Potamogeton zosteriformis

Eel-grass Pondweed

Potamogetonaceae

Potamogeton zosteriformis by Matt Keevil, 2019

***Potamogeton zosteriformis* 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

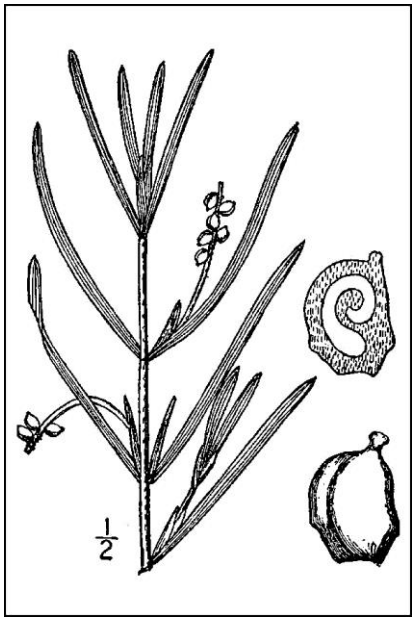
December, 2022

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

This report should be cited as follows: Dodds, Jill S. 2022. *Potamogeton zosteriformis* 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, Trenton, NJ. 17 pp.

Life History

Potamogeton zosteriformis (Eel-grass Pondweed) is a submersed aquatic herb in the pondweed family. The plants are rooted in the substrate but not rhizomatous. The freely branching stems are distinctly flattened (sometimes winged) and slender (0.6–3.2 mm wide) with constrictions at the nodes. The light green leaves are linear—ranging from 10–20 cm in length and 2–5 mm in width— and end in pointed tips. They have numerous nerves (15–35) and firm axillary stipules 1.5–3.5 cm long that are not attached to the stalkless leaf bases. The stipules persist throughout the season although they are somewhat fibrous and may become shredded at the tips. Eel-grass Pondweed generally does not produce any floating leaves but the inflorescences are held above the surface. The peduncles are stout and the cylindrical floral spikes are made up of 7–11 whorls of small flowers. The olive-green fruits are about 4–5 mm long and oblong or nearly round with narrow, wing-like, toothed dorsal keels and small beaks at their tips. (See Britton and Brown 1913, Fernald 1932 and 1950, Fassett 1957, Gleason and Cronquist 1991, Wiegleb and Kaplan 1998, Haynes and Hellquist 2020). The laterally flattened stems and linear many-nerved leaves with free stipules help to distinguish *P. zosteriformis* from other pondweeds in the northeast (Ogden 1974).



Left: Britton and Brown 1913, courtesy USDA NRCS 2022a. Right: Branches with stipules and turions by Peter M. Dziuk, 2019.

The stems of *Potamogeton zosteriformis* are annual. The plants develop winter buds (turions) that allow them to persist vegetatively until the next growing season. The turions of *P. zosteriformis* are two ranked with 3–4 shortened leaves on each side and they are relatively large, ranging from 4–7.5 cm in length (Gleason and Cronquist 1991, Haynes and Hellquist 2020). Formation of the winter buds begins early in the summer, and as the plants decompose later in the season the turions sink to the bottom where they remain buried in the substrate until they produce shoots the following spring (Knight 2014). Harman (1974) observed young *P. zosteriformis* plants emerging from their turions during early May in New York. Growth occurs rapidly: At one Manitoba site the abundance of Eel-grass Pondweed increased significantly

between June 18 and June 29 (Hann 1995), and Harman (1974) noted that plants which had sprouted in May had reached about a meter in length by mid-July. *P. zosteriformis* starts to flower and fruit during the summer and continues into the fall (Les 2020, Weakley et al. 2022) although the plants may begin to decompose in August (Harman 1974). Hough (1983) reported blooming dates beginning as early as April in New Jersey, with fruit production and dispersal occurring in July and August.

Flowers by Peter M. Dziuk, 2017.


Fruits by Jacqueline Weber, 2022.

Pollinator Dynamics

Wind pollination is prevalent in the Potamogetonaceae and the majority of species in the genus *Potamogeton* are pollinated by wind, particularly those with aerial flowers (Haynes 1978, Philbrick and Anderson 1987, Haynes et al. 1998). Dragonflies were identified as possible pollinators for pondweeds with emergent inflorescences after pollen was observed on the insects, but the transfer of pollen to other flowers was not documented (Haynes 1978) and biotic pollination has not been confirmed in any *Potamogeton* species (Philbrick and Anderson 1987).

Potamogeton zosteriformis produces copious amounts of pollen (about 40,000 pollen grains per ovule). The pollen/ovule ratio of *P. zosteriformis* was the highest recorded in a study of 17 *Potamogeton* species, and the researchers concluded that high pollen/ovule ratios in pondweeds improve the likelihood of cross-fertilization although some self-pollination may also occur (Philbrick and Anderson 1987). Production of cleistogamous flowers (flowers that remain closed and self-pollinate) is common in aquatic plants, including *Potamogeton* species (Philbrick and Les 1996), but no reports of cleistogamy in *P. zosteriformis* were found.

Seed Dispersal

Many species in the Potamogetonaceae have propagules that can float for weeks or even months (Haynes et al. 1998) but the seeds of submerged aquatic plants generally lack buoyancy or only float for a short time (Boedeltje et al. 2003). For example, experimental work with *Potamogeton perfoliatus* showed that most of the seeds dispersed in the water ended up within a meter or two of the parent plants, even when subjected to water currents higher than those typically found in the species' natural habitats (Koch et al 2010).

Fernald (1932) observed that despite ample fruit development in *Potamogeton zosteriformis*, winter buds appeared to be "the usual, if not the only, means of reproduction" for the species. During a seed bank study of 11 sites where *P. zosteriformis* was abundant only one seed of the species germinated, and the plants instead reestablished from dormant winter buds (Haag 1983). Les (2020) referred to Eel-grass Pondweed as a "vegetative annual" because of its reliance on turions rather than seeds for regeneration. The strategy is not unusual in underwater aquatic species: 98.9% of the propagules of submergent plants evaluated by Boedeltje et al. (2003) were vegetative. The turions of *P. zosteriformis* are not only a means of clonal propagation but also a mechanism for distribution as they move around in the water column, and they could be an important means of long-distance dispersal (Martin and Uhler 1939, Haynes et al. 1998, Boedeltje et al. 2003). Despite the importance of turions for reproduction, the extent of their viability is unknown (Lundholm and Simser 1999).

The seeds of *Potamogeton* species are widely acknowledged as a major food source for waterfowl (Martin and Uhler 1939, Martin 1951, Fassett 1957, Les 2020). Martin (1951) noted that the digestive process removes the tough outer seed coat, altering the appearance of the seeds, and he developed a guide for the identification of pondweed seeds (including *P. zosteriformis*) commonly found in duck gizzards. The dispersal of viable seeds following ingestion by waterfowl is well-documented, although results vary widely depending on both plant species and seed retention time (Soons et al. 2008, Wongsriphuek et al. 2008, Farmer et al. 2017). Muenscher (1936) indicated that all *Potamogeton* seeds obtained from the stomachs of wild ducks germinated rapidly.

Some *Potamogeton zosteriformis* seeds have successfully germinated in greenhouse settings (Les 2020), even without any abrasive pre-treatment to remove the hard coats (Haag 1983, Baldridge and Lodge 2014). Muenscher (1936) studied the germination requirements of *P. zosteriformis* and other pondweeds using seeds collected directly from the plants. No germination occurred when Eel-grass Pondweed seeds were maintained in dry storage, in water at room temperature, or in cool water for a year, but some seeds germinated after they had been stored in cool water for 2–3 months (5%) or 5–6 months (16%). Haag (1983) noted that even after germination has taken place, many aquatic seedlings fail to reach maturity because they are easily uprooted, damaged by floating debris, or buried by litter.

Habitat

Potamogeton zosteriformis is usually associated with the quiet or slow-moving waters of ponds, lakes, or streams (Hough 1983, Rhoads and Block 2007, Haynes and Hellquist 2020), although it can occur in tidal waters (Tiner 2009) or sites with faster rates of flow (Les 2020). Eel-grass Pondweed has also been found in prairie wetlands (Hann 1995) and beaver ponds (Ray et al. 2001) as well as bays, channels, depressions, gravel pits, inlets, lagoons, marshes, rivers, sloughs, and washes at elevations up to 2,713 meters (Les 2020). Ray et al. (2001) observed that *P. zosteriformis*, along with other narrow-leaved pondweeds, typically colonized beaver ponds within the first ten years and continued to maintain a strong presence for several more decades—particularly in sites that lacked a significant cover of floating-leaved plants.

In New Jersey, *P. zosteriformis* has been found in permanently flooded calcareous ponds (Walz et al. 2001) and most of the extant populations in the state are situated in lakes over limestone bedrock (NJNHP 2022). The pondweed is most likely to be abundant in alkaline sites but it can also range into 'softer' waters (Moyle 1945, Hellquist 1980, Weakley et al. 2022). Measures of alkalinity at sites where *P. zosteriformis* occurred ranged from 18.1–245.0 and 5.5–150.7 mg HCO_3^- $liter^{-1}$ (Moyle 1945 and Hellquist 1980, respectively) and water pH values ranging from 5.6–10.0 have been recorded at sites where the species was present (Les 2020). *P. zosteriformis* has been found rooted in fine-textured sediments (Haag 1983), and in Minnesota it usually grows in sandy or mucky substrates although it sometimes grows in silt or gravel (Minnesota Wildflowers 2022). Plants have also been observed floating freely in the water (NJNHP 2022). Les (2020) indicated that the species is not tolerant of turbidity.

In New Jersey's calcareous lakes *Potamogeton zosteriformis* is often located in relatively shallow water near the shoreline (NJNHP 2022) but throughout its range the species has been known to grow at a wide variety of depths. In Wisconsin it was reported from shallowly submerged communities that were dominated by Tapegrass (*Vallisneria americana*) but absent from similar sites where *Myriophyllum sibiricum* was prevalent (Lind and Cottam 1969). Harman (1974) described a New York community as a mid-level strata of aquatic plants occurring at an average depth of 4 meters, and in Minnesota the pondweed has been found in waters up to 6 meters deep (Minnesota Wildflowers 2022). In one Canadian lake, *P. zosteriformis* was found at depths of 12–14 meters and the plants were firmly rooted in the sediment. Less than one percent of available light could reach the pondweeds that far beneath the surface, but growth may have been facilitated by unusually warm water and oxygen in the sediment (Pip and Simmons 1986). *Potamogeton zosteriformis* has a low light compensation point, which is defined as the light intensity at which photosynthetic carbon gain equals respiratory loss, and that may allow the plants to grow in deeper locations under certain circumstances (Knopik and Newman 2018).

Wetland Indicator Status

Potamogeton zosteriformis 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 2022b)

POZO

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 native range of *Potamogeton zosteriformis* spans the northern United States and includes most of Canada (POWO 2022). The map in Figure 1 shows the extent of *P. zosteriformis* in North America.

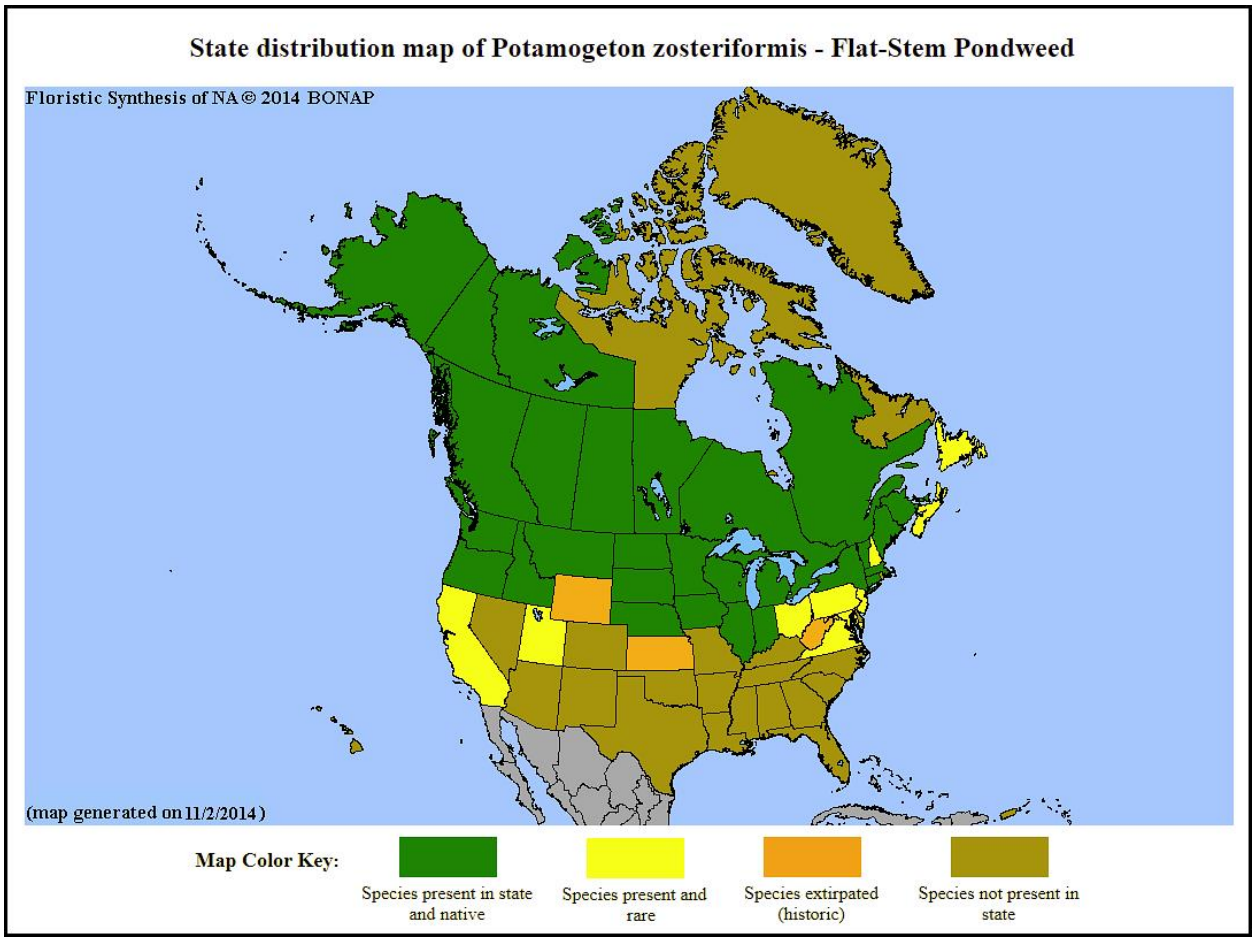


Figure 1. Distribution of P. zosteriformis in North America, adapted from BONAP (Kartesz 2015).

The USDA PLANTS Database (2022b) shows records of *Potamogeton zosteriformis* in five New Jersey counties: Bergen, Hunterdon, Morris, Sussex, and Warren (Figure 2 below). The data include historic observations and do not reflect the current distribution of the species.

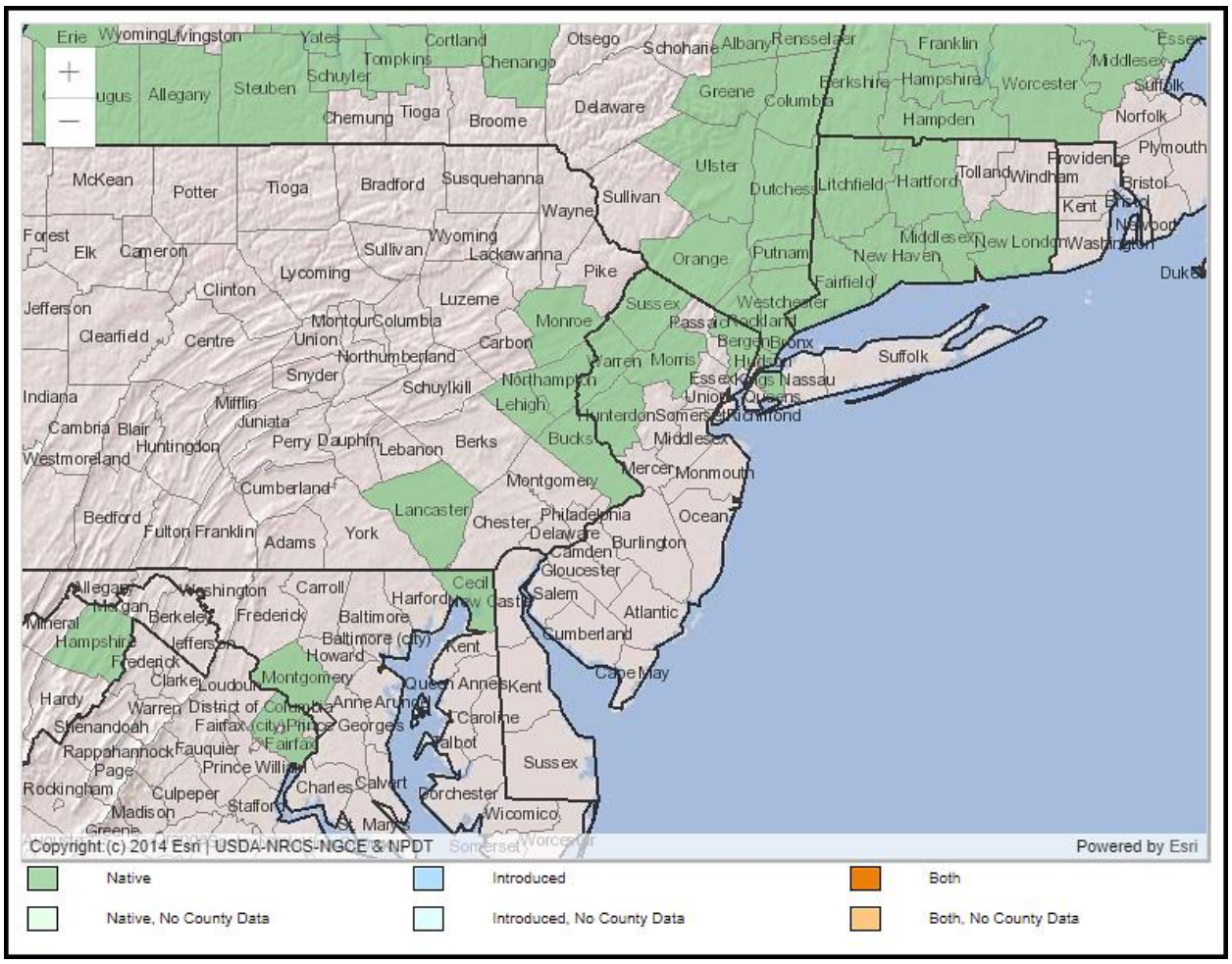


Figure 2. County records of P. zosteriformis in New Jersey and vicinity (USDA NRCS 2022b).

Conservation Status

Potamogeton zosteriformis 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 (NatureServe 2022). The map below (Figure 3) illustrates the conservation status of *P. zosteriformis* throughout its range. Eel-grass Pondweed is critically imperiled (very high risk of extinction) in six states and two provinces, imperiled (high risk of extinction) in one state, vulnerable (moderate risk of extinction) in four states and one province, and possibly extirpated in Kansas and West Virginia. The majority of the districts in which the species is rare are located along the southern and eastern edges of its range. The pondweed is secure, apparently secure, or unranked in most places where it occurs.

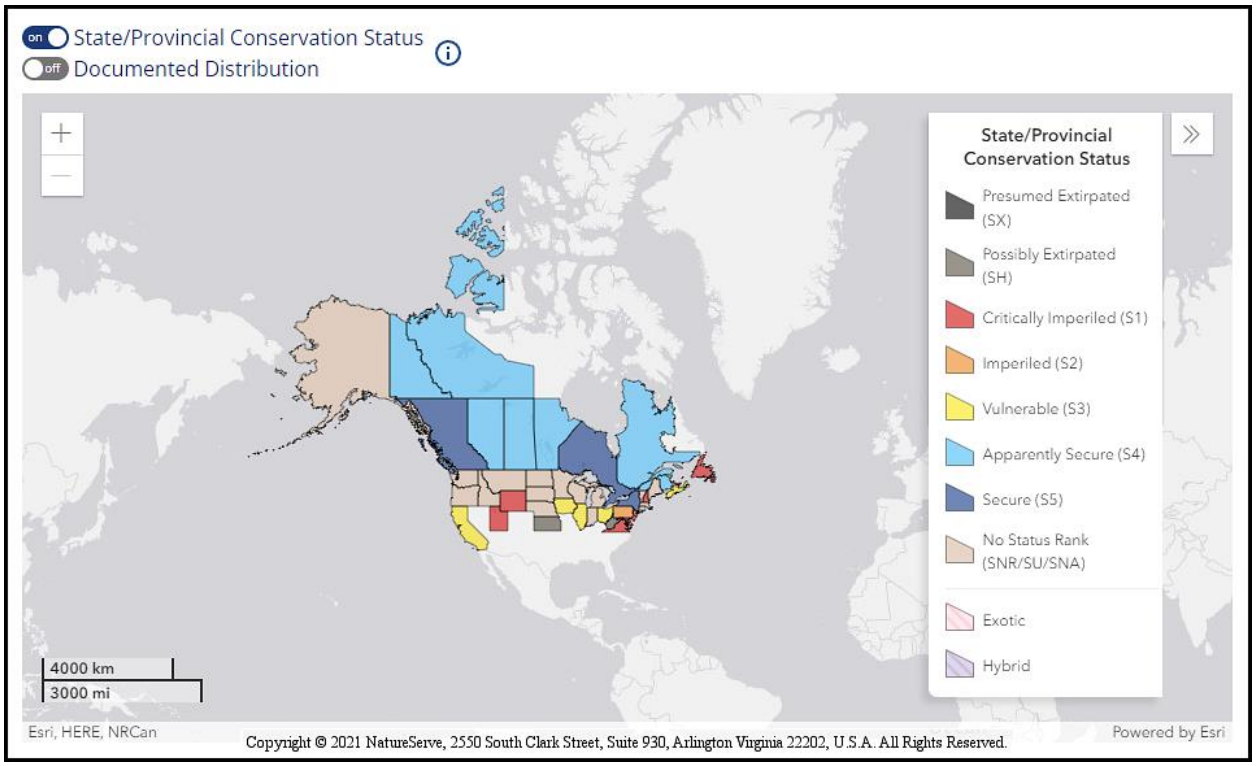


Figure 3. Conservation status of P. zosteriformis in North America (NatureServe 2022).

New Jersey is one of the states where *Potamogeton zosteriformis* is critically imperiled (NJNHP 2022). The S1 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. *P. zosteriformis* 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 the pondweed 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).

Potamogeton zosteriformis was first described less than a century ago so it was not included in the state's early floras, although specimens originating from some New Jersey populations between 1867–1910 were listed as representative in the initial description (Fernald 1932). Seven confirmed occurrences are presently tracked in the Natural Heritage Database, including two that are ranked as historical. The five extant populations are located in Morris and Sussex counties (NJNHP 2022).

Threats

Changes in habitat conditions that reduce light availability in the water column are likely to be detrimental to *Potamogeton zosteriformis*. As previously noted, Eel-grass Pondweed is intolerant of turbid conditions and unlikely to persist at sites where light is limited by dense

populations of water-milfoil (*Myriophyllum* spp.) or floating-leaved plants. At one site in New Jersey *Myriophyllum spicatum*, a highly invasive aquatic plant, has been noted as a threat to the rare pondweed (NJNHP 2022). *M. spicatum* spreads rapidly and branches profusely, shading out other submerged species, and pollution or other disturbances can give the exotic water-milfoil an added advantage over native aquatic flora (Kaufman and Kaufman 2007). The dense growth of *M. spicatum* can interfere with human recreational activities such as fishing, swimming or boating, making it a frequent target for eradication, but efforts to remove the invasive species using herbicides or mechanical means can become secondary threats to native plants in the same community (Kaufman and Kaufman 2007, NJNHP 2022).

Potamogeton zosteriformis plants support a rich invertebrate fauna but most of the species use the plants primarily as a resting substrate or shelter (Hann 1995). However, there are a number of insects that can damage the pondweed plants. The larvae of shore flies in the genus *Hydrellia* are leaf miners that excavate the leaves and stems of aquatic plants for food and pupal chambers. The immature insects survive underwater by penetrating the plant tissue with sharp, hollow spines in order to obtain oxygen from intercellular gas chambers. *Hydrellia* species documented on *P. zosteriformis* include *H. ascita*, *H. bergi*, *H. curalis*, *H. itascae*, and *H. luctuosa* (Berg 1949, Deonier 1971).

Potamogeton zosteriformis is also one of several pondweeds that serves as a larval food plant for *Parapoynx badiusalis*, the Chestnut-marked Pondweed Moth (Berg 1950). The larvae of *Parapoynx* species are equipped with gills so they can acquire oxygen directly from the water while feeding on the submerged pondweed leaves, and their activity can sometimes result in defoliation (Berg 1949). The Chestnut-marked Pondweed Moth occurs in New Jersey, although it is not abundant in the state (personal observation). While insect herbivory alone is not likely to threaten *P. zosteriformis* it can affect the competitive ability of the plants (Harms and Grodowitz 2009).

Parapoynx badiusalis from Morris County, NJ by J. S. Dodds, 2020.

A more serious threat may be emerging from the Rusty Crayfish (*Orconectes rusticus*). The species is native to western Ohio and adjacent states, but as a result of the live bait trade the large crayfish has become widely established throughout the continental United States during the past 50 years (Lodge et al. 2000). Crayfish are omnivorous and their diet includes aquatic vegetation, which is obtained by clipping the stems of plants near the substrate. The process is somewhat wasteful, as large fragments are often inadvertently released, and the presence of the crayfish can reduce the density of aquatic plants (Lodge et al. 1994). Wilson et al. (2004) tracked the spread

of Rusty Crayfish after their introduction into a Wisconsin Lake, reporting that once they became abundant in areas where aquatic macrophytes were growing the species richness and abundance of the flora declined, sometimes by as much as 80%. *Potamogeton zosteriformis* was not found in lakes with well-established populations of *O. rusticus* although the pondweed was present in comparable habitats where the crayfish were absent or in the early stages of invasion (Baldridge and Lodge 2014). Current range information indicates that the invasive crayfish has become established in three northern New Jersey counties (Durland et al. 2022).

Potamogeton zosteriformis relies heavily on vegetative reproduction, which is best suited for the maintenance of extant populations. The pondweed's poor regeneration from seed hampers its ability to colonize new sites when old habitats become unsuitable. A study of factors that influence the distribution of pondweeds in the Great Lakes region found that the extent of *P. zosteriformis* was partially governed by spatial variables such as location and proximity between suitable habitats, suggesting that the abundance of the species is limited by barriers to dispersal (Beck and Alahuhta 2017).

Changing climactic conditions could usher in new challenges for *Potamogeton zosteriformis*. Many of the places where the pondweed is already imperiled are located along the southern border of its range (see Figure 3) where it may be subjected to rising temperatures. Beck and Alahuhta (2017) found that the distribution of *P. zosteriformis* was positively correlated with low winter temperatures, and there is some evidence that the seeds require a period of cold stratification in order to germinate (Muenscher 1836). Populations of Eel-grass Pondweed in New Jersey are also likely to experience changing precipitation patterns that result in more intense storms and lengthier droughts (Hill et al. 2020). Stormwater runoff can introduce pollutants and increase turbidity, making existing habitats less suitable for *P. zosteriformis* and more susceptible to colonization by exotic species.

Management Summary and Recommendations

Invasive species management appears to be the priority for at least one New Jersey population of *Potamogeton zosteriformis,* as long as it can be done in a way that does not further endanger the pondweed or other rare flora with which it may co-occur. Kaufman and Kaufman (2007) noted that there is a native milfoil-weevil (*Euhrychiopsis lecontei*) that preferentially feeds on *Myriophyllum spicatum,* which could prove to be useful for managing the spread of the invasive plant.

As the climate continues to heat up, competition from other nonindigenous species is likely to increase. For example, *Potamogeton crispus* is an introduced pondweed that thrives in warmer waters (Beck and Alahuhta 2017). Regular monitoring of extant *P. zosteriformis* populations is recommended in order to identify emerging threats so they can be managed in a timely fashion.

Maintenance of water quality at sites that support healthy populations of *P. zosteriformis* should also be a consideration in management planning. Cooperation with the owners of adjacent lands may be needed in order to limit the introduction of silt or pollutants into lakes, ponds, or streams

that support the pondweed, and that is likely to be increasingly important as severe storms become more frequent.

Synonyms

The accepted botanical name of the species is *Potamogeton zosteriformis* Fernald. Orthographic variants, synonyms, and common names are listed below. The name *Potamogeton compressus* L. has sometimes been misapplied to Eel-grass Pondweed but *P. compressus* is a Eurasian species (Fernald 1932, Wiegleb and Kaplan 1998, ITIS 2022, POWO 2022, USDA NRCS 2022b).

Botanical Synonyms	Common Names
Potamogeton zosterifolius var. *americanus* A. Benn	Eel-grass Pondweed
Potamogeton zosterifolius var. *minor* Hook	Flatstem Pondweed
Potamogeton zosterifolius ssp. *zosteriformis* (Fernald) Hultén	

References

Baldridge, Ashley K. and David M. Lodge. 2014. Long-term studies of crayfish-invaded lakes reveal limited potential for macrophyte recovery from the seed bank. Freshwater Science 23(3): 788–797.

Beck, M. W. and J. Alahuhta. 2017. Ecological determinants of *Potamogeton* taxa in glacial lakes: assemblage composition, species richness, and species-level approach. Aquatic Sciences 79(3): 427–441.

Berg, Clifford O. 1949. Limnological relations of insects to plants of the genus *Potamogeton*. Transactions of the American Microscopical Society 68(4): 279–291.

Berg, Clifford O. 1950. Biology of certain aquatic caterpillars (Pyralididae: *Nymphula* spp.) which feed on *Potamogeton*. Transactions of the American Microscopical Society 69(3): 254–266.

Boedeltje, Ger, Jan P. Bakker, Renée M. Bekker, Jan M. van Groenendael, and Martin Soesbergen. 2003. Plant dispersal in a lowland stream in relation to occurrence and three specific life-history traits of the species in the species pool. Journal of Ecology 91: 855–866.

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.

Deonier, D. L. 1971. A systematic and ecological Study of nearctic *Hydrellia* (Diptera: Ephydridae). Smithsonian. Contributions to Zoology 68: 1–147.

Durland, Donahou, A., W. Conard, K. Dettloff, A. Fusaro, and R. Sturtevant. 2022. *Faxonius rusticus* (Girard, 1852): U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL. Accessed December 19, 2022 at https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=214

Dziuk, Peter M. 2017 and 2019. *Potamogeton zosteriformis*. Images courtesy of Minnesota Wildflowers, https://www.minnesotawildflowers.info/aquatic/flat-stem-pondweed 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.

Farmer, Jaime A., Elisabeth B. Webb, Robert A. Pierce II, and Kevin W. Bradley. 2017. Evaluating the potential for weed seed dispersal based on waterfowl consumption and seed viability. Pest Management Science 73(12): 2592–2603.

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

Fernald, M. L. 1932. The linear-leaved North American species of *Potamogeton*, section Axillares. Memoirs of the American Academy of Arts and Sciences 17(1): 1–183.

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

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.

Haag, R. W. 1983. Emergence of seedlings of aquatic macrophytes from lake sediments. Canadian Journal of Botany 61(1): 148–156.

Hann, Brenda J. 1995. Invertebrate associations with submersed aquatic plants in a prairie wetland. UFS (Delta Marsh) Annual Report 30: 78-84. Available at http://www.mb1870.org/deltamarsh/annualreports/1995/hann2.pdf

Harman, Willard N. 1974. Phenology and physiognomy of the hydrophyte community in Otsego Lake, N.Y. Rhodora 76(808): 497–508.

Harms, Nathan E. and M. J. Grodowitz. 2009. Insect herbivores of aquatic and wetland plants in the United States: A checklist from literature. Journal of Aquatic Plant Management 47: 73–96.

Haynes, Robert R. 1978. The Potamogetonaceae in the southeastern United States. Journal of the Arnold Arboretum 59: 170–191.

Haynes, R. R., D. H. Les, and L. B. Holm-Nielsen. 1998. In Klaus Kubitzki and T. Stuzel (eds). The Families and Genera of Vascular Plants, Volume 4: Flowering Plants. Monocotyledons: Alismatanae and Commelinanae (Except Gramineae). Springer-Verlag. 521 pp.

Haynes, Robert R. and C. Barre Hellquist. Page updated November 5, 2020. *Potamogeton zosteriformis* Fernald. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico [Online]. 22+ vols. New York and Oxford. Accessed December 15, 2022 at http://floranorthamerica.org/Potamogeton_zosteriformis

Hellquist, C. Barre. 1980. Correlation of alkalinity and the distribution of *Potamogeton* in New England. Rhodora 82(830): 331–344.

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.

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

ITIS (Integrated Taxonomic Information System). Accessed December 15, 2022 at http://www.itis.gov

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)].

Kaufman, Sylvan Ramsey and Wallace Kaufman. 2007. Invasive Plants: Guide to the Impacts and Control of Common North American Species. Stackpole Books, Mechanicsburg, PA. 458 pp.

Keevil, Matt. 2019. Photo of *Potamogeton zosteriformis* from Ontario. Shared via iNaturalist at https://www.inaturalist.org/observations/31426864, licensed by https://creativecommons.org/licenses/by-nc/4.0/

Knight, Susan. 2014. A winter's tale: Aquatic plants under ice. Lakeline, Winter 2014: 32-37. Available at http://www.nalms.org/wp-content/uploads/LakeLine/34-4/Articles/34-4-9.pdf

Knopik, Joshua M. and Raymond M. Newman. 2018. Transplanting aquatic macrophytes to restore the littoral community of a eutrophic lake after the removal of common carp. Lake and Reservoir Management 34(4): 365–375.

Koch, Evamaria W., M. Stephen Ailstock, Dale M. Booth, Deborah J. Shafer, and A. Dale Magoun. 2010. The role of currents and waves in the dispersal of submersed angiosperm seeds and seedlings. Restoration Ecology 18(4): 584–595.

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

Lind, Christopher T. and Grant Cottam. 1969. The submerged aquatics of University Bay: A study in eutrophication. The American Midland Naturalist 81(2): 353–369.

Lodge, David M., Mark W. Kershner, Jane E. Aloi, and Alan P. Covich. 1994. Effects of an omnivorous crayfish (*Orconectes rusticus*) on a freshwater littoral food web. Ecology 75(5): 1265–1281.

Lodge, David M., Christopher A. Taylor, David M. Holdich, and Jostein Skurdal. 2000. Nonindigenous crayfishes threaten North American freshwater biodiversity: Lessons from Europe. Fisheries 25(8): 7–20.

Lundholm, Jeremy T. and W. Len Simser. 1999. Regeneration of submerged macrophyte populations in a disturbed Lake Ontario coastal marsh. Journal of Great Lakes Research 25(2): 395–400.

Martin, Alexander C. 1951. Identifying pondweed seeds eaten by ducks. The Journal of Wildlife Management 15(3): 253–258.

Martin, A. C. and Uhler, F. M. 1939. Food of Game Ducks in United States and Canada. U. S. Department of Agriculture, Technical Bulletin 634. 156 pp.

Minnesota Wildflowers. 2022. *Potamogeton zosteriformis* (Flat-stem Pondweed). Retrieved December 19, 2022 from https://www.minnesotawildflowers.info/aquatic/flat-stem-pondweed

Moyle, John B. 1945. Some chemical factors influencing the distribution of aquatic plants in Minnesota. American Midland Naturalist 34(2): 402–420.

Muenscher, W. C. 1936. The germination of seeds of *Potamogeton*. Annals of Botany 50(200): 805–821.

NatureServe. 2022. NatureServe Explorer [web application]. NatureServe, Arlington, VA. Accessed December 15, 2022 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.

Ogden, E. C. 1974. *Potamogeton* in New York. New York State Museum Bulletin 423. University of the State of New York, Albany, NY.

Philbrick, C. Thomas and Gregory J. Anderson. 1987. Implications of pollen/ovule ratios and pollen size for the reproductive biology of *Potamogeton* and autogamy in aquatic angiosperms. Systematic Botany 12(1): 98–105.

Philbrick, C. Thomas and Donald H. Les. 1996. Evolution of aquatic angiosperm reproductive systems. BioScience 46(11): 813–826.

Pip, Eva and Kent Simmons. 1986. Aquatic angiosperms at unusual depths in Shoal Lake, Manitoba-Ontario. The Canadian field Naturalist 100: 354–358.

POWO. 2022. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Retrieved December 15, 2022 from http://www.plantsoftheworldonline.org/

Ray, A. M., A. J. Rebertus, and H. L. Ray. 2001. Macrophyte succession in Minnesota beaver ponds. Canadian Journal of Botany 79: 487–499.

Rhoads, Ann Fowler and Timothy A. Block. 2007. The Plants of Pennsylvania. University of Pennsylvania Press, Philadelphia, PA. 1042 pp.

Soons, Merel B., Cornelius van der Vlugt, Barth van Lith, Gerrit W. Heil, and Marcel Klaassen. 2008. Small seed size increases the potential for dispersal of wetland plants by ducks. Journal of Ecology 96: 619–627.

Tiner, Ralph W. 2009. Field Guide to Tidal Wetland Plants of the Northeastern United States and Neighboring Canada. University of Massachusetts Press, Amherst, MA. 459 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). 2022a. *Potamogeton zosteriformis* 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). 2022b. PLANTS profile for *Potamogeton zosteriformis* (Flatstem Pondweed). The PLANTS Database, National Plant Data Team, Greensboro, NC. Accessed December 15, 2022 at http://plants.usda.gov

Walz, Kathleen Strakosch, Robert J. Canace, James Boyle, Ron Witte, Michael S. Serfes, William Honachefsky, John Kurtz, and Rick Dutko . 2001. Identification and Protection of Reference Wetland Natural Communities in New Jersey: Calcareous Sinkhole Ponds of the

Kittatinny Valley. New Jersey Department of Environmental Protection, Division of Parks and Forestry, Office of Natural Lands Management, Natural Heritage Program, Trenton, NJ. 306 pp.

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.

Weber, Jacqueline. 2022. Photo of *Potamogeton zosteriformis* from Ontario. Shared via iNaturalist at https://www.inaturalist.org/observations/133667612, licensed by https://creativecommons.org/licenses/by-nc/4.0/

Wiegleb, G. and Z. Kaplan. 1998. An account of the species of *Potamogeton* L. (Potamogetonaceae). Folia Geobotanica 33: 241–316.

Wilson, Karen A., John J. Magnuson, David M. Lodge, Anna M. Hill, Timothy K. Kratz, William L. Perry, and Theodore V. Willis. 2004. A long-term rusty crayfish (*Orconectes rusticus*) invasion: Dispersal patterns and community change in a north temperate lake. Canadian Journal of Fish and Aquatic Science 61: 2255–2266.

Wongsriphuek, Chanpen, Bruce D. Dugger, and Anne M. Bartuszevige. 2008. Dispersal of wetland plant seeds by Mallards: Influence of gut passage on recovery, retention, and germination. Wetlands 28(2): 290–299.