. Accessed June 2016.

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

PEER (Public Employees for Environmental Responsibility). 2023. Off-Road "Wreckreation" Plagues Public Lands. Accessed February 9, 2023 at https://peer.org/areas-of-work/public-lands/off-road-wreckreation/

POWO. 2023. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Accessed February 6, 2023 at http://www.plantsoftheworldonline.org/

Ring, Richard M., Elizabeth A. Spencer, and Kathleen Strakosch Walz. 2013. Vulnerability of 70 Plant Species of Greatest Conservation Need to Climate Change in New Jersey. New York Natural Heritage Program, Albany, NY and New Jersey Natural Heritage Program, Department of Environmental Protection, Office of Natural Lands Management, Trenton, NJ, for NatureServe #DDCF-0F-001a, Arlington, VA. 38 pp.

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

Rodas, Steven. 2022. Illegal off-road vehicles continue to tear up N.J. forests. Advocates push for crackdown. NJ Advance Media for NJ.com, accessed February 9, 2023 at https://www.nj.com/news/2022/10/illegal-off-road-vehicles-continue-to-tear-up-nj-forests-advocates-push-for-crackdown.html

Rogers, George K. 1983. The general of Alismataceae in the southeastern United States. Journal of the Arnold Arboretum 64(3): 383–420.

Sierra Forest Legacy. 2008. Off-Road Vehicles. Accessed February 9, 2023 at https://www.sierraforestlegacy.org/FC_FireForestEcology/TFH_OHV.php

Sinnott, Edmund W. 1912. The pond flora of Cape Cod. Rhodora 14(158): 25–34.

Smith, Jared G. 1895. A revision of the North American species of *Sagittaria* and *Lophotocarpus*. Missouri Botanical Garden, Sixth Annual Report: 27–63.

Snyder, David. 1996. The genus *Rhexia* in New Jersey. Bartonia 59: 55–70.

Sorrie, B.A. 1987. Notes on the rare flora of Massachusetts. Rhodora 89(858): 113–196.

Stone, Witmer. 1911. The Plants of Southern New Jersey. Quarterman Publications, Boston, MA. 828 pp.

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.

Taylor, Norman. 1915. Flora of the vicinity of New York - A contribution to plant geography. Memoirs of the New York Botanical Garden 5: 1–683.

Tiner, R. W. 2003. Geographically isolated wetlands of the United States. Wetlands 23: 494–516.

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. *Sagittaria teres* 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 *Sagittaria teres* (Slender Arrowhead). The PLANTS Database, National Plant Data Team, Greensboro, NC. Accessed February 6, 2023 at http://plants.usda.gov

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.

Wooten, Jean W. 1973. Taxonomy of seven species of *Sagittaria* from eastern North America. Brittonia 25(1): 64–74.

Young, Stephen M. 2012. Online Conservation Guide for *Sagittaria teres*, prepared for the New York Natural Heritage Program. Accessed February 6, 2023 at https://guides.nynhp.org/quill-leaf-arrowhead/

Zaremba, R. E. and E. E. Lamont. 1993. The status of the coastal plain pondshore community in New York. Bulletin of the Torrey Botanical Club 120: 180–187.

Zebryk, Tad M. 2004. Inland sandy acid pondshores in the lower Connecticut River valley, Hampden County, Massachusetts. Rhodora 106(925): 66–76.