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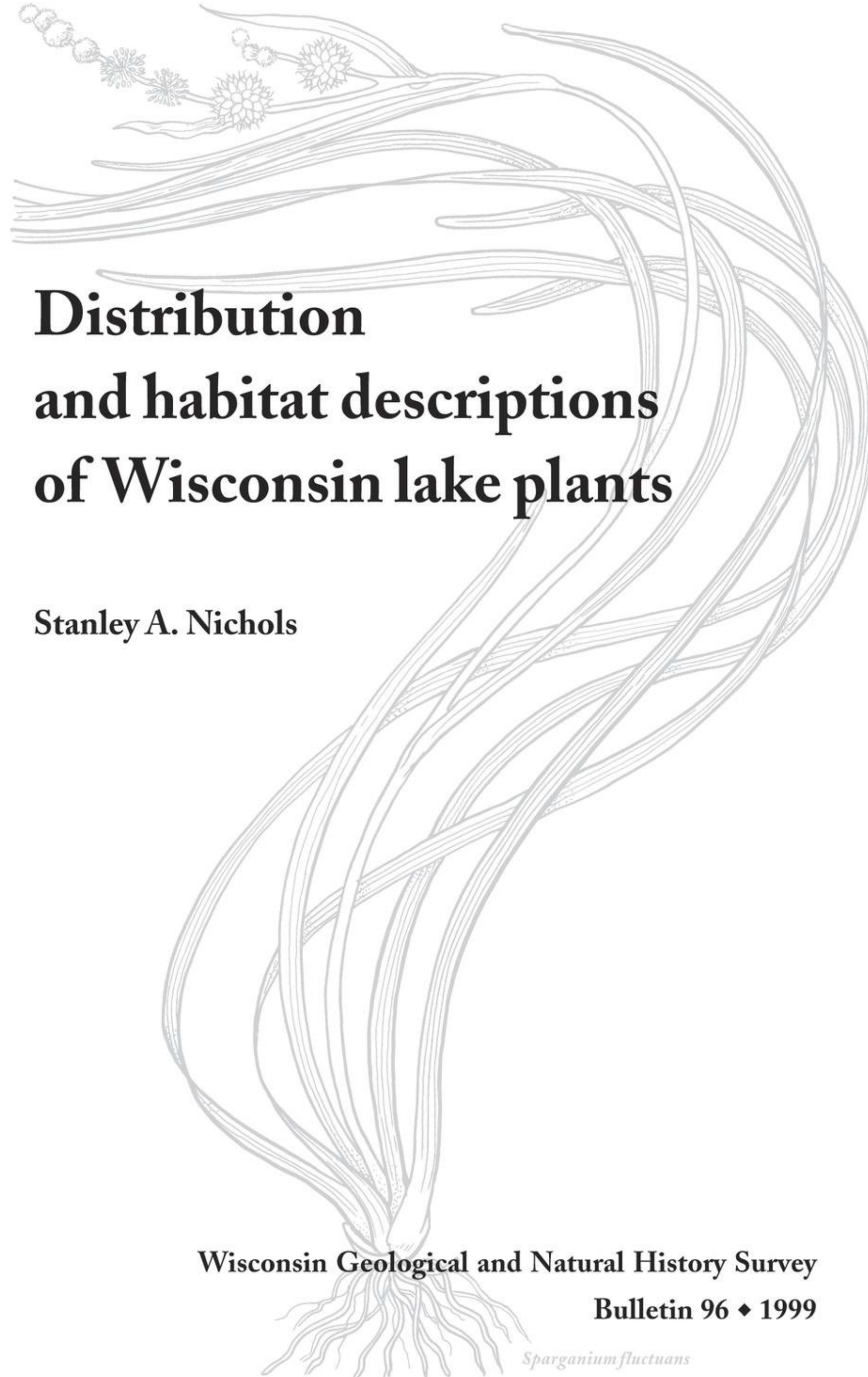

Distribution and habitat descriptions of Wisconsin lake plants

Stanley A. Nichols

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Sparganium fluctuans

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Mission of the Wisconsin Geological and Natural History Survey
The Survey conducts earth-science surveys, field studies, and research. We provide objective scientific information about the geology, mineral resources, water resources, soil, climate, and biology of Wisconsin. We collect, interpret, disseminate, and archive natural resource information. We communicate the results of our activities through publications, technical talks, and responses to inquiries from the public. These activities support informed decision-making by government, industry, business, and individual citizens of Wisconsin.

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Abstract

In this report I provide information about Wisconsin lake plants that can be useful to aquatic ecologists, lake managers, and educators interested in the ecology and proper management of the lake-plant resource. Because the information presented here is open to interpretation, the report does not dwell on interpretation—readers can use the information in ways that fit their needs.

For this report I gathered and synthesized information from herbaria and from the literature to describe the habitat patterns of Wisconsin lake plants. I examined these patterns by studying each plant's geographic distribution and distribution with regard to physical and chemical parameters, including water depth, pH, total alkalinity, conductivity, substrate preference, and turbidity tolerance. I compared species distributions along gradients of physical and chemical parameters and similarity of habitats.

Geographic distribution within Wisconsin, flowering and fruiting dates, and associations with other lake-plant species are shown on a species-by-species basis. Geographic distribution information allowed plants to be placed in an ecoregional context within the state and species distributions to be compared to generalized gradients of summer total phosphorus, sulfate, magnesium, total alkalinity, chloride, and calcium in Wisconsin lakes.

Most lake plants in Wisconsin are infrequent to common and are found over a limited to moderate range of habitat conditions. A few are rare and have a limited habitat range; these species are likely to need protection. Some species are abundant and can thrive over a broad range of habitats—these species are most likely to cause aquatic nuisances. Species that have a limited distribution in the state are often at the northern or southern edge of their distribution range or their preferred habitat is found only in a single ecoregion. Most species are common in the ecoregion(s) in which their preferred habitat is found. The

descriptions of species habitats in this report can be used in combination with information from other studies to build a regional, continental, or global perspective of species habitats.

Most physical-chemical distributions are skewed toward low values (shallow water, low alkalinity and conductivity, and so forth), and the minimum values where species are found are much more similar to each other than the maximum values are to each other. Skewed distributions in Wisconsin could be strongly influenced by the limited choice of habitat that the plants have to grow in when compared to a broad range of habitat over their entire distribution range. Species having similar habitat requirements are not necessarily found growing together; habitat similarities do not predict species associations very well.

Overview

Introduction

Lake plants as a group are not well understood, but the need for understanding them is great. The role they play in littoral zone ecology is increasingly being appreciated (Engel, 1990; Carpenter and Lodge, 1986). Lake plants can have positive and negative impacts upon lake use, and a few cause nuisance conditions, especially in some of Wisconsin's largest and most heavily used lakes. Much research has been conducted for a limited number of species, generally about those that are the worst aquatic nuisances or those that make particularly interesting laboratory subjects. Protecting the resource and managing it for beneficial purposes, yet meeting lake-user demands for increased water-based recreation, make aquatic plant management increasingly complex and an understanding of lake-plant ecology increasingly important.

This report is the third in a series (Nichols and Martin, 1990; Nichols and Vennie, 1991) of publications designed to increase the understanding of lake-plant biology and to help protect and manage lake plants in the future. In this volume I report the distribution patterns of lake-plant species; this method of describing habitat can lead to hypotheses that can be rigorously tested in the field or laboratory.

Wisconsin has a diverse lake flora (Nichols and Martin, 1990). Each species has limits to the habitat in which it will thrive and survive. Species with similar habitat requirements tend to grow together, but because the number of environmental factors that may influence plant growth is large, no two species have exactly the same habitat requirements. Studying the ecology of each species in each lake would be a never-ending task. However, studying how plants group themselves gives insights into the needs of the group, if the habitat requirements of some group members are known.

For example, consider the "isoetid" species. They are a group of small, rosette plants, including *Eriocaulon aquaticum, Gratiola aurea, Isoetes lacustris, Litorella uniflora,* and *Lobelia dortmanna*, that are found in low-alkalinity lakes of northern Wisconsin. These species have unique mechanisms for obtaining and conserving carbon for photosynthesis (Adams, 1985). Not all plants found in this habitat have been studied and they are a taxonomically diverse group, but they all need some mechanism for obtaining carbon in a low-carbon environment. The mechanisms already known would be suspected in the unstudied species because the species are functionally related for dealing with the same habitat limitations.

Many of the species studied are widespread. This report helps define the habitat of these species over a limited part of their range and complements other studies (Crow and Hellquist, 1981, 1982, 1983, 1985; Hellquist and Crow, 1980, 1981, 1982, 1984; Pip, 1979, 1984; Beal, 1977; Kadono, 1982; Moyle, 1945; Seddon, 1972; Hutchinson, 1975) to build regional, continental, and global perspectives of plant distributions and habitat requirements. This may be especially important where habitat requirements differ because of ecotypic variation.

It is not the purpose of this report to revise the taxonomy of any species or plant group. Taxonomy is discussed where needed to clarify environmental interpretations or to aid identification of particularly difficult-to-identify species.

Many plant-identification manuals provide information about the habitat in which plants are found. Descriptions, especially those found in Voss (1972, 1985), Crow and Hellquist (1981, 1982, 1983, 1985), and Hellquist and Crow (1980, 1981, 1982, 1984), supplement the information found here. The difference between those descriptions and the ones provided here lies in the statistical analyses placed on observations in this study.

This volume is a pioneering effort rather than a final definitive report. It is in part a plea for investigators to look more closely at lake plants. Careful observation and good records in accessible locations will greatly aid the further refinement of the information presented here. Even if later studies show that the information presented here needs major revision, the report has served its purpose if it stimulates investigators to study this interesting component of the natural world.

The setting: Patterns in the landscape

Because of its approximately 14,500 lakes (fig. 1), which vary widely in size, shape, morphometry, chemistry, and mode of origin (Lillie and Mason, 1983), Wisconsin is a good setting for the study of lake plants. Lakes largely re-

Figure 1. Landforms map of Wisconsin, showing general distribution of lakes.

flect the landscape in which they are found, so it is important to understand the patterns in that landscape before looking at the distribution of individual species.

Omernick and Gallant (1988) divided the state in five relatively homogeneous areas that they called ecoregions to serve as a framework for resource management: the Northern Lakes and Forests, North Central Hardwood Forests, Southeastern Wisconsin Till Plain, Driftless Area, and Western Corn Belt (fig. 2). They developed these regions on the basis of a combination of land-use factors, surface landforms, potential natural vegetation, and soils. Although general, these regions were useful to this study because many aquatic plant species are broadly tolerant of environmental conditions.

The Northern Lakes and Forests Ecoregion contains the majority of the state's lakes. Most Wisconsin lakes greater than 10 ha in area and more than 2 m deep are located in this region. Lakes in this ecoregion generally have low levels of calcium, magnesium, chloride, turbidity, nutrients, and chlorophyll *a* (Lillie and Mason, 1983). Many lakes are brown stained and have low pH.

Many lakes in the North Central Hardwood Forests Ecoregion are less than 40 ha in area. Alkalinities there closely resemble those of the southern regions; nitrogen, phosphorus, chloride, turbidity, chlorophyll *a,* and water clarity are similar to those found in northern regions (Lillie and Mason, 1983). Water quality is generally very good in this region.

High alkalinity, calcium, magnesium, and pH levels are characteristic of the Southeastern Wisconsin Till Plain Ecoregion (Lillie and Mason, 1983). Water quality and clarity are generally below statewide averages, but water quality varies considerably. High human population levels are found here; consequently, these lakes are most likely to suffer from human impacts.

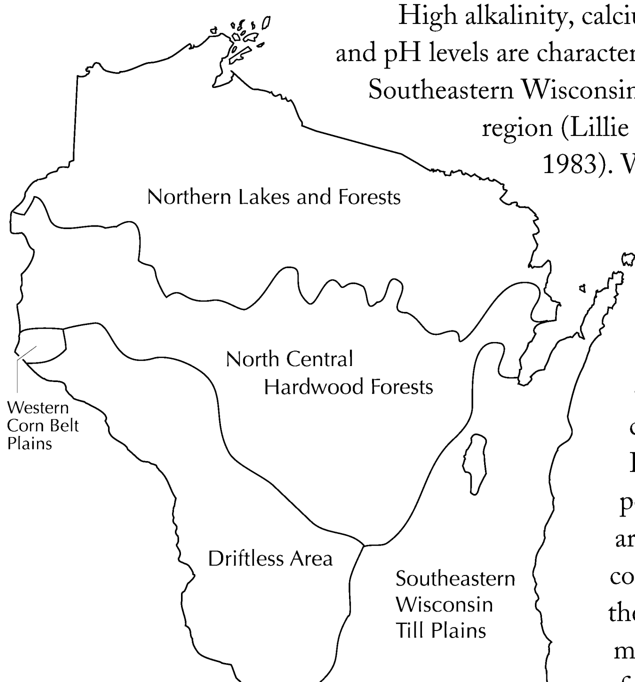


Figure 2. Map of Wisconsin, showing Omernick and Gallant (1988) ecoregions[1].

[1] Figures 2–8 are drawn at the same scale as the plant-distribution maps. Photocopying these figures on clear acetate provides an easy way to view species distributions in relation to various habitat factors.

There are not many lakes in the Driftless Area Ecoregion. They are mostly shallow, eutrophic impoundments. Generally, water quality is poor. Such a small area of the Western Corn Belt Ecoregion is found in the state that it was not considered in these analyses.

Water quality varies considerably between the ecoregions. A high percentage of lakes in the Northern Lakes and Forests Ecoregion has good water quality. Each region has some lakes that have poor water quality, and each lake has some unique characteristics. The best water quality and clarity, although perhaps not the best conditions for plant growth, are coincidental with low nutrient levels (Lillie and Mason, 1983). Depending on size, shape, depth, stratification characteristics, water sources, drainage type, and watershed characteristics, a lake may or may not reflect regional conditions.

Patterns of specific factors can be defined in more detail when treated separately. These factors often correspond generally, but not precisely, with ecoregions. Maps show summer total phosphorus (fig. 3; Omernick and others, 1988), sulfate, magnesium, alkalinity, chloride, and calcium (figs. 4–8; Lillie and Mason, 1983). These factors are either discussed in this report, discussed by other authors as an important cause of plant distribution (see references to regional studies in *Introduction* section), or form a component of a factor discussed in this report or by other authors. I examine the factors in conjunction with plant-distribution patterns to help refine more general distribution information by ecoregion.

Species described

In this report I describe only plant distributions in lakes. To be considered a lake, a water body had to be classified as a lake or impoundment in the Wisconsin Department of

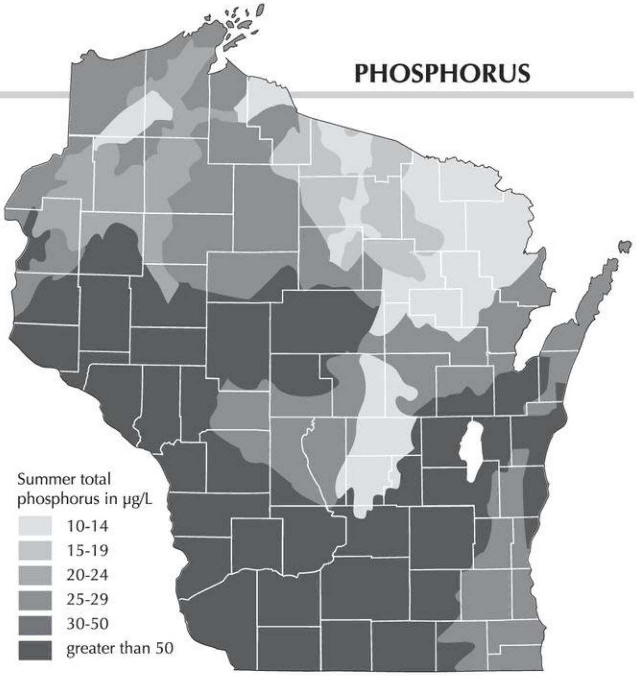


Figure 3. Generalized distributional gradient of summer total phosphorus of Wisconsin lakes (after Omernick and others, 1988).

Natural Resources Surface Water Inventory. Neither aquatic plants nor lake plants have been precisely defined (Curtis, 1959; Beal, 1977). The species I describe were taken from a list (Nichols and Martin, 1990) developed by compiling species found in a variety of lake-plant surveys. To this list were added submersed, floating-leaf, and free-floating species found by Read (1982); deleted were emergent species that were found in less than 2 percent of the lakes in the Wisconsin lake plant database of Nichols and Martin (1990). For this report, a lake plant is a plant that was found by people doing lake surveys. They are mostly plants that could be sampled or collected from a boat.

This list is dynamic. *Armoracia lacustris* (A. Gray) Al-Shebaz & V. Bates and *Ranunculus gmelinii* DC., for example, were on the original plant list, but they are not included here because no distribution records could be confirmed for lakes. Recently, however, *A. lacustris* was collected in the Peshtigo Flowage in Oconto County (R. Krueger, written communication) and *Rotala ramosior* (L.)

Figure 4. Generalized distributional gradient of sulfate of Wisconsin lakes (after Lillie and Mason, 1983).

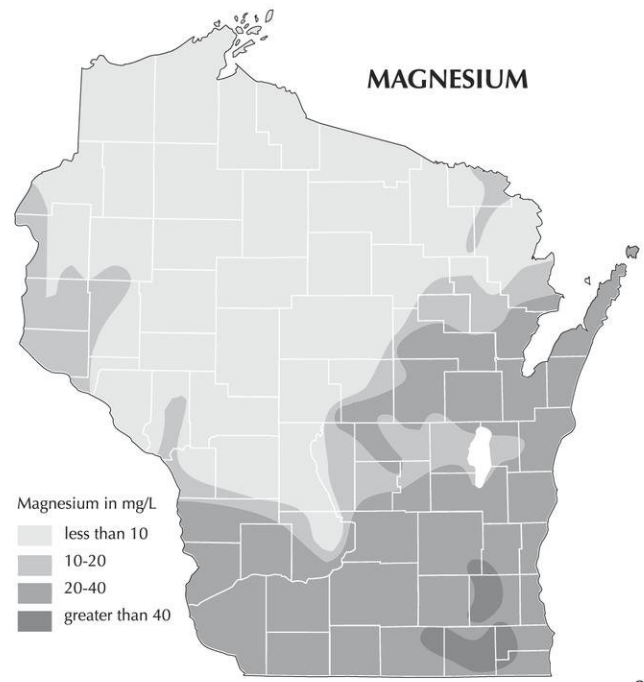


Figure 5. Generalized distributional gradient of magnesium of Wisconsin lakes (after Lillie and Mason, 1983).

Figure 6. Generalized distributional gradient of total alkalinity of Wisconsin lakes (after Lillie and Mason, 1983).

Elliott was collected in the summer of 1994 as a submergent species in the Rainbow Flowage, Oneida County (Weber and others, 1995). When reports confirm additional species, they should be added to the list.

Naming of plant species follows Gleason and Cronquist (1991), who consolidated the taxonomic literature and tended to lump species that were previously difficult to identify.

Distributions

Aquatic plants are not evenly or even randomly distributed across the state. Habitat preferences of common plants are easy to describe because information is readily available. However, information about rare plants is much more limited, and describing their distributions and habitat preference is more tenuous.

Information about depth distribution, substrate preference, or common associates involve habitat close to the

Figure 7. Generalized distributional gradient of chloride of Wisconsin lakes (after Lillie and Mason, 1983).

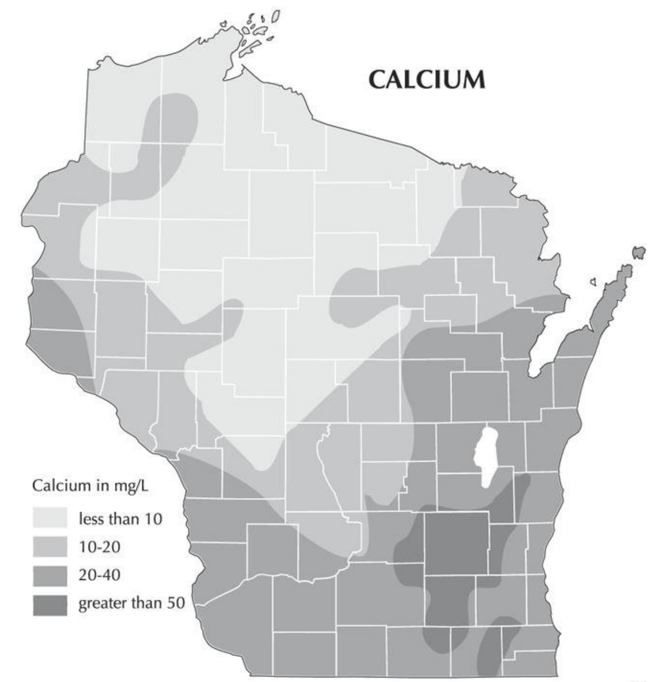


Figure 8. Generalized distributional gradient of calcium of Wisconsin lakes (after Lillie and Mason, 1983).

plant, but broad geographic areas must be considered when determining distributions related to chemical factors. Scale and ecosystem hierarchy also need to be taken into account in analyses describing habitat factors (Farmer and Adams, 1991). For this report I used some measurements that were taken within the square meter within which the plant grew; others were recorded for the lake where a plant was found. Where data were less available, I compared the pattern of plant distribution to regional patterns of water chemistry, such as calcium ion or mean summer total phosphorus.

Scale and hierarchy must also be considered when interpreting the results. Consider *Typha latifolia* and *Scirpus validus*. Photosynthetically, these emergent species should have no problem growing in turbid water, but they do not show a positive association with turbidity (Nichols, 1992). Turbid water may indicate other limiting factors, such as abundant carp (*Cyprinus carpio*) or strong wave action. Similarly, calcium ions could determine the ability of a lake to support or not support snails that browse on certain macrophytes. Snail populations could determine the plant's ability to thrive there. In these cases, the plant may be limited at a different hierarchical scale than is defined by the immediate physiological tolerances of the plant.

In this report I do not necessarily make these interpretations, but report the results of a series of tests. These results may seem unusual on the basis of present knowledge, but present knowledge is limited.

Database development

Data sources

I developed two databases for determining species distributions. One database, which describes the vegetation in 448 lakes, is based on information taken from the literature cited in Nichols and Martin (1990). The database covers a wide geographic area (at least one lake each from 50 of the

72 Wisconsin counties is represented) and offers the ability to study plant communities in lakes. Although recognized authorities like Norman Fassett, John Steenis, and Neil Hotchkiss conducted many surveys included in the database, there are limitations to the quality control of survey data. In many instances voucher specimens were not placed in herbaria; therefore, the accuracy of identifications cannot be verified. Some of the records used in this database were collected by the Wisconsin Department of Natural Resources for the assessment of potential scientific areas or the status of rare, endangered, or threatened plant species.

A second database was developed from herbarium specimens from University of Wisconsin–Madison, University of Wisconsin–Milwaukee, University of Wisconsin–Oshkosh, University of Wisconsin–Stevens Point, University of Wisconsin–La Crosse, Milwaukee Public Museum, and the private collections of Susan Borman (Wisconsin Department of Natural Resources) and Galen Smith (University of Wisconsin–Whitewater, retired). Plant distribution data came from 1,142 lakes. When compared to a random data set of Wisconsin lakes (Lillie and Mason, 1983), the lakes in this group were slightly larger in area, slightly more alkaline, and similar in pH.

The advantage of using herbarium specimens is the ability to confirm species, but often collections are made from limited geographic areas. Combining the two databases provided good geographic coverage of the state and assessed a broad spectrum of lake-habitat conditions.

In addition, information about depth distribution, substrate preference, turbidity tolerance, and associated species came primarily from Nichols (1990, 1992), in which the data sources and analysis techniques are explained. Physical and chemical data for each lake in which plants were found were taken from the Wisconsin Department of Natural Resources Surface Water Inventory.

Search strategies

It is probably neither possible nor necessary to record every occurrence of every lake plant in the state. Any effort to do so is outdated with the next new collection.

For this report, I developed a search strategy that first recorded all plants of interest in the University of Wisconsin–Madison herbarium and the previously described literature database (Nichols and Martin, 1990). Preliminary analyses of these data indicated that interpretable distribution patterns began to appear when a species was found in approximately 20 lakes; therefore, if the above data sources yielded 20 separate and useable locations (see next paragraph for a definition of useable location), more records were not collected for that species. Further efforts were focused on undercollected species. When a new data source was used, all records for a species in that source were collected. Collections would not stop at 20 locations, but information for that species would not be collected from subsequent data sources if the total number of separate and useable locations for a species exceeded 20. Sample-size goals were not always met, especially with rare or undercollected species. These species were included in the report, but less can be said about their habitat requirements and with less confidence than for well represented species.

A useable location was one that could be identified as a water body found in the Wisconsin Department of Natural Resources Surface Water Inventory. This was necessary for assigning habitat and locational attributes to the collection point. This definition of useable eliminated some information because poor locational data did not allow plant occurrence to be linked to a specific lake. It also eliminated the use of some regional studies that reported plant location on a geographic basis (for example, by county), but did not give exact location by lake.

Because of the search strategy used, the distributions shown in this report differ from those found in many traditional plant-distribution maps. The mapping and plotting objectives were to link plant locations to lakes with defined habitat and locational attributes. The habitat and locational attributes of these lakes help define plant habitat by showing statistical distributions of habitat characteristics or by placing the plant in an ecoregion or area of the state with known habitat characteristics. Traditional range maps often place a locational point in some geopolitical region that may or may not relate to habitat.

Plant distributions in two significant water bodies were consciously ignored: in the Great Lakes and in the pools of the Upper Mississippi River. These water bodies cross many ecoregions, and collections are much more difficult to link to specific locational or habitat characteristics. Extensive aquatic plant information for the Upper Mississippi River is available from the U.S. Geological Survey Biological Resources Division (Sara Rogers, National Biological Service, Onalaska, Wisconsin, verbal communication, 1995).

Data handling

The data were entered in an R:BASE® (Microrim, 1987) database-management system. The files were sorted by species and the literature and herbarium data were combined for most analyses. For geographic and chemical distributions, duplicate data were deleted to eliminate any bias introduced by having multiple occurrences of a plant in a lake. If a plant was found in a lake from herbarium and literature sources, the occurrence was noted as a herbarium record. Because of the search strategy used, some distribution points noted as literature sources may have voucher specimens in herbaria that were not searched for that species.

All phenological records are based on herbarium specimens. To avoid unfair bias, duplicates that were obviously replicates of a single collection were eliminated. However, two or more plants collected from the same lake on the same day were retained for phenological analysis if they displayed different phenological characteristics (for instance, one plant might be flowering and the other in fruit).

Methods, analyses, and definitions

Geographic distributions

Distribution maps were plotted using PC ARC/INFO® (Environmental Systems Research Institute, 1990); symbols indicate whether the source of the data was a herbarium specimen or a literature citation. Herbarium sources were preferred because they can be confirmed. Unconfirmed data were considered most suspect when a distribution point lay far outside the range shown by the confirmed data.

I use the terminology of Nichols and Vennie (1991) to describe the abundance of plants and indicate how frequently a species was found by Nichols and Martin (1990). A species was *abundant* if found in 35 percent or more of the lakes surveyed; *common,* in 15 to 34 percent of the lakes; *infrequent,* in 2 to 14 percent of the lakes; *rare,* in less than 2 percent of the lakes. The species abundance in lakes does not necessarily reflect its total abundance in the state's flora. Some plants that are only infrequently or rarely found in lakes could be common in streams, marshes, or other aquatic sites. It also became obvious when working with these plants that some species are undercollected or underreported. This sometimes occurs with species that are so common that people do not bother to record or collect them. It is noted in the species descriptions if this appears to be the case.

Depth distribution and water chemistry

Boxplots (fig. 9) illustrate depth distribution and water chemistry. There are several advantages to using boxplots (Reckhow and Chapra, 1983). Boxplots use medians as the measure of central tendency. Medians are robust and efficient under non-normal distribution conditions (Reckhow and Chapra, 1983), which is often the situation for these distributions. Medians are also not strongly influenced by outliers. These are important considerations for cases in which several sources of potential error, such as misidentified species, nonrepresentative water samples, or data-entry error in large databases, could influence data analyses and interpretation. Median statistics minimize problems caused by these potential errors.

The notch shows a confidence interval for the median. The definition of notch by Reckhow and Chapra (1983) was used in this study. It provides an approximate 95 percent confidence interval for comparison of medians.

The endpoints of the boxplots were either the maximum and minimum values or were trimmed to the positive and negative inner fence (Minitab, 1991), whichever values were the least. This further reduces misinterpretation caused by outlier data and displays the distribution for the species on the basis of the most typical of approximately 90 to 100 percent of the distribution points. The influence of this is clearly seen with depth distributions. *Najas flexilis,*

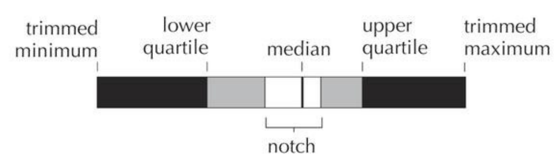


Figure 9. Generalized boxplot construction showing the location and pattern used to display depth and chemical distributions.

for example, has been reported in water depths greater than 7 m (Nichols, 1992). The positive end point plotted here is 3.2 m. Any plants found in depths greater than 3.2 m were considered outliers and were not typical of the depth distribution; therefore, they were not plotted.

When 20 or more data points were available, a full boxplot, including end points, quartiles, median, and notch, shows the data distribution. If 10 to 19 data points were available, the notch was not plotted. Individual points were plotted if there were fewer than 10 data points (for example, *Elatine triandra* Schkuhr.). Preliminary analyses calculated the number of unique locations required to reduce the notch width to a set percentage of the median (for example, 5% and 10%). In many cases the number needed far exceeded the number available; in these cases, the median is not as precisely defined (that is, the notch is wider) as would be expected with more samples.

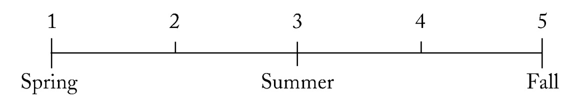
In some cases, part of a boxplot may obscure other parts. An order of precedence was established so that the median and ends were plotted first, then the notch, and finally the quartiles. A wide notch may cover a quartile.

The water-chemistry patterns studied are not independent of one another and understanding the relationship, especially between alkalinity and pH, can help explain apparent anomalies in some distributions. Water-chemistry parameters can vary considerably from day to day and location to location in a lake. This variability is not reflected in the analyses presented here.

I use specific terms to describe the water-chemistry distributions of each plant. These terms compare the range occupied by a species to the total range occupied by all species. If a species has *broad* distribution, its range covered 75 percent or more of the range of all species. A *moderate* distribution covered 50 to 74 percent, a *limited* range 25 to 49

Table 1. Flowering and fruiting times and their weights for averaging.

	Flowering/fruiting date	Weight
spring	before June 22	1
early summer	June 22–July 22	2
midsummer	July 23–August 22	3
late summer	August 23–September 22	4
fall	after September 22	5



percent, and a *narrow* range less than 25 percent of the total distribution range.

Flowering and fruiting times

Flowering and fruiting times were established as a weighted average of five or more flowering or fruiting dates (table 1). The weighted average placed flowering and fruiting times on the spring to fall (1–5) scale.

Considerable variation would be expected in flowering and fruiting times on the basis of year to year climatic variation, south to north distribution of the plants, location of the plants in the water column (shallow or deep water), and aspect (south- or north-facing shore, for example). Because flowering and fruiting information was collected from herbarium specimens, it is not known whether the record represented first flowers or fruits or old flowers and fruits. In some cases, average flowering and fruiting dates can be misleading. *Myriophyllum spicatum,* for example, can flower and fruit more than once during the growing season. Average dates are between true flowering and fruiting times. Other species for which this might occur are not known, but the problem is probably minor.

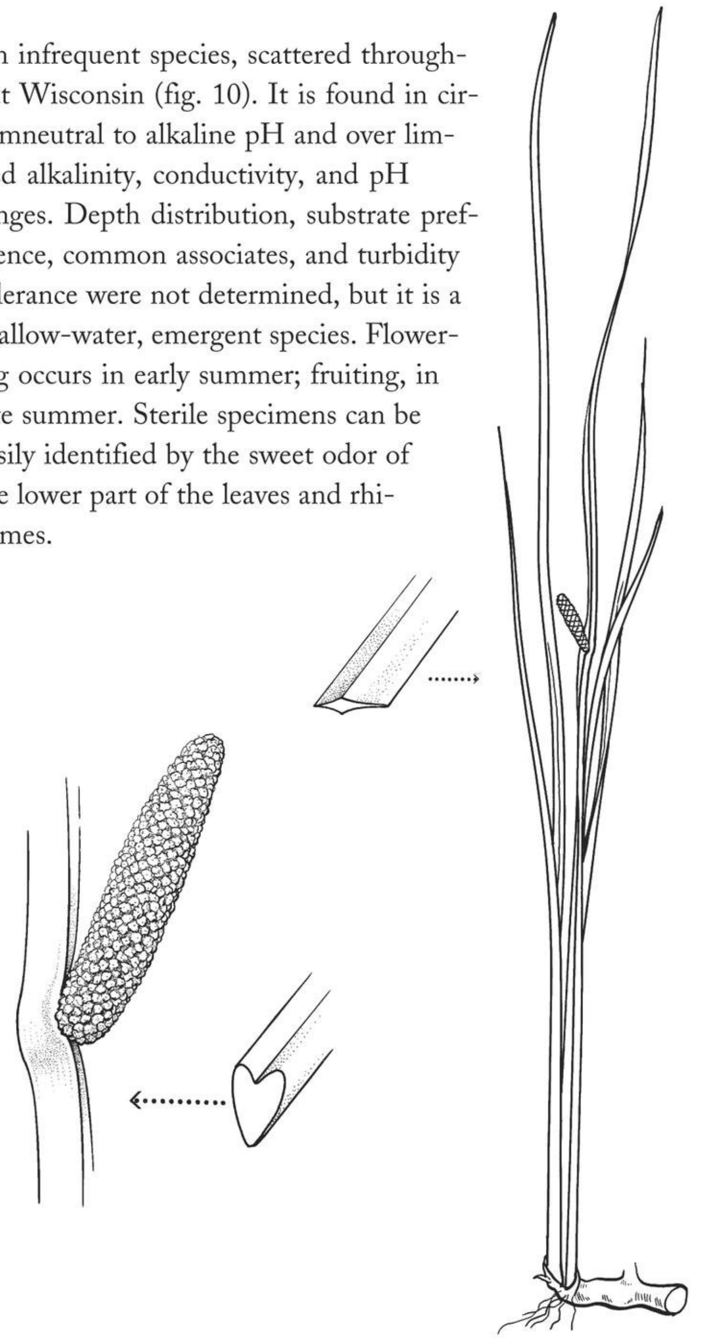
Substrate preference, turbidity tolerance, and common associates

The statistics used for determining substrate preference, turbidity tolerance, and common associates are explained in Nichols (1990, 1992). Species were determined to prefer a substrate if they had a positive association with that substrate. A species was called turbidity tolerant if it had a positive association with turbid water. A common associate was arbitrarily defined as a plant that showed a positive Cole's index value of 0.15 with the species of interest (Nichols, 1990). There is an important distinction between plants that had no associates (that is, the data were analyzed and no positive association greater than 0.15 was found) and plants for which not enough data were available to do a valid analysis; therefore, associates are unknown.

GEOGRAPHIC AND HABITAT DISTRIBUTION, BY SPECIES

I have organized this section alphabetically by scientific name of the plant. For each species, a map showing its geographic distribution is provided along with boxplots of depth, pH, conductivity, and alkalinity distributions, if available. Phenological, substrate, and turbidity information is also provided, if available. The abundance of the plant as part of the total lake flora, common associates of the plant, and a synthesis of habitat information are discussed for each species. A drawing and taxonomic information are also included, where appropriate.

An infrequent species, scattered throughout Wisconsin (fig. 10). It is found in circumneutral to alkaline pH and over limited alkalinity, conductivity, and pH ranges. Depth distribution, substrate preference, common associates, and turbidity tolerance were not determined, but it is a shallow-water, emergent species. Flowering occurs in early summer; fruiting, in late summer. Sterile specimens can be easily identified by the sweet odor of the lower part of the leaves and rhizomes.



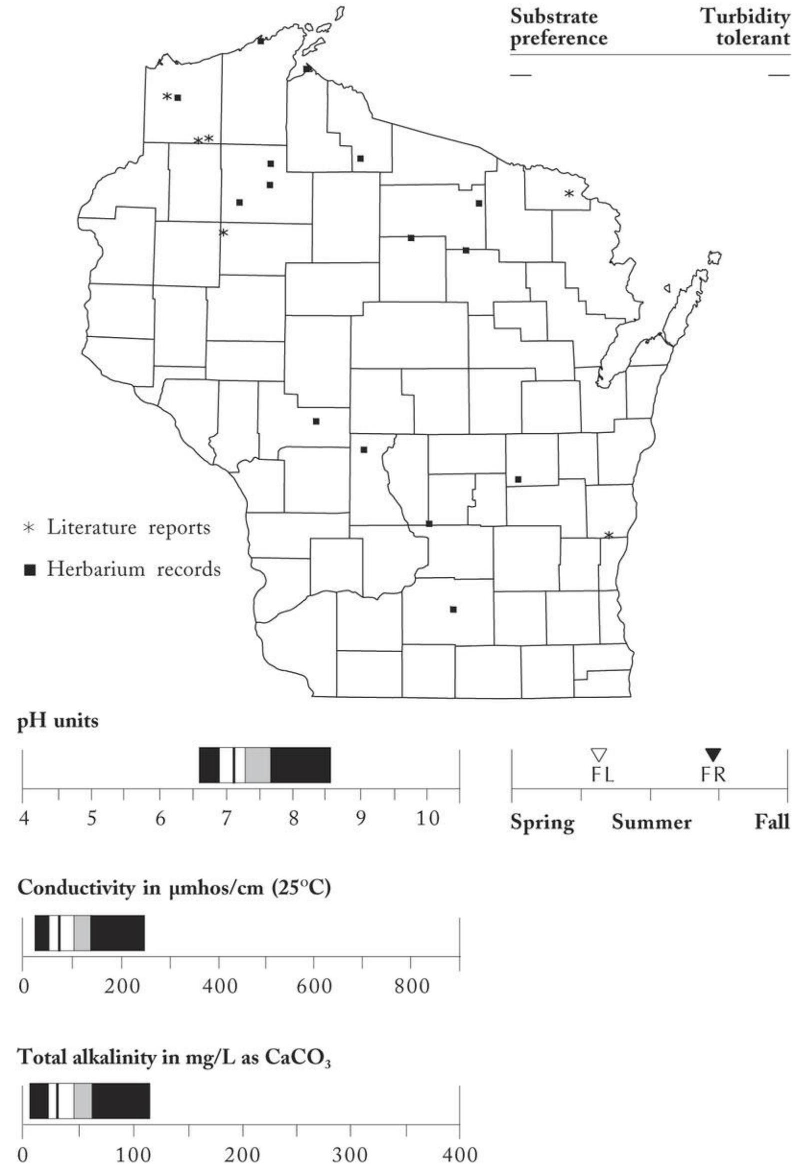
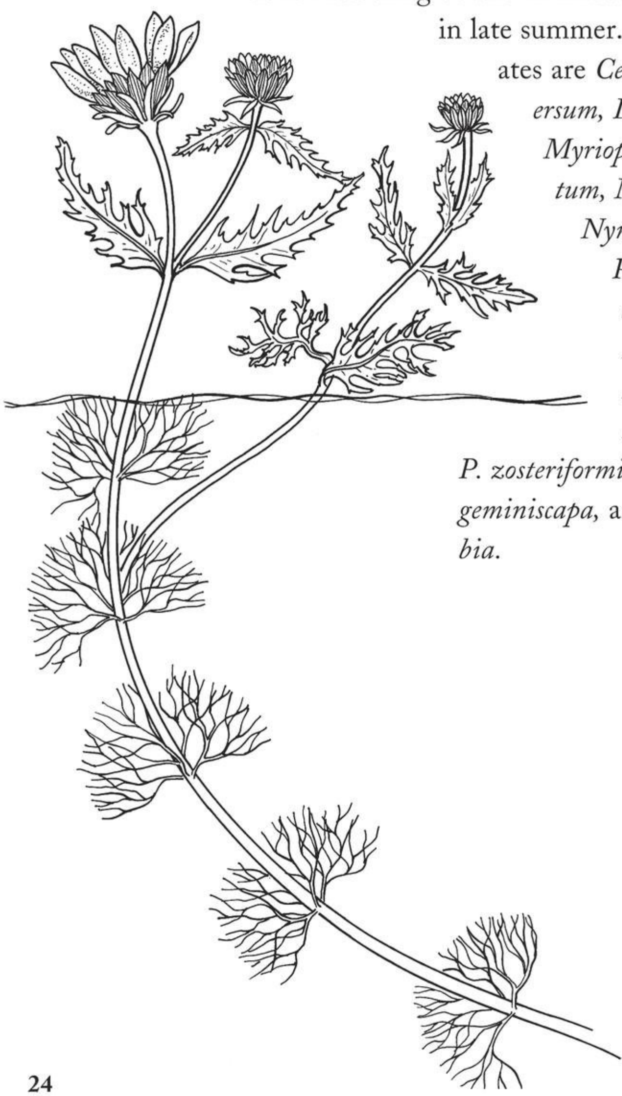


Figure 10. Distribution and habitat characteristics of *Acorus calamus* L.

An infrequent species, found primarily in northern Wisconsin, but also in the eastern part of the state (fig. 11). It prefers soft substrate, is not turbidity tolerant, and is found in water depths to 2.7 m. It shows a narrow conductivity distribution, a limited alkalinity distribution, and a moderate pH distribution. Flowering occurs in midsummer; fruiting, in late summer. Common associates are *Ceratophyllum demersum*, *Lemna trisulca*, *Myriophyllum verticillatum*, *Najas flexilis*, *Nymphaea odorata*, *Potamogeton amplifolius*, *P. praelongus*, *P. pusillus*, *P. richardsonii*, *P. zosteriformis*, *Utricularia geminiscapa*, and *Zosterella dubia*.



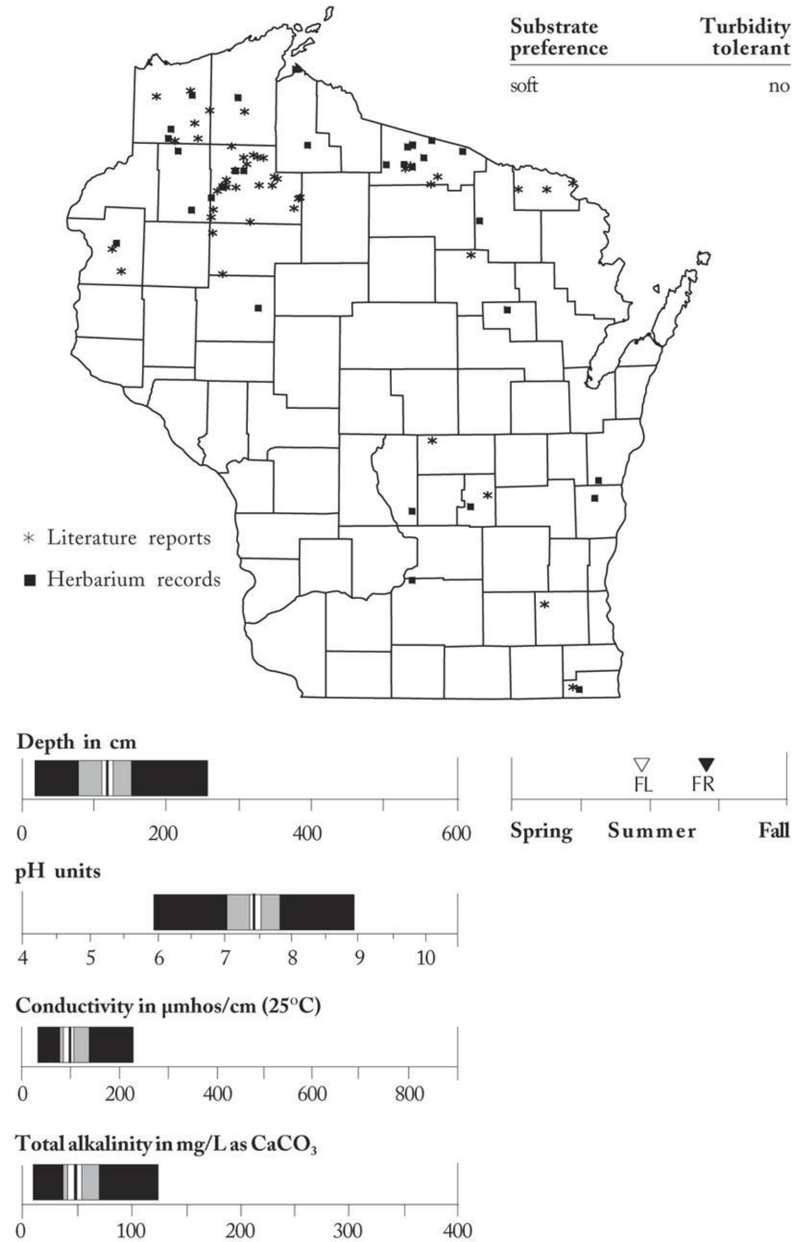
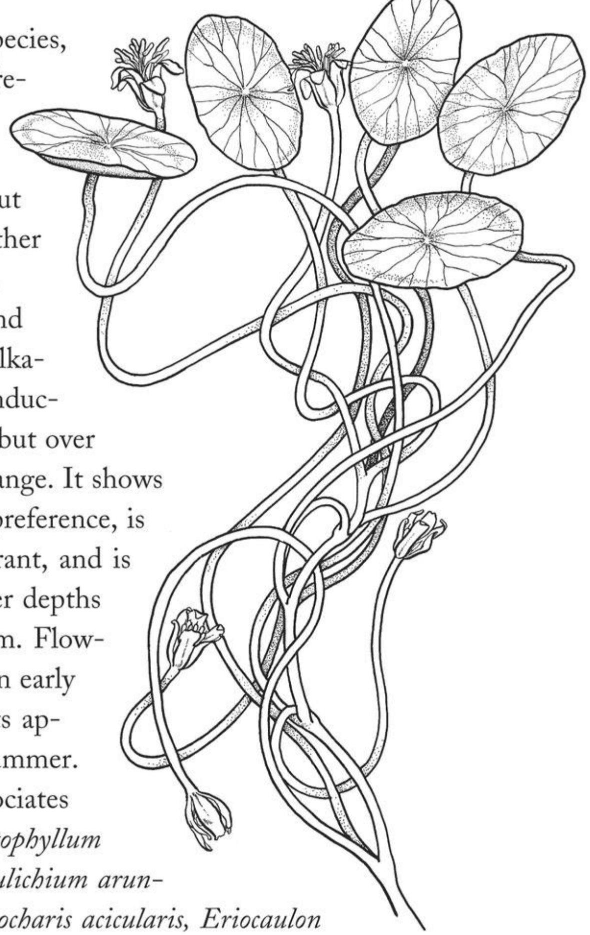


Figure 11. Distribution and habitat characteristics of *Bidens beckii* Torr.

Brasenia schreberi J.F. Gmelin



A common species, found most frequently in northern Wisconsin, but scattered at other locations (fig. 12). It is found over limited alkalinity and conductivity ranges, but over a broad pH range. It shows no substrate preference, is turbidity tolerant, and is found in water depths to about 2.9 m. Flowering occurs in early summer; fruits appear in midsummer. Common associates include *Ceratophyllum echinatum, Dulichium arundinaceum, Eleocharis acicularis, Eriocaulon aquaticum, Myriophyllum farwellii, Nuphar variegata, Nymphaea odorata, Polygonum amphibium, Potamogeton oakesianus, Sagittaria rigida, Sparganium chlorocarpum, Utricularia gibba, U. intermedia,* and *U. vulgaris.* It also shows a strong negative association with many species, including *Ceratophyllum demersum, Elodea canadensis, Myriophyllum spicatum, M. verticillatum, Najas flexilis, Potamogeton praelongus, P. zosteriformis,* and *Vallisneria americana.* This species may not be tolerant of much human impact.

water-shield

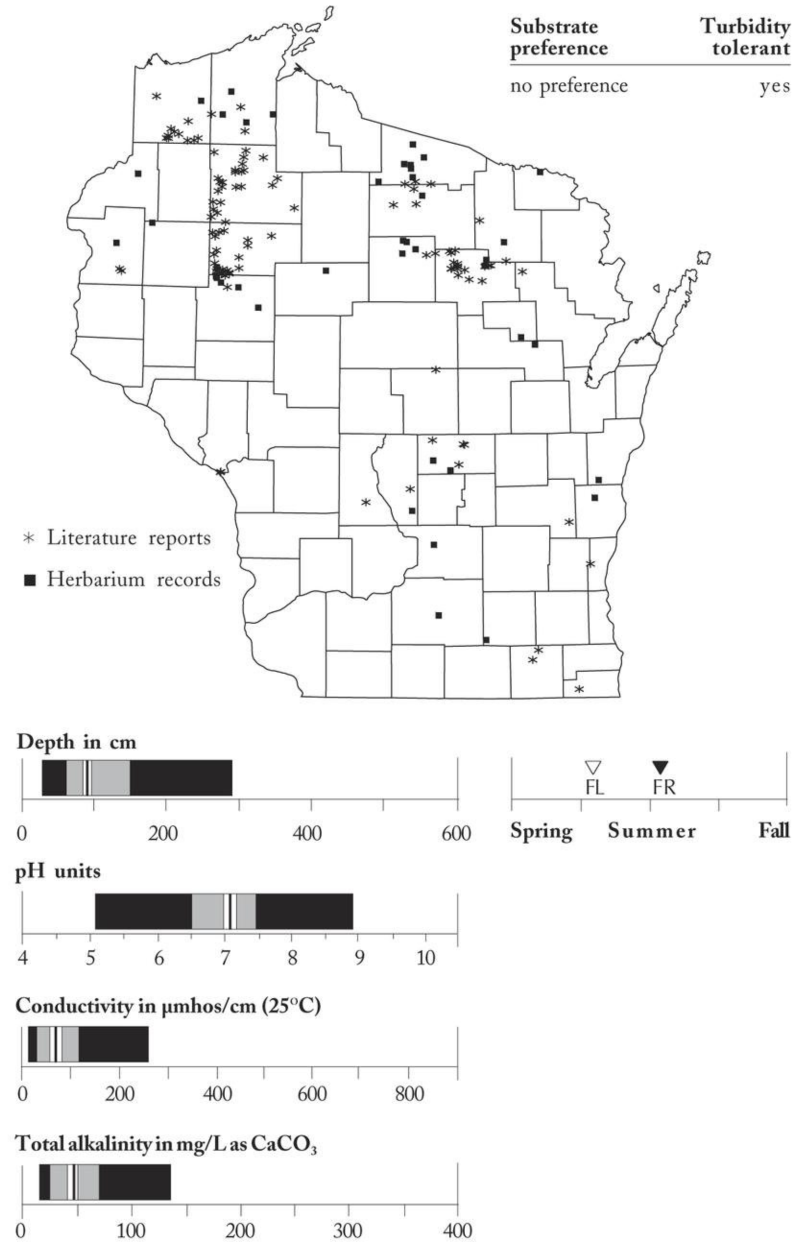
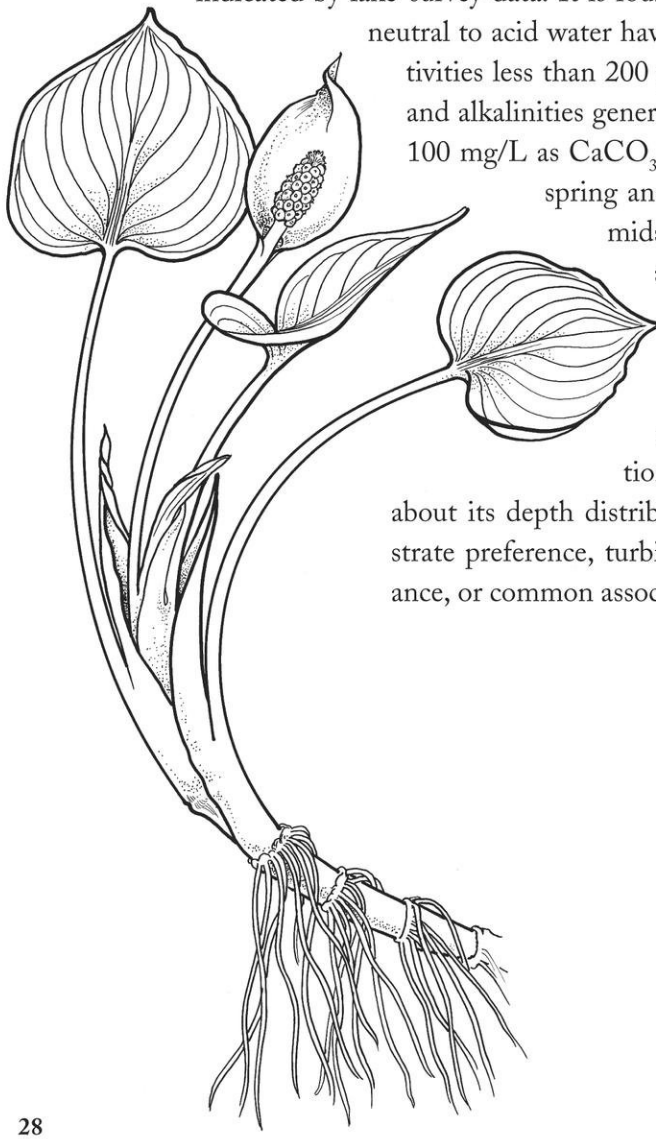


Figure 12. Distribution and habitat characteristics of *Brasenia schreberi* J.F. Gmelin.

Calla palustris L.

Common in wooded swamps, marshes, and bogs of northern Wisconsin (fig. 13). It is also found along marshy shores of lakes, but it is probably overlooked by persons doing lake surveys and is probably more common than the infrequent status indicated by lake-survey data. It is found in circumneutral to acid water having conductivities less than 200 µmhos/cm and alkalinities generally less than 100 mg/L as $CaCO_3$. It flowers in spring and fruits in midsummer. It is a shallow-water, emergent species, but no information is available about its depth distribution, substrate preference, turbidity tolerance, or common associates.



water-arum

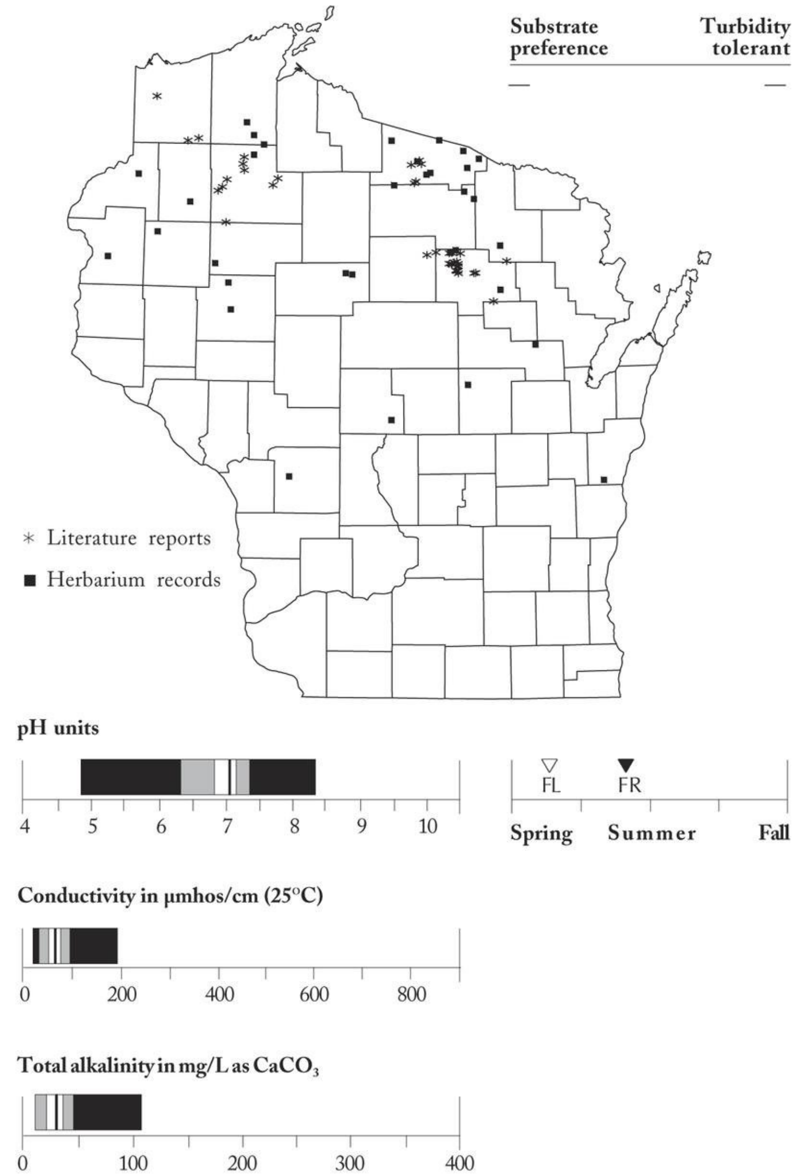
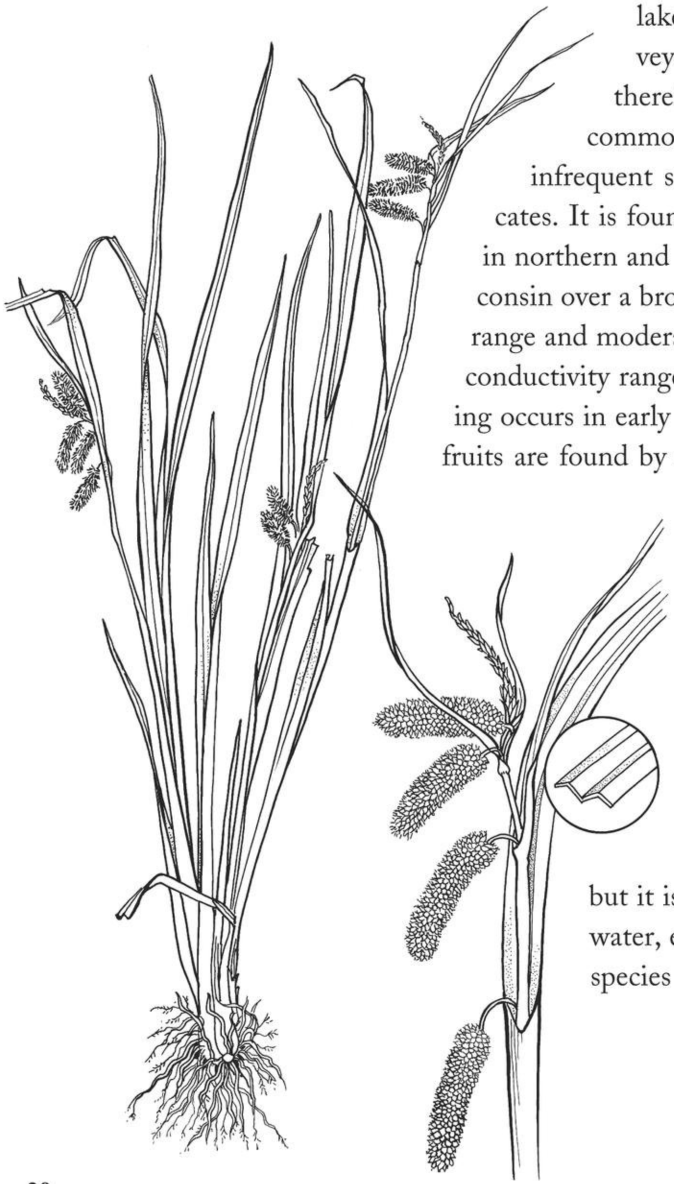


Figure 13. Distribution and habitat characteristics of *Calla palustris* L.

Carex comosa F. Boott — bristly sedge

An infrequently cited plant, found in marshes, rivers, bogs, open spots in swamps, and along wet shores and in shallow lakes and ponds (fig. 14). It is probably overlooked by many lake-plant surveyors and is therefore more common than its infrequent status indicates. It is found primarily in northern and eastern Wisconsin over a broad alkalinity range and moderate pH and conductivity ranges. Flowering occurs in early summer and fruits are found by midsummer. Common associates, substrate preference, turbidity tolerance, and depth distribution are unknown, but it is a shallow-water, emergent species in lakes.



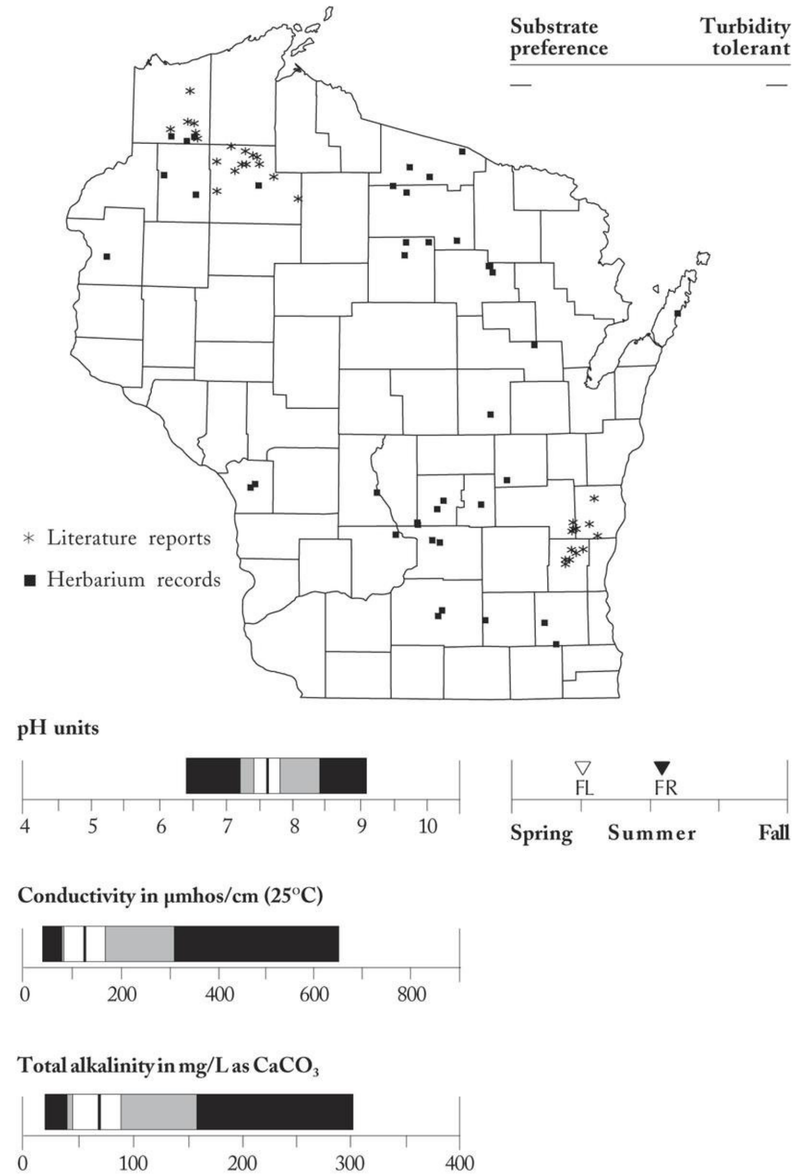
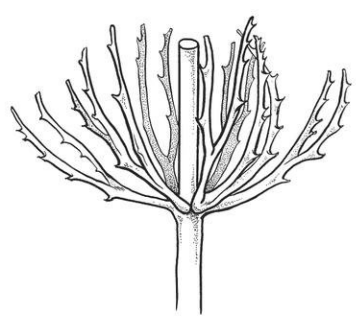
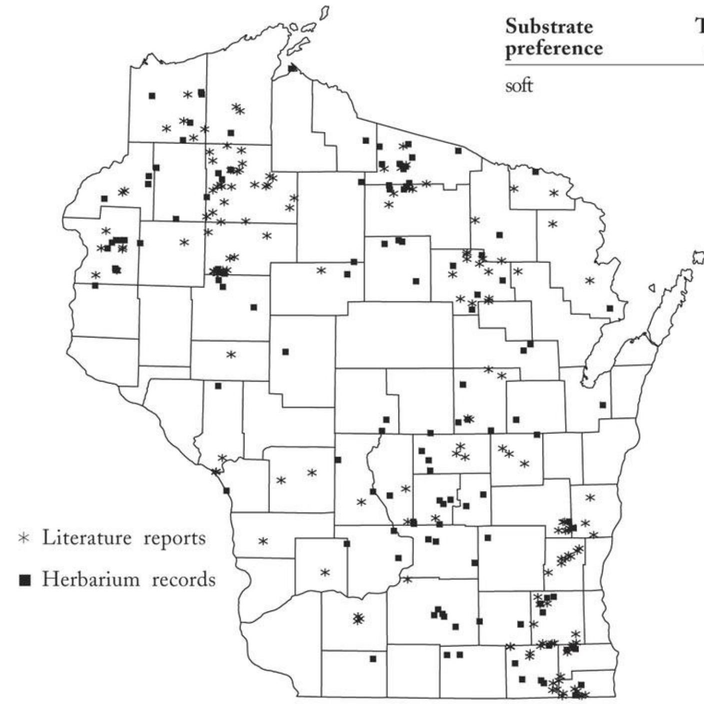


Figure 14. Distribution and habitat characteristics of *Carex comosa* F. Boott.

The most common aquatic vascular plant in the state, on the basis of frequency of occurrence in lakes (fig. 15). It is found over a broad range of water chemistries and in water depths to 4.5 m. It prefers soft substrates and is turbidity tolerant. Flowering and fruiting are not common, but occur in midsummer. Common associates are many, including *Bidens beckii*, *Elodea canadensis*, *Lemna minor*, *L. trisulca*, *Myriophyllum heterophyllum*, *M. sibiricum*, *M. verticillatum*, *Nymphaea odorata*, *Potamogeton crispus*, *P. diversifolius*, *P. foliosus*, *P. praelongus*, *P. pusillus*, *P. richardsonii*, *P. vaginatus*, *P. zosteriformis*, *Ranunculus longirostris*, *Spirodela polyrhiza*, *Utricularia geminiscapa*, *Wolffia columbiana*, and *Zosterella dubia*.



Substrate preference	Turbidity tolerant
soft	yes



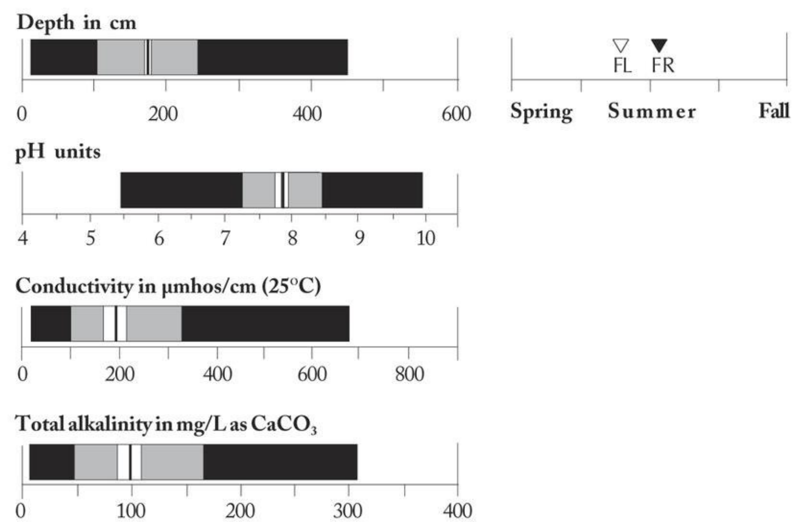
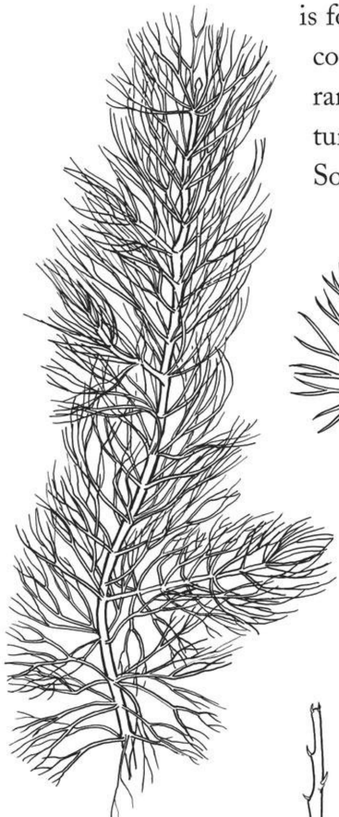
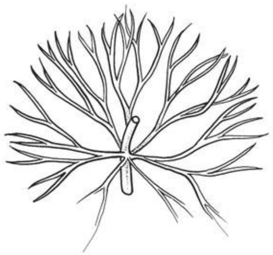


Figure 15. Distribution and habitat characteristics of *Ceratophyllum demersum* L.

Ceratophyllum echinatum A. Gray

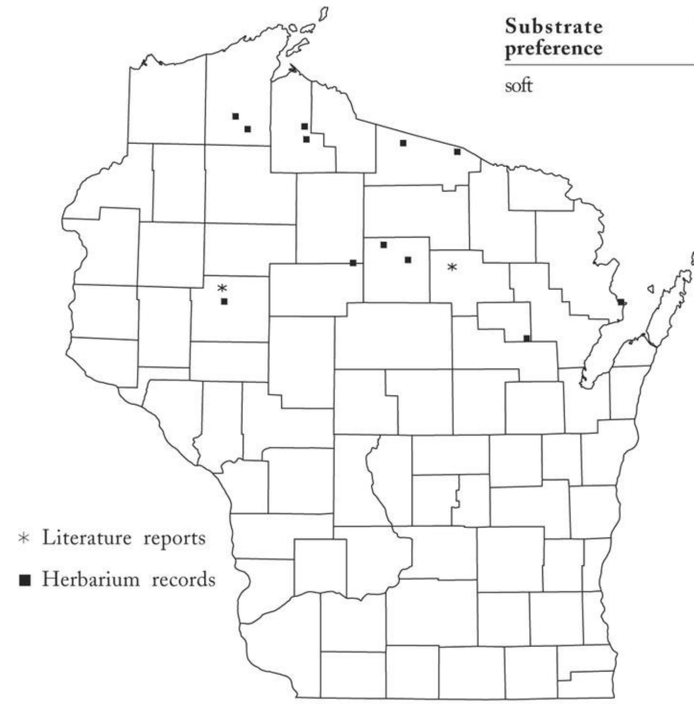
A rare plant, found almost entirely within the Northern Lakes and Forests Ecoregion, where low calcium, chloride, magnesium, and sulfate water is common (fig. 16). It prefers soft substrate and grows in water depths to 3 m. It is found over narrow and low alkalinity and conductivity ranges and a moderate pH range. Flowering and fruiting dates and turbidity tolerance were not determined. Some lateral branches and new growth of *C. demersum* might be confused with *C. echinatum*. The most reliable distinguishing characteristic is leaf forking (Voss, 1985): *Ceratophyllum echinatum* leaves are forked three times (eight ultimate segments); *C. demersum* leaves, one or two times. The significance of fruit differences described in some keys is not universally agreed upon (Voss, 1985), and both species are seldom found in fruit. Common associates are *Dulichium arundinaceum, Nymphaea odorata, Polygonum amphibium, Potamogeton natans, P. pusillus, Sagittaria rigida, Sparganium chlorocarpum,* and *Utricularia vulgaris.*





spiny hornwort

Substrate preference	Turbidity tolerant
soft	—



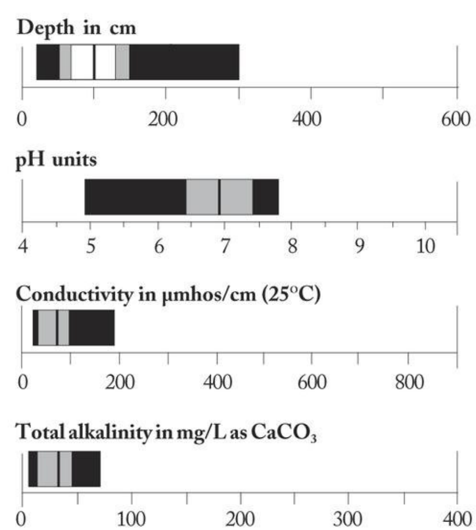
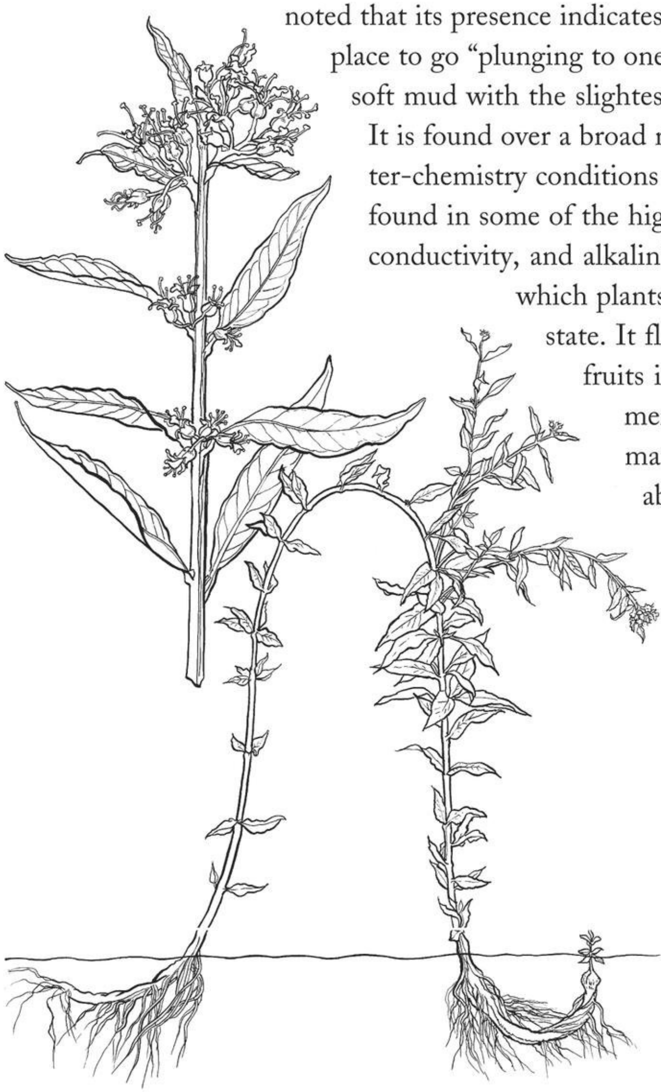


Figure 16. Distribution and habitat characteristics of *Ceratophyllum echinatum* A. Gray.

Decodon verticillatus (L.) Elliott

An infrequent species, scattered throughout the state. No information is available about depth distribution, turbidity tolerance, or substrate preference (fig. 17). However, it is a shallow-water, emergent species that sometimes forms floating mats. It generally grows in very soft substrates. Voss (1985) noted that its presence indicates a good place to go "plunging to one's waist in soft mud with the slightest misstep." It is found over a broad range of water-chemistry conditions and can be found in some of the highest pH, conductivity, and alkalinity water in which plants grow in the state. It flowers and fruits in late summer. No information is available about its common associates.



swamp loosestrife

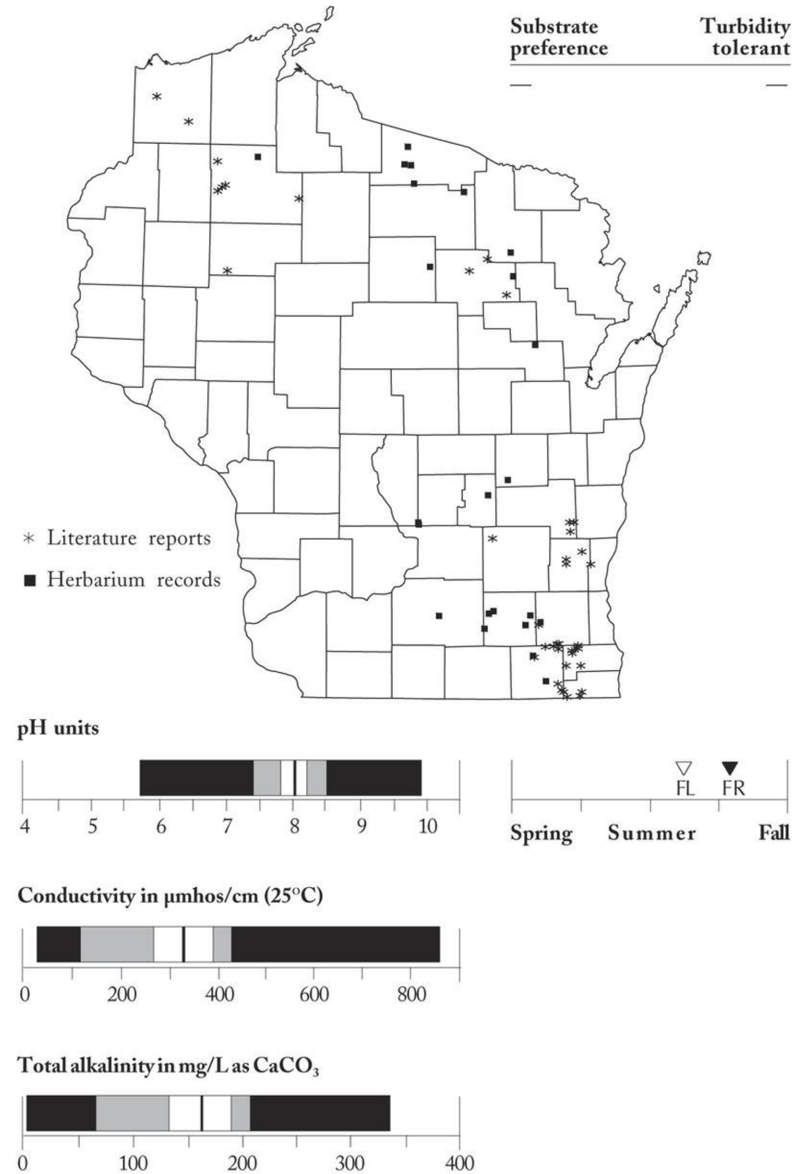
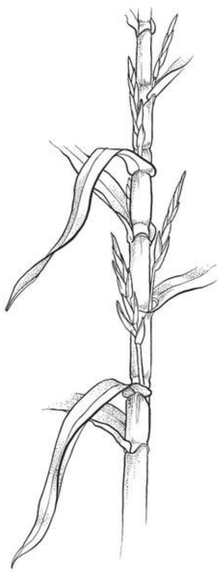


Figure 17. Distribution and habitat characteristics of *Decodon verticillatus* (L.) Elliott.

A common species, found statewide, but reported more frequently in northern Wisconsin (fig. 18). It is found in water depths to 1.5 m, but it is most common in water less than 1 m deep. It is turbidity tolerant and prefers soft substrate. It is found over a broad pH range, but in low conductivity and alkalinity water. Flowering occurs in midsummer; fruiting, in late summer. Common associates are *Brasenia schreberi, Ceratophyllum echinatum, Nymphaea odorata, Polygonum amphibium, Potamogeton pusillus, Sagittaria rigida, Sparganium chlorocarpum,* and *Utricularia vulgaris.*



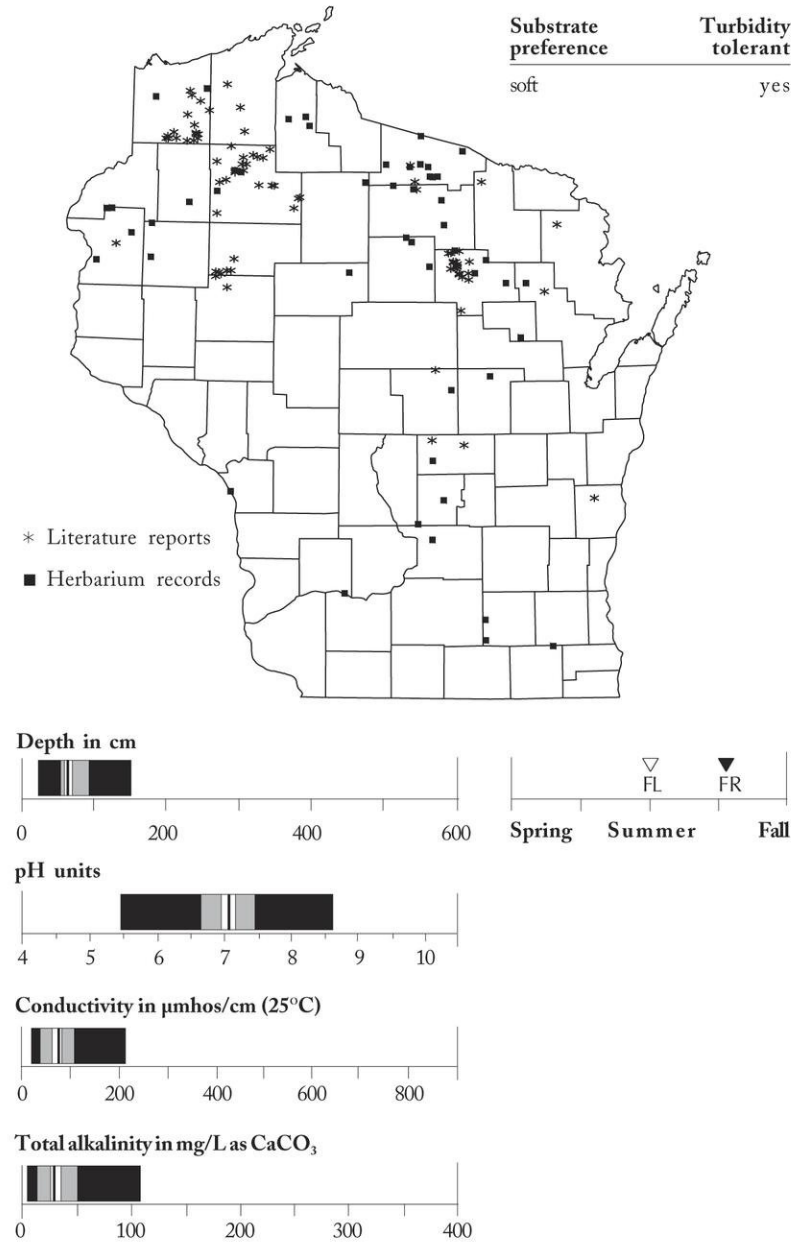
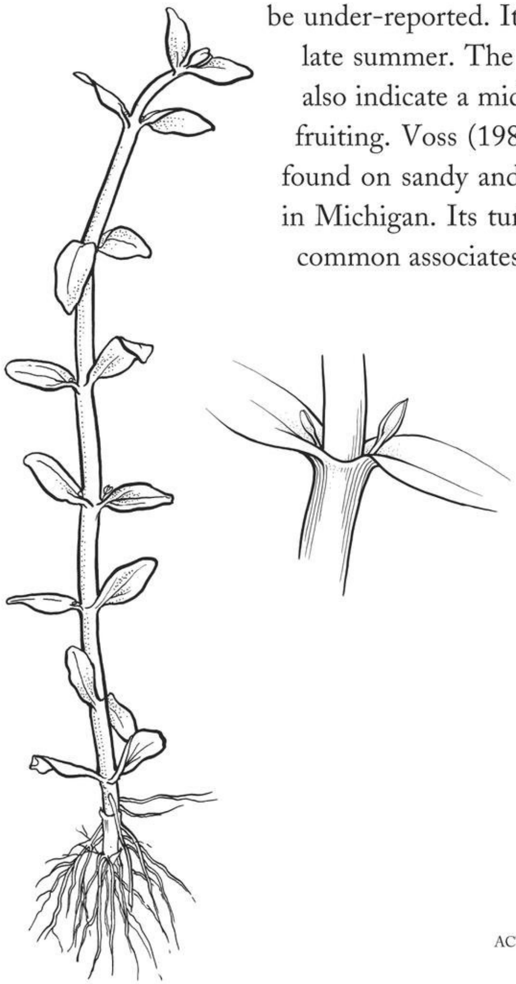


Figure 18. Distribution and habitat characteristics of *Dulichium arundinaceum* (L.) Britton.

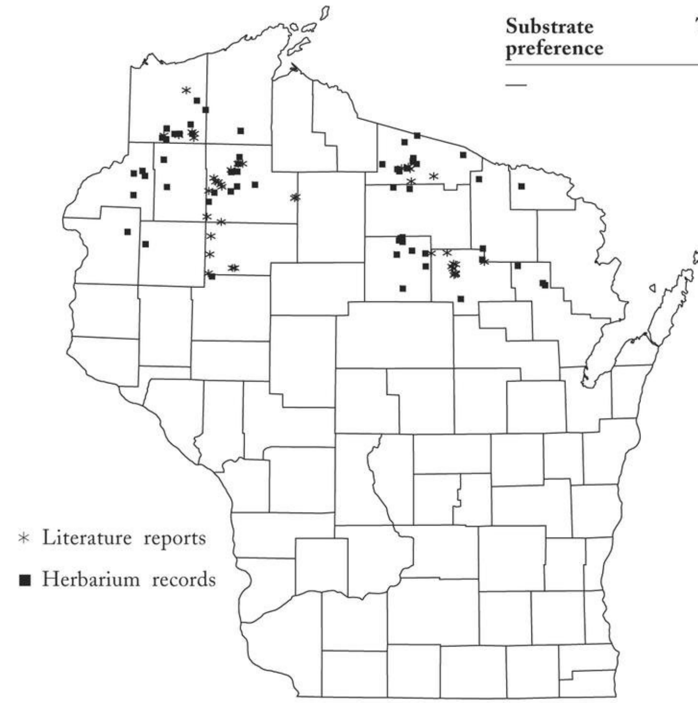
Elatine minima (Nutt.) Fisher & C.A. Meyer

An infrequent species, found in low conductivity, low alkalinity lakes primarily within the Northern Lakes and Forests Ecoregion. It is found over a broad but circumneutral pH range and in water generally less than 2 m deep. Because of its small size, it is easily overlooked and may be under-reported. It flowers in middle to late summer. The few plants with fruits also indicate a middle to late summer fruiting. Voss (1985) reported that it is found on sandy and sandy–mucky bottoms in Michigan. Its turbidity tolerance and common associates were not determined.



ACTUAL SIZE

matted waterwort



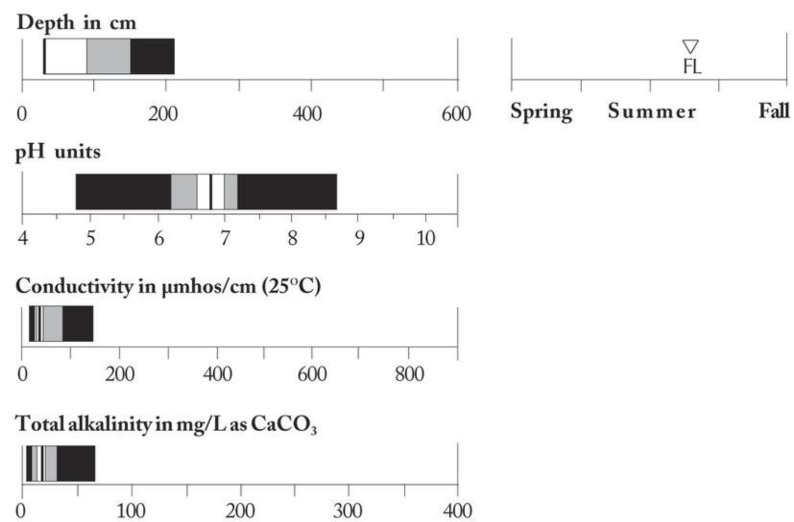
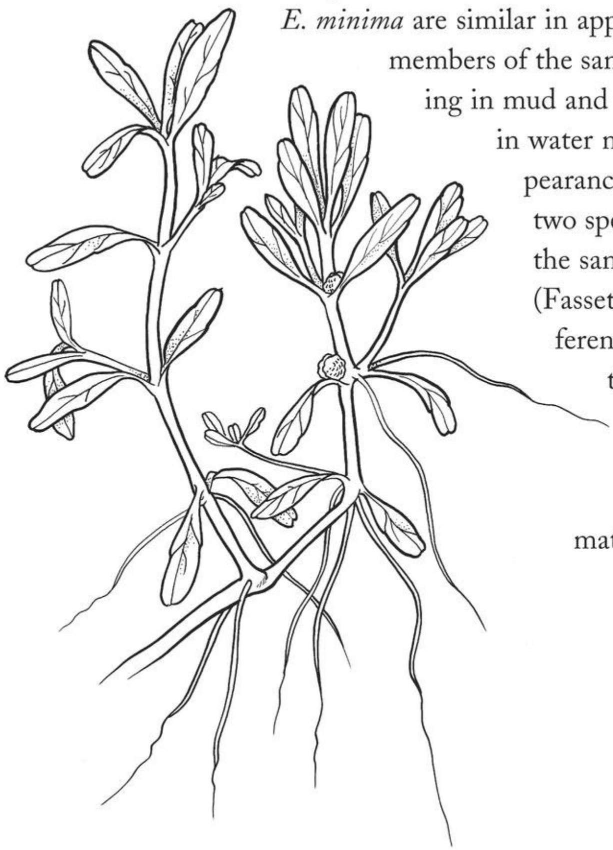


Figure 19. Distribution and habitat characteristics of *Elatine minima* (Nutt.) Fisher & C.A. Meyer.

Elatine triandra Schkuhr.

A rare species, found at only four locations in Wisconsin (fig. 20). Fassett (1930b) thought it was associated with the Johnstown moraine, where he collected it in Adams County. He also collected it in an unidentified pond in Columbia County (not shown in fig. 20) and in Round Lake in Polk County. The most recent record is a 1971 collection from the Chippewa Flowage in Sawyer County. Because it is so rare, little could be determined about its habitat preference, flowering and fruiting dates, or common associates. It is normally a plant of the western United States, and it is also found in Europe and Asia. *Elatine triandra* and *E. minima* are similar in appearance, and members of the same species growing in mud and those growing in water may differ in appearance more than the two species growing in the same habitat (Fassett, 1969). Differentiation between the two species is based on microscopic examination of mature seeds.



matted waterwort

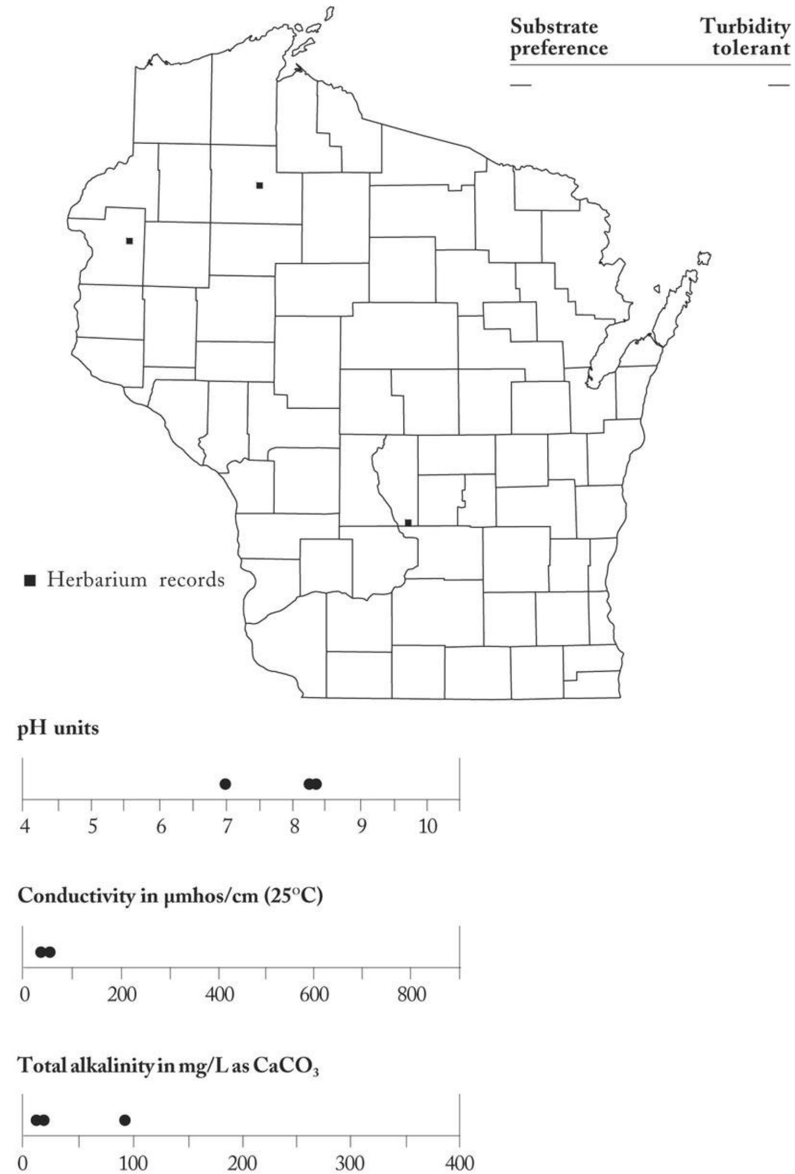


Figure 20. Distribution and habitat characteristics of *Elatine triandra* Schkuhr.

A common plant, found more frequently in northern Wisconsin and scattered in the remainder of the state (fig. 21). Greene (1953) reported that it is also common along the Mississippi River. It prefers hard substrate, is turbidity tolerant, and grows in water depths to 2.1 m. At times it will form a dense carpet or turf of plants on wet shores and in submersed areas. It is found over a broad and circumneutral pH range, but only has limited conductivity and alkalinity ranges. Few flowering plants were found; fruiting occurs in midsummer. *Brasenia schreberi* is its only common associate.

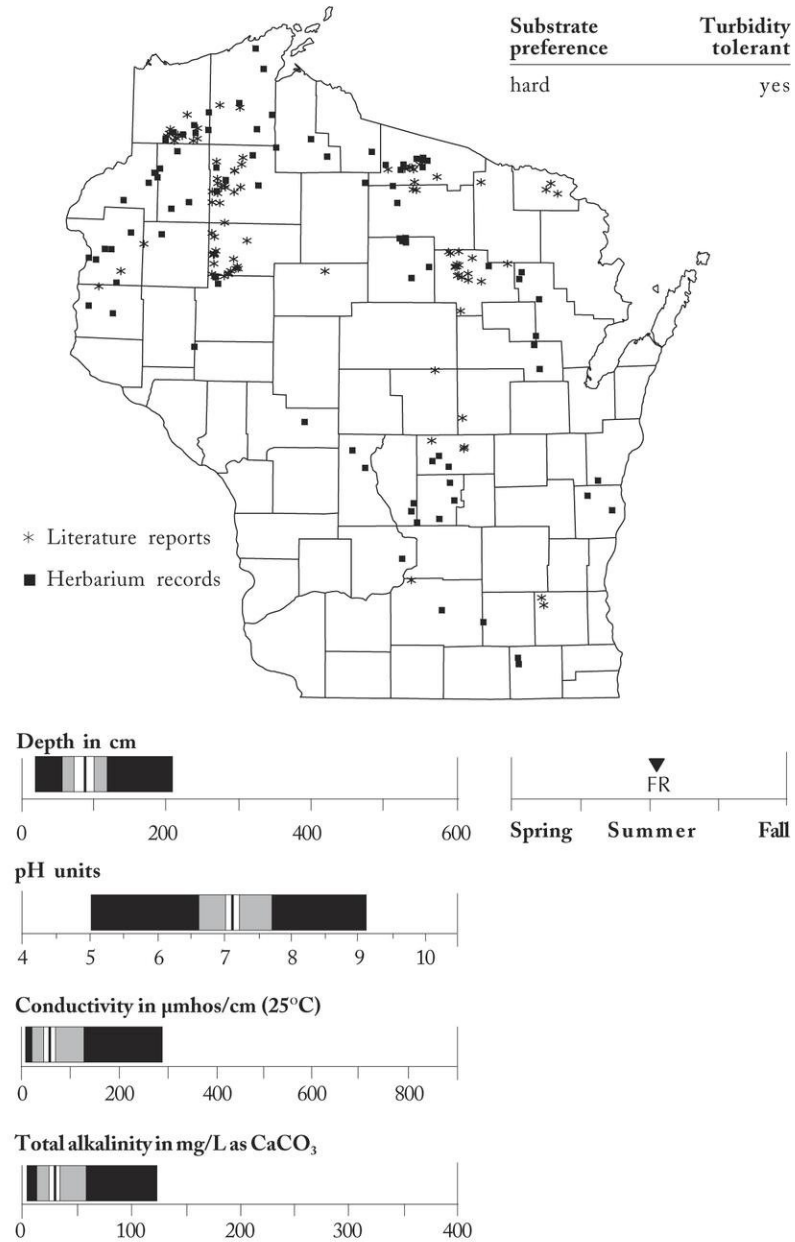
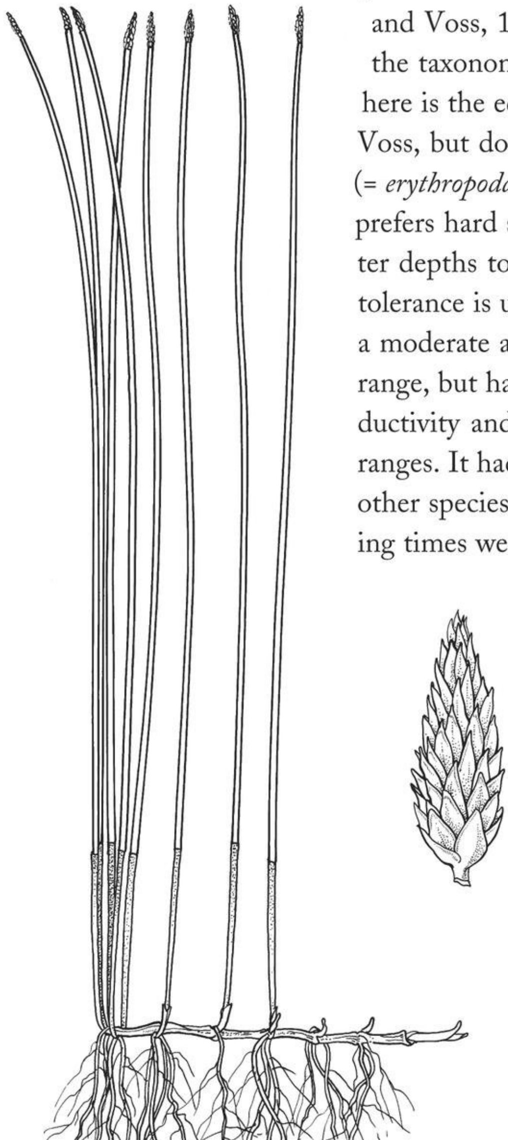


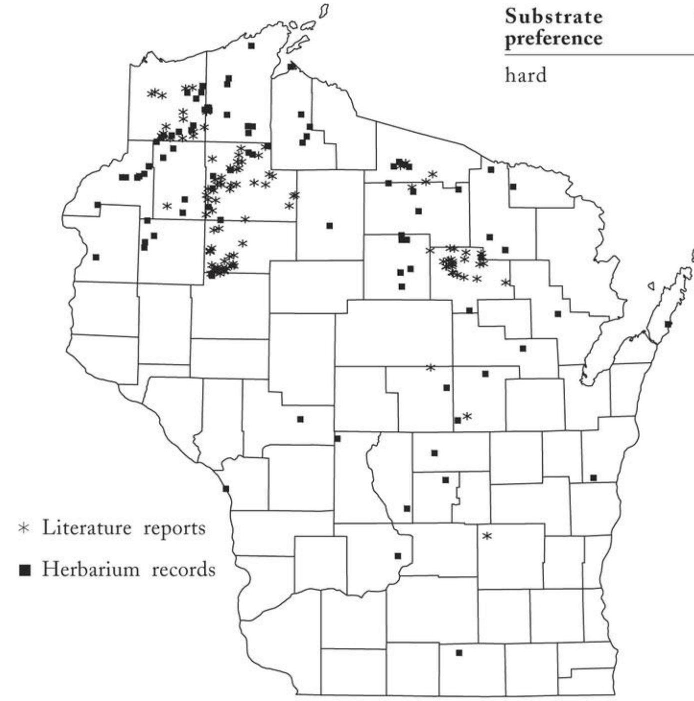
Figure 21. Distribution and habitat characteristics of *Eleocharis acicularis* (L.) Roemer & Schultes.

Eleocharis palustris L.

A common plant, especially in northern and central Wisconsin lakes (fig. 22). *Eleocharis erythropoda* Steudel, *E. calva* Torr., and *E. smallii* Britton have been lumped under *E. palustris* L. (see Gleason and Cronquist, 1991, and Voss, 1972, for a discussion of the taxonomy). *Eleocharis palustris* here is the equivalent of *E. smallii* in Voss, but does not include *E. calva* (= *erythropoda*). *Eleocharis palustris* prefers hard substrate, is found in water depths to 2.1 m, and its turbidity tolerance is unknown. It is found over a moderate and circumneutral pH range, but has narrow and low conductivity and limited alkalinity ranges. It had a low association with other species, and flowering and fruiting times were not established.



Substrate preference	Turbidity tolerant
hard	—



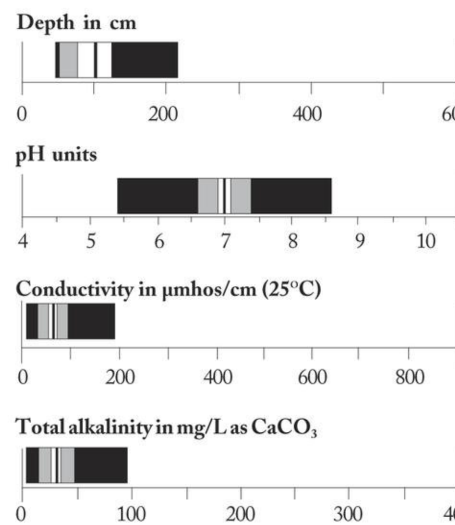
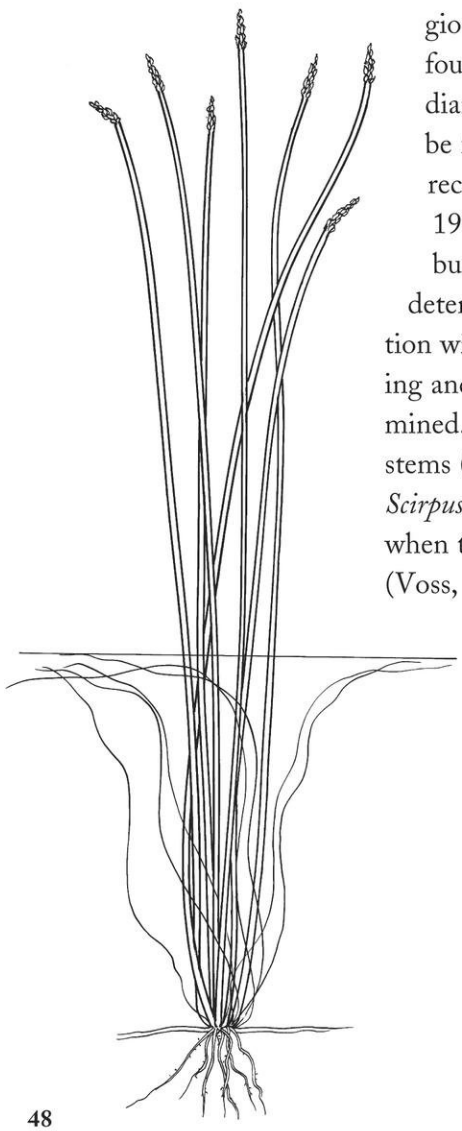
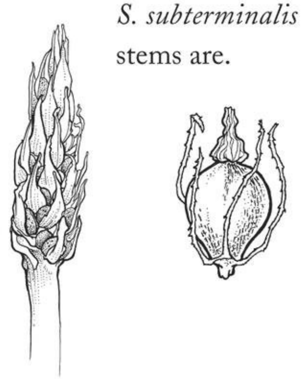


Figure 22. Distribution and habitat characteristics of *Eleocharis palustris* L.

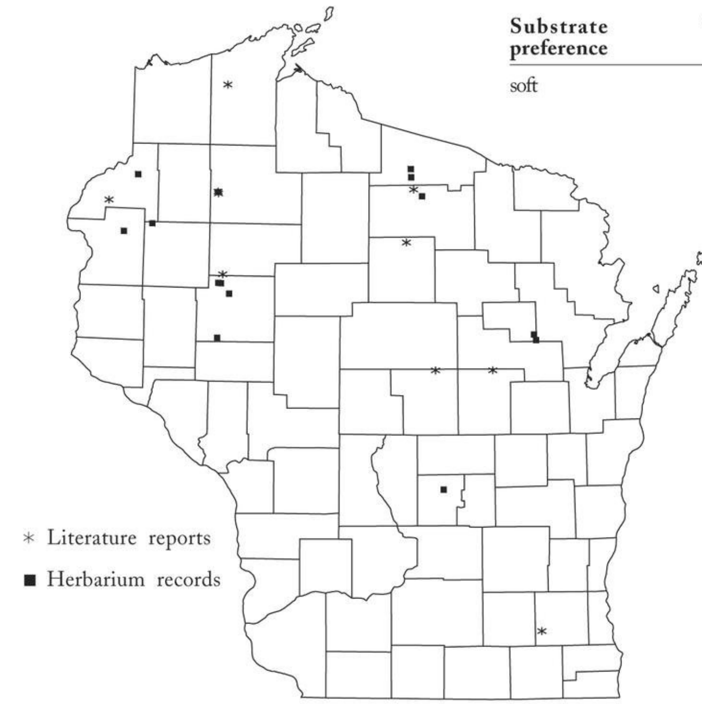
Eleocharis robbinsii Oakes

An infrequent species, primarily of northern Wisconsin (fig. 23). It is found over narrow and low ranges of alkalinity and conductivity, but over a moderate pH range. Except for a single literature citation in Waukesha County, all locations are within the less than 10 mg/L sulfate region. An emergent plant, it is found in shallow water at a median depth of about 1 m and can be found on shore, especially on recently exposed shorelines (Voss, 1972). It prefers soft substrate but turbidity tolerance was not determined. It had a low association with all other species and flowering and fruiting dates were not determined. Numerous limp, capillary stems (culms), similar to those of *Scirpus subterminalis*, can be produced when the plant is growing in water (Voss, 1972). However, *E. robbinsii* stems are not expanded at the bottom as *S. subterminalis* stems are.





Substrate preference	Turbidity tolerant
soft	—



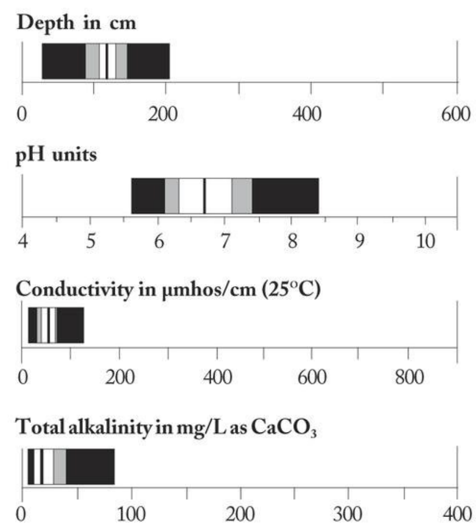


Figure 23. Distribution and habitat characteristics of *Eleocharis robbinsii* Oakes.

Elodea canadensis Michx.

An abundant plant, distributed statewide (fig. 24). It ranks second only to *Ceratophyllum demersum* in frequency of occurrence in lakes. It prefers soft substrate, is turbidity tolerant, and is found in water depths to 3.9 m. It has a broad but generally alkaline pH distribution and moderate conductivity and alkalinity distributions. Flowering occurs in early summer; fruiting, in middle to late summer. Common associates are *Ceratophyllum demersum*, *Lemna minor*, *L. trisulca*, *Potamogeton crispus*, *P. diversifolius*, *P. foliosus*, *P. vaginatus*, *Sagittaria latifolia*, *Spirodela polyrhiza*, and *Typha latifolia*.

common waterweed

Substrate preference	Turbidity tolerant
soft	yes

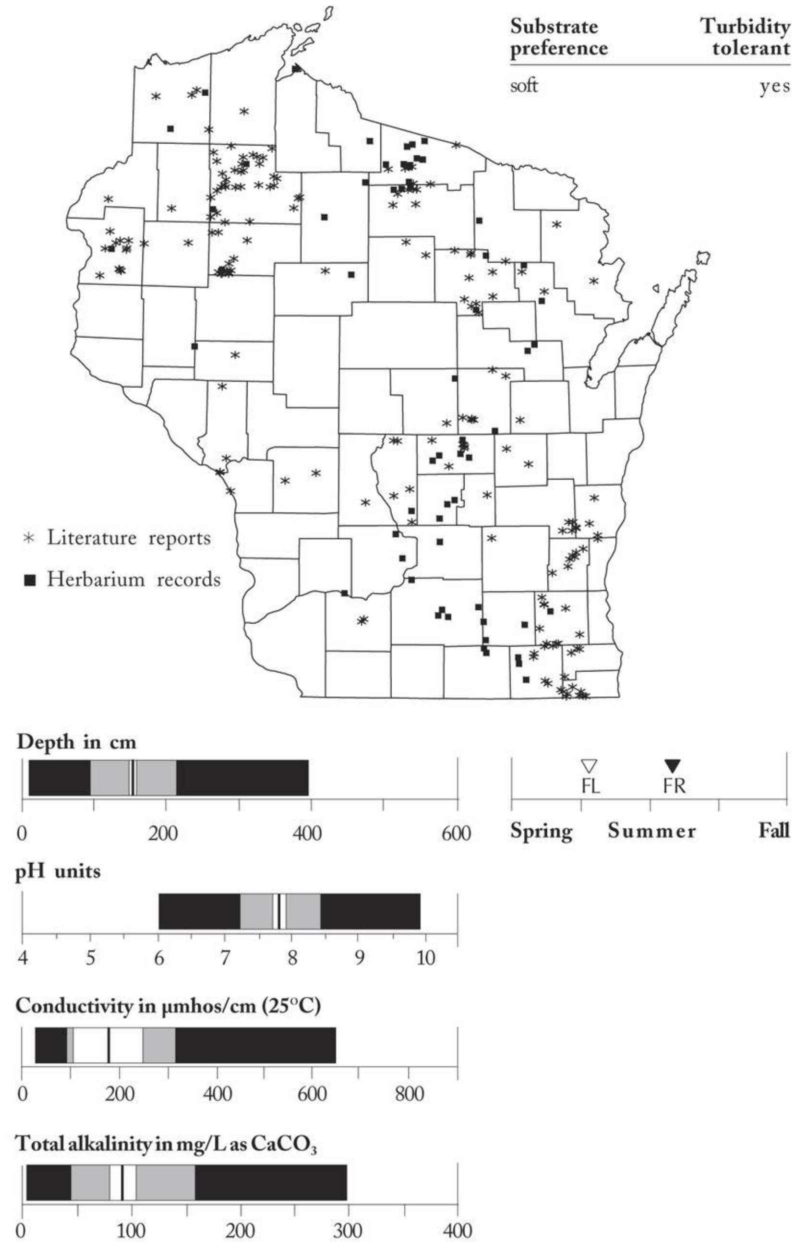
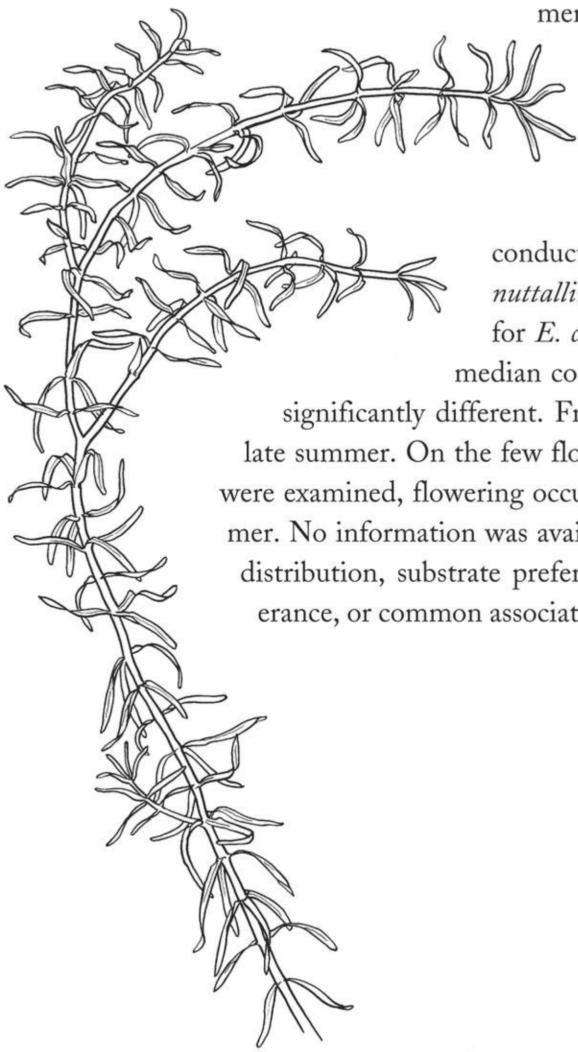


Figure 24. Distribution and habitat characteristics of *Elodea canadensis* Michx.

Elodea nuttallii (Planchon) St. John

A rare species, scattered statewide (fig. 25). *Elodea nuttallii* is usually distinctively small leaved and delicate compared to the much more common *E. canadensis,* but vegetative material could be confused with depauperate *E. canadensis* specimens. *Elodea nuttallii* is generally found in lower alkalinity and lower pH water than *E. canadensis.* The conductivity range for *E. nuttallii* is not as broad as for *E. canadensis,* but the median conductivity was not significantly different. Fruiting occurs in late summer. On the few flowering plants that were examined, flowering occurred in early summer. No information was available about depth distribution, substrate preference, turbidity tolerance, or common associates.



slenderwaterweed

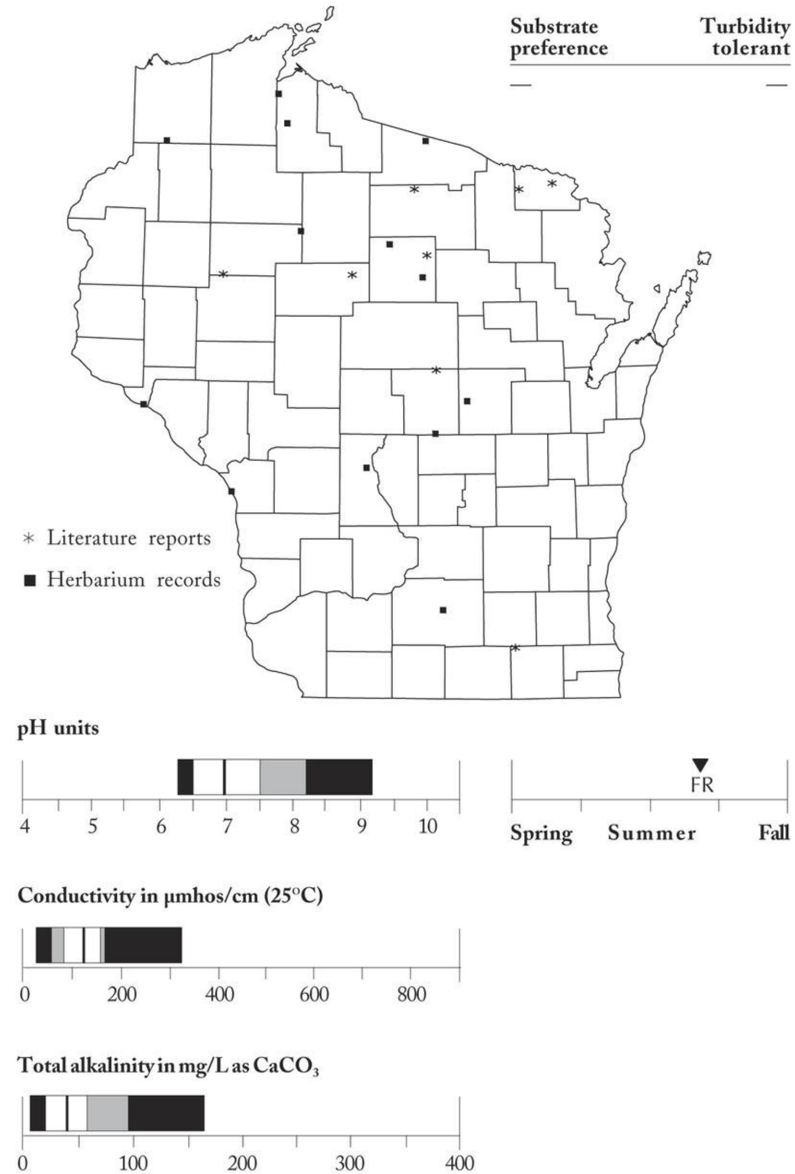
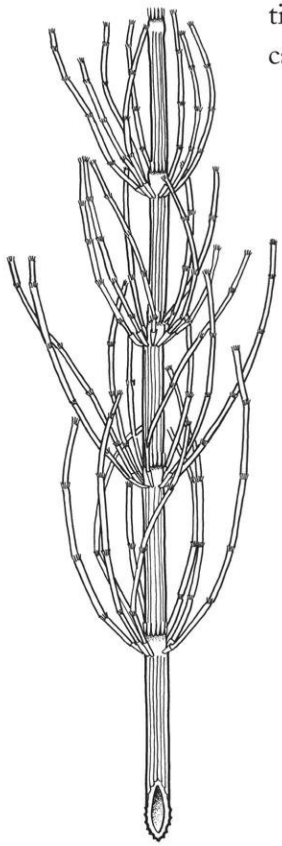
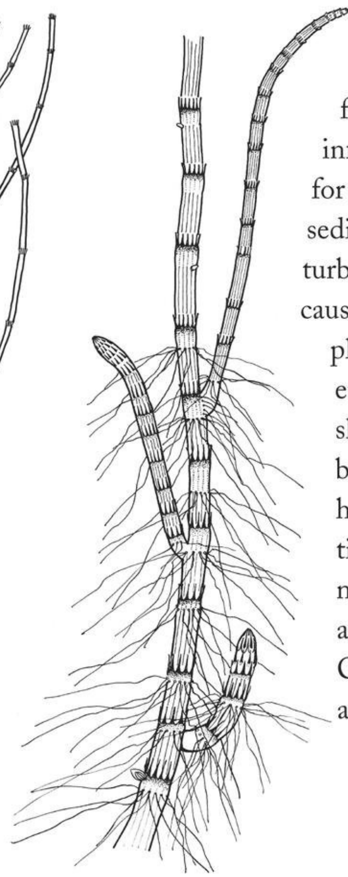


Figure 25. Distribution and habitat characteristics of *Elodea nuttallii* (Planchon) St. John.

Equisetum fluviatile L.

A common species, found statewide (Hauke, 1965), but infrequently as part of a lake flora (fig. 26). It emerges in May as a simple unbranched stem and becomes more branched as the season progresses (Hauke, 1965), which could cause confusion in identifying the plant. In cross section, an *E. fluviatile* stem has a large central cavity and no side cavities. This characteristic helps separate *E. fluviatile* from other *Equisetum* species. *Equisetum fluviatile* is not a flowering plant; therefore, flowering date is inappropriate, but plants with terminal cones were found in spring. No information is available for depth distribution, sediment preference, or turbidity tolerance. Because it is an emergent plant found in a variety of wet places, a shallow-water distribution is suspected. It has a limited conductivity distribution and moderate alkalinity and pH distributions. Common associates are unknown.





water horsetail

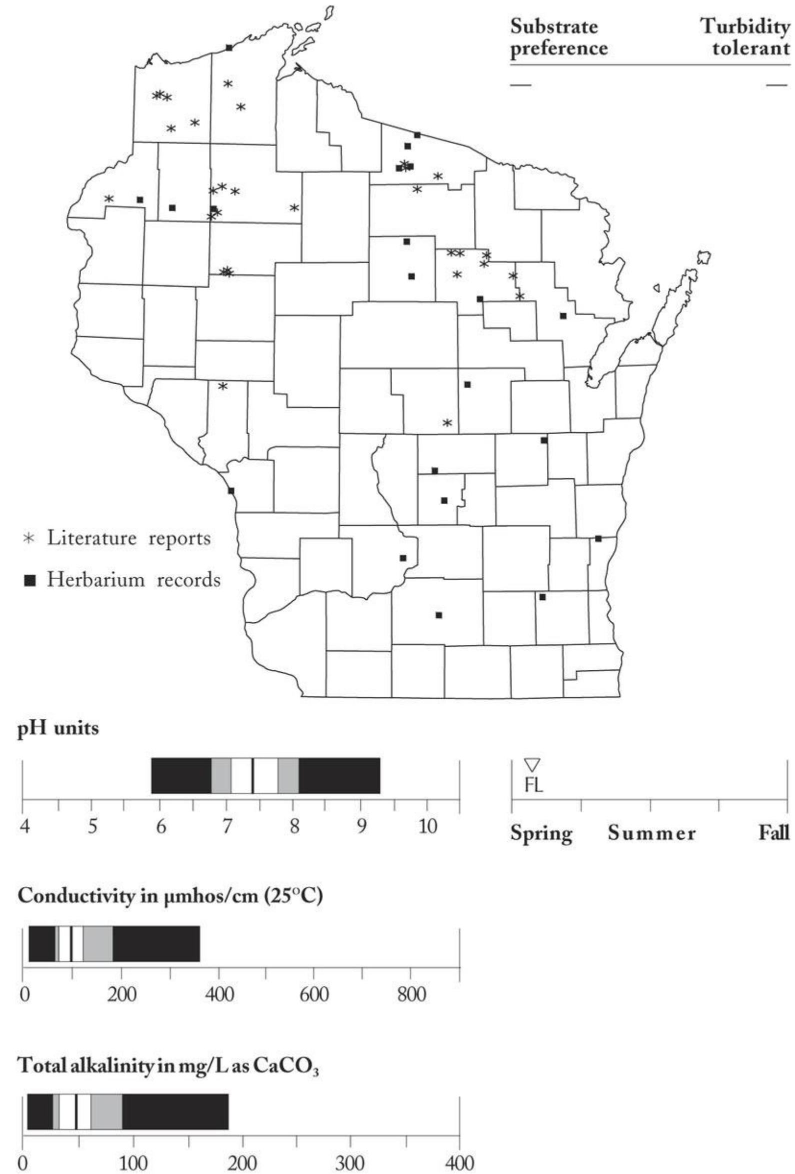
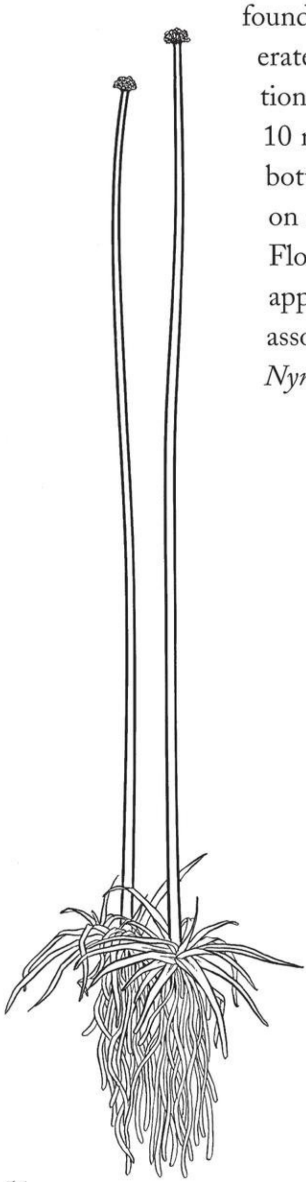
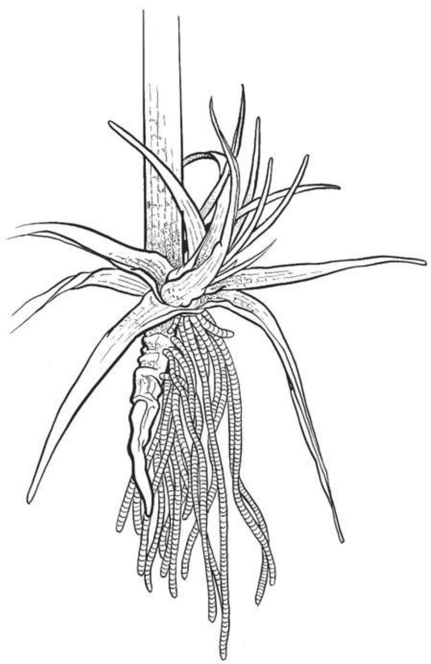


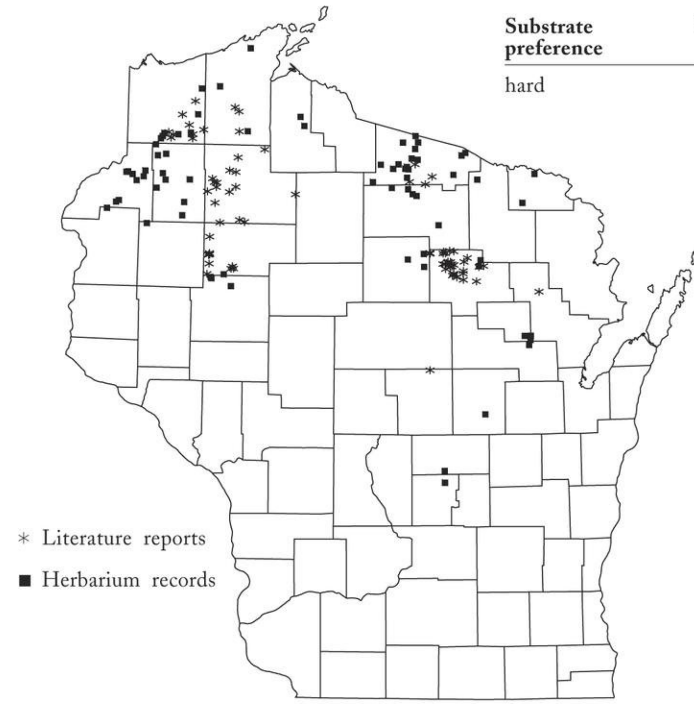
Figure 26. Distribution and habitat characteristics of *Equisetum fluviatile* L.

A common species, found primarily in the low conductivity, low alkalinity water of northern and central Wisconsin (fig. 27). It prefers hard substrate, is not turbidity tolerant, and is found in water depths to 2.6 m. It has a moderate pH distribution and all known distribution points are in areas with sulfates less than 10 mg/L. It can form dense turfs on the lake bottom and flowering heads usually emerge on scapes up to 40 cm long (Voss, 1972). Flowering occurs in midsummer and fruits appear in middle to late summer. Common associates include *Brasenia schreberi* and *Nymphaea odorata*.





Substrate preference	Turbidity tolerant
hard	no



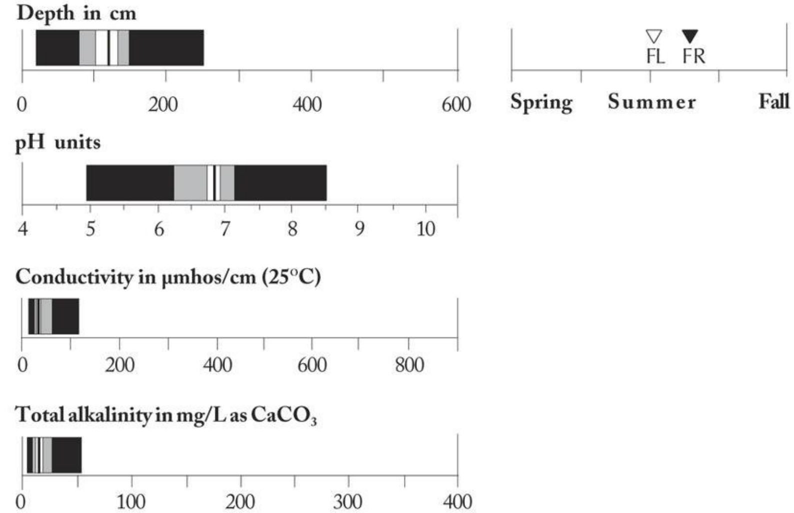
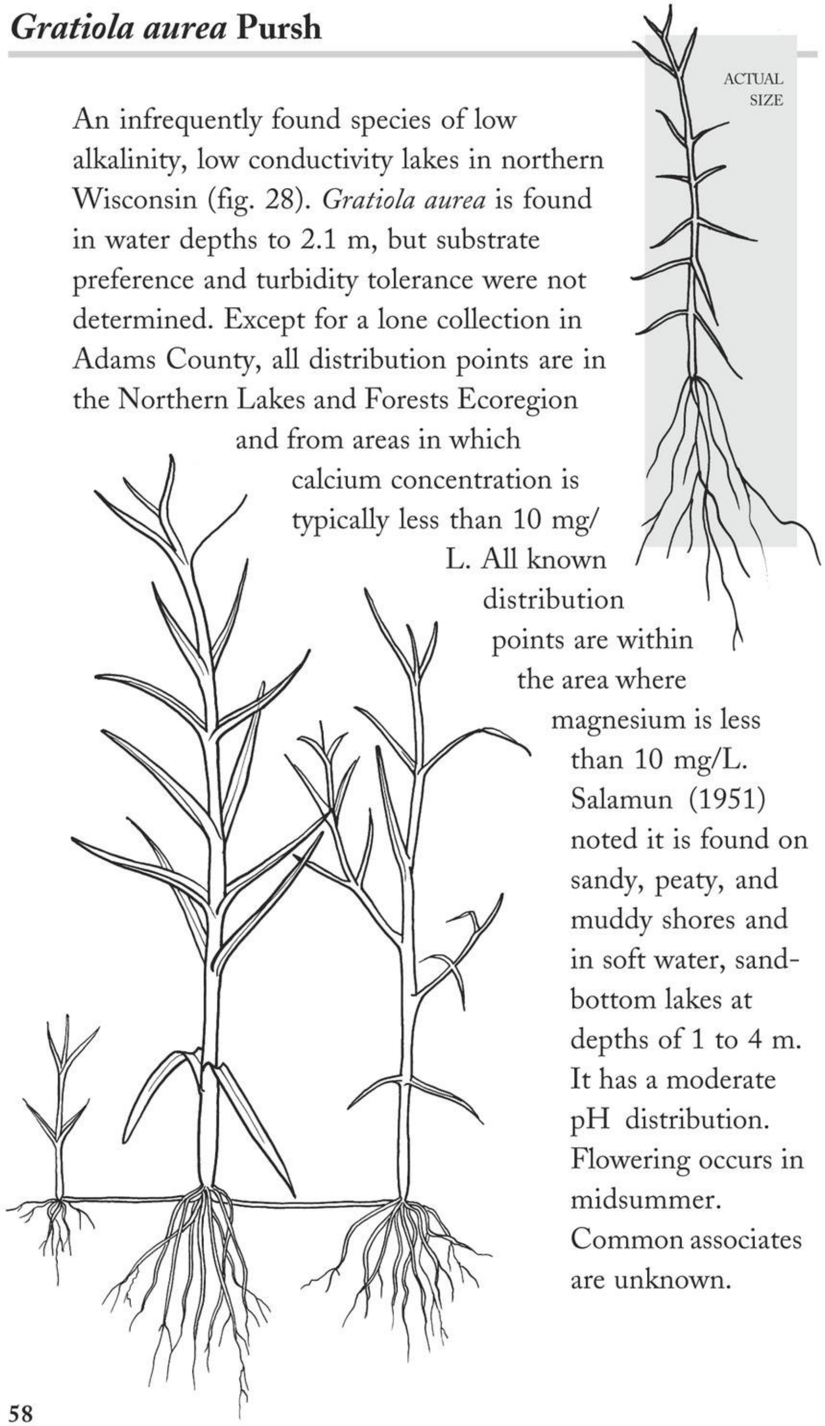


Figure 27. Distribution and habitat characteristics of *Eriocaulon aquaticum* (Hill) Druce.

Gratiola aurea Pursh



An infrequently found species of low alkalinity, low conductivity lakes in northern Wisconsin (fig. 28). *Gratiola aurea* is found in water depths to 2.1 m, but substrate preference and turbidity tolerance were not determined. Except for a lone collection in Adams County, all distribution points are in the Northern Lakes and Forests Ecoregion and from areas in which calcium concentration is typically less than 10 mg/L. All known distribution points are within the area where magnesium is less than 10 mg/L. Salamun (1951) noted it is found on sandy, peaty, and muddy shores and in soft water, sand-bottom lakes at depths of 1 to 4 m. It has a moderate pH distribution. Flowering occurs in midsummer. Common associates are unknown.

hedge-hyssop

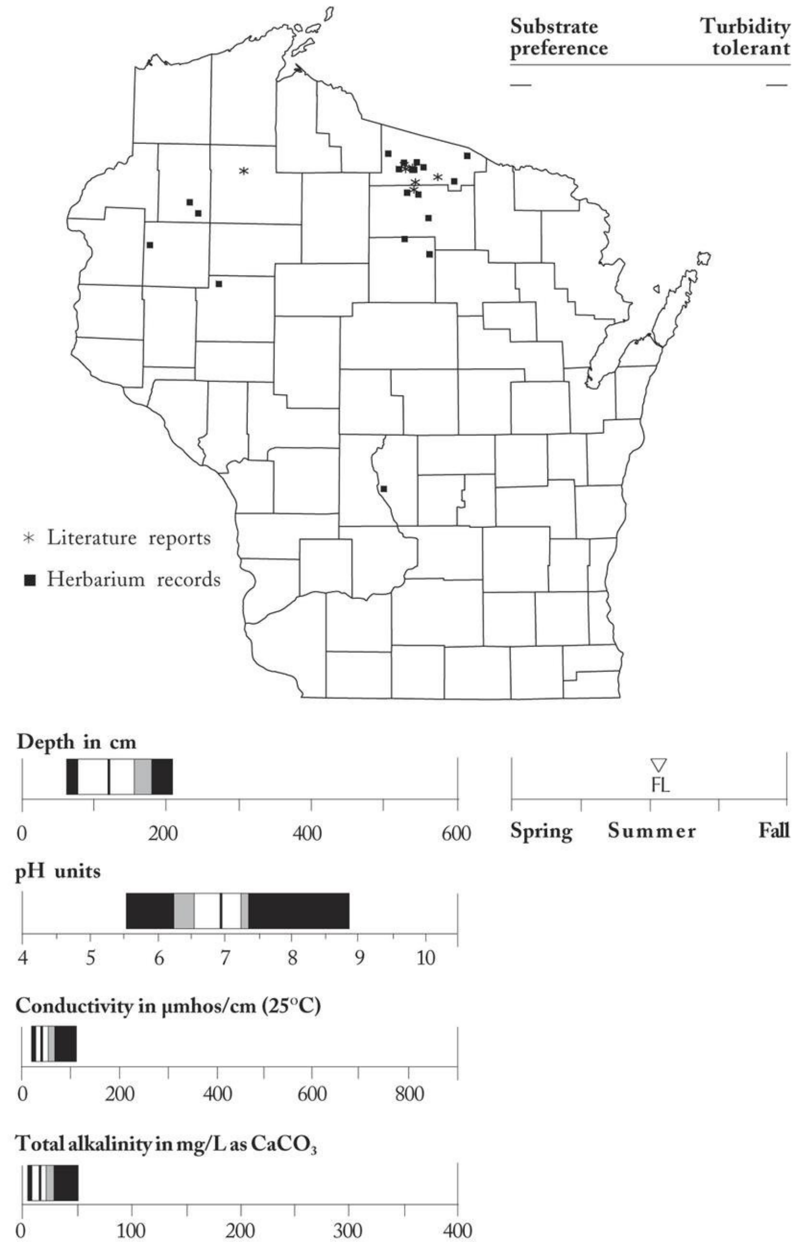
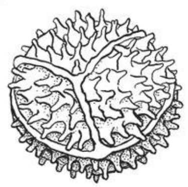
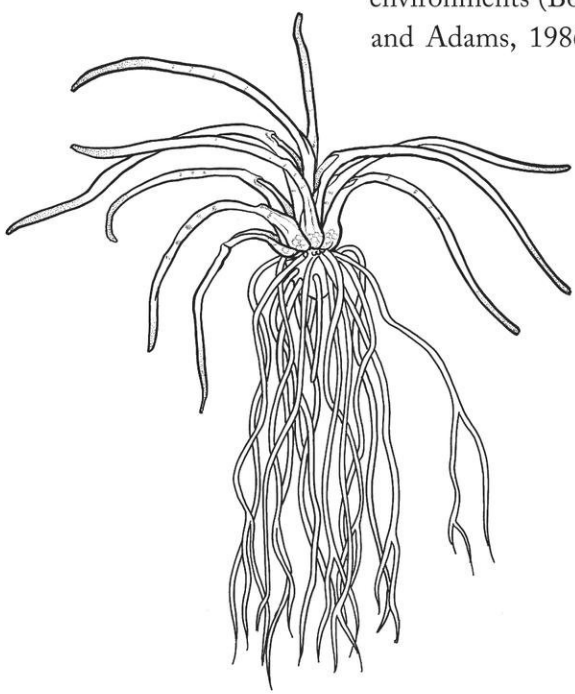


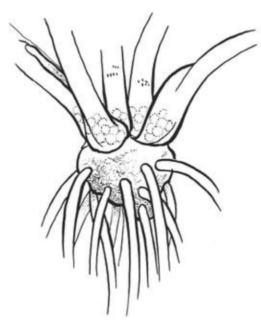
Figure 28. Distribution and habitat characteristics of *Gratiola aurea* Pursh.

Isoetes echinospora Dur.

A rare plant, found in low alkalinity, low conductivity lakes of northern Wisconsin (fig. 29). It grows to water depths of 3 m and shows no substrate preference. Turbidity tolerance is unknown and *I. echinospora* shows low association with all other species. It is found over a moderate and circumneutral pH range. Except for a collection from Devils Lake, Sauk County, all distribution points were in the Northern Lakes and Forests Ecoregion and in areas of low magnesium and chloride concentrations. This is not a flowering plant, so flowering and fruiting are inappropriate terms; however, megaspores are found in late summer. This is one of the isoetid species that has unique photosynthetic mechanisms for growing in very low carbon environments (Boston and Adams, 1986).

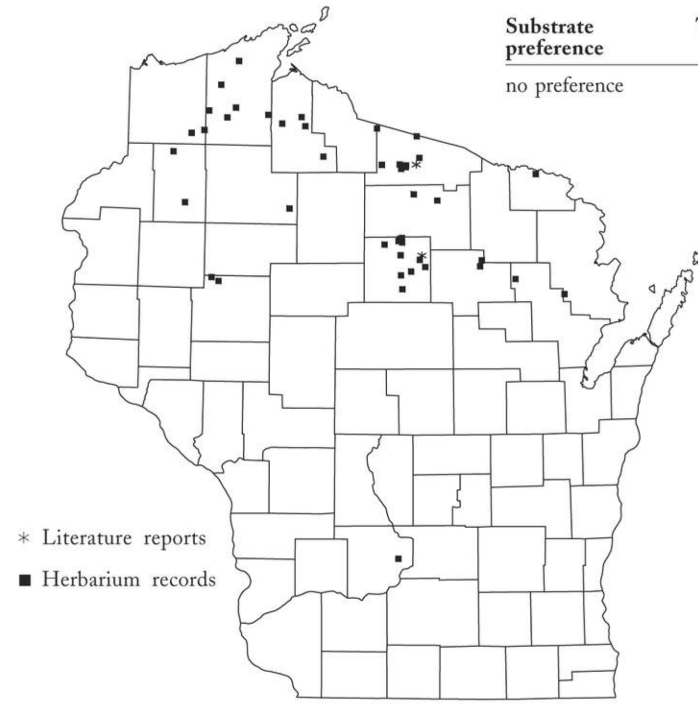






spiny-spore quillwort

Substrate preference	Turbidity tolerant
no preference	—



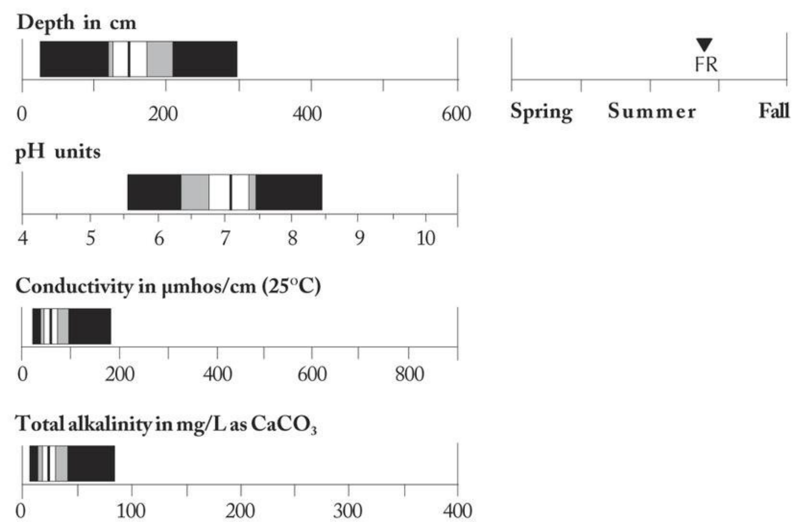


Figure 29. Distribution and habitat characteristics of *Isoetes echinospora* Dur.

Isoetes lacustris L.

Found in low conductivity, low alkalinity, northern Wisconsin lakes (fig. 30). *Isoetes lacustris* and *I. echinospora* appear similar and have similar habitat characteristics. *Isoetes lacustris* may be more common than *I. echinospora,* may be found in deeper water, may produce megaspores earlier in the growing season, and prefers hard substrate. Spore characteristics separate the two species: *Isoetes echinospora* megaspores are covered with spine-like projections, and the megaspores of *I. lacustris* have flattened and ridge-like protuberances. No common associates were found, but it showed a strong, negative association with *Ceratophyllum demersum.* Photosynthetically, this is another isoetid species.

lake quillwort

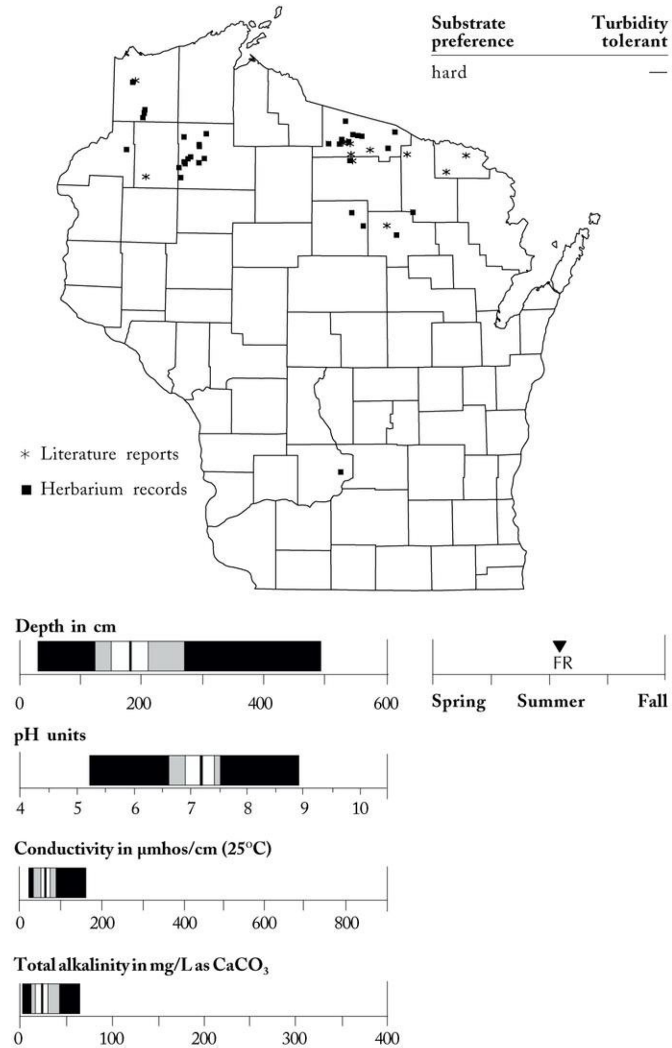
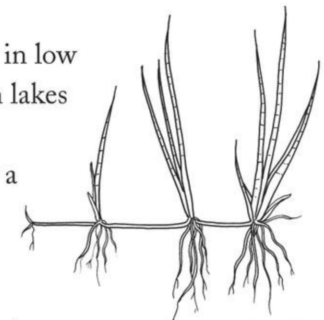
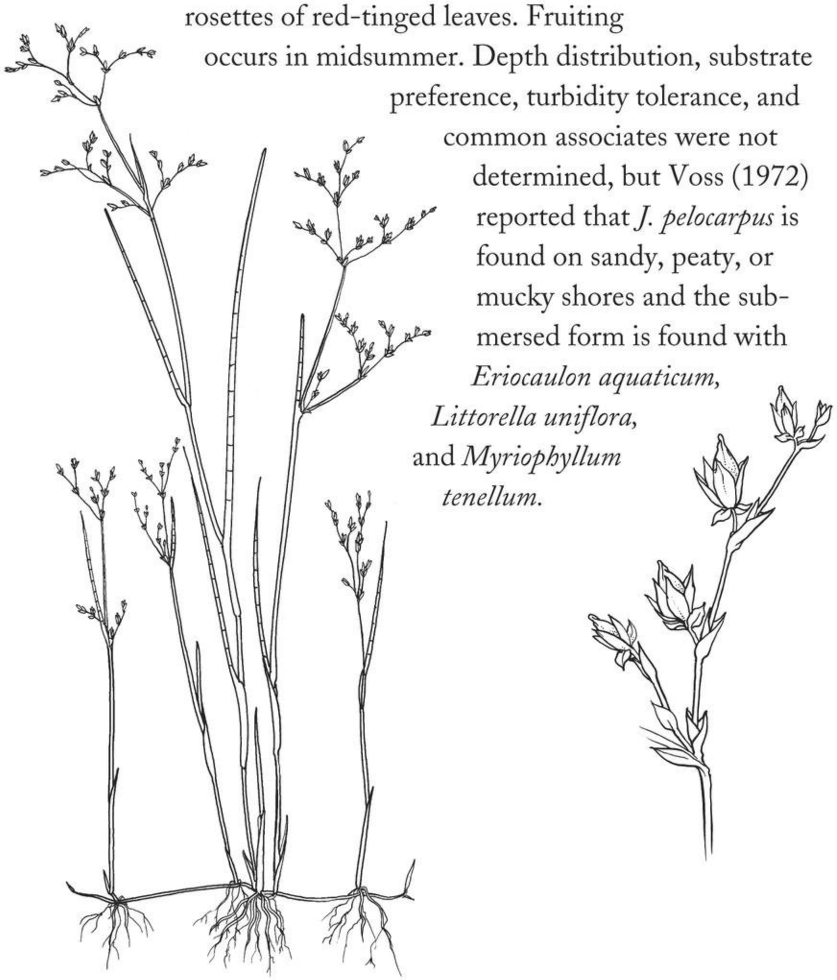


Figure 30. Distribution and habitat characteristics of *Isoetes lacustris* L.

Juncus pelocarpus E. Meyer



A common species, found primarily in low alkalinity, low conductivity northern lakes and in scattered locations in central Wisconsin (fig. 31). It is found over a moderate and circumneutral pH range. It is generally a shallow-water, emergent species, but there is a submersed, sterile form with flattened rosettes of red-tinged leaves. Fruiting occurs in midsummer. Depth distribution, substrate preference, turbidity tolerance, and common associates were not determined, but Voss (1972) reported that *J. pelocarpus* is found on sandy, peaty, or mucky shores and the submersed form is found with *Eriocaulon aquaticum*, *Littorella uniflora*, and *Myriophyllum tenellum*.



brown-fruited rush

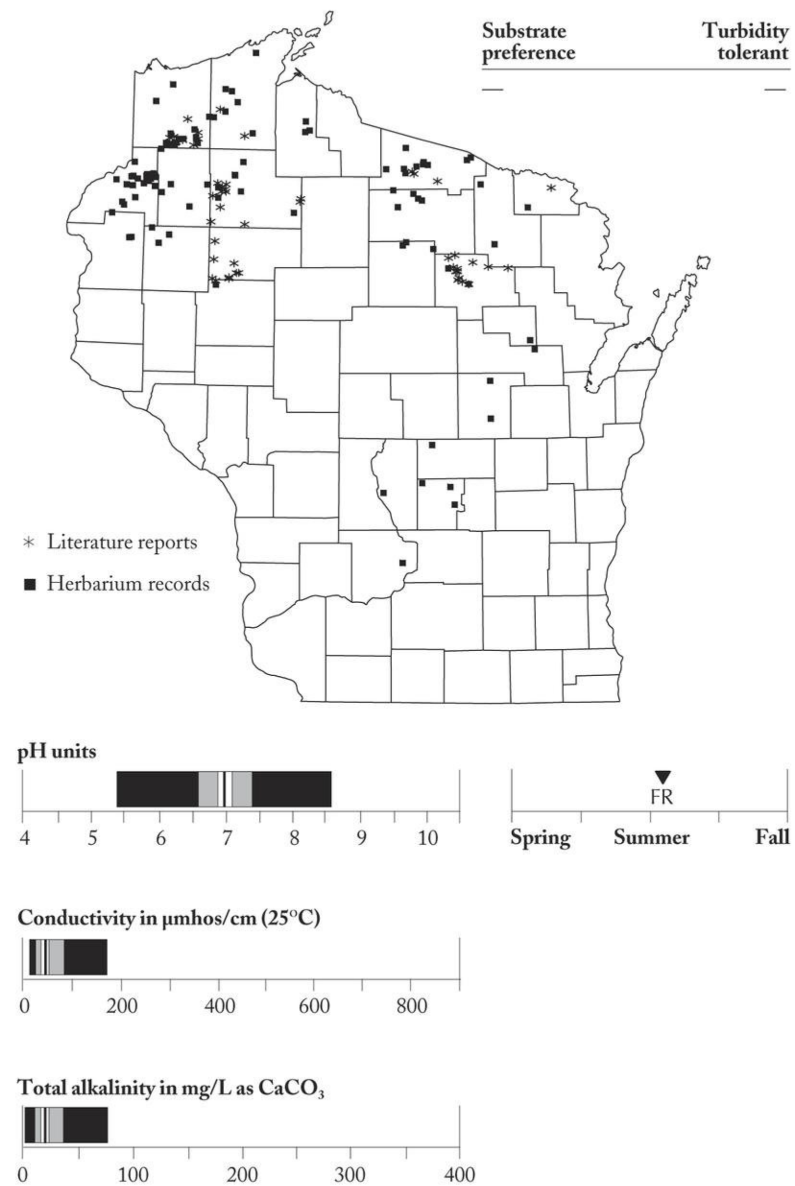
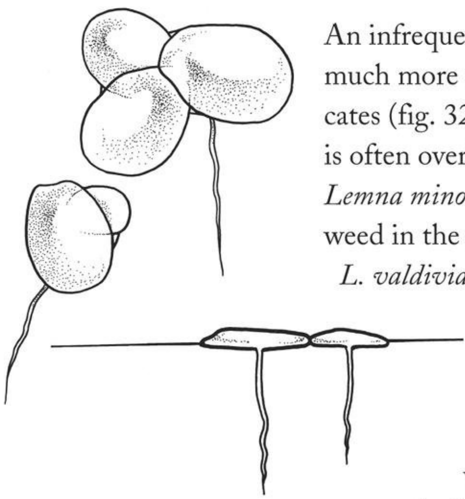


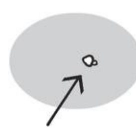
Figure 31. Distribution and habitat characteristics of *Juncus pelocarpus* E. Meyer.

Lemna minor L.

small duckweed



An infrequently cited plant, but probably much more common than its status indicates (fig. 32). Because of its small size, it is often overlooked and undercollected. *Lemna minor* is the common small duckweed in the state, and it is unlikely that *L. valdiviana* Phil., *L. perpusilla* Torr., and *L. turionifera* L., similar looking species, are separated from *L. minor* during lake surveys. *Lemna valdiviana* was only found at two locations in Michigan (Voss, 1972); it is probably equally rare in Wisconsin. *Lemna perpusilla* (Voss, 1972) and *L. turionifera* (Voss, 1972; Gleason and Cronquist, 1991) are lumped with *L. minor* by some authors. *Lemna minor* is found statewide over a moderate pH range and broad ranges of alkalinity and conductivity. Because of its free-floating habit, a discussion of depth distribution, substrate preference, and turbidity tolerance is inappropriate. It is confined to quiet water and rarely flowers (Voss, 1972). Common associates are *Ceratophyllum demersum, Elodea canadensis, Potamogeton crispus, P. diversifolius, P. foliosus, P. nodosus, P. vaginatus, P. zosteriformis, Ranunculus longirostris, Sagittaria latifolia, S. rigida, Spirodela polyrhiza, Typha latifolia,* and *Wolffia columbiana.*



ACTUAL SIZE

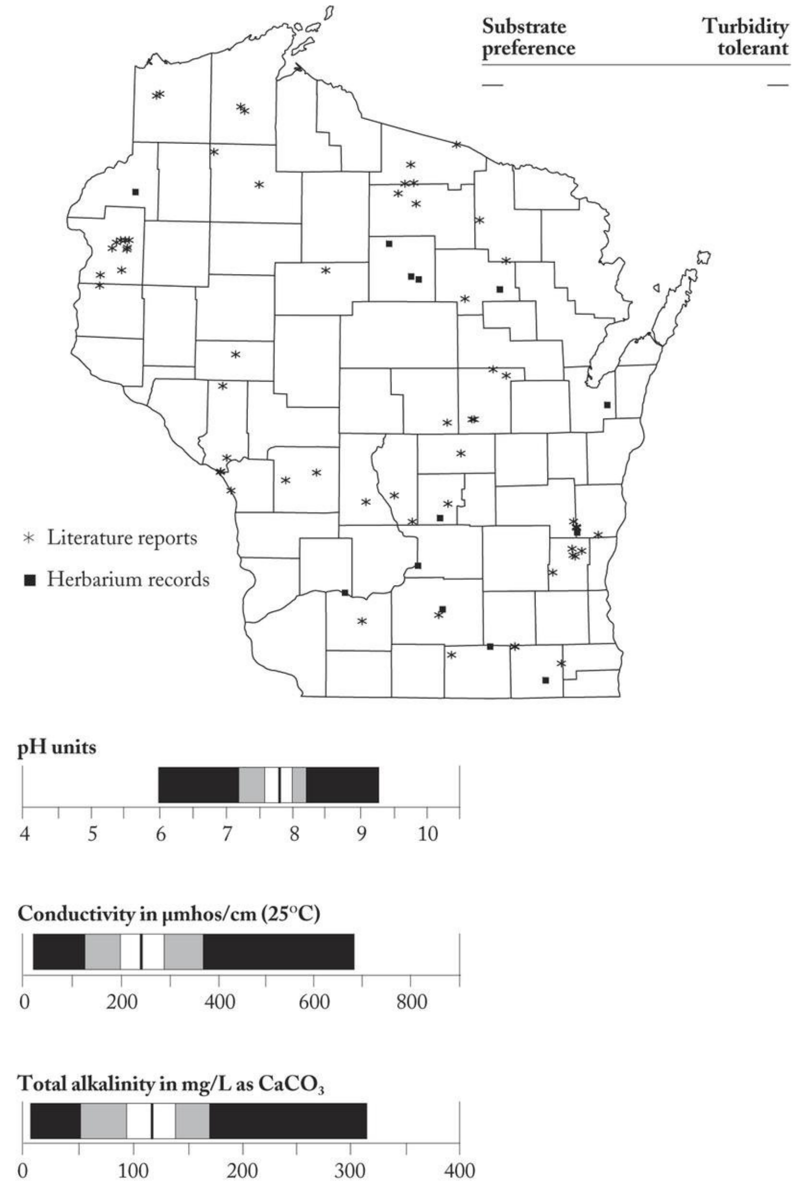
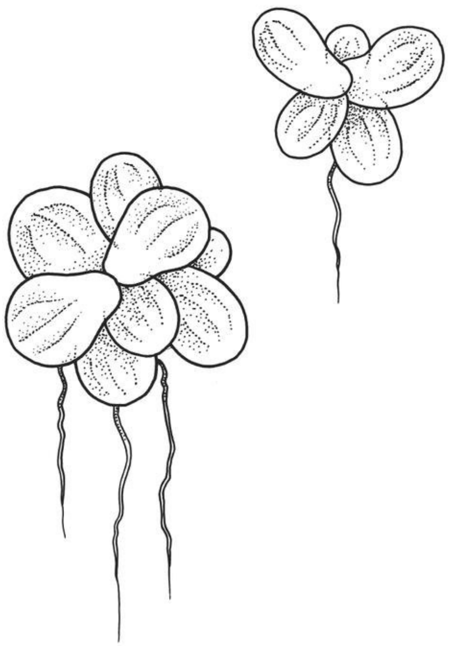


Figure 32. Distribution and habitat characteristics of *Lemna minor* L.

Lemna perpusilla Torr.

Seldom separated in the field from *L. minor*. Joints with unequally rounded sides and a root tip sheath that tapers to a sharp point are the chief characteristics that separate this species from *L. minor*. Voss (1972) elected to call them a single species for Michigan. Where *L. perpusilla* was identified, its median alkalinity, pH, and conductivity were very similar to those of *L. minor* (fig. 33).



least duckweed

Substrate preference	Turbidity tolerant
—	—

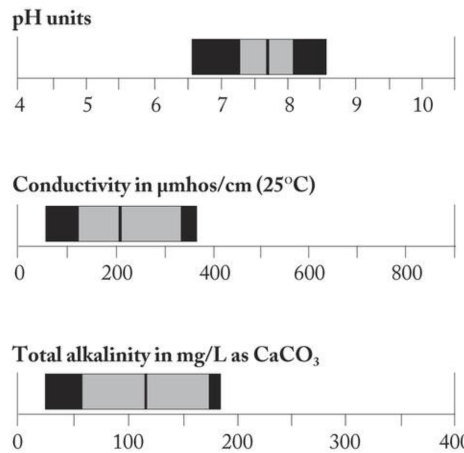
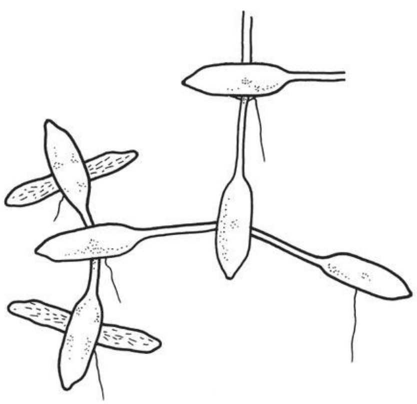
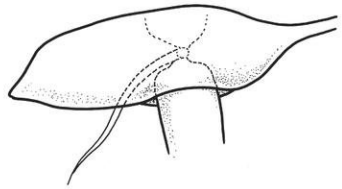


Figure 33. Distribution and habitat characteristics of *Lemna perpusilla* Torr.

Lemna trisulca L.

An infrequent plant (fig. 34). It is not as common as *L. minor,* but it is probably more common than its infrequent status indicates. It is small and often grows in tangled masses beneath the water, where it is easily overlooked. It is not commonly associated with *L. minor*, although it is found statewide in habitats similar to those where *L. minor* is found. Common associates are *Bidens beckii, Ceratophyllum demersum, Elodea canadensis, Myriophyllum verticillatum, Nymphaea odorata, Potamogeton diversifolius, P. praelongus, P. zosteriformis, Ranunculus longirostris, Spirodela polyrhiza, Utricularia geminiscapa, Wolffia columbiana,* and *Zosterella dubia.*





forked duckweed

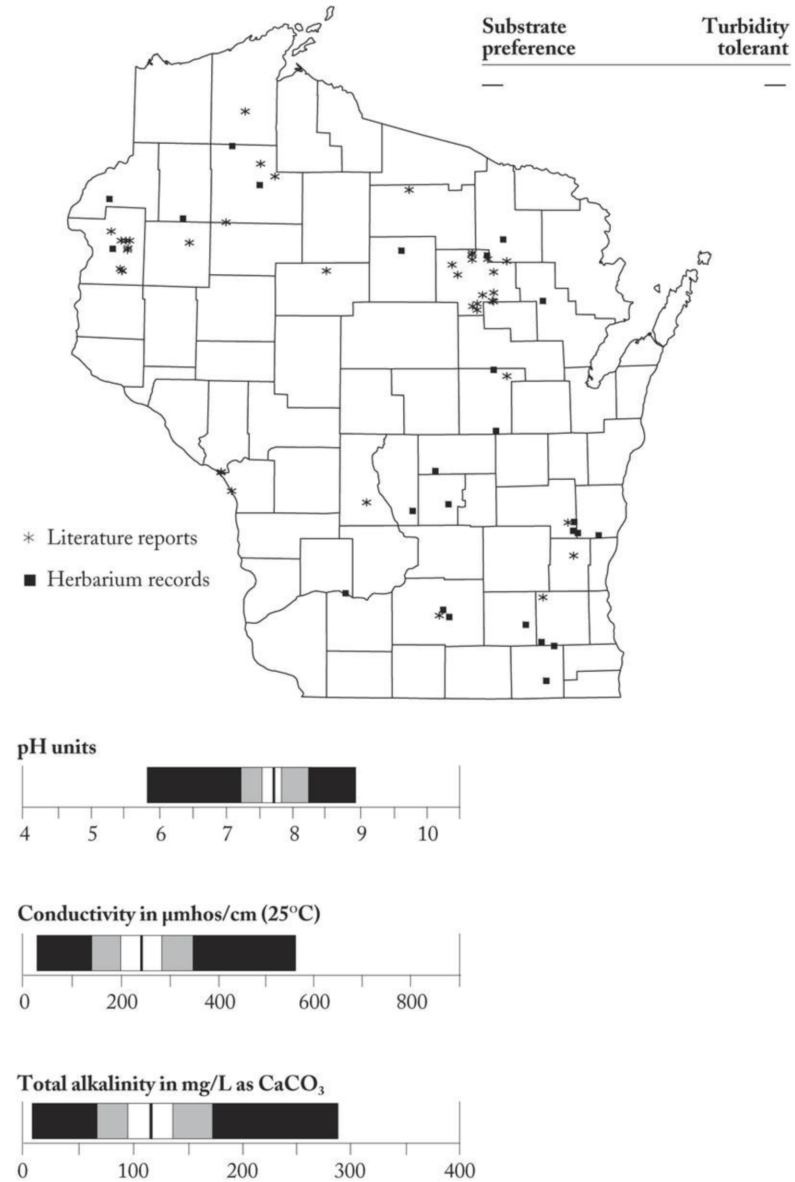
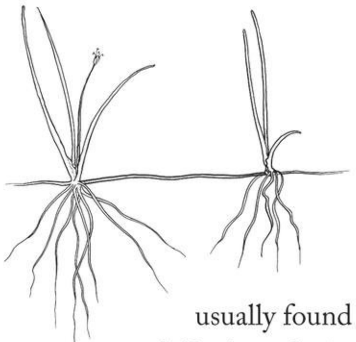
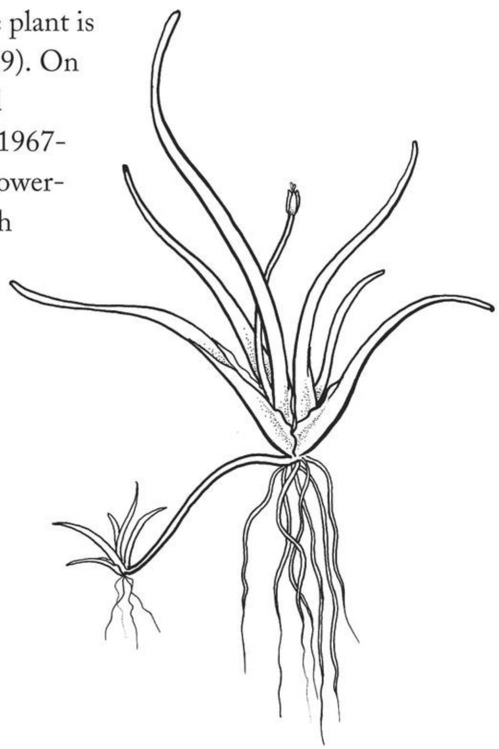


Figure 34. Distribution and habitat characteristics of *Lemna trisulca* L.

Littorella uniflora (L.) Asch.



An infrequent plant, found primarily in low alkalinity, low conductivity, low pH lakes within the Northern Lakes and Forests Ecoregion (fig. 35). Because of its small size, it may be more common than its infrequent status indicates. It is usually found in a submersed, sterile state that is often difficult to distinguish from *Ranunculus reptans* (Fassett, 1969). It is found over narrow conductivity and alkalinity ranges and over a moderate pH range. No flowering or fruiting dates, depth distribution, substrate preference, turbidity tolerance, or common associates were determined. Flowering is rare and apparently occurs as the water recedes and the plant is exposed (Fassett, 1969). On the basis of cultivated specimens, Tessene (1967-68) reported plants flowering from June through August. Flowering could be induced in emersed plants under long day conditions. Reproduction is mainly vegetative by means of stolons.



plantain shoreweed

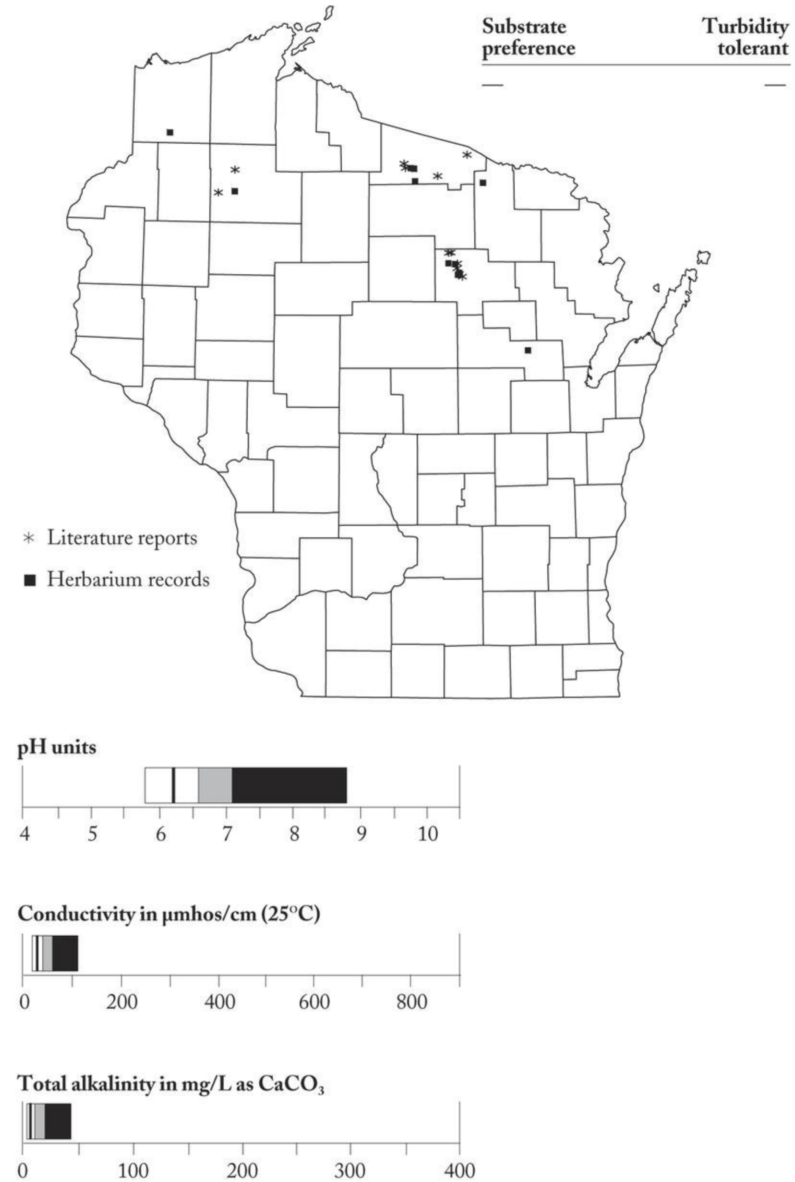
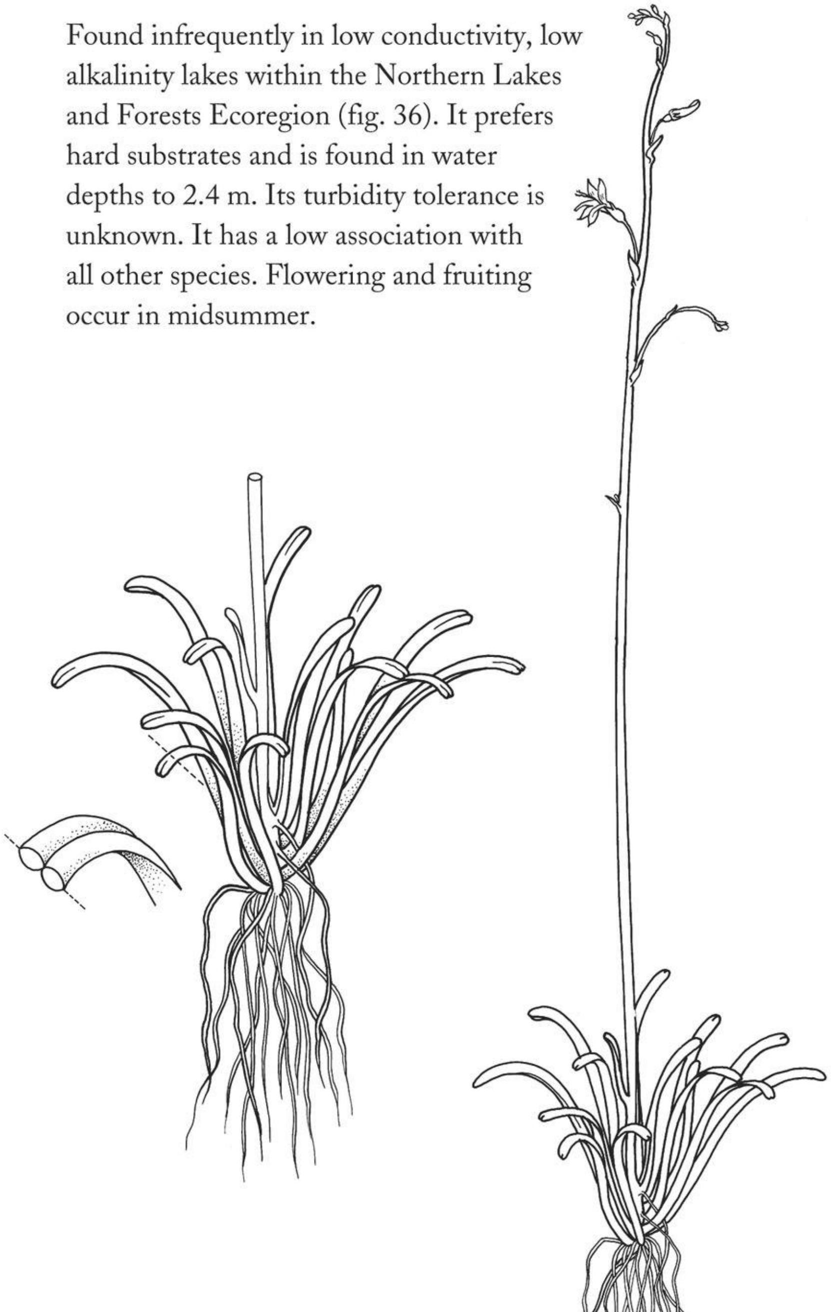


Figure 35. Distribution and habitat characteristics of *Littorella uniflora* (L.) Asch.

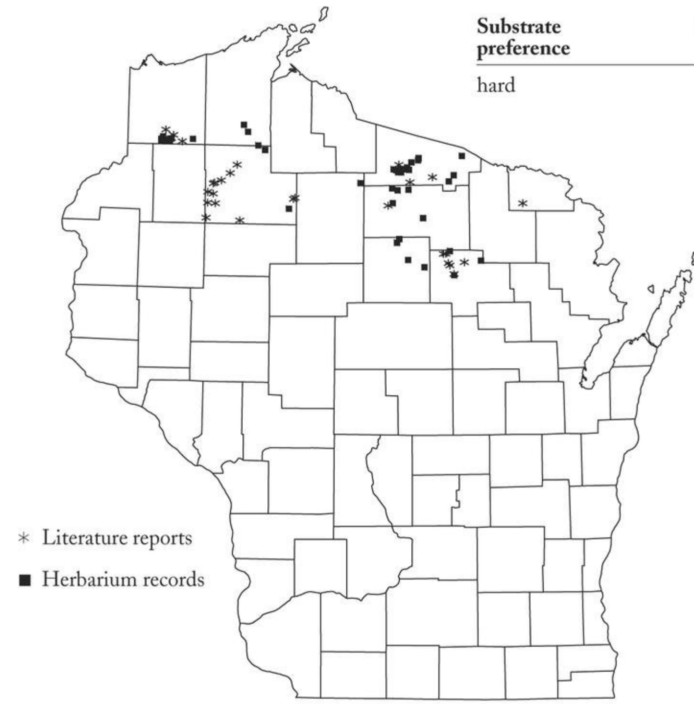
Lobelia dortmanna L.

Found infrequently in low conductivity, low alkalinity lakes within the Northern Lakes and Forests Ecoregion (fig. 36). It prefers hard substrates and is found in water depths to 2.4 m. Its turbidity tolerance is unknown. It has a low association with all other species. Flowering and fruiting occur in midsummer.



water lobelia

Substrate preference	Turbidity tolerant
hard	—



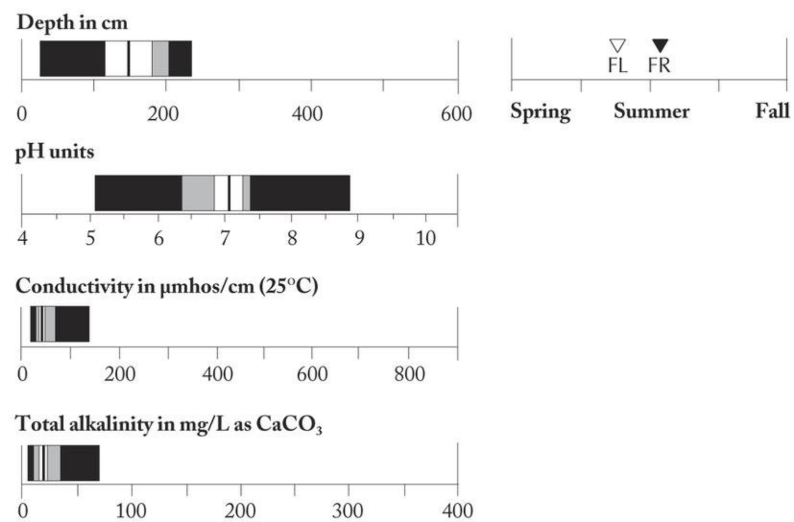


Figure 36. Distribution and habitat characteristics of *Lobelia dortmanna* L.

Myriophyllum alterniflorum DC.

An infrequent species, generally found in the Northern Lakes and Forests Ecoregion (fig. 37). Outliers were found in Waushara and Walworth Counties. It appears that Wisconsin is on the southern edge of the distribution range of this species. All distribution points but one were in areas where chloride concentrations were less than 3 mg/L. This species can usually be distinguished from other milfoils because it has dense, short (usually less than 1.2 mm long) leaves on an often sinuous, much-branched stem (Voss, 1985). The uppermost flowers in the spike are alternate. It is found in low conductivity and alkalinity water but over a moderate pH range. Not enough information was available to determine flowering and fruiting dates, depth distribution, substrate preference, turbidity tolerance, or association with other species.

alternate flowered water-milfoil

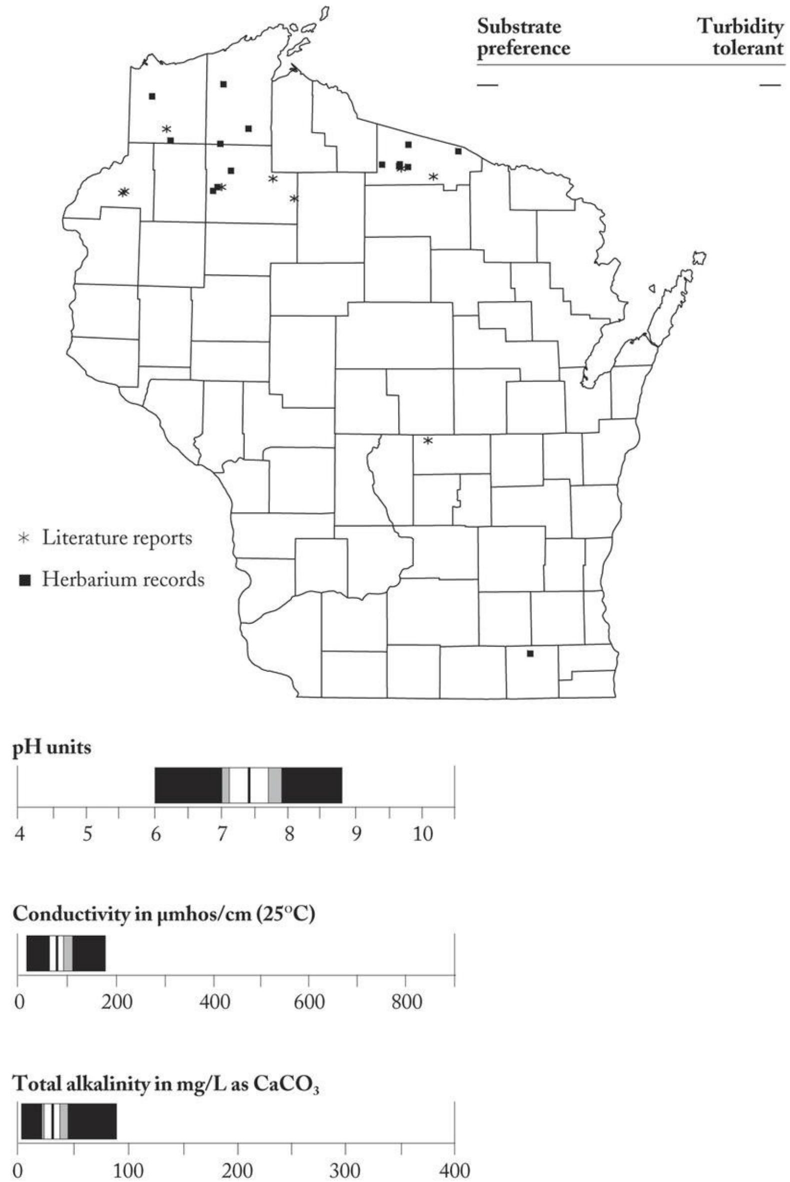
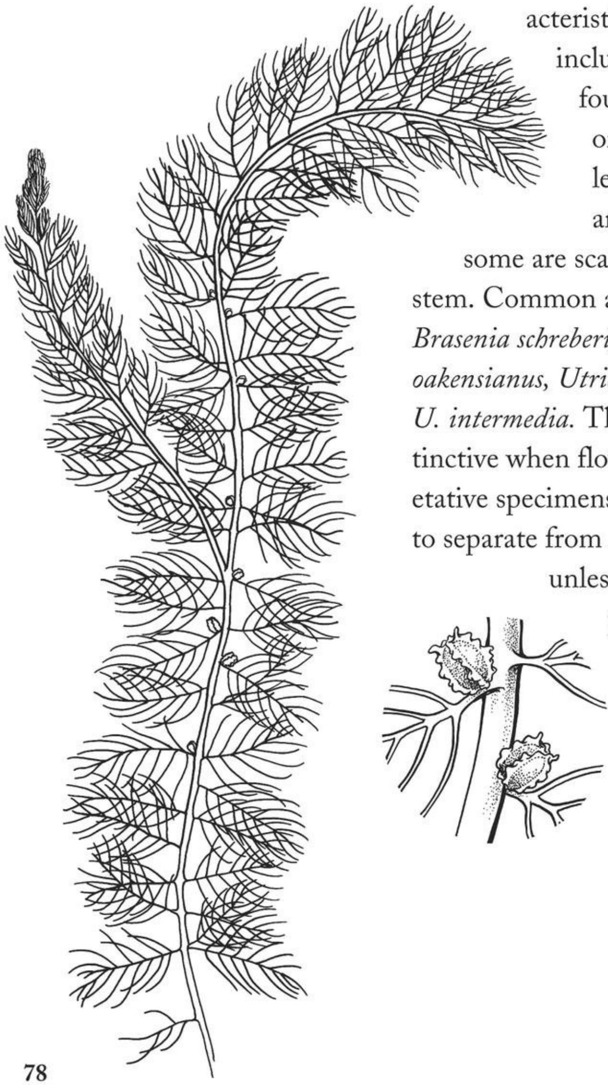


Figure 37. Distribution and habitat characteristics of *Myriophyllum alterniflorum* DC.

A rare plant, found primarily in low alkalinity and low conductivity water of Wisconsin (fig. 38). It prefers soft substrate, is found over narrow conductivity and alkalinity but moderate pH ranges at a median depth of 1.8 m. It flowers in early summer, but no fruiting date or turbidity tolerance was determined.

Some useful identifying characteristics of this species include flowers that are found in the axils of ordinary submersed leaves; some leaves are whorled and some are scattered along the stem. Common associates include *Brasenia schreberi, Potamogeton oakensianus, Utricularia gibba,* and *U. intermedia.* This species is distinctive when flowering, but vegetative specimens may be difficult to separate from *M. heterophyllum* unless turions are present in late summer (Voss, 1985).



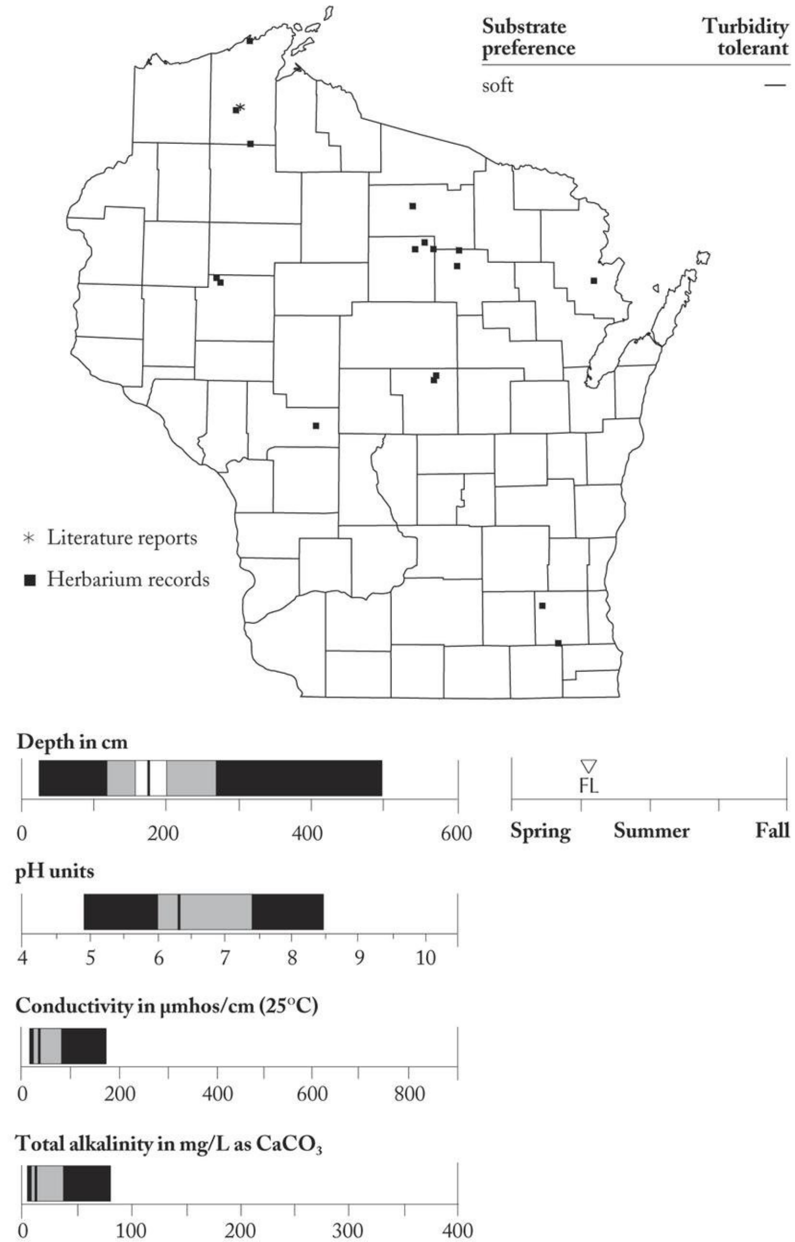
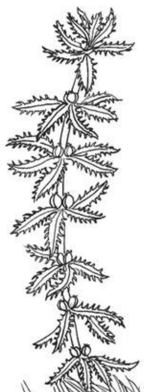
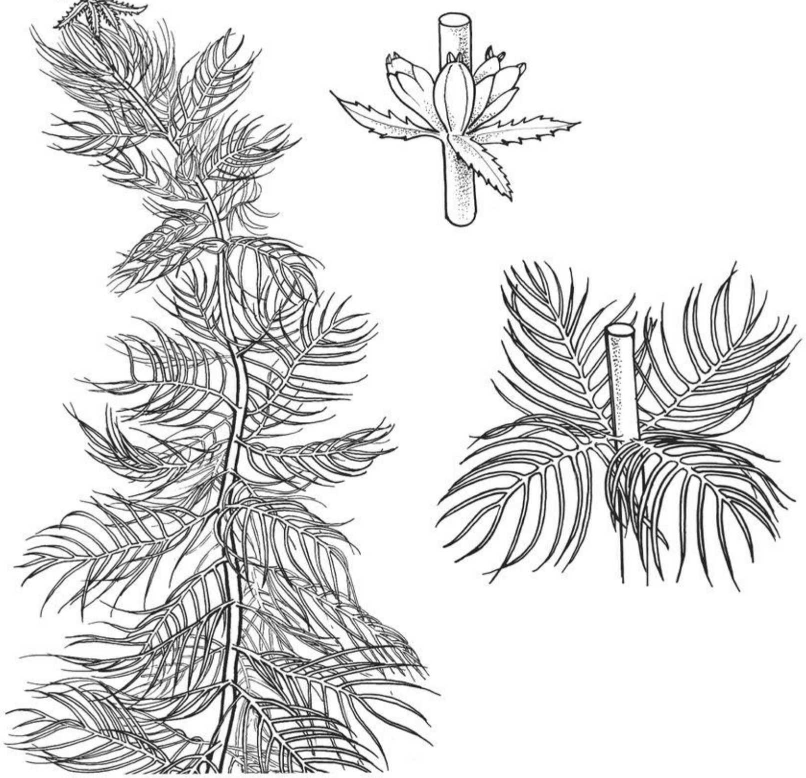


Figure 38. Distribution and habitat characteristics of *Myriophyllum farwellii* Morong.

An infrequent species, found over moderate ranges of alkalinity, pH, and conductivity at scattered locations in Wisconsin (fig. 39). It shows no substrate preference and is found in water depths to 5 m. It flowers in early summer, but fruiting dates and turbidity tolerance were not determined. Common associates include *Ceratophyllum demersum*, *Potamogeton pusillus*, *P. richardsonii*, and *P. zosteriformis*. Because it has short internodes and usually more than four leaves per node, it looks like a thick green rope underwater (Voss, 1985). This species is more abundant south of Wisconsin (Gleason and Cronquist, 1991).





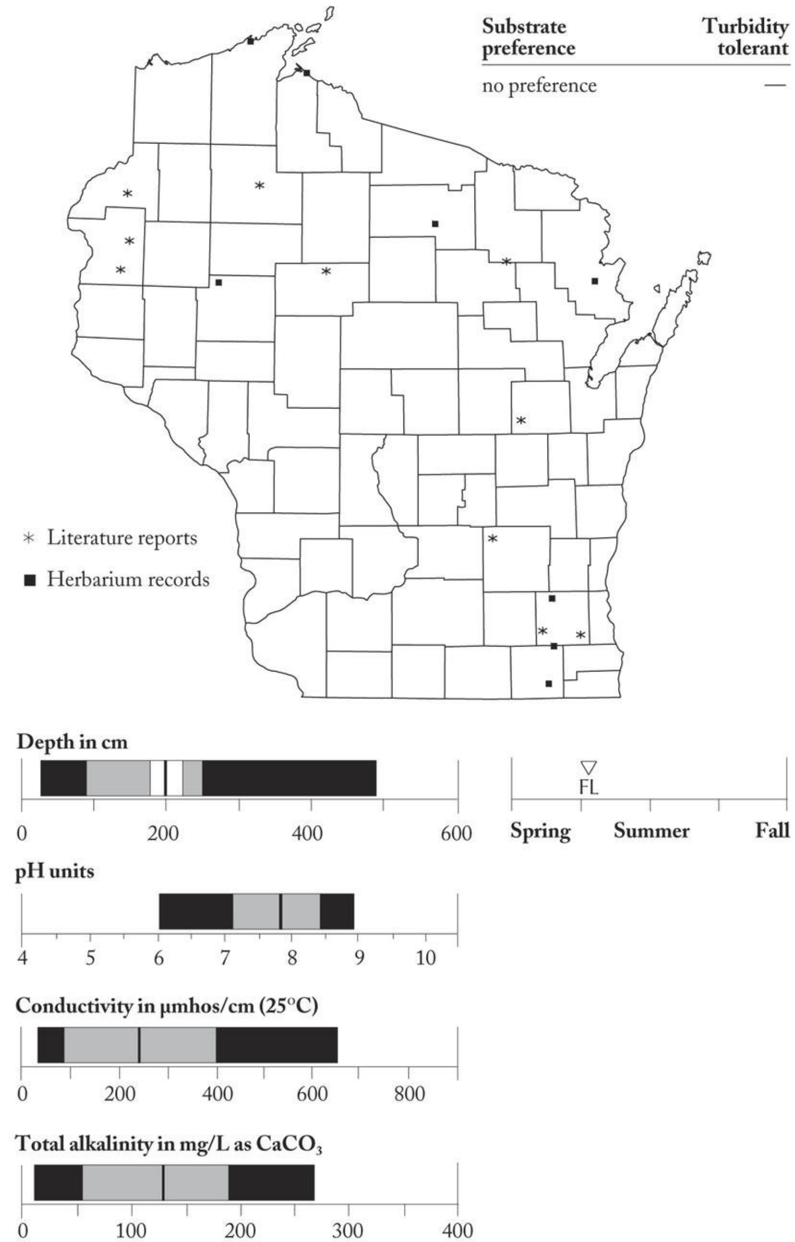


Figure 39. Distribution and habitat characteristics of *Myriophyllum heterophyllum* Michx.

Myriophyllum humile (Raf.) Morong

A rare species, found in the Northern Lakes and Forests Ecoregion (fig. 40). Crow and Hellquist (1983) found this species in shallow sandy or muddy margins of low alkalinity, acid lakes in New England. From the limited information available, it appears to grow in low alkalinity, low conductivity lakes in Wisconsin, but pH varies widely. Because of its rarity, other characteristics of the plant are unknown. Although the species is reported to be found sparingly in Minnesota (Ownby and Morely, 1991), it was not reported in Michigan by Voss (1985) or in earlier Wisconsin studies (Fassett, 1930c). Distribution information is based solely on literature reports. *Myriophyllum humile* shares many characteristics with *M. farwellii.* Foliage leaves are partially scattered and partially whorled along the stem, and flowers are in the axils of leaves instead of terminal spikes. *Myriophyllum humile* does not produce winter buds in the fall; *M. farwellii* does.

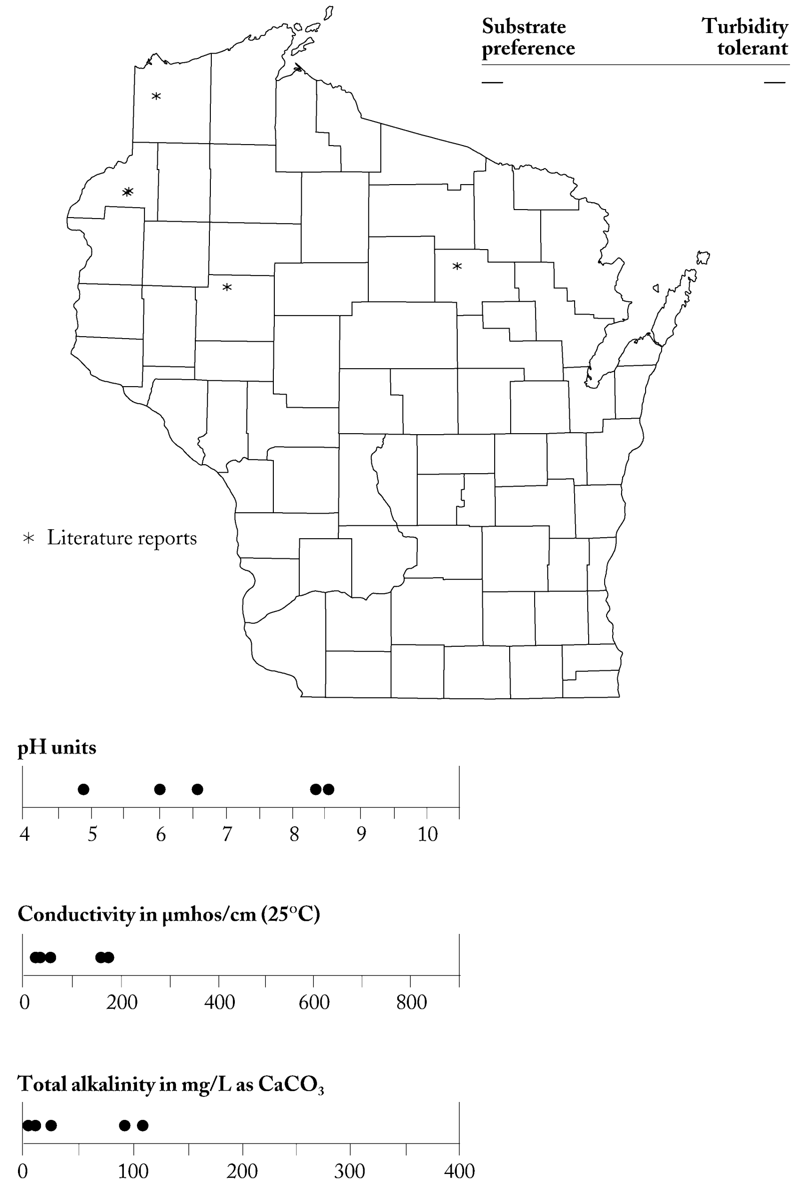
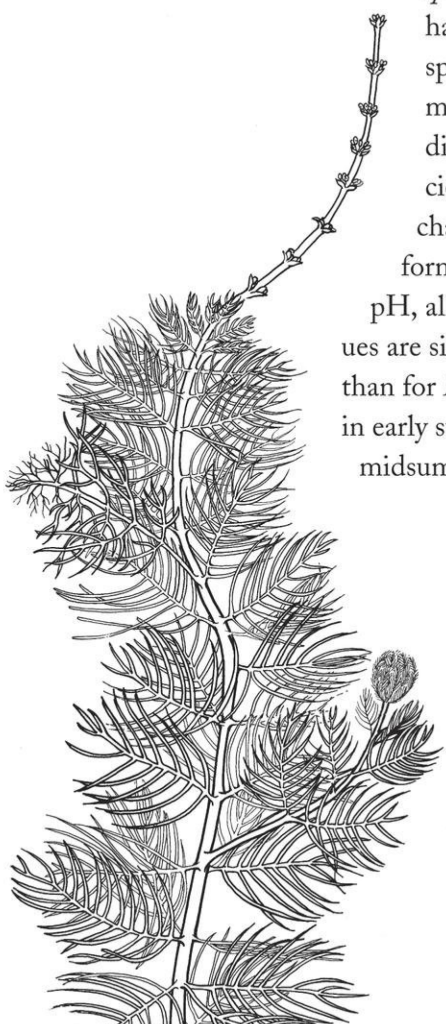


Figure 40. Distribution and habitat characteristics of *Myriophyllum humile* (Raf.) Morong.

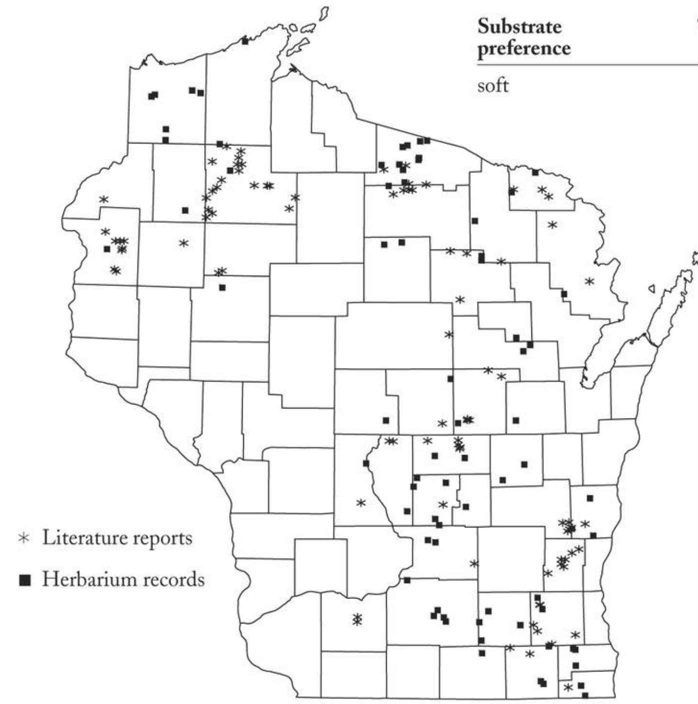
Myriophyllum sibiricum Komarov

The most common milfoil in the state; widespread in northern and eastern Wisconsin (fig. 41). It can grow in water more than 4 m deep, prefers soft substrate, and is not turbidity tolerant. It grows over a broad alkalinity range and moderate conductivity and pH ranges. Its only common associate is *Ceratophyllum demersum.* This species is easily confused with *M. spicatum,* and the two species have been lumped together and split a number of times. During most of the growing season, it is difficult to separate the two species on the basis of vegetative characteristics, but *M. sibiricum* forms turions in the fall. Median pH, alkalinity, and conductivity values are significantly less for this species than for *M. spicatum.* Flowering occurs in early summer, and fruits are found by midsummer.



spiked water-milfoil

Substrate preference	Turbidity tolerant
soft	no



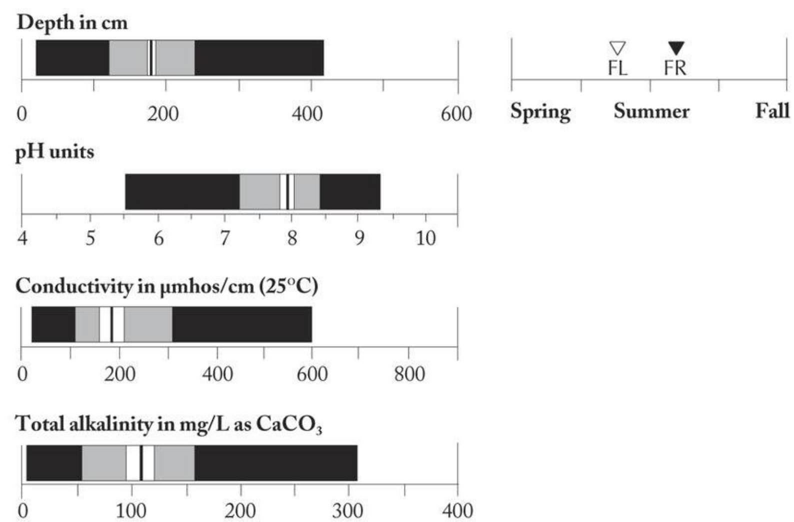
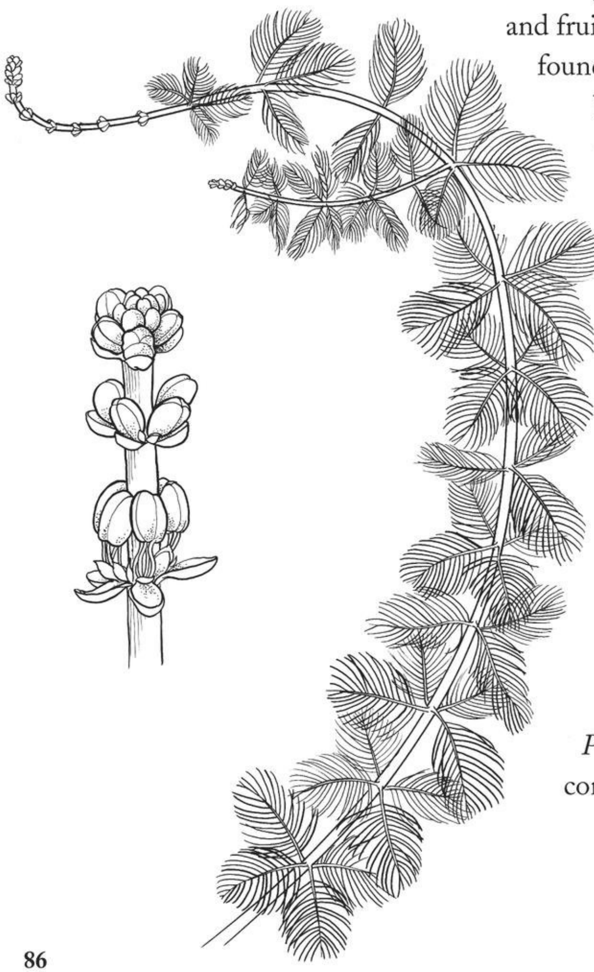


Figure 41. Distribution and habitat characteristics of *Myriophyllum sibiricum* Komarov.

Myriophyllum spicatum L.

A Eurasian invader, found infrequently in the southern half of the state, but becoming more common and spreading to northern and western regions (fig. 42). It is found over broad alkalinity, moderate conductivity, and moderate but high pH ranges. It can grow in water depths greater than 4 m, shows no substrate preference, and is not turbidity tolerant. The average fruiting date is middle to late summer; however, it can flower and fruit twice, once in early summer and once in late summer. The late flowering can be prolonged and fruiting plants can be found into early November. Because of its confusing taxonomy and name changes (see *M. sibiricum* description), no specimen reported before 1960, when it was first thought to invade Wisconsin, was included in this analysis. *Potamogeton illinoensis* and *P. strictifolius* are common associates.



Eurasian water-milfoil

Substrate preference	Turbidity tolerant
no preference	no

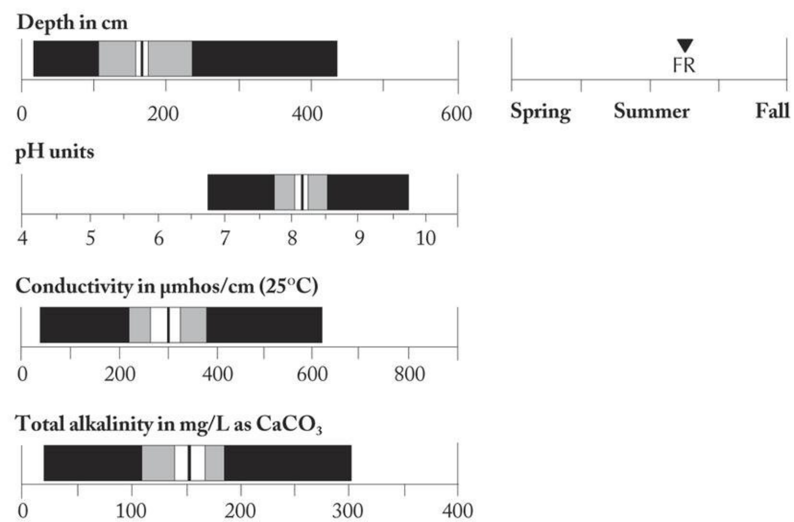
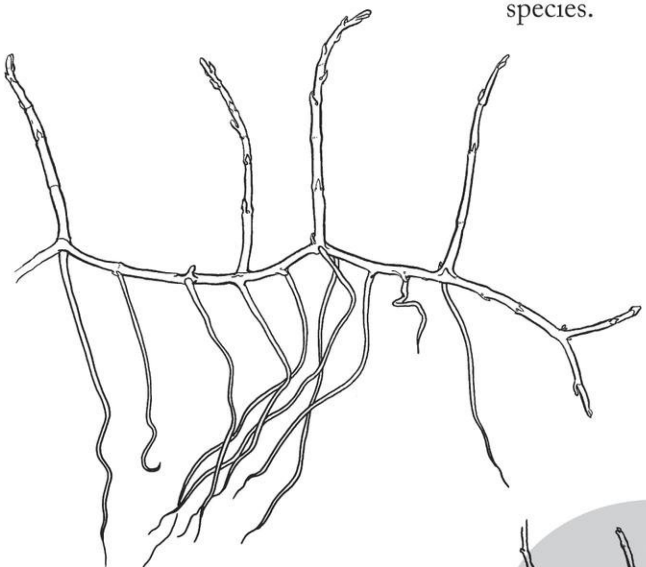
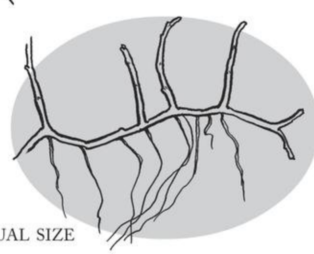


Figure 42. Distribution and habitat characteristics of *Myriophyllum spicatum* L.

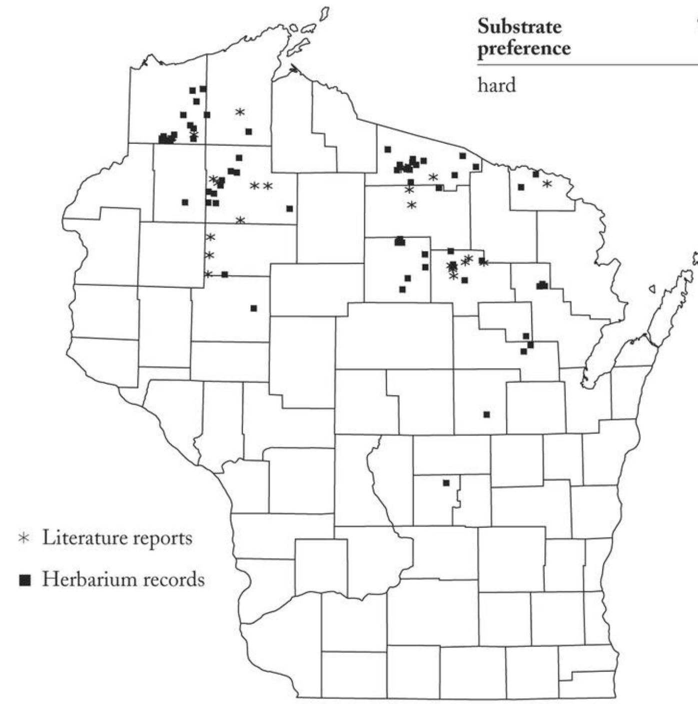
An infrequent species, found in low conductivity, low alkalinity, circumneutral water in northern Wisconsin (fig. 43). All distribution points were either in the Northern Lakes and Forests Ecoregion or in low chloride, low sulfate areas in the rest of the state. *Myriophyllum tenellum* prefers hard substrates; turbidity tolerance was not determined. It grows in water up to 4 m deep. In deep water it can form dense turfs of leafless stems that arise singly along buried rhizomes. In shallow water emersed tips produce flowers and fruits. Flowers and fruits are found in midsummer. *Myriophyllum tenellum* does not commonly associate with any other species.





ACTUAL SIZE

Substrate preference	Turbidity tolerant
hard	—



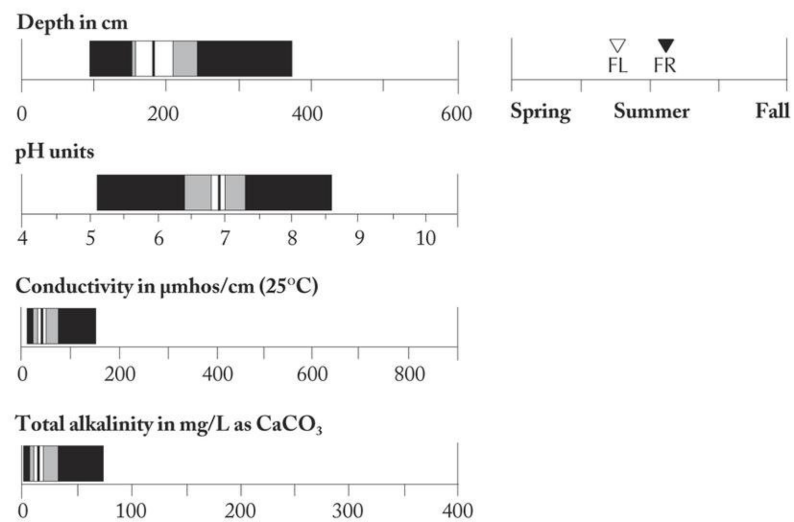
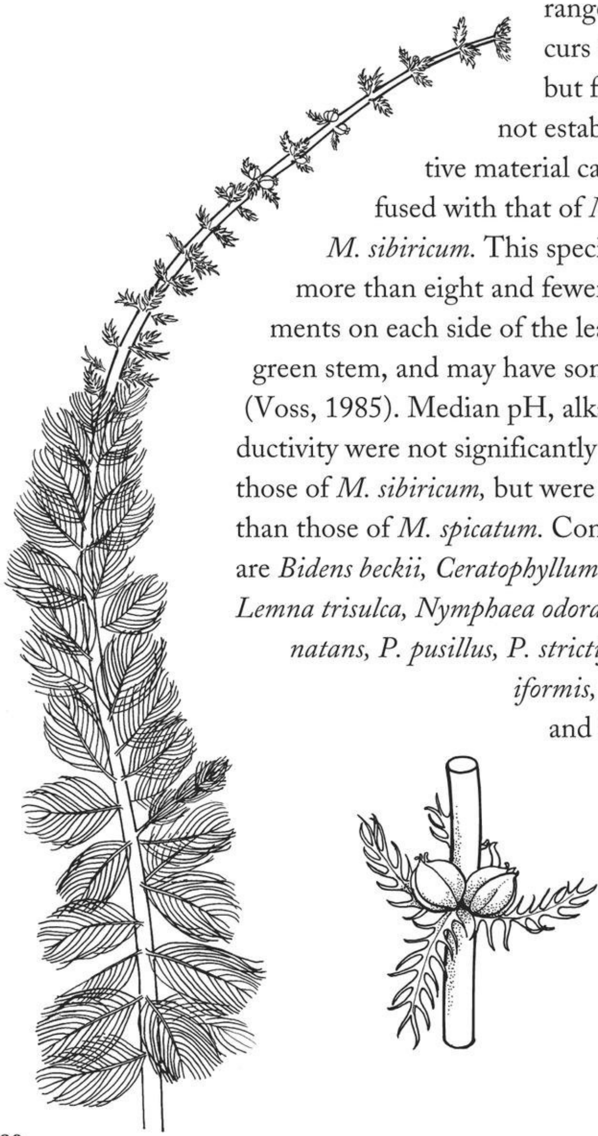


Figure 43. Distribution and habitat characteristics of *Myriophyllum tenellum* Bigelow.

Myriophyllum verticillatum L.

whorled water-milfoil

An infrequent species, found in northern and eastern Wisconsin (fig. 44). It grows in water depths to 4 m, shows no substrate preference, and is not turbidity tolerant. It grows over a broad pH range and moderate conductivity and alkalinity ranges. Flowering occurs in midsummer, but fruiting time was not established. Vegetative material can be easily confused with that of *M. spicatum* and *M. sibiricum.* This species generally has more than eight and fewer than 14 segments on each side of the leaf, has a brown to green stem, and may have some sessile leaves (Voss, 1985). Median pH, alkalinity, and conductivity were not significantly different than those of *M. sibiricum,* but were significantly less than those of *M. spicatum.* Common associates are *Bidens beckii, Ceratophyllum demersum, Lemna trisulca, Nymphaea odorata, Potamogeton natans, P. pusillus, P. strictifolius, P. zosteriformis, Typha latifolia,* and *Zosterella dubia.*



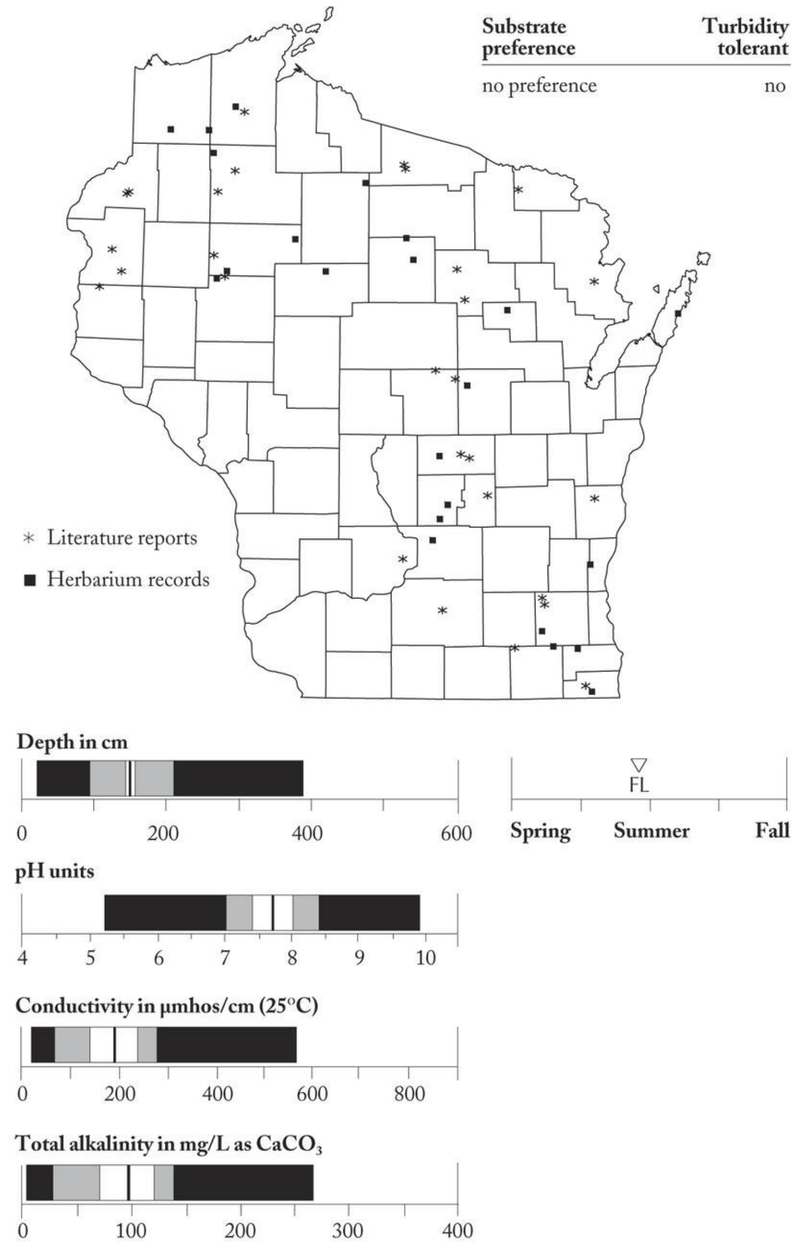
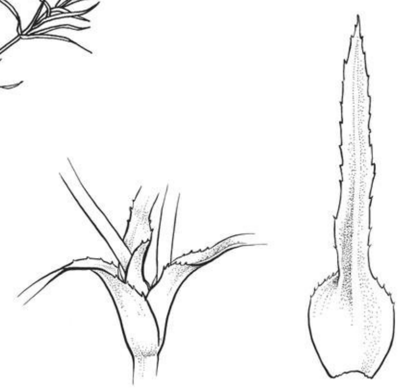


Figure 44. Distribution and habitat characteristics of *Myriophyllum verticillatum* L.

Abundant statewide. *Najas flexilis* often acts as a pioneer species by invading open or disturbed areas (Engel and Nichols, 1984) (fig. 45). It is found growing in water depths greater than 3 m, prefers hard substrates, and is not turbidity tolerant. This plant can tolerate broad alkalinity and conductivity ranges and a moderate pH range. It is an annual plant that flowers in early summer and fruits abundantly in middle to late summer. It is an important duck food. It is an exceedingly variable species; the differences between individuals are probably due in large part to habitat factors (Voss, 1972). The leaf base is tapered. Common associates are *Bidens beckii*, *Potamogeton gramineus*, *P. illinoensis*, *P. pusillus*, *P. strictifolius*, and *Vallisneria americana*.



Substrate preference	Turbidity tolerant
hard	no

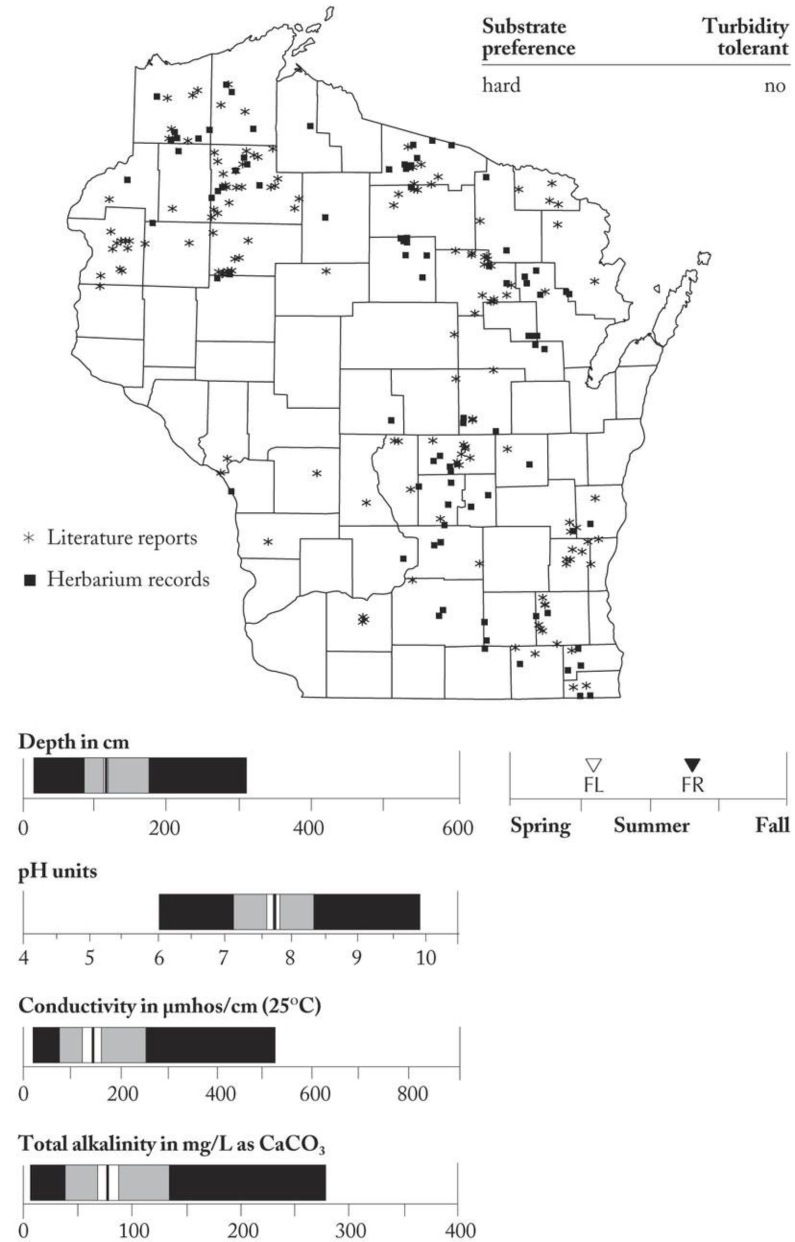
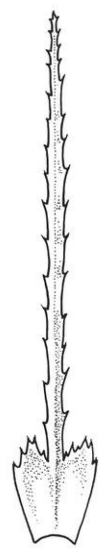


Figure 45. Distribution and habitat characteristics of *Najas flexilis* (Willd.) Rostkov & Schmidt.

Najas gracillima (A. Braun) Magnus

A rare species, found mostly in the Northern Lakes and Forests Ecoregion in areas of low alkalinity and conductivity water (fig. 46). It has a narrow alkalinity and conductivity range and a limited pH range. All distribution points were in regions of low chloride, magnesium, and calcium concentrations. It is found at a median depth of 1.5 m. Substrate preference, turbidity tolerance, flowering date, and common associates were not determined. It fruits in late summer. Voss (1972) found it primarily in muck-bottom lakes in Michigan. It is intolerant of pollution and is becoming rarer throughout its range (Gleason and Cronquist, 1991). Lobe-like widenings of the leaf base is a useful characteristic for identifying vegetative material of this species.



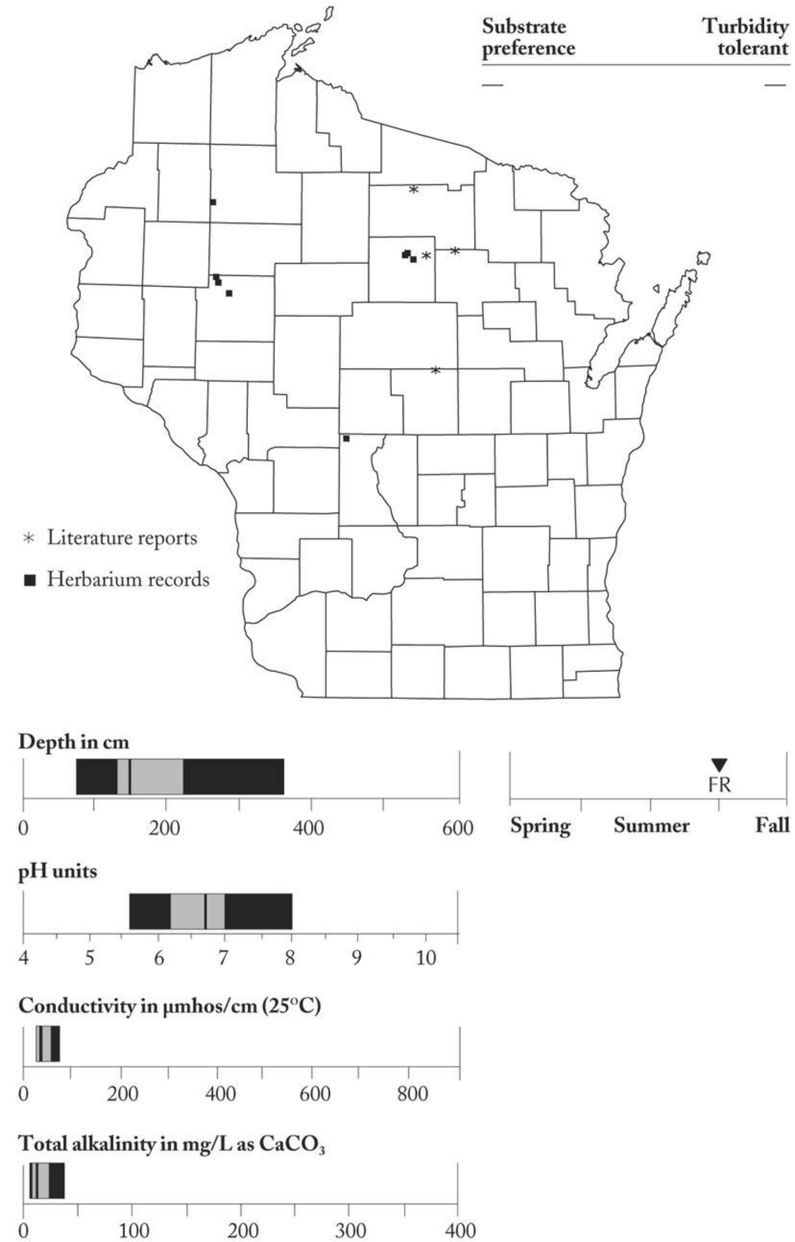


Figure 46. Distribution and habitat characteristics of *Najas gracillima* (A. Braun) Magnus.

Najas guadalupensis (Sprengel) Magnus

A rare species, found over moderate alkalinity and conductivity ranges and a limited and fairly high pH range (fig. 47). Not enough information was available to determine substrate preference, turbidity tolerance, depth distribution, flowering date, or common associates. Fruiting occurs in midsummer. Voss (1972) stated that this species grows in depths of at least 4 m of water in Michigan. It is reportedly more common south of Wisconsin (Beal, 1977; Winterringer and Lopinot, 1966), and it ranges into Mexico (Hellquist and Crow, 1980). Similar to that of *N. flexilis,* the leaf base of *N. guadalupensis* is tapered and not lobed; however, the leaf tips of *N. guadalupensis* are acute or rounded, not sharply pointed as are those of *N. flexilis.*

southern naiad

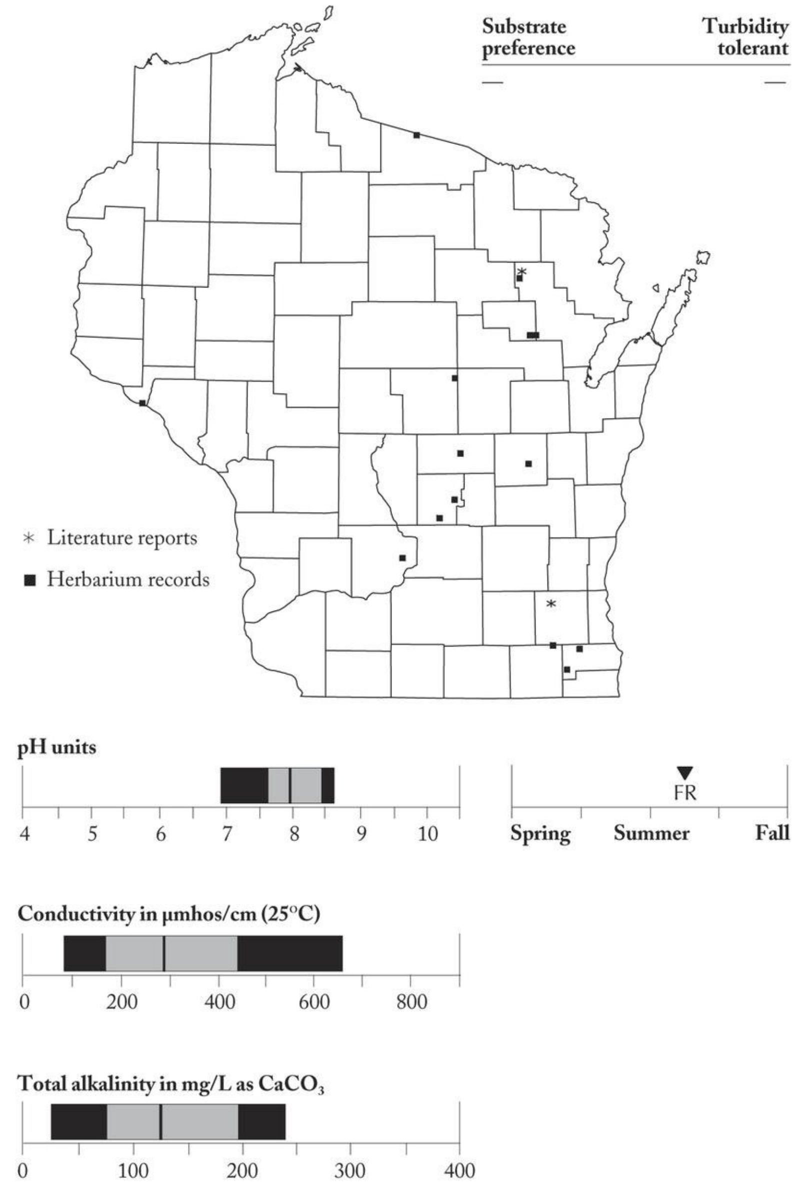


Figure 47. Distribution and habitat characteristics of *Najas guadalupensis* (Sprengel) Magnus.

Najas marina L.

An infrequent species, found in high alkalinity, high conductivity, high pH water within the Southeastern Wisconsin Till Plain Ecoregion (fig. 48). All distribution points were in areas where alkalinities were greater than 30 mg/L, and all but one point were in areas where chloride concentrations were greater than 10 mg/L. This species may be increasing its range; it was reported at only one location in 1951 (Ross and Calhoun, 1951). Its maximum depth range is approximately 3 m and it prefers soft substrate. Turbidity tolerance and flowering dates were not determined. Fruiting occurs in late summer. *Najas marina* does not associate with any other species.

spiny naiad

Substrate preference	Turbidity tolerant
soft	—

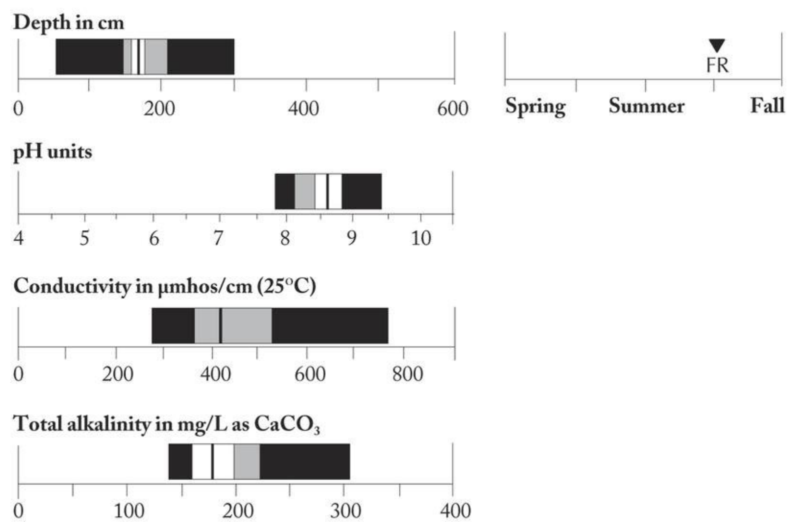
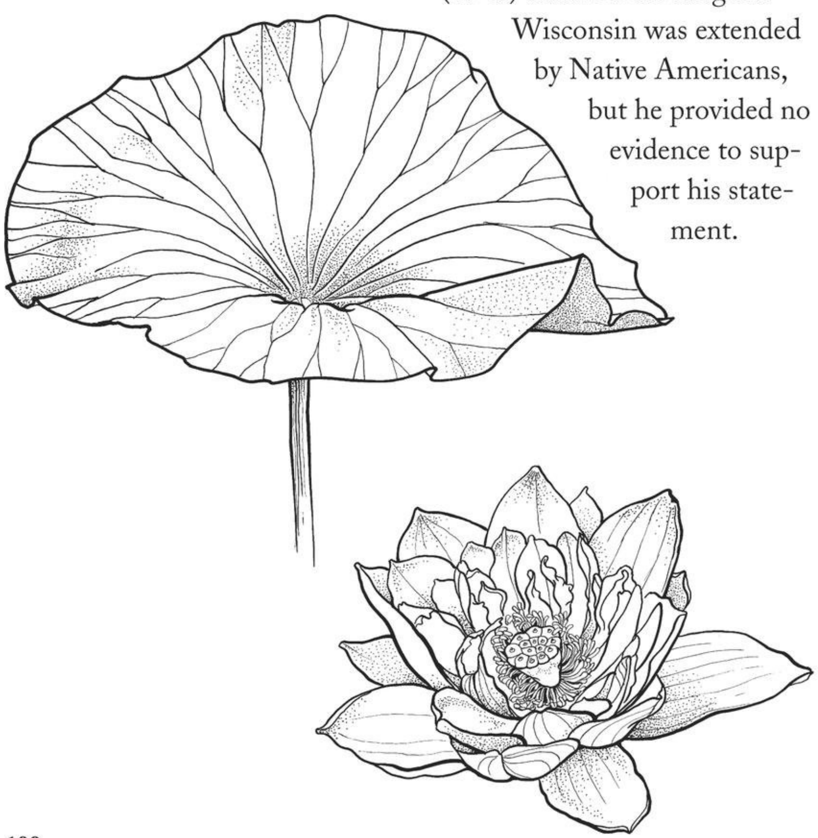


Figure 48. Distribution and habitat characteristics of *Najas marina* L.

Nelumbo lutea (Willd.) Pers.

A rare species, in inland lakes of Wisconsin (fig. 49). It is much more common in sloughs and pools of the Mississippi River north to Pepin County (Fassett, 1946). Wisconsin is on the northern edge of the range for this species, and no distribution points were found in the Northern Lakes and Forests Ecoregion. It is found over limited alkalinity, pH, and conductivity ranges. Substrate preference, turbidity tolerance, common associates, and depth distribution were not determined. Because it produces large, round, floating, or emergent leaves, it is restricted to shallow water and is probably turbidity tolerant. It flowers in midsummer and fruits by late summer. Fassett (1946) believed the range in Wisconsin was extended by Native Americans, but he provided no evidence to support his statement.



American lotus

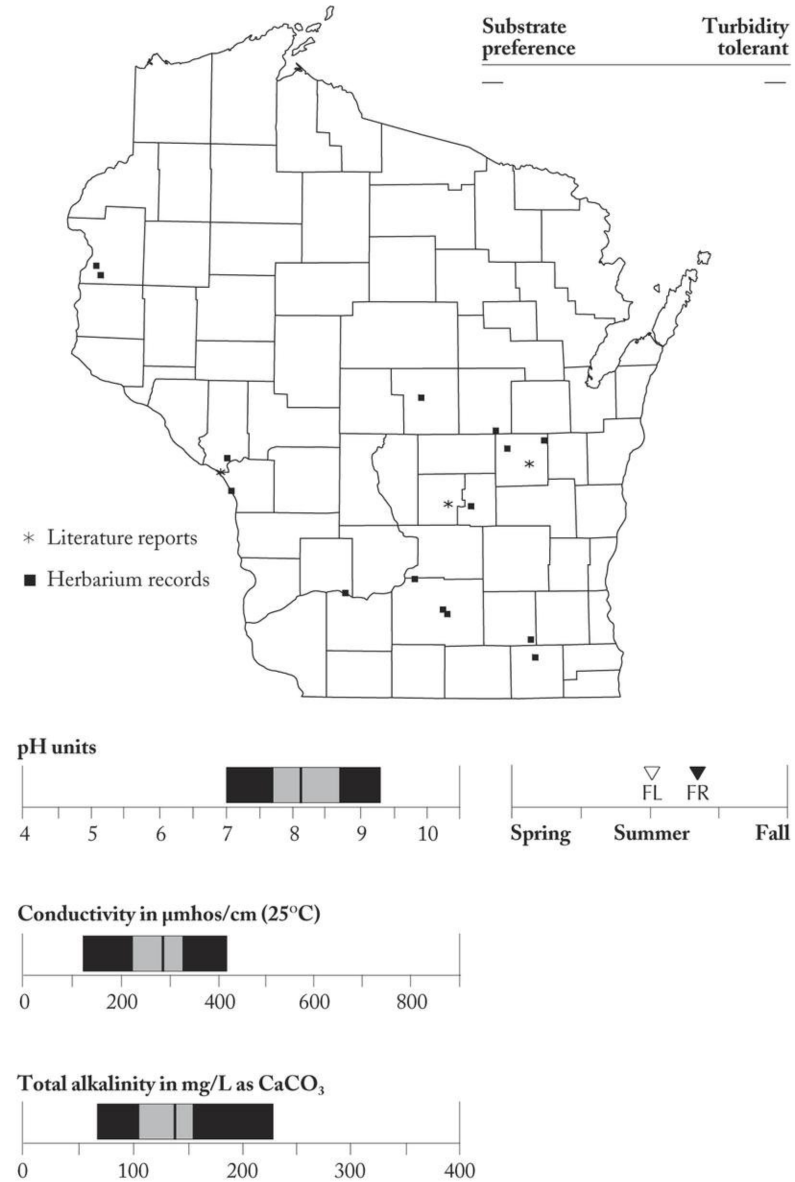


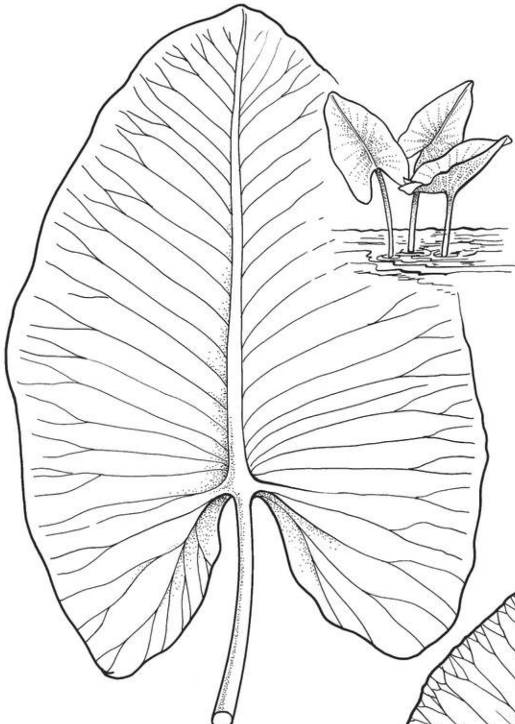
Figure 49. Distribution and habitat characteristics of *Nelumbo lutea* (Willd.) Pers.

A species with naming problems (fig. 50). These problems make discussing the habitat of the *Nuphar* species difficult and tenuous. Gleason and Cronquist (1991) recognized two large-leaf species found in the state: *Nuphar variegata* Durand and *N. advena* (Aiton) Aiton f. The taxonomic distinction between the two is not difficult, but because of name changes it is not reliably known which species is being discussed in lake reports.

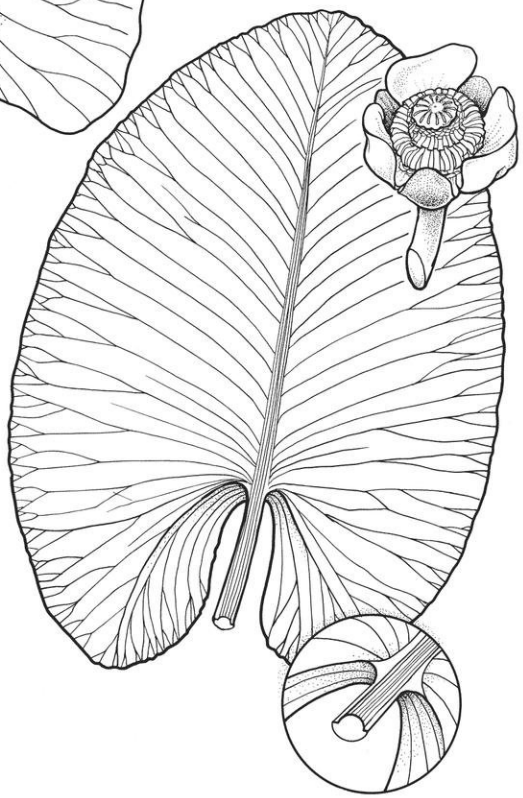
Nuphar variegata is the most common *Nuphar* in the state; it is spread statewide and is abundant. Wisconsin is on the northern edge of the range of *N. advena*. Herbarium specimens and Fassett (1946) placed *N. advena* in southeastern Wisconsin, except for one specimen from Hill's Lake in Oconto County. The southerly distribution of *N. advena* fits with its distribution in Michigan (Voss, 1985). It is ranked common, but this ranking is based on old lake reports. On the basis of herbarium specimens, this species is much rarer than *N. variegata* in the state. My analyses found that the median pH, conductivity, and alkalinity are higher for *N. variegata* than for *N. advena,* which would not be the case if *N. advena* were found only in southeastern Wisconsin lakes, where pH, conductivity, and alkalinity are high. Both species prefer soft substrate and are found in water 2 m or less deep. Turbidity tolerance is not a consideration because both species have floating leaves that quickly reach the water surface in the spring. Flowering and fruiting dates were not determined, but *N. variegata* is commonly seen flowering by early June. Common associates of *N. variegata* are *Brasenia schreberi, Nymphaea odorata,* and *Polygonum amphibium.*

Nuphar microphylla (Pers.) Fern. is usually distinctive when it is a flowering adult. The species is found in low conductivity, low alkalinity water of northern Wisconsin. *Nuphar* x *rubrodisca* Morong is thought to be a hybrid between *N. microphylla* and *N. variegata* (Voss, 1985; Hellquist and Crow, 1984). The median pH, conductivity, and alkalinity for *N. variegata, N.* x *rubrodisca,* and *N. microphylla* are the same, but *N. variegata* has the broadest distribution range, followed by *N.* x *rubrodisca,* and then *N. microphylla.* In Wisconsin it appears that *N.* x *rubrodisca* is found in areas other than where the ranges of the two parent species overlap.

Identification problems arise when working with small-sized vegetative material. It is never certain whether the specimen is a depauperate *N. variegata* or one of the smaller species. In *N. microphylla* the blade notch can be two-thirds or more the length of the midrib, and in *N.* x *rubrodisca* the blade notch is about half the length of the midrib. There is not agreement whether the petiole of *N. microphylla* is rounded in cross section (Voss, 1985) or flattened on top (Gleason and Cronquist, 1991). The whole group needs more careful study, with more collections, careful field identification, and study of the influence that habitat has on common taxonomic characteristics such as leaf and petiole size and shape. The other option is to treat the *Nuphars* as a single polymorphic species (Beal, 1956). Because of the confusion between *N. variegata* and *N. advena,* their geographic and chemical distributions are combined in figure 50A.

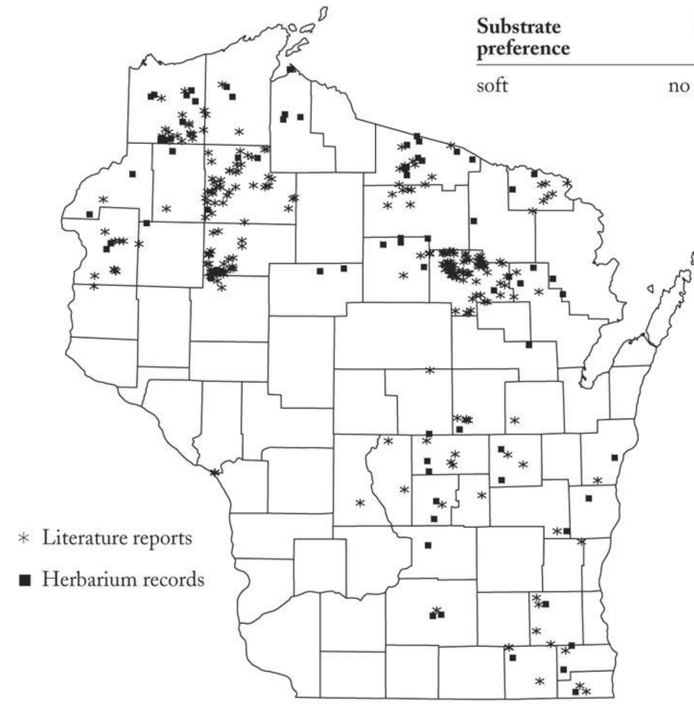


Nuphar advena



Nuphar variegata

Substrate preference	Turbidity tolerant
soft	no preference



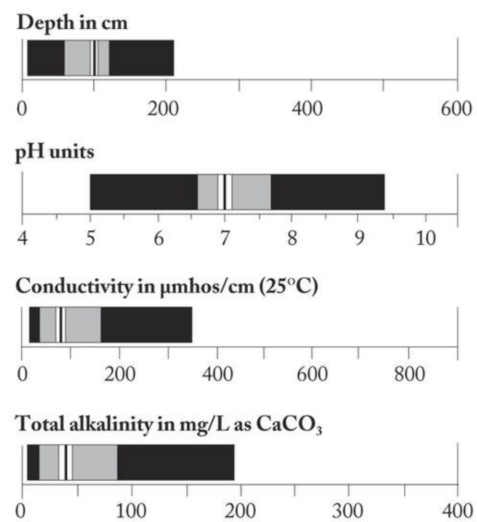
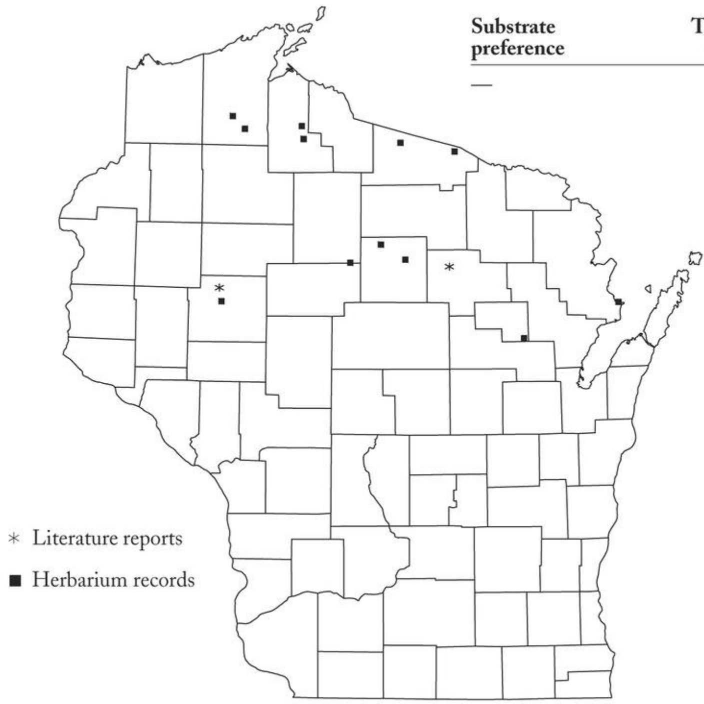


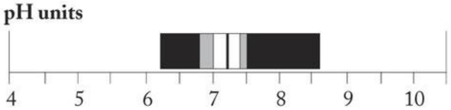
Figure 50A. Distribution and habitat characteristics of *Nuphar variegata* and *advena.*

Nuphar microphylla

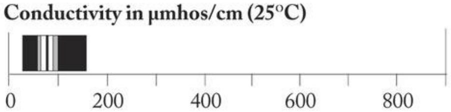
Substrate preference	Turbidity tolerant
—	—



pH units



Conductivity in µmhos/cm (25°C)



Total alkalinity in mg/L as $CaCO_3$

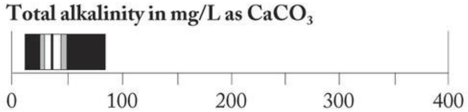
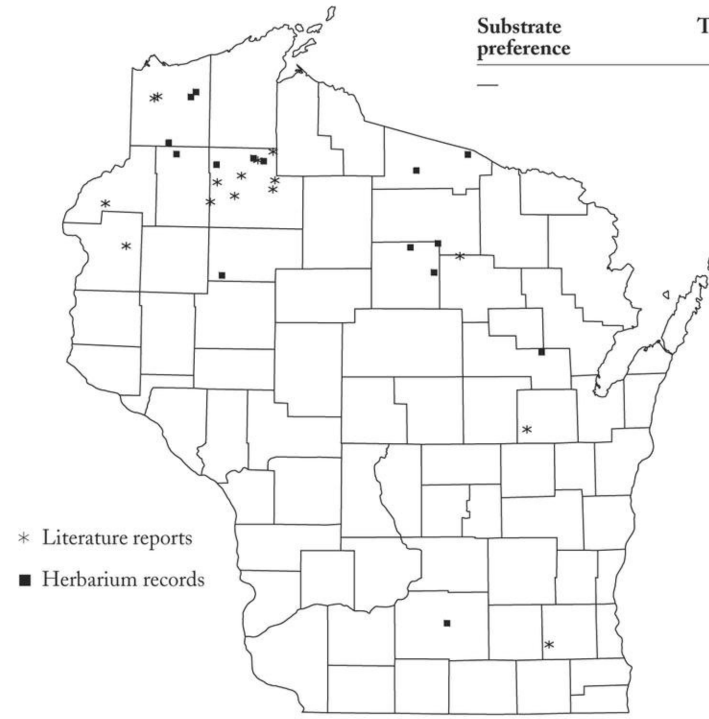


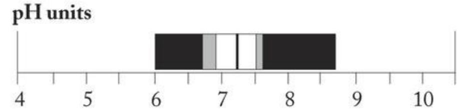
Figure 50B. Distribution and habitat characteristics of *Nuphar microphylla.*

Nuphar x *rubrodisca* Morong

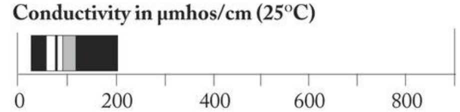
Substrate preference	Turbidity tolerant
—	—



pH units



Conductivity in µmhos/cm (25°C)



Total alkalinity in mg/L as $CaCO_3$

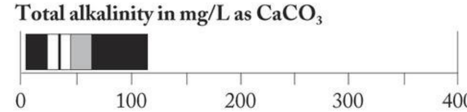
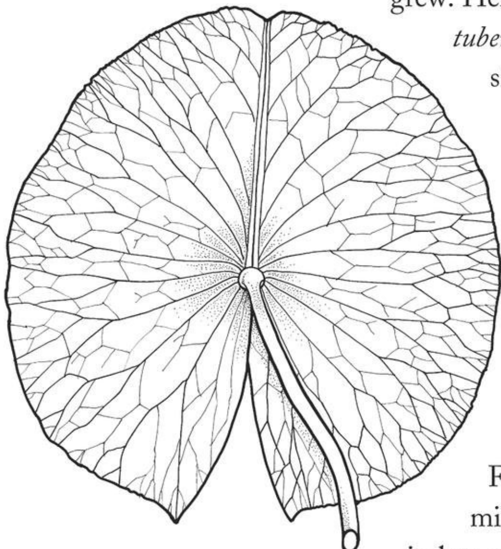


Figure 50C. Distribution and habitat characteristics of *Nuphar* x *rubrodisca* Morong.

Nymphaea odorata Aiton

Abundant and widespread in the state (fig. 51). For a long time, white water lilies in Wisconsin were separated into two species, *N. odorata* and *N. tuberosa* Paine. Gleason and Cronquist (1991) considered them a single species, as did Voss (1985) for Michigan plants. Investigations cited by Voss (1985) suggested that characteristics used to separate the species were largely controlled by the habitat in which the plants grew. Here, *N. odorata* and *N. tuberosa* are considered a single species.



Nymphaea odorata is found over moderate alkalinity and conductivity ranges and a wide pH range. Its median depth range is 1 m. It shows no substrate or turbidity preference. Flowering occurs in midsummer and fruiting in late summer. Common associates include *Bidens beckii*, *Brasenia schreberi*, *Ceratophyllum demersum*, *C. echinatum*, *Dulichium arundinaceum*, *Eriocaulon aquaticum*, *Lemna trisulca*, *Myriophyllum verticillatum*, *Nuphar variegata*, *Polygonum amphibium*, *Potamogeton pusillus*, *Sagittaria latifolia*, *S. rigida*, *Sparganium chlorocarpum*, *Spirodela polyrhiza*, *Utricularia geminiscapa*, *U. vulgaris*, *Wolffia columbiana*, and *Zosterella dubia*.

fragrant water-lily

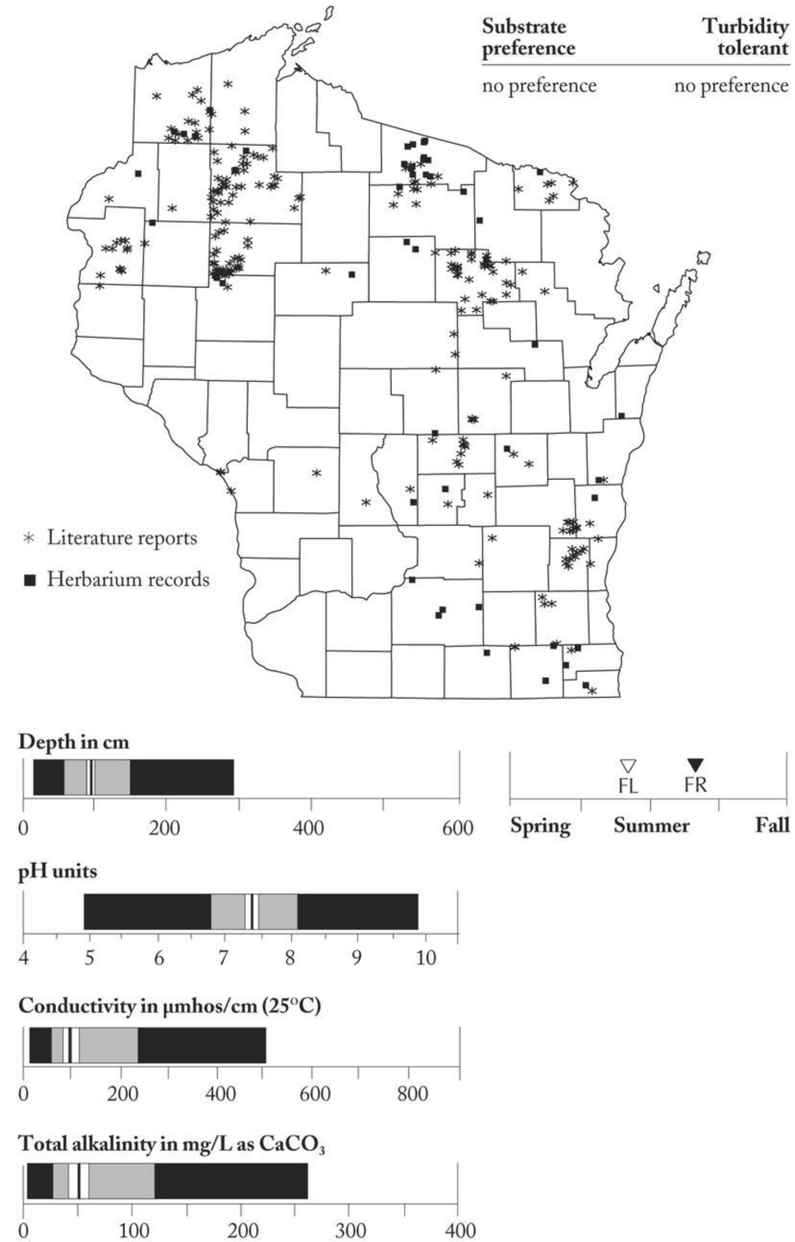


Figure 51. Distribution and habitat characteristics of *Nymphaea odorata* Aiton.

Nymphaea tetragona Georgi

A circumpolar species of cold lakes and ponds. Wisconsin is on the southern edge of the distribution range of this species (fig. 52). Hellquist and Crow (1984) reported it is found in protected water of moderate alkalinity in Maine. It appears to grow in moderate alkalinity water in Wisconsin, but it is so rare that little can be said about its habitat preferences, common associates, or flowering and fruiting phenology. *Nymphaea odorata* plants with small leaves and flowers that grow in deep water or in nutrient limited conditions, such as bog pools, could be confused with *N. tetragona.* Allegedly, *N. tetragona* lacks fragrance, and its flowers open only in the afternoon; *N. odorata* flowers open in the morning. The leaves of *N. tetragona* are elliptical in outline with an open, deep sinus; *N. odorata* plants have more orbicular leaves with a shallow leaf sinus. Few people Wisconsin have seen *N. tetragona* in the field to confirm these comparisons.

pygmy water-lily

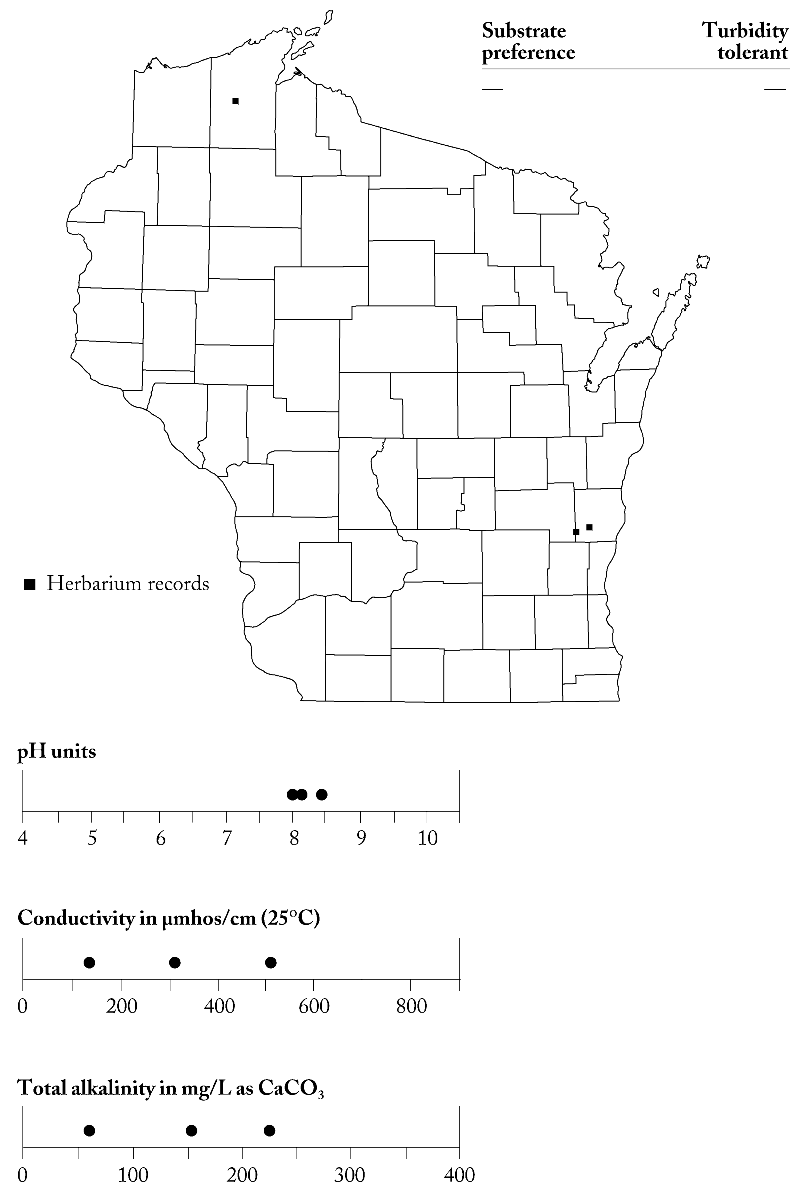
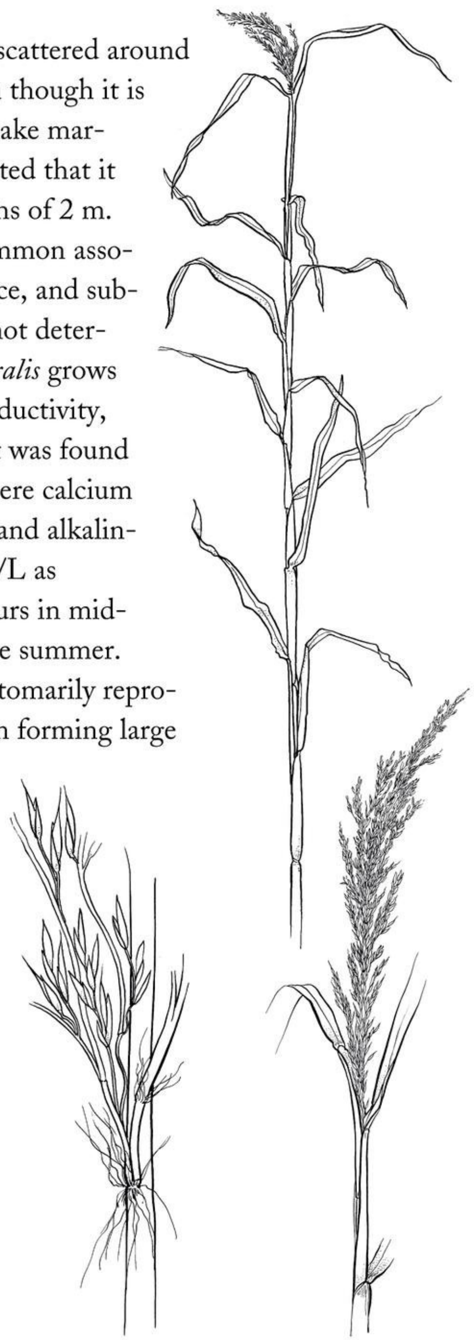


Figure 52. Distribution and habitat characteristics of *Nymphaea tetragona* Georgi.

Phragmites australis (Cav.) Trin.

An infrequent species, scattered around the state (fig. 53). Even though it is an emergent found on lake margins, Voss (1972) reported that it can grow to water depths of 2 m. Depth distribution, common associates, turbidity tolerance, and substrate preference were not determined. *Phragmites australis* grows over moderate pH, conductivity, and alkalinity ranges. It was found at only one location where calcium was less than 10 mg/L and alkalinity was less than 15 mg/L as $CaCO_3$. Flowering occurs in midsummer; fruiting, in late summer. However, the plant customarily reproduces vegetatively, often forming large monotypic colonies by rhizomes or stolons.



common reed

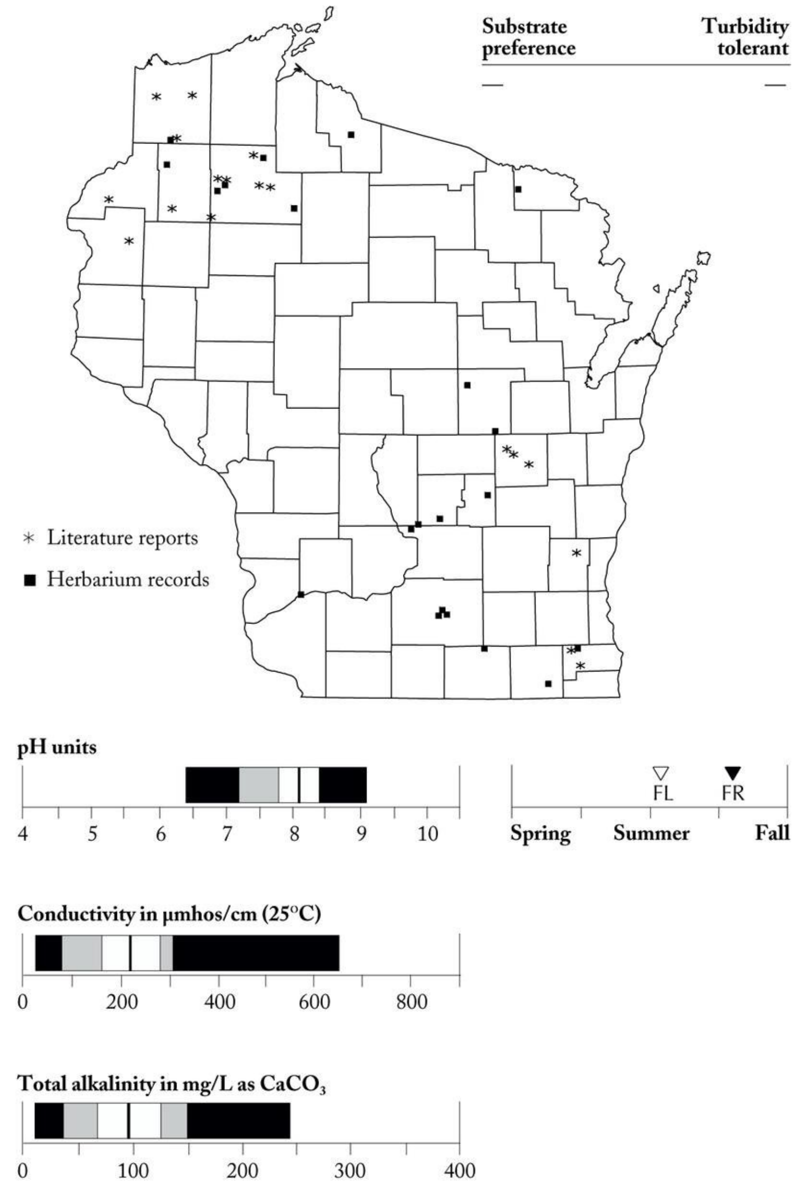
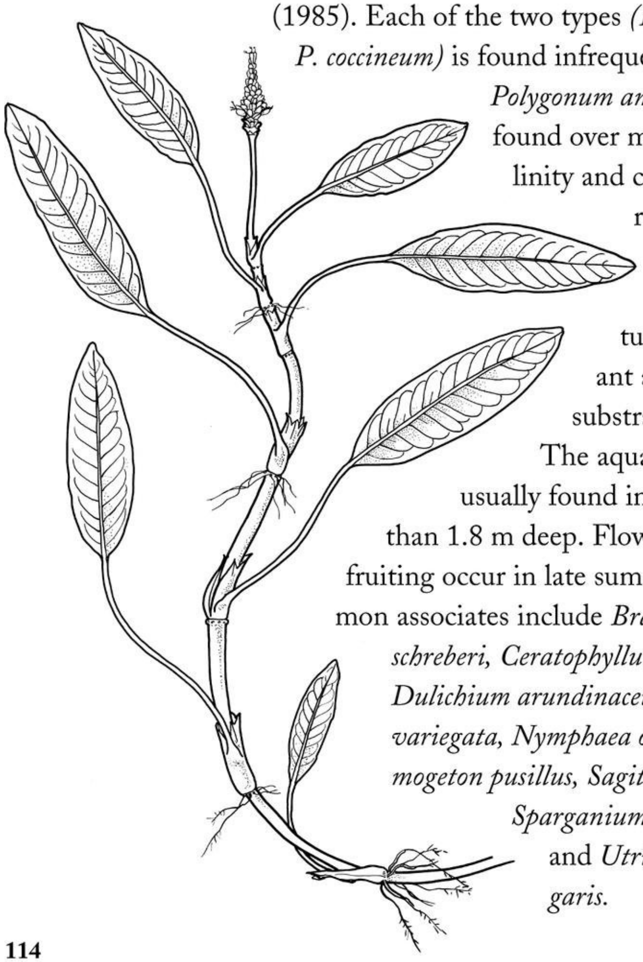


Figure 53. Distribution and habitat characteristics of *Phragmites australis* (Cav.) Trin.

Can be aquatic, amphibious, or terrestrial (fig. 54). Because habitat differences cause wide variation in characteristics, more than 100 names (specific and infraspecific) have been applied to this diverse complex (Voss, 1985). The two species commonly recognized in Wisconsin were *P. natans* for plants with prostrate stems and floating leaves and *P. coccineum* for plants with erect stems and no floating leaves. The combination of the two species by Gleason and Cronquist (1991) is welcome; it was based on considerable experimental work cited by Voss (1985). Each of the two types *(P. natans* and *P. coccineum)* is found infrequently in lakes. *Polygonum amphibium* is found over moderate alkalinity and conductivity ranges and a broad pH range. It is turbidity tolerant and shows no substrate preference. The aquatic form is usually found in water less than 1.8 m deep. Flowering and fruiting occur in late summer. Common associates include *Brasenia schreberi, Ceratophyllum echinatum, Dulichium arundinaceum, Nuphar variegata, Nymphaea odorata, Potamogeton pusillus, Sagittaria latifolia, Sparganium chlorocarpum,* and *Utricularia vulgaris.*



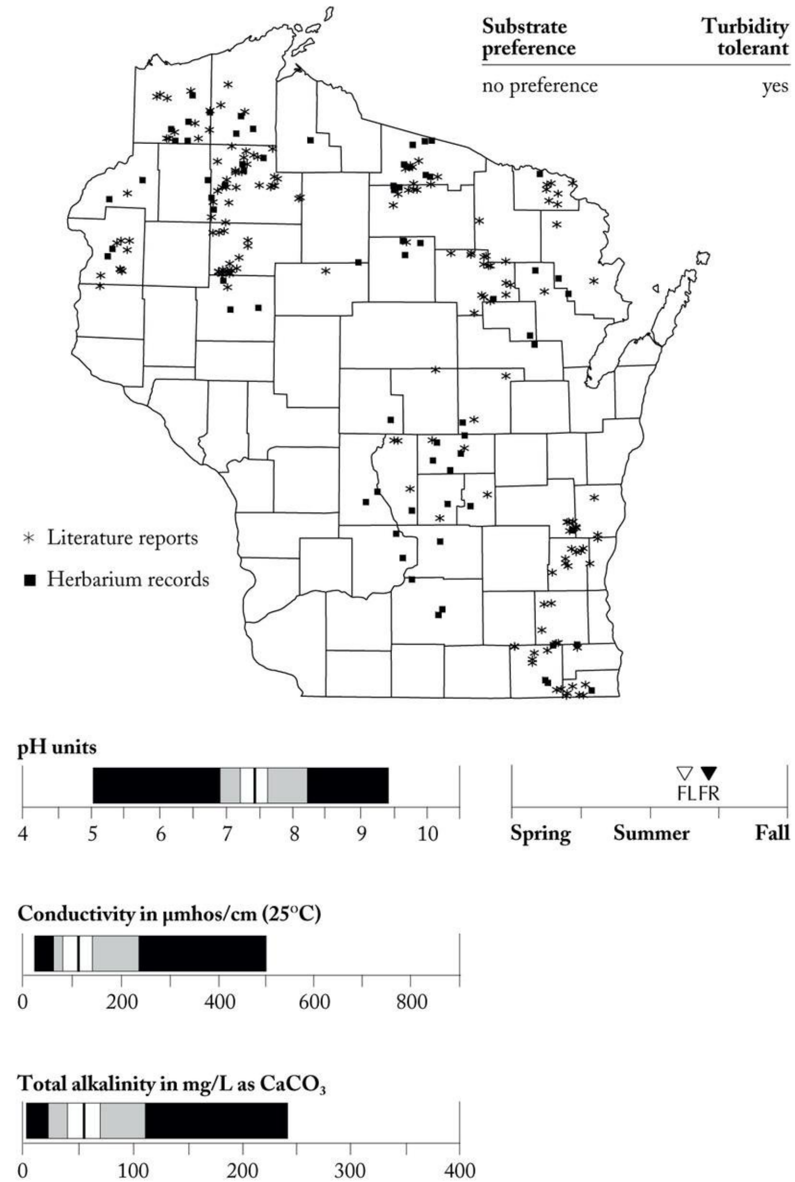
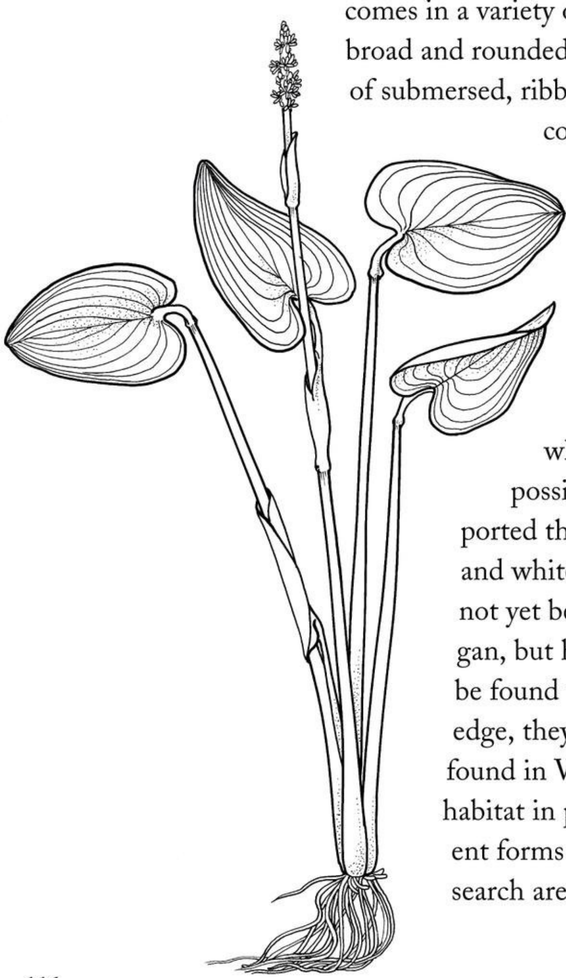


Figure 54. Distribution and habitat characteristics of *Polygonum amphibium* L.

An aesthetically pleasing plant, found commonly around lake shores in northern and eastern Wisconsin (fig. 55). It can grow in water depths up to 1.9 m and shows no substrate preference. An emergent species, turbid water should not affect it photosynthetically; however, it is most likely found in clear water lakes. It grows over a broad pH and alkalinity range, but an unexpectedly narrow conductivity. No common associates were determined, and the plant can grow in monotypic patches. It comes in a variety of leaf shapes from broad and rounded to narrow to a rosette of submersed, ribbon-shaped leaves that could be confused with the submersed leaves of *Sagittaria* and *Sparganium.* Flowering occurs in midsummer. A dense spike of blue flowers is common; white flowers are also possible. Voss (1972) reported that the ribbon-leaved and white-flowered forms have not yet been reported in Michigan, but he suspected they will be found there. To my knowledge, they have not yet been found in Wisconsin. The role of habitat in producing the different forms is an interesting research area.



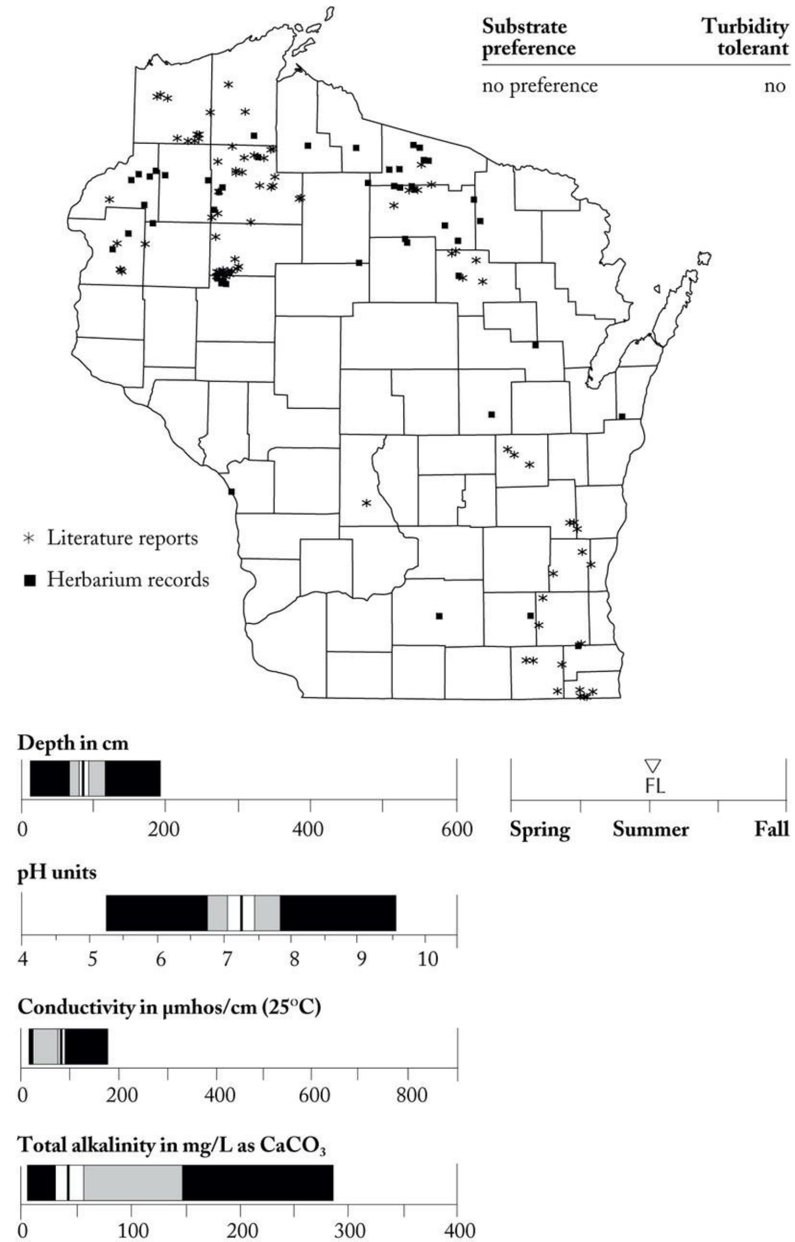


Figure 55. Distribution and habitat characteristics of *Pontederia cordata* L.

Potamogeton alpinus Balbis

An infrequent species, found over moderate alkalinity and conductivity ranges and a broad pH range in northern and eastern Wisconsin (fig. 56). Depth range, turbidity tolerance, substrate preference, and common associates were not determined. Flowering occurs in early summer; fruiting, in midsummer. Voss (1972) noted that in Michigan this species is found in shallow to deep, but usually cold water, such as spring-fed lakes and streams. From the limited information available, this also appears to be the case for Wisconsin. Sessile submersed leaves with curved sides and a reticulate zone along the midrib are useful characteristics for identifying this species. The plants are usually strongly tinged with red, especially when dried.

alpine pondweed

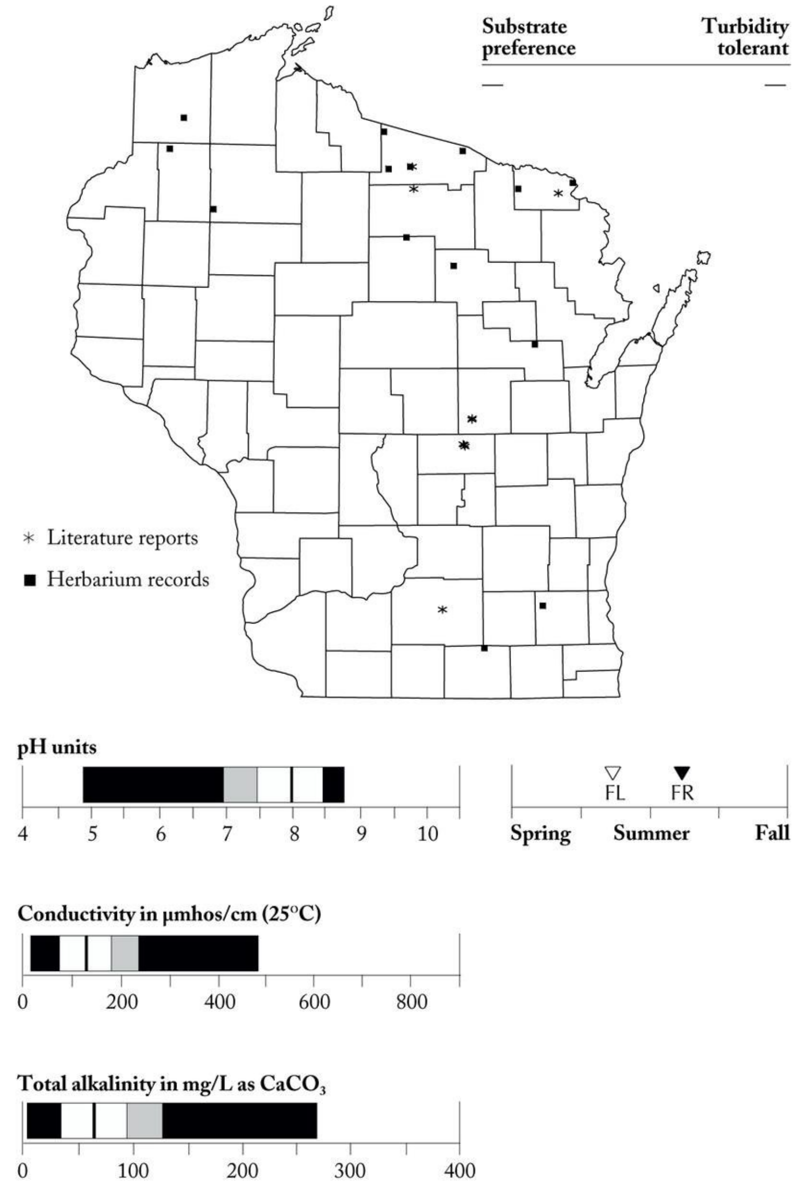
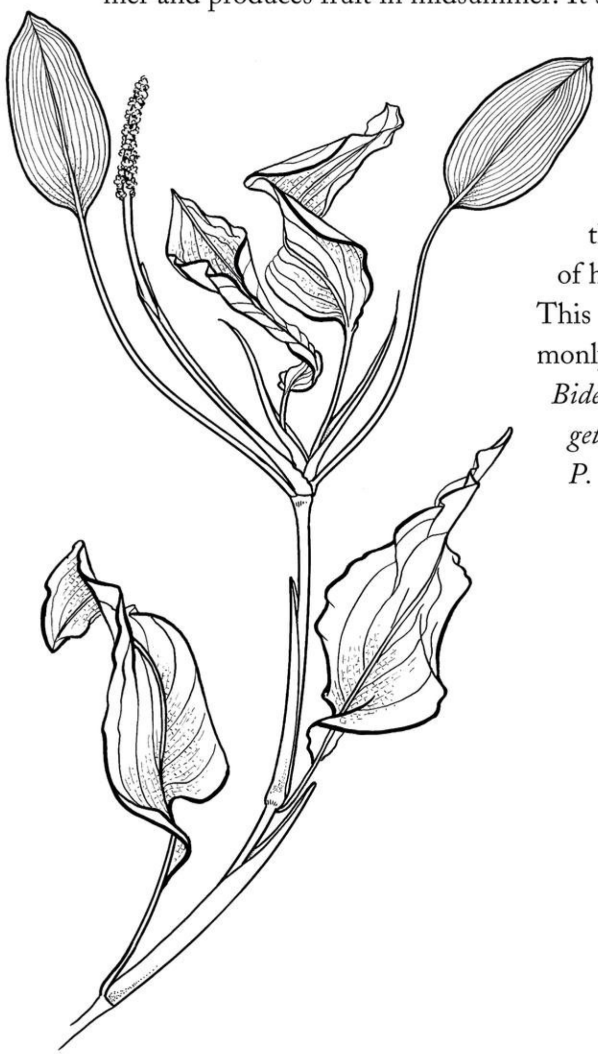


Figure 56. Distribution and habitat characteristics of *Potamogeton alpinus* Balbis.

Potamogeton amplifolius Tuckerman

One of the most abundant pondweeds in eastern and northern Wisconsin lakes (fig. 57). It prefers soft bottoms and mid-water depths. It is found over a broad pH range and moderate conductivity and alkalinity ranges. Its seeds are food for waterfowl and the plant provides fish cover. It flowers in early summer and produces fruit in midsummer. It shows no turbidity preference, but it has been extirpated from some southern Wisconsin lakes that have a history of heavy human use. This species is commonly associated with *Bidens beckii*, *Potamogeton robbinsii*, and *P. strictifolius*.



large-leaf pondweed

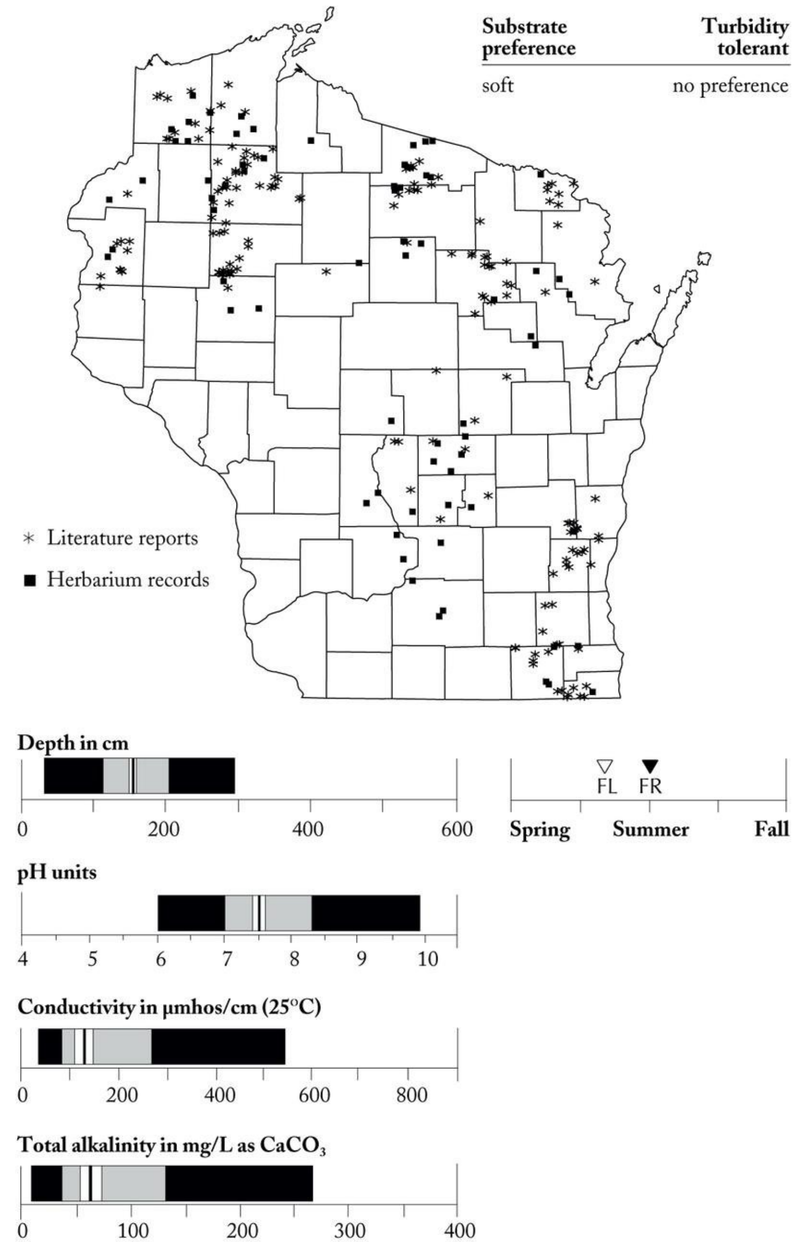
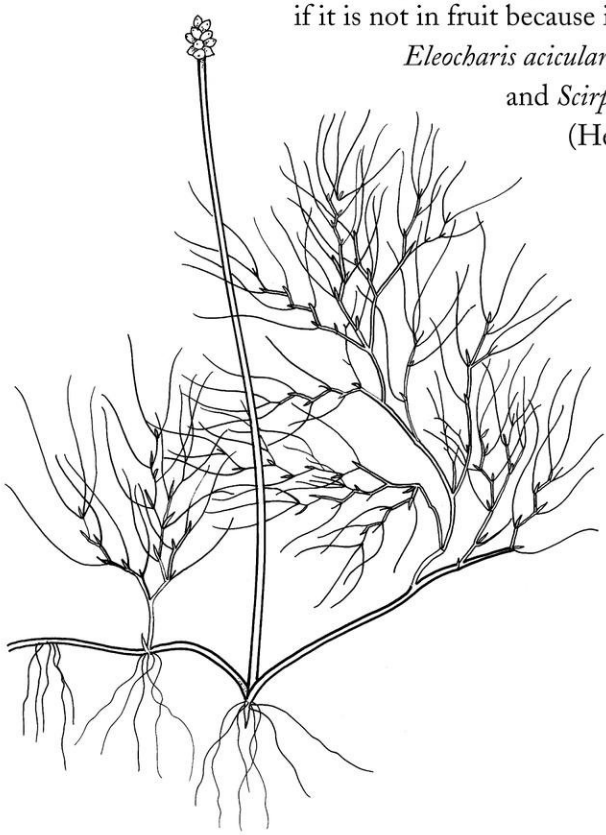


Figure 57. Distribution and habitat characteristics of *Potamogeton amplifolius* Tuckerman.

Potamogeton confervoides Reichb.

A rare species, found primarily in northern Wisconsin lakes (fig. 58). It has limited alkalinity and conductivity ranges and a moderate pH range. Substrate preference, turbidity tolerance, depth distribution, flowering and fruiting dates, and common associates were not determined.

Hellquist and Crow (1980) found this species in the most acid water of New England—pH was as low as 5.0 and alkalinity approached 0.0 mg/L as $CaCO_3$. The low pH for Wisconsin was 4.8 and the median was 6.4, but it also appears to be found in Wisconsin in higher pH and alkalinity water than in New England. It may be easily overlooked if it is not in fruit because it blends in with *Eleocharis acicularis, E. robbinsii,* and *Scirpus subterminalis* (Hellquist and Crow, 1980).



algal pondweed

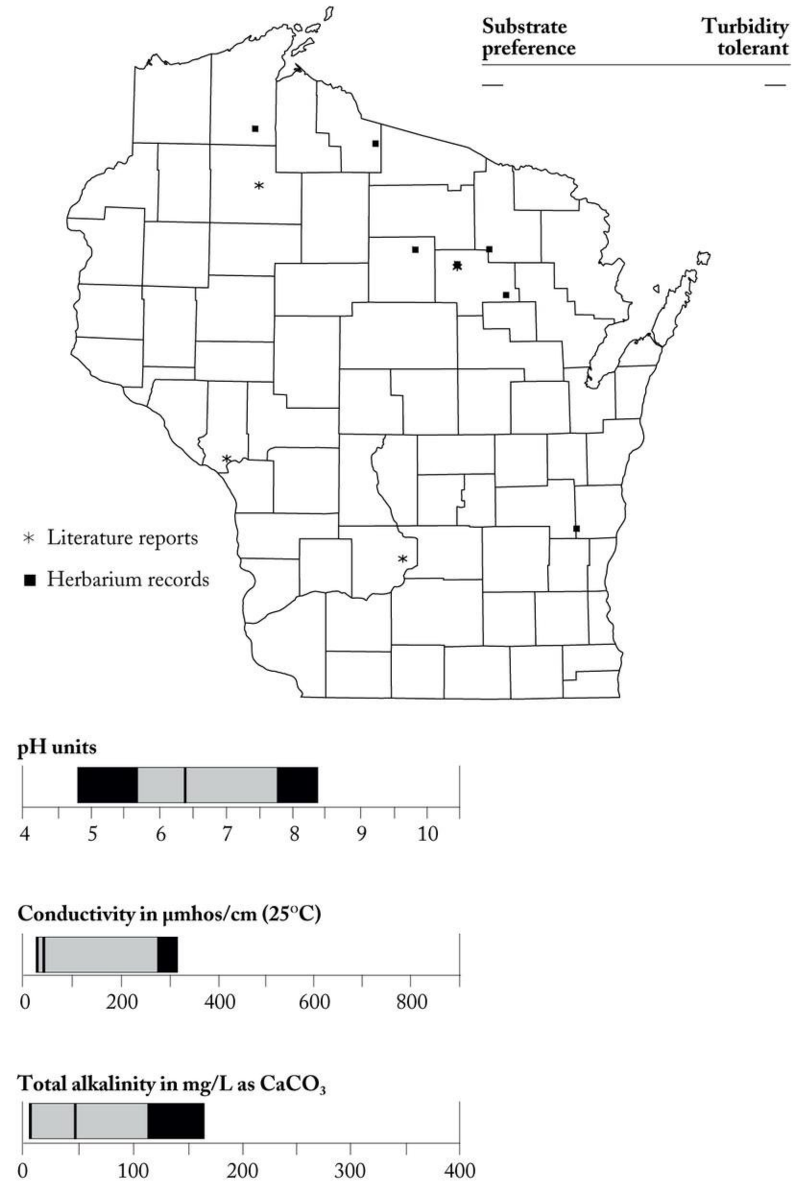
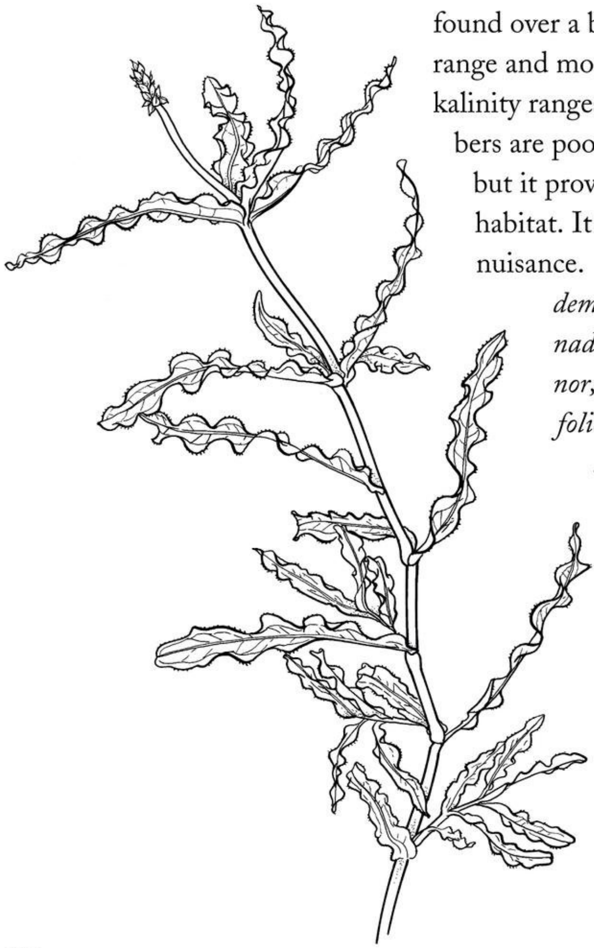
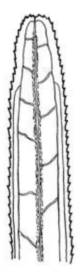


Figure 58. Distribution and habitat characteristics of *Potamogeton confervoides* Reichb.

A Eurasian invader first collected in the state in 1905 (Ross and Calhoun, 1951). It may have been initially introduced with fish stocking (Stuckey, 1979). It is common in southern and western Wisconsin (fig. 59). It prefers soft substrates, shallow water, is turbidity tolerant, and is often associated with degraded water quality. It grows, flowers, fruits, and produces vegetative buds in spring and early summer and dies back by early to mid-July. The vegetative buds sprout in early autumn and overwinter under the ice. It is found over a broad conductivity range and moderate pH and alkalinity ranges. Its seeds and tubers are poor waterfowl food, but it provides some fish habitat. It can become a nuisance. *Ceratophyllum demersum*, *Elodea canadensis*, *Lemna minor*, *Potamogeton foliosus*, *Sagittaria latifolia*, and *Typha latifolia* are its common associates.





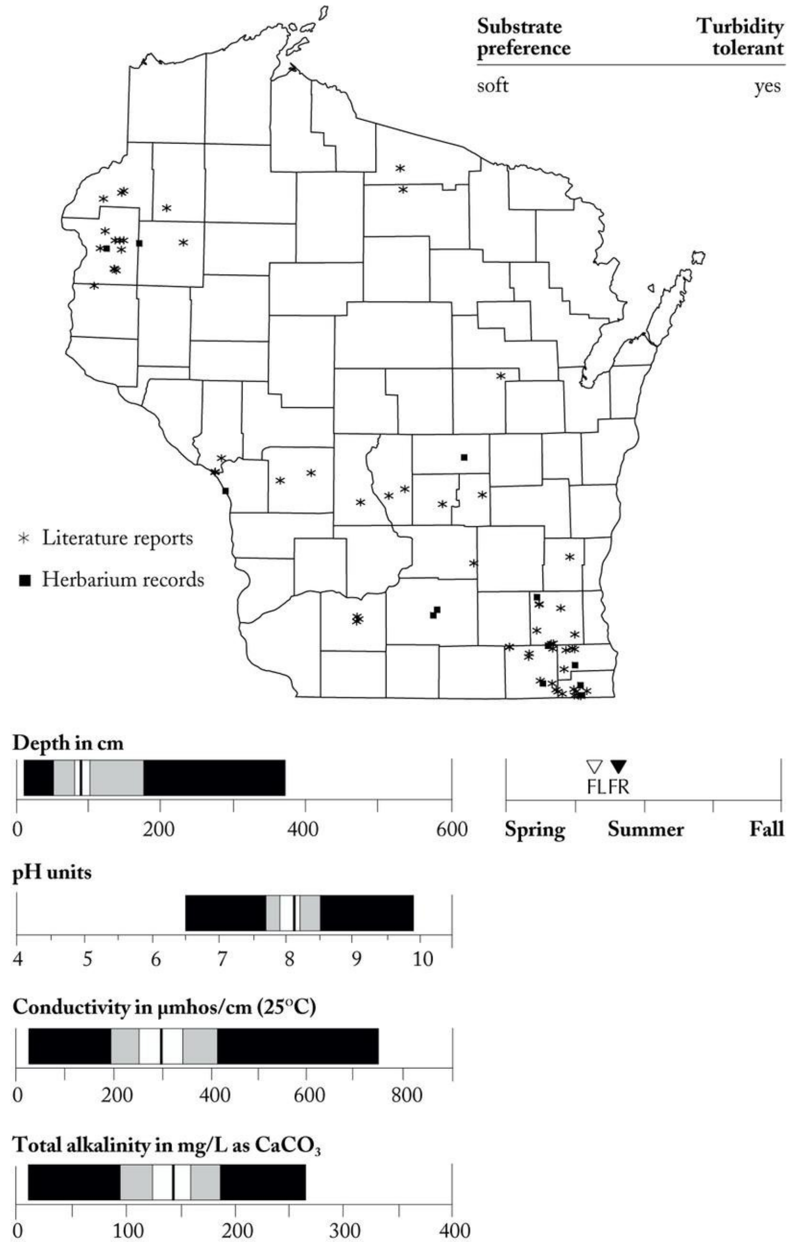
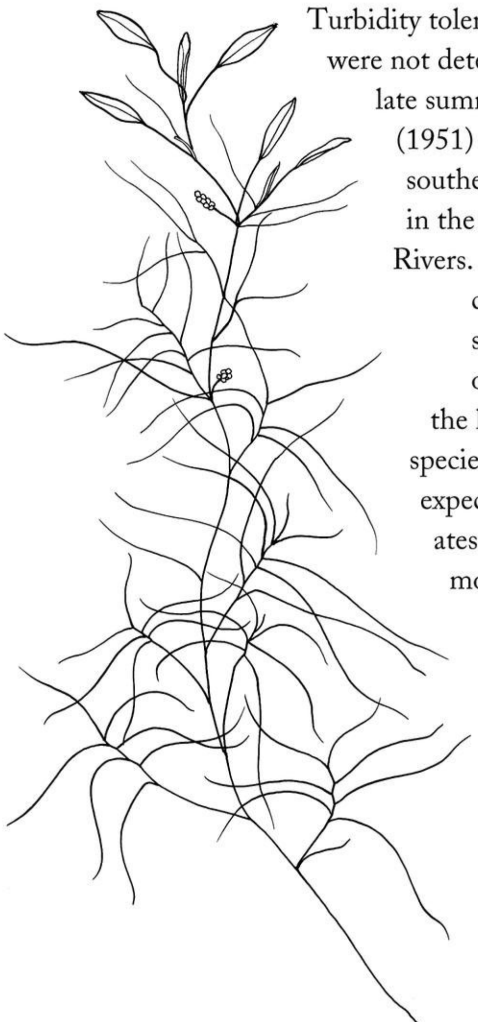


Figure 59. Distribution and habitat characteristics of *Potamogeton crispus* L.

Potamogeton diversifolius Raf.

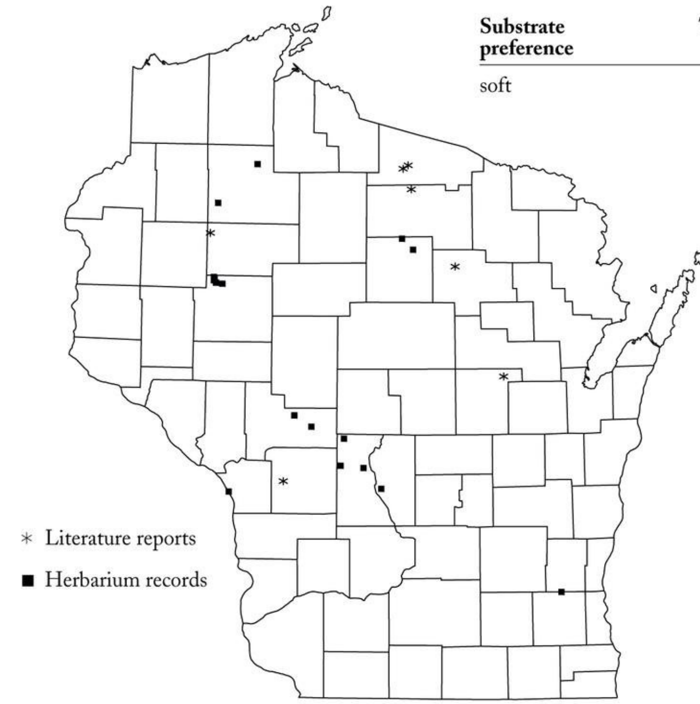
A rare Wisconsin plant (fig. 60). Gleason and Cronquist (1991) considered *P. capillaceus* Poiret as part of this species. Voss (1972) maintained the distinction for Michigan plants and only reported *P. capillaceus. Potamogeton diversifolius* is found over low and narrow alkalinity and conductivity ranges and a moderate pH range. Maximum growth depth is less than 1.8 m, and it prefers soft substrate. Turbidity tolerance and flowering dates were not determined. Fruiting occurs in late summer. Ross and Calhoun (1951) described *P. diversifolius* as a southern species found primarily in the Mississippi and Chippewa Rivers. *Potamogeton capillaceus* is a coastal plain species found sparingly in soft water lakes of central Wisconsin. Given the habitat preferences of this species, it has a surprising and unexpected array of common associates. Many of its associates are more commonly found in higher alkalinity and conductivity water.

Common associates include *Ceratophyllum demersum, Elodea canadensis, Lemna minor, L. trisulca, Potamogeton zosteriformis, Ranunculus longirostris, Spirodela polyrhiza,* and *Wolffia columbiana.*



water-thread pondweed

Substrate preference	Turbidity tolerant
soft	—



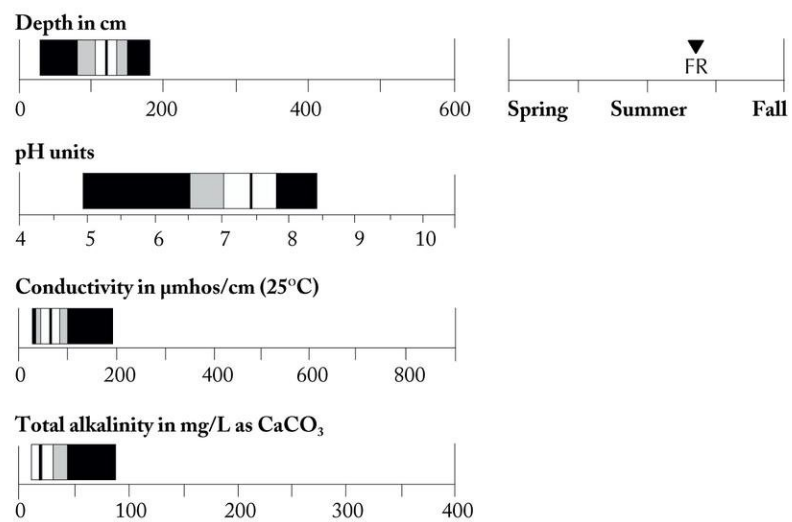
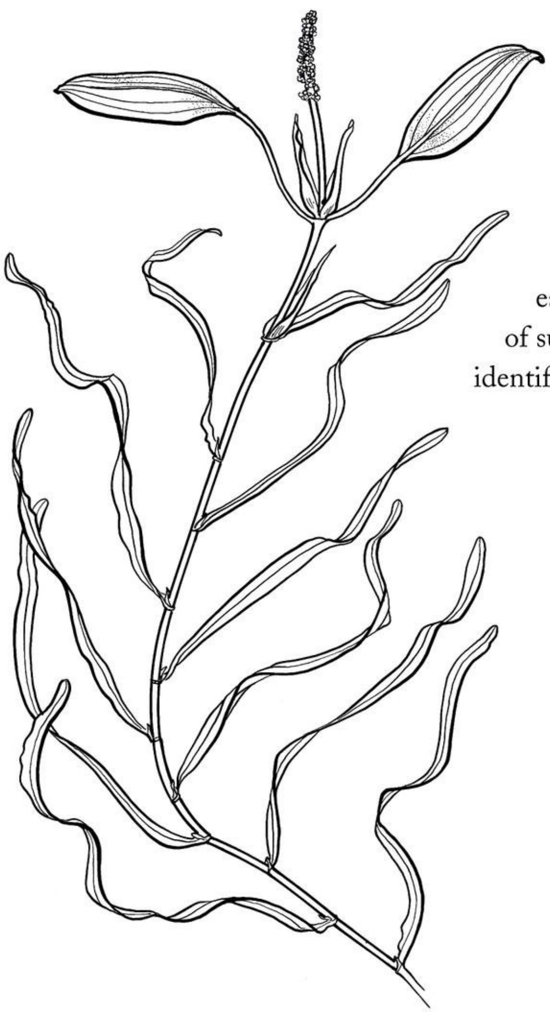
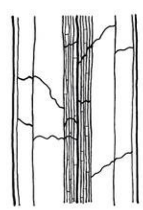


Figure 60. Distribution and habitat characteristics of *Potamogeton diversifolius* Raf.

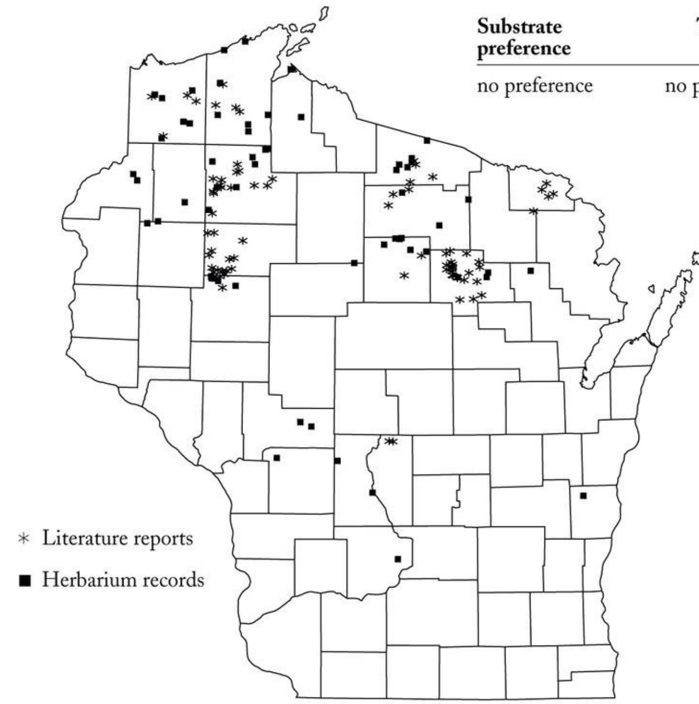
Potamogeton epihydrus Raf.

A common plant in northern Wisconsin lakes, also found in central Wisconsin (fig. 61). All distribution points but one were in areas where magnesium concentrations were less than 10 mg/L. It is found in low conductivity and low alkalinity water and over a moderate pH range. It shows no substrate or turbidity preference and has a median growth depth of about 1 m. It flowers and fruits in midsummer, and its seeds, tubers, and foliage are good waterfowl food. This species has no common associates. A broad reticulate region on each side of the midrib of submersed leaves aids identification.





ribbon-leaf pondweed



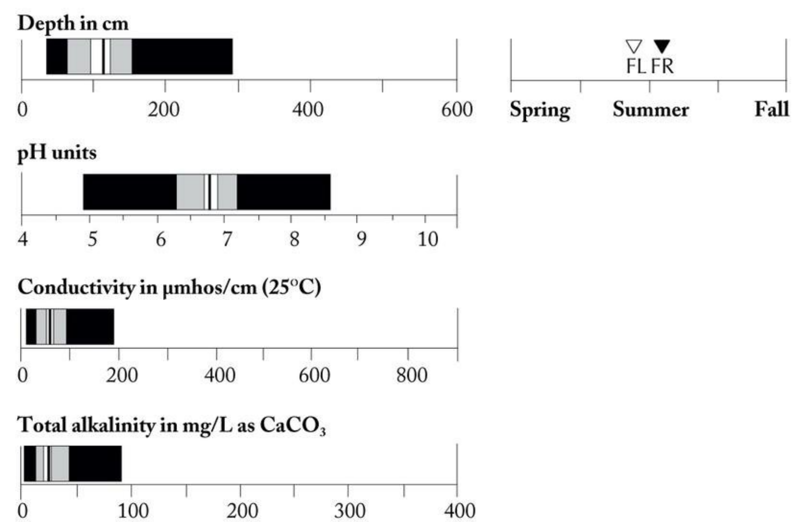


Figure 61. Distribution and habitat characteristics of *Potamogeton epihydrus* Raf.

Potamogeton filiformis Pers.

An infrequent species, found over moderate alkalinity and conductivity and limited pH ranges in northern and eastern Wisconsin (fig. 62). It shows no substrate preference and has a maximum growth depth of 2.7 m. It flowers and fruits in early summer. Voss (1972) noted that this species fruits best in shallow water over a sandy bottom. No common associates were found and turbidity tolerance was not determined. This species looks much like *P. pectinatus*, but has blunt rather than long, tapering leaves. The leaf tips of *P. filiformis* can have a tiny notch, but a strong lens is needed to see this characteristic. Vegetative material might also be mistaken for *Ruppia maritima* (Voss, 1972).

thread-leaf pondweed

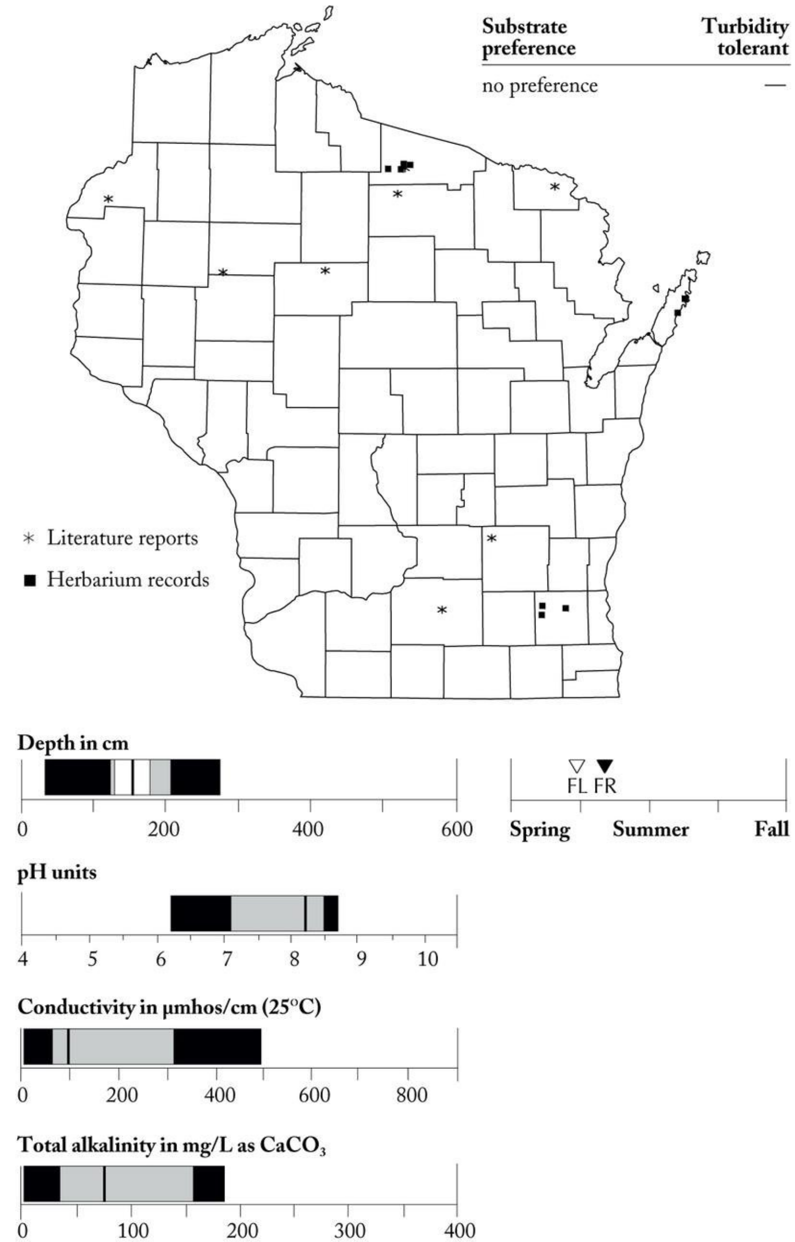


Figure 62. Distribution and habitat characteristics of *Potamogeton filiformis* Pers.

An infrequent species, spread evenly across the state (fig. 63). It is found primarily in shallow water, prefers soft substrates, and is turbidity tolerant. Typically, it is found in alkaline pH water and over a broad alkalinity range and a moderate conductivity range. It flowers in early summer and produces fruit by midsummer. Seeds, tubers, and foliage are good waterfowl food, and the plant provides fish habitat. Common associates include *Ceratophyllum demersum, Elodea canadensis, Lemna minor, Potamogeton crispus, P. vaginatus, Sagittaria latifolia,* and *Typha latifolia.* Sterile specimens are difficult to distinguish from *P. pusillus* (Voss, 1972).

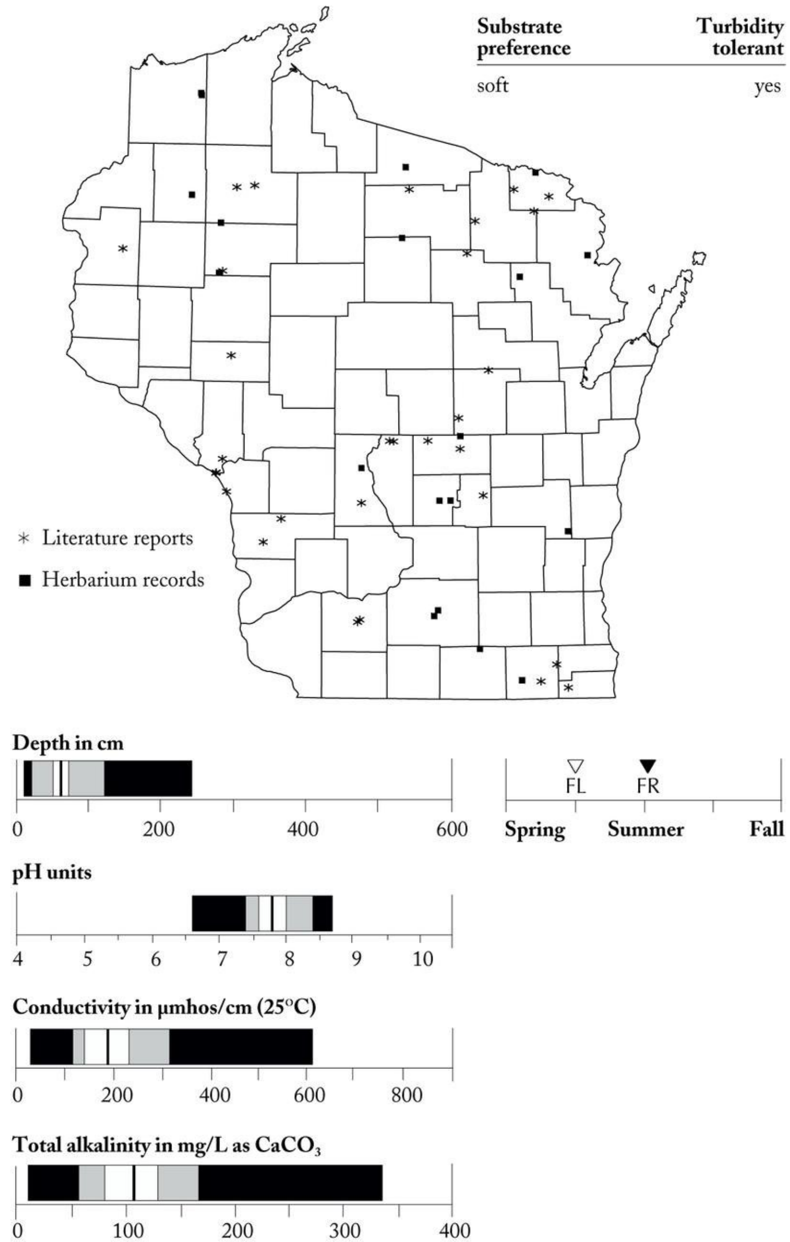
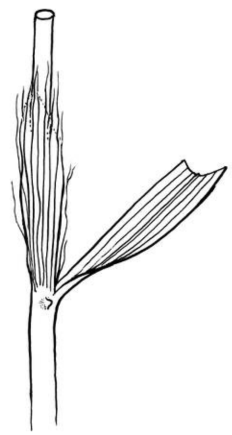


Figure 63. Distribution and habitat characteristics of *Potamogeton foliosus* Raf.

Potamogeton friesii Rupr.

An infrequent species, found in eastern and northern Wisconsin (fig. 64). It has a broad alkalinity range, a moderate and generally alkaline pH range, and a moderate conductivity range. Not enough information was available to describe its depth distribution, substrate preference, common associates, or turbidity tolerance. Voss (1972) found it in quiet and flowing water in Michigan and in water depths to 6 m. Fibrous, white stipules help identify this species. It may intergrade with *P. strictifolius*, and it is sometimes hard to distinguish between the two species (Voss, 1972). It flowers early in the summer and fruits by midsummer.



Fries pondweed

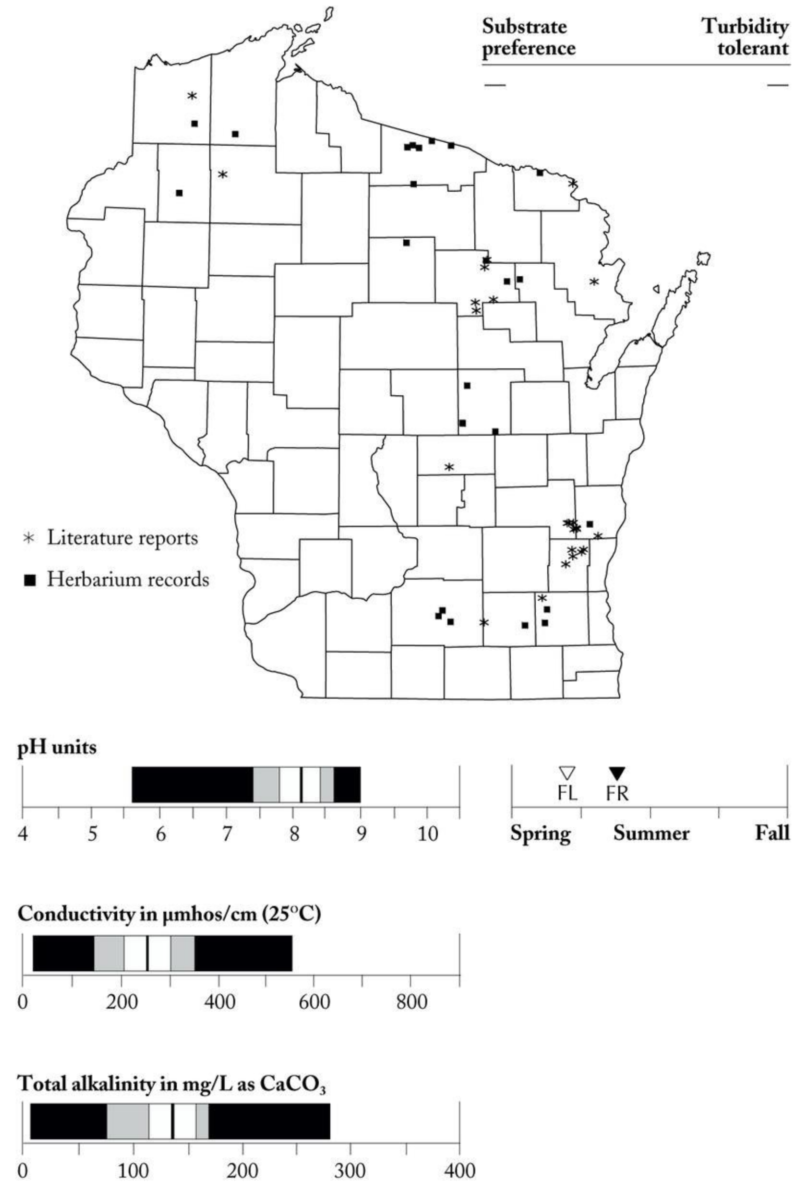
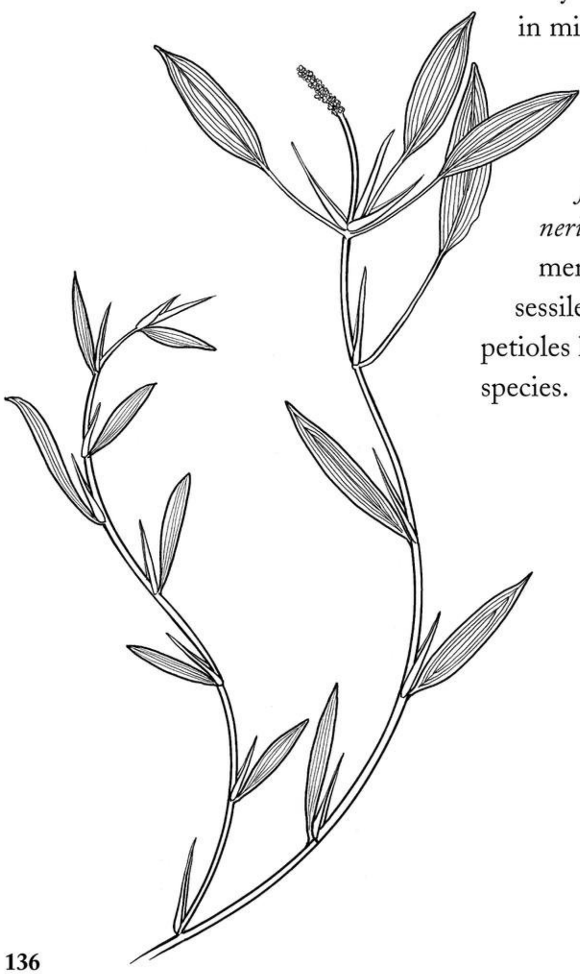


Figure 64. Distribution and habitat characteristics of *Potamogeton friesii* Rupr.

A common species, widely distributed in the state. *Potamogeton gramineus* is an extremely variable species that has a number of varieties that may be the result of habitat differences (fig. 65; Fassett, 1969). It also hybridizes with most broad-leaved pondweeds (Hellquist and Crow, 1980). It is found over broad alkalinity and pH ranges and a limited conductivity range. It grows at a median depth of 1.1 m, prefers hard substrate, but shows no turbidity preference. Flowering occurs in early summer; fruiting, in midsummer. Common associates include *Chara* spp., *Najas flexilis*, and *Vallisneria americana*. Submersed leaves that are sessile or have very short petioles help identify this species.



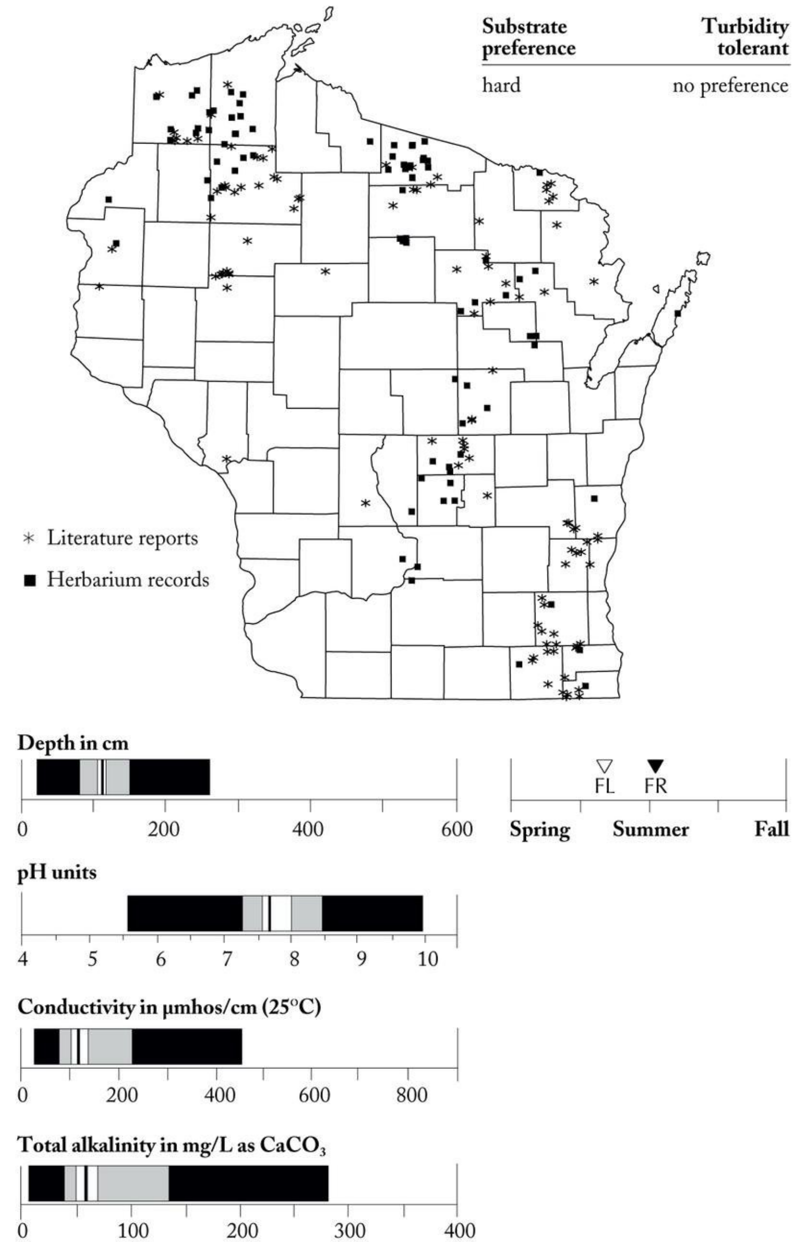


Figure 65. Distribution and habitat characteristics of *Potamogeton gramineus* L.

Potamogeton illinoensis Morong

An infrequent, broad-leaf pondweed of eastern and northern Wisconsin (fig. 66). It is found over a broad alkalinity range, a moderate and high pH range, and a moderate conductivity range. It flowers and fruits in midsummer and shows no substrate preference. It is not turbidity tolerant and is probably becoming increasingly rare where water clarity has decreased. It is commonly found in water less than 2 m deep, but its maximum depth distribution is greater than 3 m. Associates are *Chara* spp., *Myriophyllum spicatum*, *Najas flexilis*, and *Potamogeton strictifolius*. It can be difficult to separate it from large-leaved varieties of *P. gramineus* (Voss, 1972).

Illinois pondweed

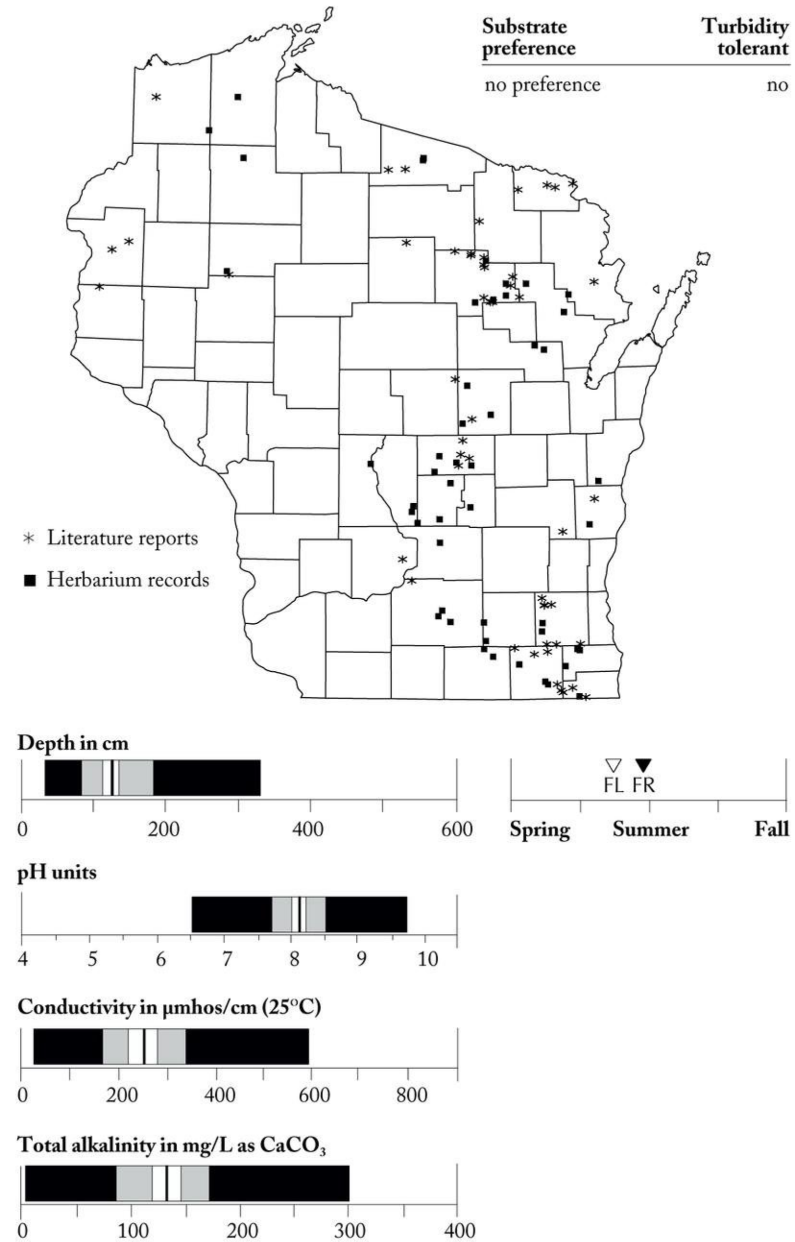


Figure 66. Distribution and habitat characteristics of *Potamogeton illinoensis* Morong.

An abundant species, found over a wide area of the state (fig. 67). It shows no substrate preference and is most commonly found in water less than 1.5 m deep. It can grow in highly turbid water (Engel and Nichols, 1994), but shows no turbidity preference. It is found over a broad range of water chemistries. Flowering occurs in early summer and it fruits by midsummer. Associates are *Ceratophyllum echinatum, Myriophyllum verticillatum, Potamogeton pusillus, P. strictifolius, P. zosteriformis, Sparganium chlorocarpum,* and *Utricularia vulgaris.* A floating leaf with a heart-shaped base helps identify this species.

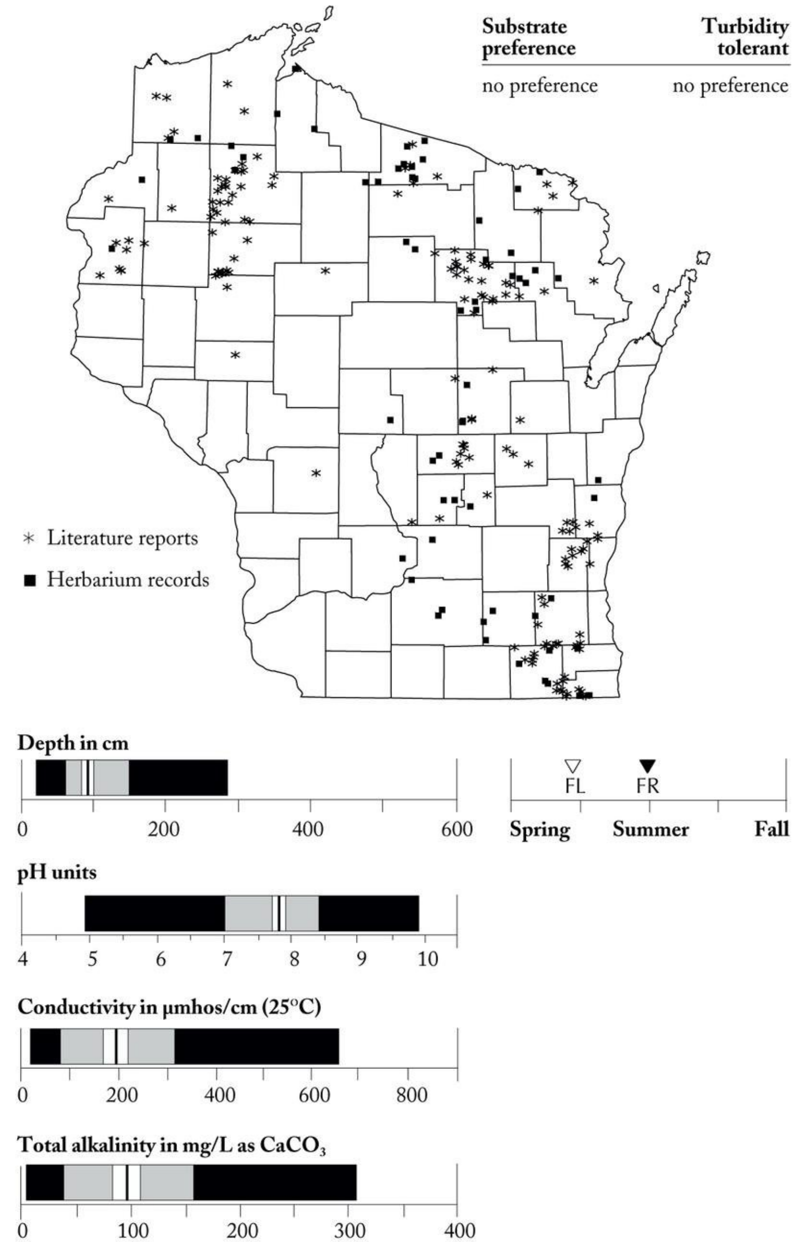
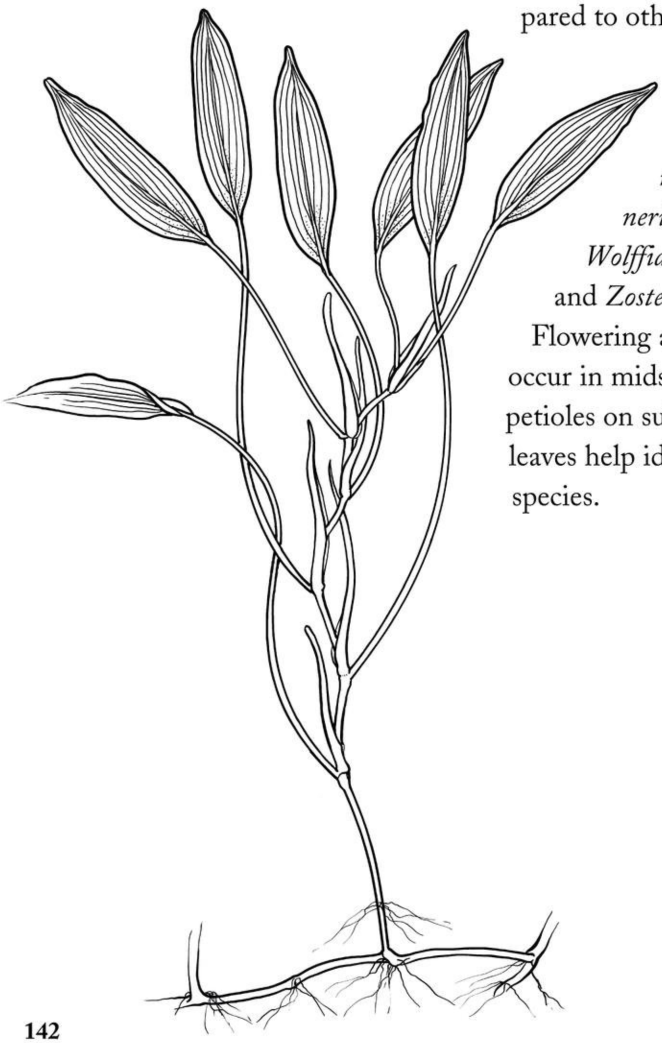


Figure 67. Distribution and habitat characteristics of *Potamogeton natans* L.

Potamogeton nodosus Poiret

long-leaf pondweed

An infrequent species, most common in southeastern Wisconsin, but found statewide (fig. 68). It is more common in flowing water than its infrequent status in lakes indicates (Ross and Calhoun, 1951). It is usually found in water about 1 m deep, shows no substrate preference, and is turbidity tolerant. Its median pH, conductivity, and alkalinity values are the highest of all the pondweeds studied and are high compared to other species. Common associates are *Lemna minor*, *Vallisneria americana*, *Wolffia columbiana*, and *Zosterella dubia*. Flowering and fruiting occur in midsummer. Long petioles on submersed leaves help identify this species.



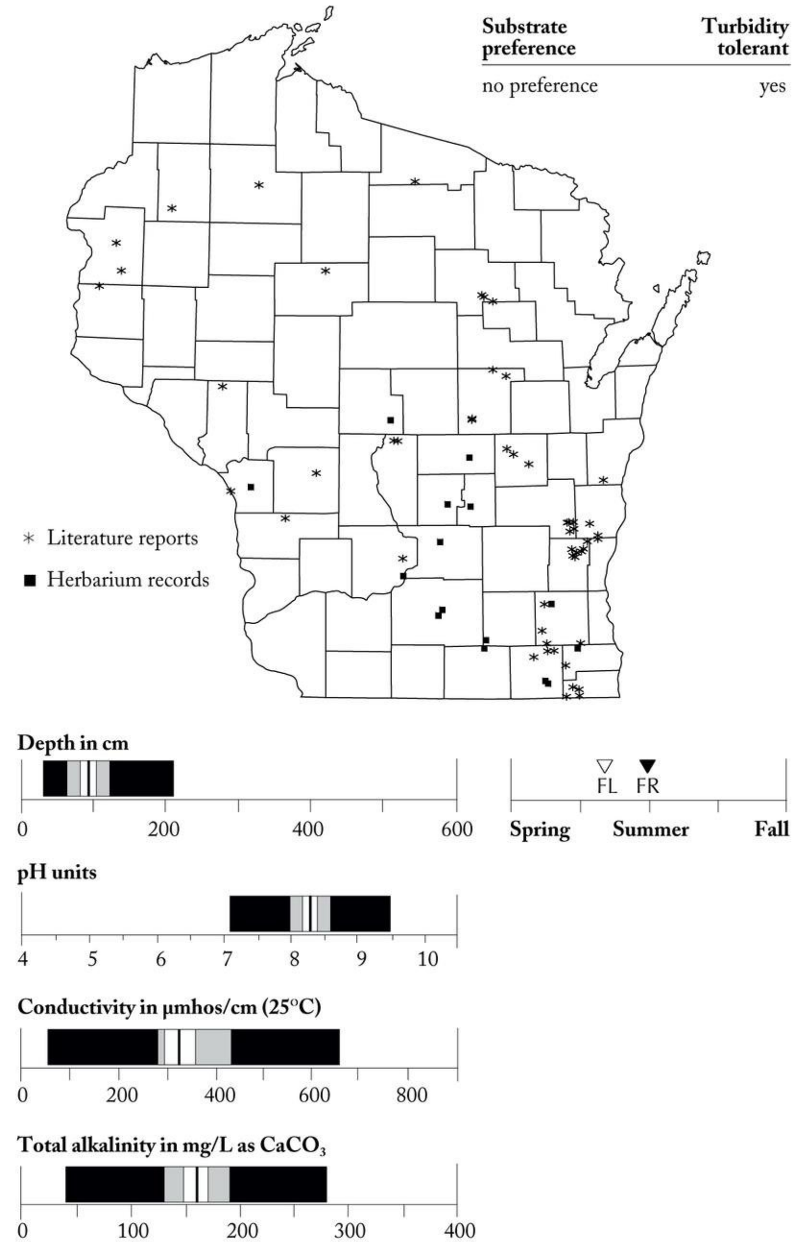


Figure 68. Distribution and habitat characteristics of *Potamogeton nodosus* Poiret.

Potamogeton oakesianus Robbins

An infrequent species, found over a moderate alkalinity range, a narrow conductivity range, and a broad pH range at scattered locations across the state (fig. 69). It grows at a median depth of 0.6 m and prefers hard substrate. It flowers in early summer. No fruiting dates or turbidity tolerance were determined. Common associates include *Brasenia schreberi*, *Myriophyllum farwellii*, *Utricularia gibba*, and *U. intermedia*. Vegetatively, this species looks like a delicate form of *P. natans*. Fruits are needed to separate *P. oakesianus* from *P. natans* if identification is questionable.

Oakes' pondweed

Substrate preference	Turbidity tolerant
hard	—

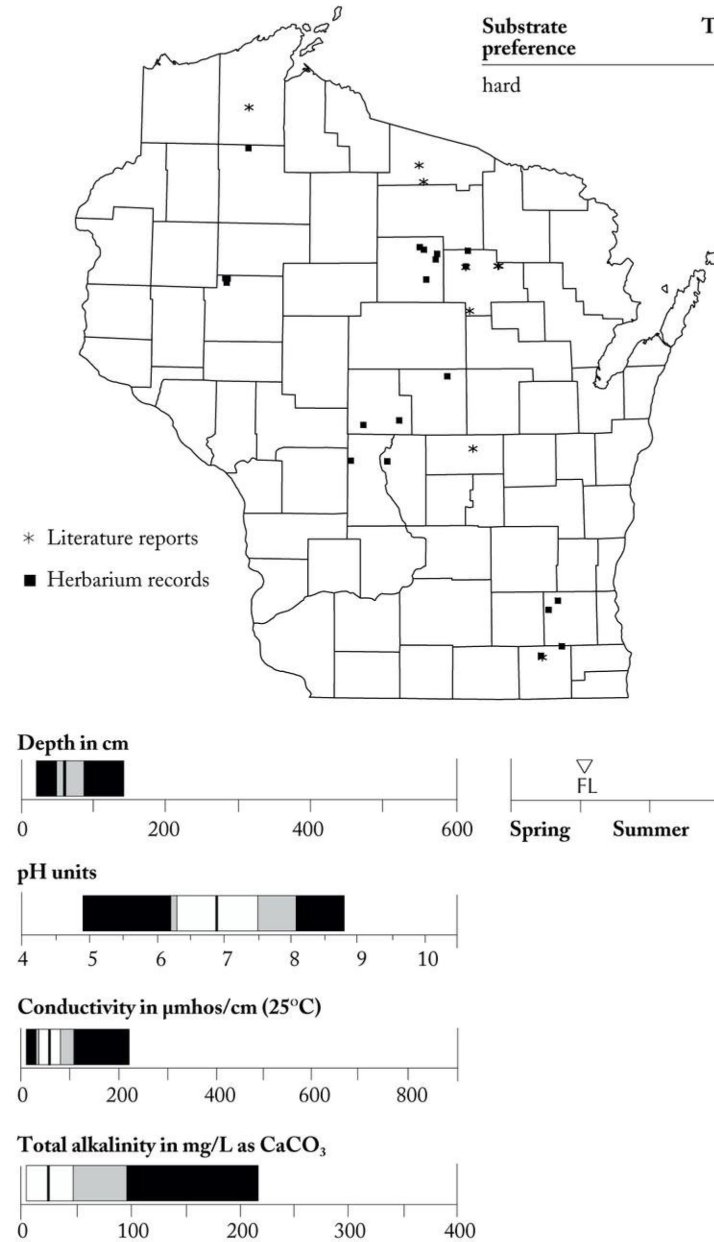


Figure 68. Distribution and habitat characteristics of *Potamogeton oakesianus* Robbins.

An infrequent species, found over limited alkalinity, pH, and conductivity ranges in Wisconsin lakes (fig. 70). It grows in water depths to 1.8 m, prefers soft substrate, and fruits in midsummer. Flowering date and turbidity tolerance were not determined. No common associates were found. All distribution points except one in Waukesha County were in the Northern Lakes and Forests Ecoregion. This species prefers cold lakes and streams and is on the southern edge of its distribution range in Wisconsin (Ross and Calhoun, 1951; Hellquist and Crow, 1980). *Potamogeton obtusifolius* is a narrow-leaved pondweed that is difficult to identify using only vegetative material. Some characteristics to look for are nodal glands, non-fibrous stipules, rounded leaf tips, a light-colored cellular reticulate band along the leaf midrib, and principal leaves that are somewhat red, especially when dried.

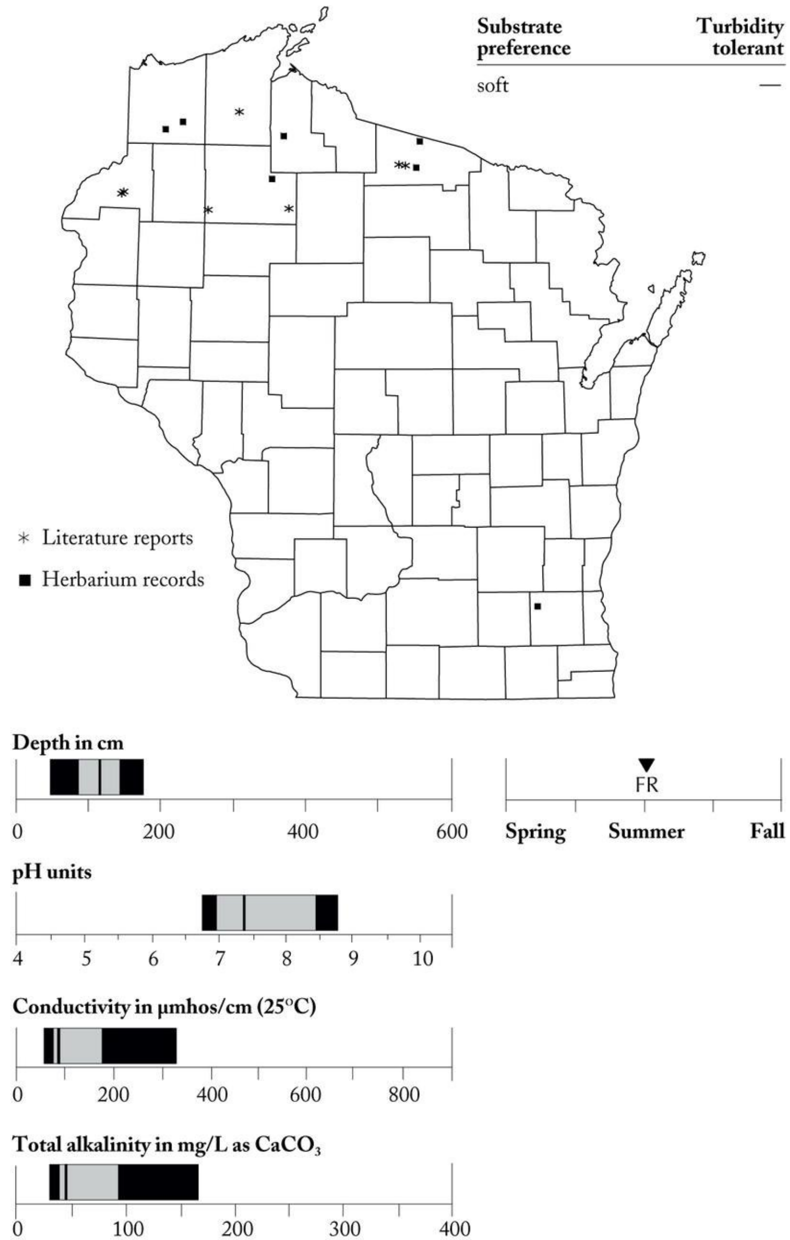
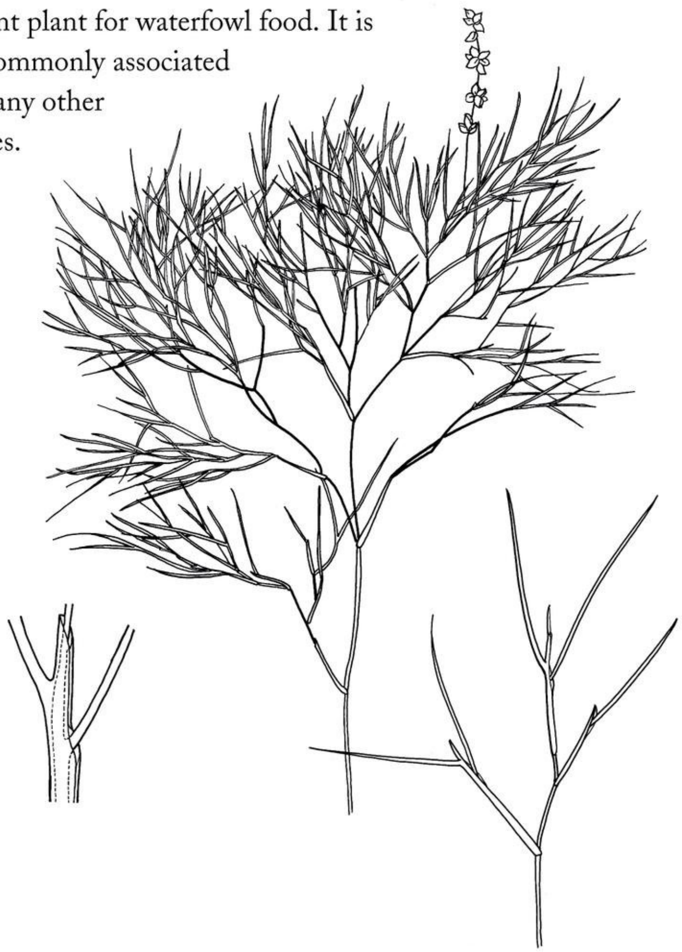
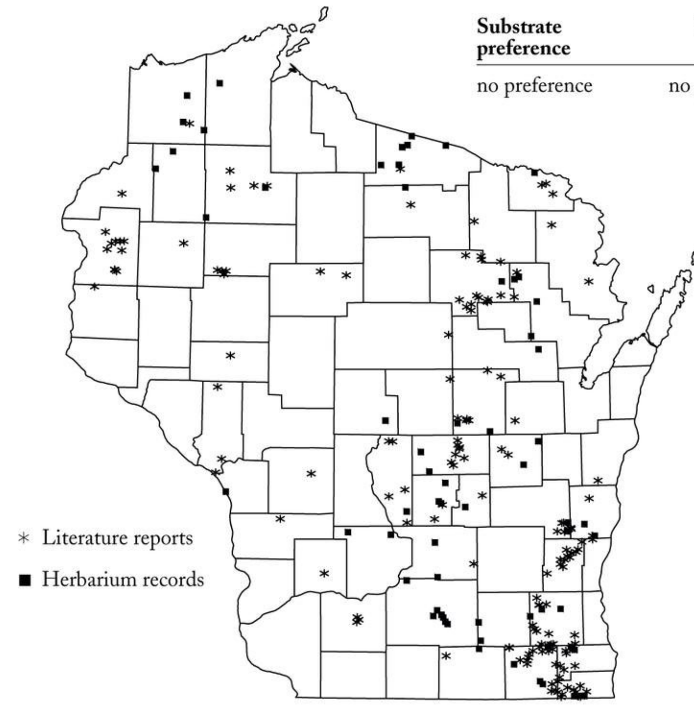


Figure 70. Distribution and habitat characteristics of *Potamogeton obtusifolius* Mert. & Koch.

An abundant species, found over most of the state (fig. 71). It shows no substrate or turbidity preference. It can survive poor water-quality conditions (Engel and Nichols, 1994). It has a broad alkalinity range and moderate conductivity and pH ranges; the upper limit of its pH range is among the highest of all the plants studied. Growth can take place in water depths greater than 4 m, but growth in 1 to 2 m is more typical. It flowers in spring and fruits by midsummer. Abundant production of seeds and tubers make it an important plant for waterfowl food. It is not commonly associated with any other species.



Substrate preference	Turbidity tolerant
no preference	no preference



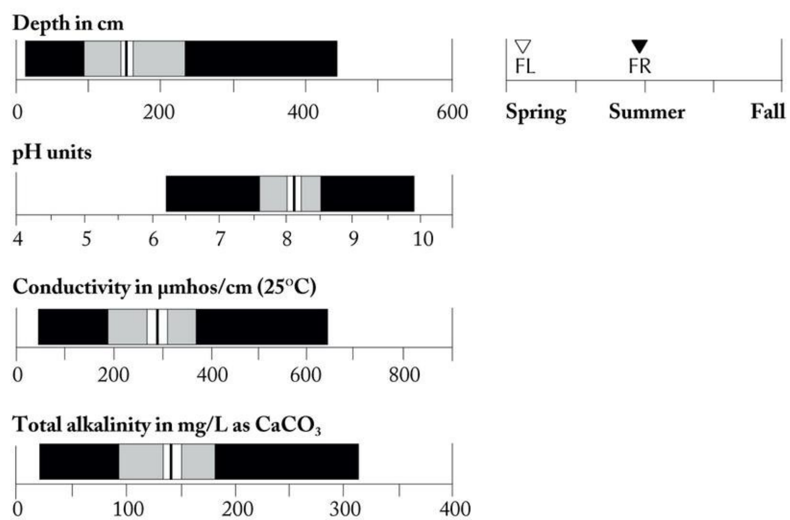
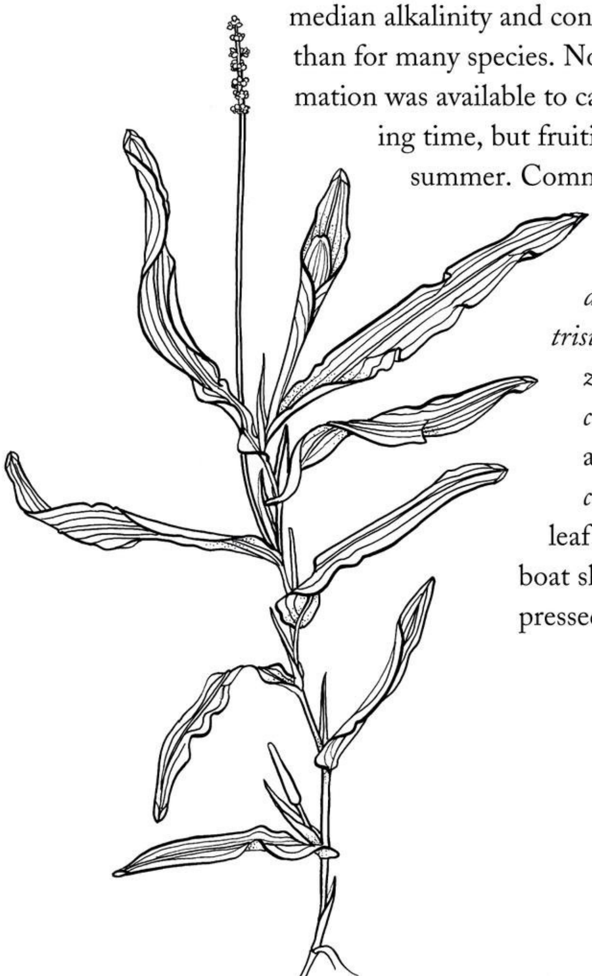
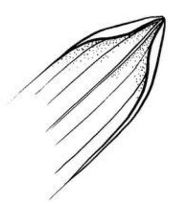


Figure 71. Distribution and habitat characteristics of *Potamogeton pectinatus* L.

Potamogeton praelongus Wulfen

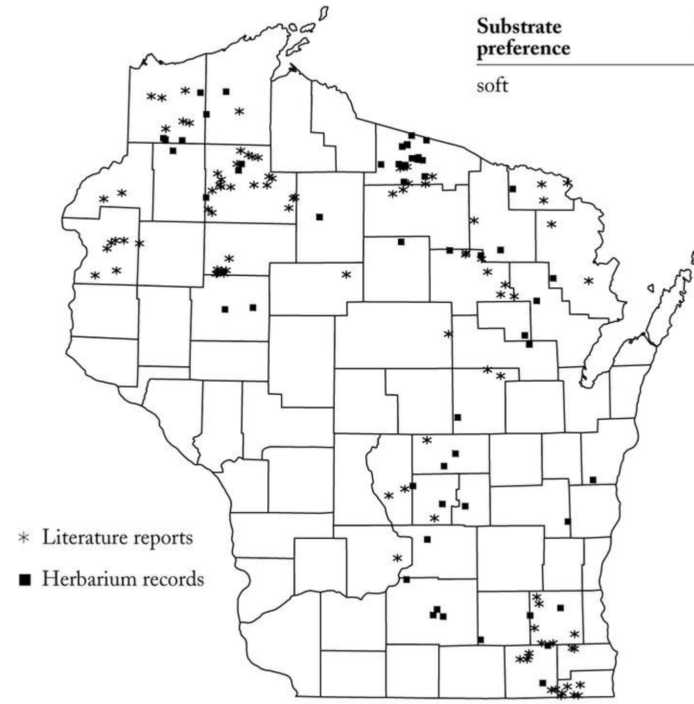
A common plant, found most frequently in northern and eastern Wisconsin lakes (fig. 72). *Potamogeton praelongus* in Wisconsin lakes is generally found in water less than 4 m deep, but Voss (1972) reported some plants in Michigan in water 7 m deep. It prefers soft substrate and is not turbidity tolerant. It is found over a broad pH range, a moderate alkalinity range, and a limited conductivity range. The high end of the pH range is among the highest of the species studied, but median alkalinity and conductivity are lower than for many species. Not enough information was available to calculate a flowering time, but fruiting occurs in early summer. Common associates are *Bidens beckii*, *Ceratophyllum demersum*, *Lemna trisulca*, *Potamogeton zosteriformis*, *Utricularia geminiscapa*, and *Wolffia columbiana*. The leaf tips are usually boat shaped; when pressed flat, they split.





white-stem pondweed

Substrate preference	Turbidity tolerant
soft	no



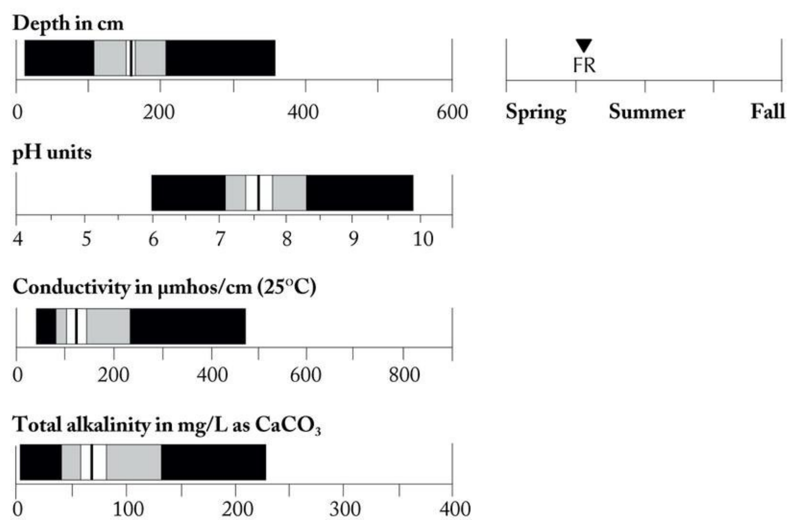
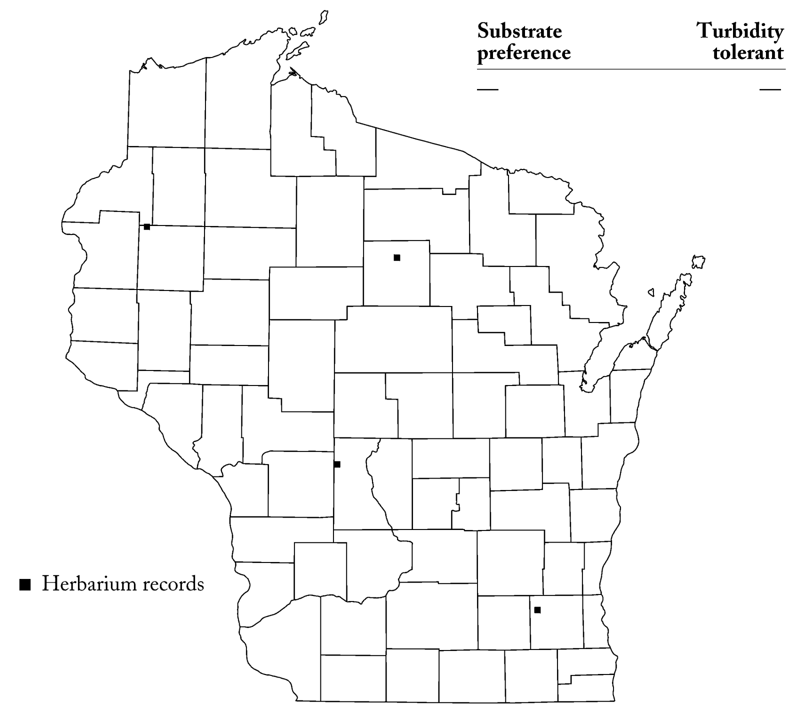


Figure 72. Distribution and habitat characteristics of *Potamogeton praelongus* Wulfen.

Potamogeton pulcher Tuckerman

A rare species, found only in four Wisconsin lakes (fig. 73). Because of its rarity, little could be determined about its ecological characteristics. It is locally abundant in acid water of New England (Hellquist and Crow, 1980). On the basis of the limited data available, it appears not to be confined entirely to acid water in Wisconsin. Wisconsin seems to be on the western edge of its range. The stems and petioles of this species are conspicuously black-spotted or mottled and the blades of the floating leaves are slightly heart shaped at the base (Voss, 1972).

spotted pondweed



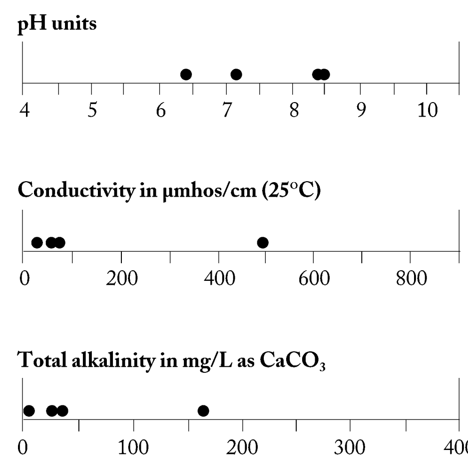
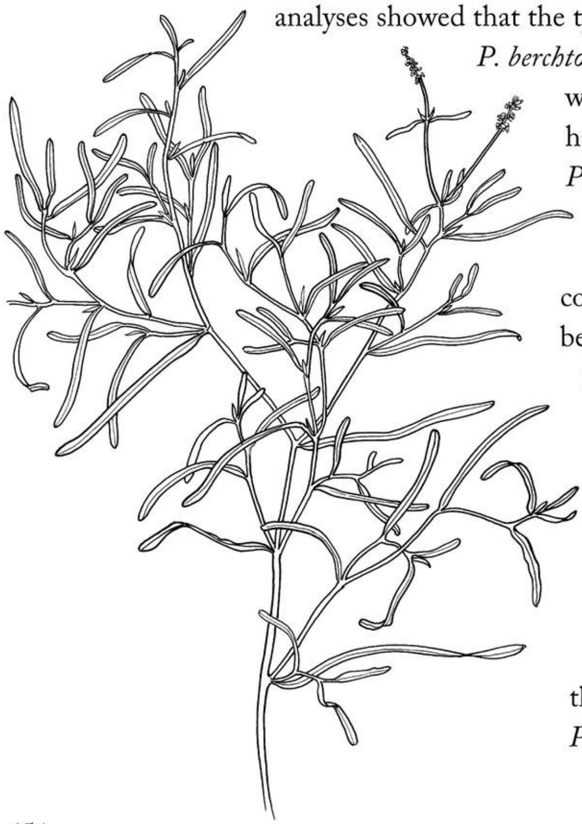


Figure 73. Distribution and habitat characteristics of *Potamogeton pulcher* Tuckerman.

Potamogeton pusillus L.

A common species, widespread in Wisconsin (fig. 74). It is found over moderate ranges of alkalinity and pH and a limited conductivity range. It grows to a depth of 2.6 m and is turbidity tolerant. Flowering occurs in early summer and fruiting in midsummer. Common associates include *Bidens beckii, Ceratophyllum demersum, C. echinatum, Dulichium arundinaceum, Myriophyllum heterophyllum, M. verticillatum, Najas flexilis, Nymphaea odorata, Polygonum amphibium, Potamogeton natans, P. richardsonii, Sparganium chlorocarpum, Utricularia geminiscapa, U. vulgaris,* and *Vallisneria americana. Potamogeton berchtoldii* Fieber was previously separated from *P. pusillus*; now the two are combined (Gleason and Cronquist, 1991). My analyses showed that the type identified as *P. berchtoldii* grows in deeper water and prefers harder substrate than *P. pusillus*. There was no difference in median alkalinity, conductivity, or pH between sites where the two plant types grow. The glands at the base of some leaves of *P. pusillus* are sometimes useful for separating sterile specimens of this species from *P. foliosus*.



small pondweed

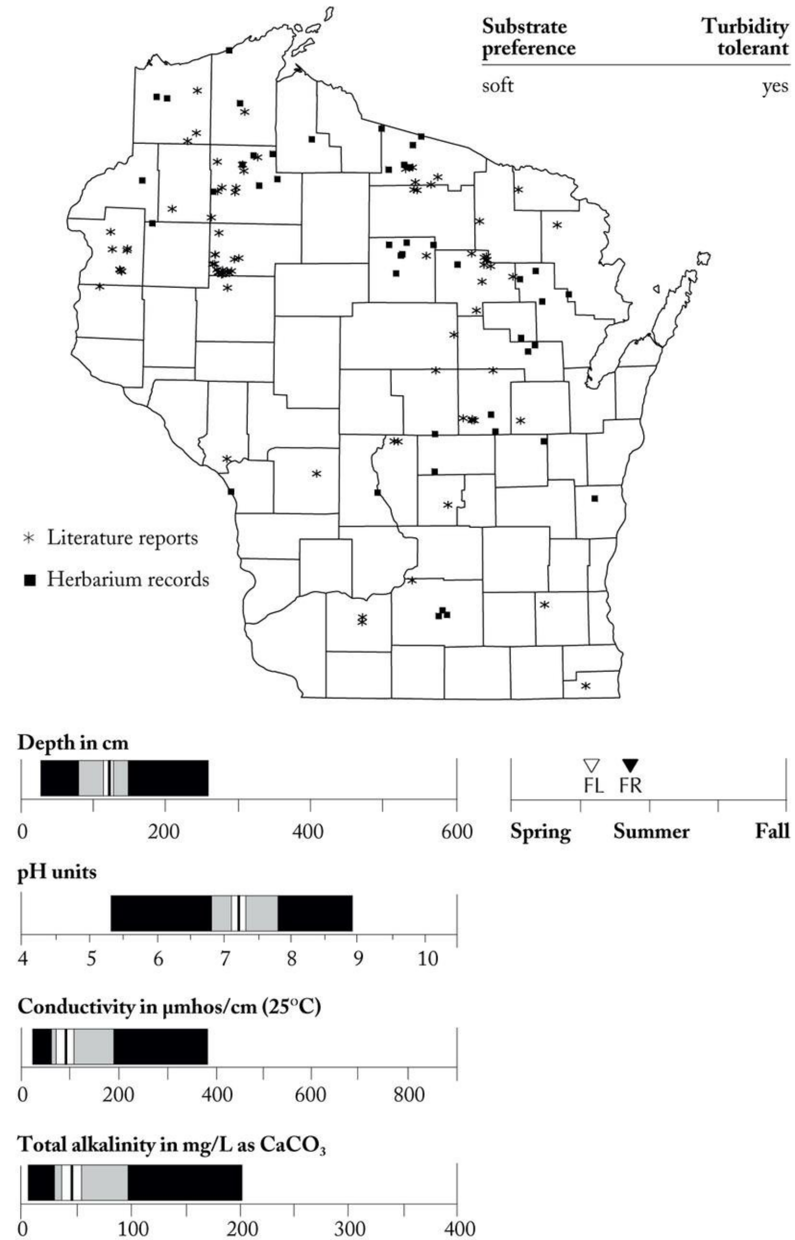
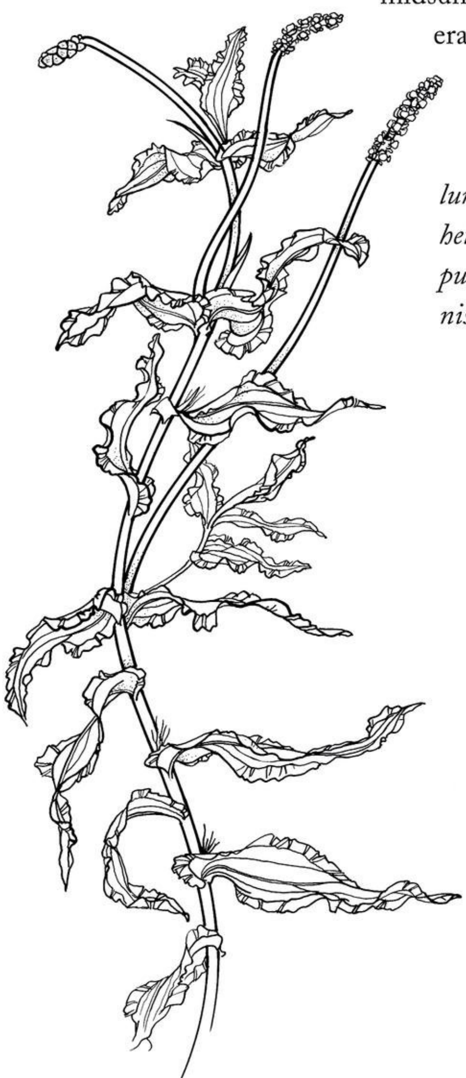
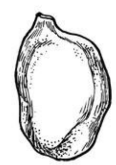


Figure 74. Distribution and habitat characteristics of *Potamogeton pusillus* L.

Potamogeton richardsonii (Ar. Bennett) Rydb.

A common plant in many lakes and ponds of the state (fig. 75). It shows no turbidity or substrate preference and can withstand environmental disturbance (Davis and Brinson, 1980). It is many times the only broad-leaf pondweed found in degraded water. Flowering occurs in early summer; fruiting, by midsummer. It is found over moderate ranges of water chemistries and in water depths to 4 m. Common associates are *Bidens beckii*, *Ceratophyllum demersum*, *Myriophyllum heterophyllum*, *Potamogeton pusillus*, and *Utricularia geminiscapa.*





clasping-leaf pondweed

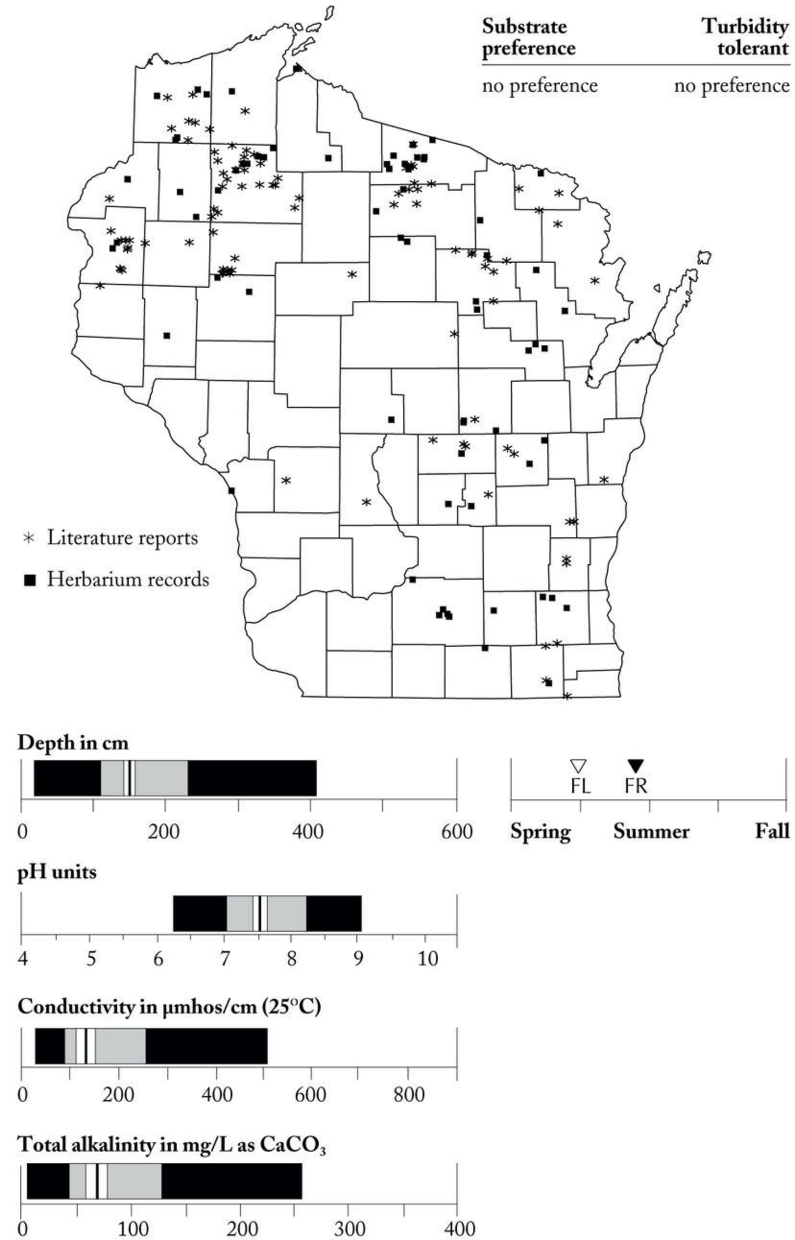
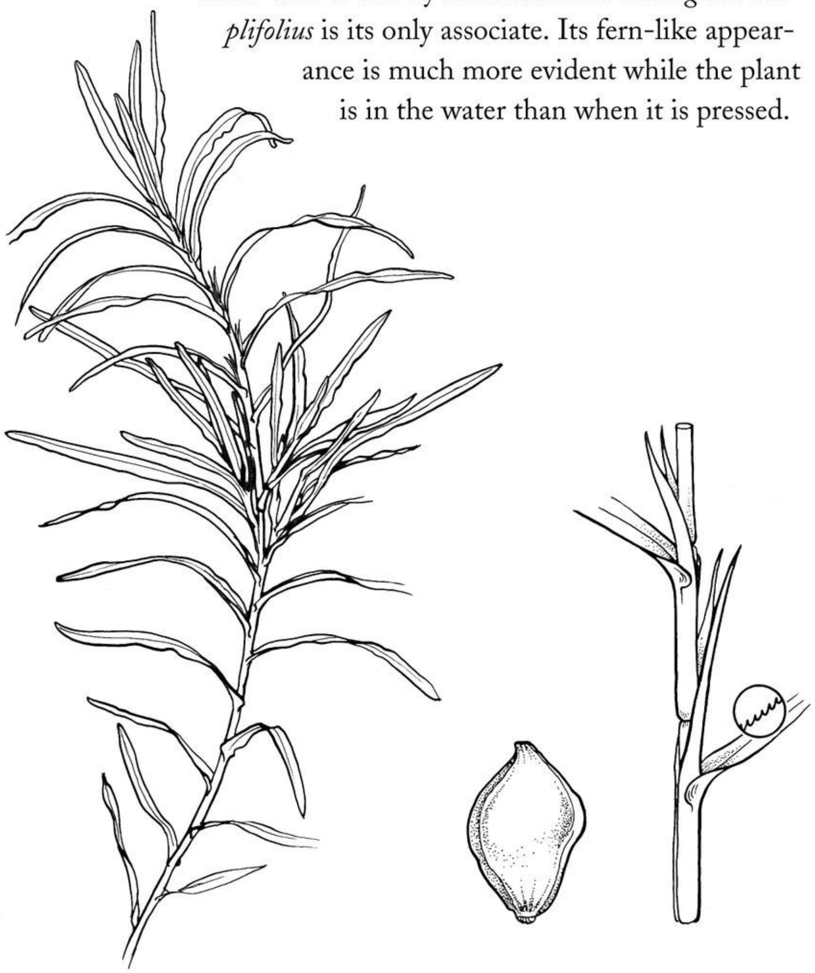


Figure 75. Distribution and habitat characteristics of *Potamogeton richardsonii* (Ar. Bennett) Rydb.

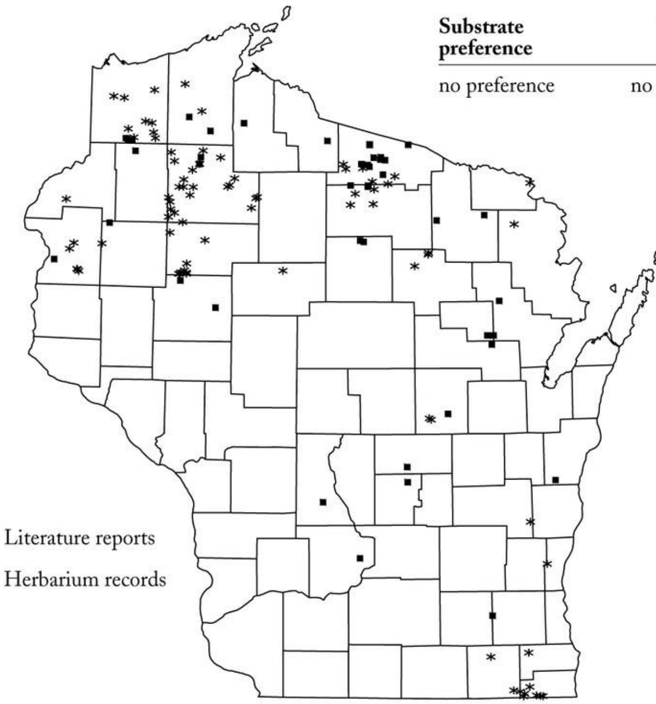
Potamogeton robbinsii Oakes

A common species, found primarily in northern but also in eastern Wisconsin (fig. 76). It shows no substrate or turbidity preference. Its median growth depth is the deepest of any of the pondweeds in the state—it grows in water up to 4.5 m deep. It has a broad pH range, but is found over limited conductivity and alkalinity ranges. Voss (1972) reported that flowers and fruits are rare. No flowering date was established, but fruits were found by midsummer. *Potamogeton amplifolius* is its only associate. Its fern-like appearance is much more evident while the plant is in the water than when it is pressed.



fern pondweed

Substrate preference	Turbidity tolerant
no preference	no preference



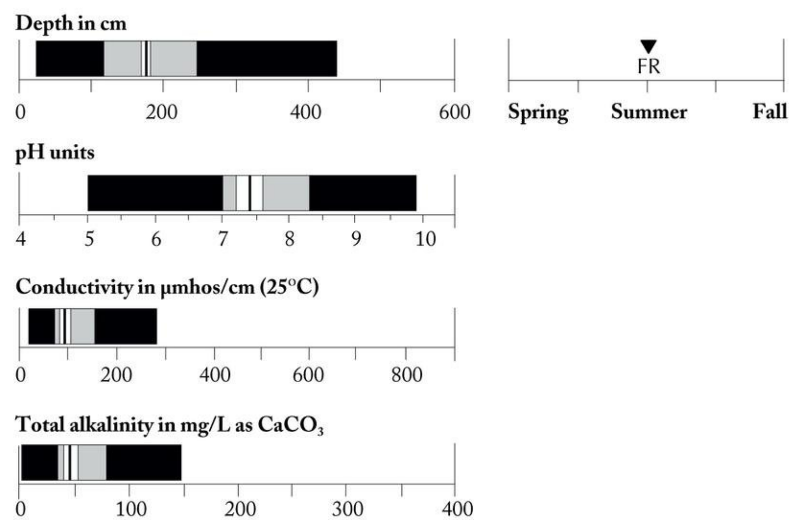


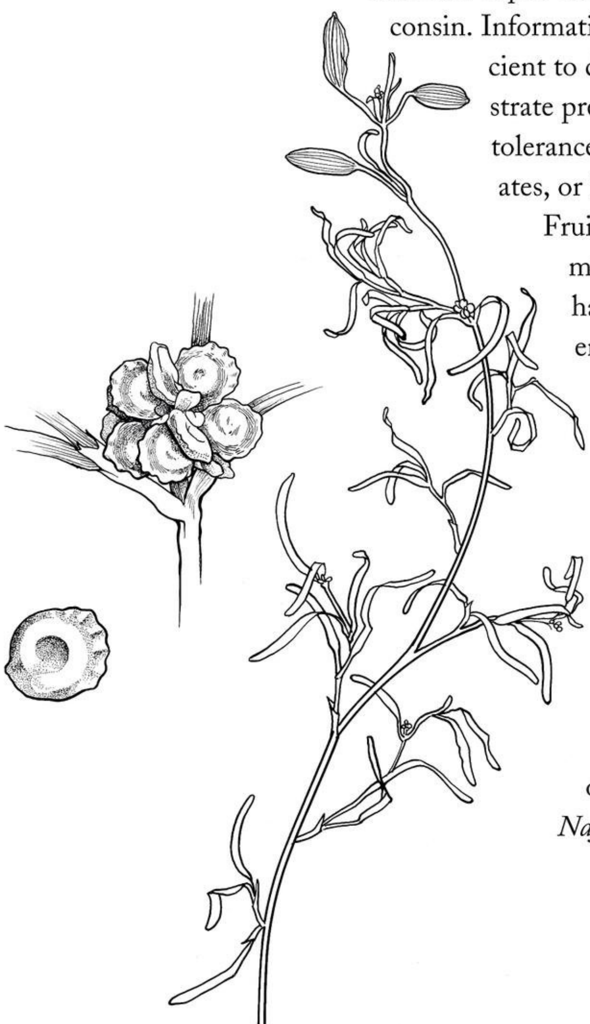
Figure 76. Distribution and habitat characteristics of *Potamogeton robbinsii* Oakes.

Potamogeton spirillus Tuckerman

An infrequent plant in circumneutral pH but low alkalinity and conductivity water in northern Wisconsin (fig. 77). Except for one unconfirmed report in Waukesha County, all distribution points were in the lowest chloride, calcium, sulfate, and magnesium areas of the state. In Michigan it is usually found in shallow water (Voss, 1972), but data were insufficient to describe its depth distribution in Wisconsin. Information was not sufficient to determine its substrate preference, turbidity tolerance, common associates, or flowering date.

Fruits are found in midsummer and have a visibly coiled embryo, which aids identification.

Field identification of vegetative plants is also aided by submersed leaves that are often curved, giving the whole bushy plant the aspect of a broad-leaved *Najas* (Voss, 1972).



spiral-fruited pondweed

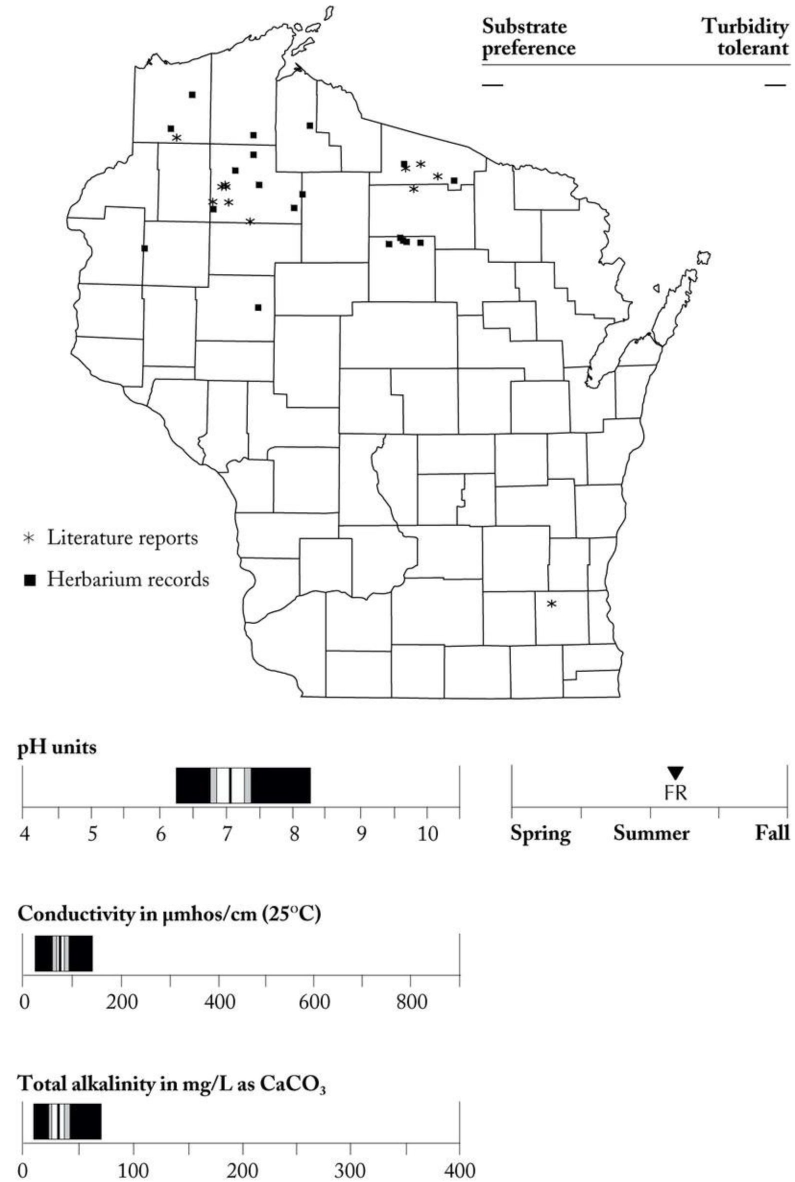


Figure 77. Distribution and habitat characteristics of *Potamogeton spirillus* Tuckerman.

Potamogeton strictifolius Ar. Bennett

An infrequent species, scattered over northern and eastern Wisconsin (fig. 78). It is found in water depths up to 3 m, and it prefers hard bottoms. No information is available on turbidity tolerance. *Potamogeton strictifolius* may intergrade with *P. friesii*, and it is sometimes hard to distinguish between the two species (Voss, 1972). Unlike *P. friesii*, *P. strictifolius* has a bristle-like leaf tip, glands at the base of the leaf that are inconspicuous or absent, and no cellular-reticulate band along the leaf midrib. It is found more frequently in lower alkalinity and conductivity water than is *P. friesii*, but it is found over a broader pH range. All distribution points except for three references in the literature database in eastern Wisconsin were in areas where sulfate concentration was less than 10 mg/L. The flowering and fruiting dates of both species are very similar. Common associates are *Myriophyllum spicatum*, *M. verticillatum*, *Najas flexilis*, *Potamogeton amplifolius*, *P. illinoensis*, and *P. natans*.

stiff pondweed

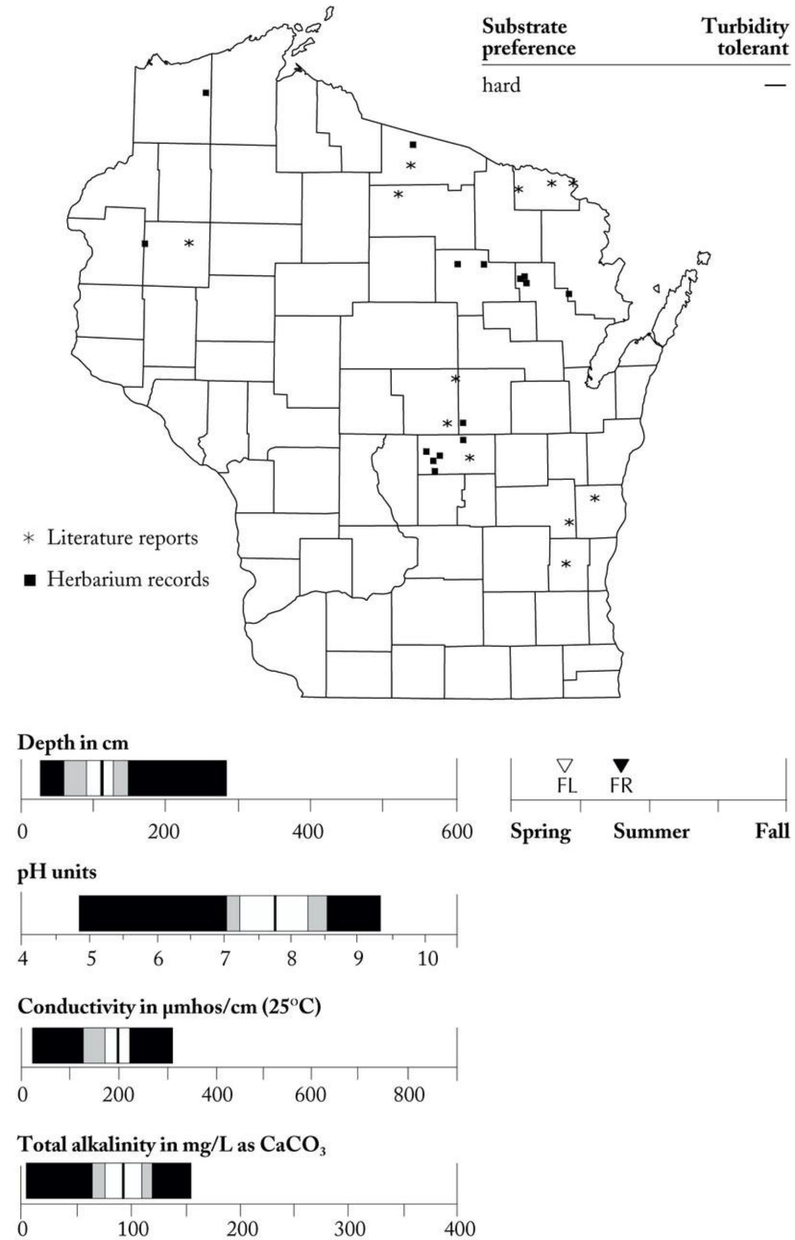
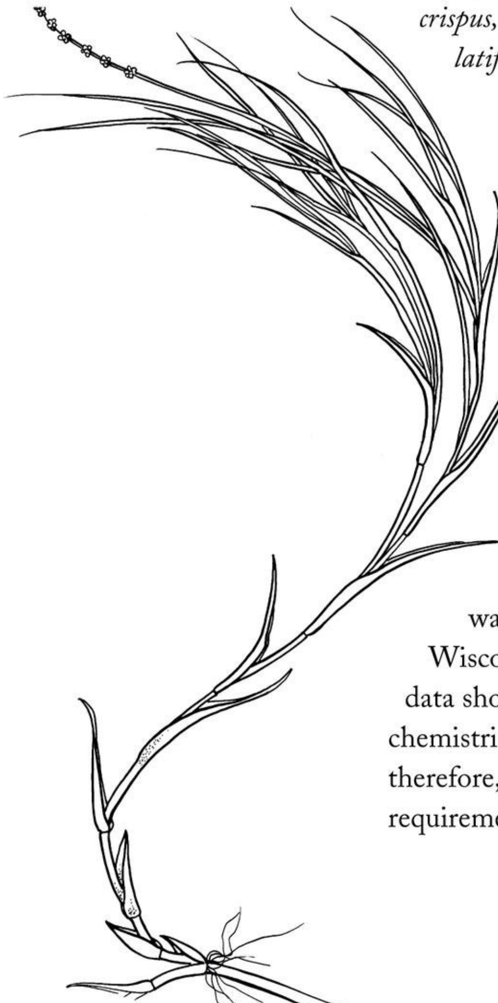


Figure 78. Distribution and habitat characteristics of *Potamogeton strictifolius* Ar. Bennett.

Potamogeton vaginatus Turcz.

A rare species, widely scattered across the state (fig. 79). Because of its rarity, the pH, alkalinity, and conductivity distributions, turbidity tolerance, and flowering date were not determined. It seems to prefer shallow water and shows no substrate preference. Fruiting occurs in early summer. Common associates are *Ceratophyllum demersum, Elodea canadensis, Lemna minor, Nymphaea odorata, Potamogeton crispus, P. zosteriformis, Sagittaria latifolia,* and *Typha latifolia.*



Wisconsin is on the southern edge of the range for this species (Gleason and Cronquist, 1991). According to Gleason and Cronquist (1991), Fassett (1969), and Voss (1972), it prefers deep, hard, alkaline, brackish, and cold spring-fed water. Neither deep nor cold water is consistent with Wisconsin findings, and limited data show that Wisconsin water chemistries are widely distributed; therefore, hardness and alkalinity requirements are also questionable.

swift-water pondweed

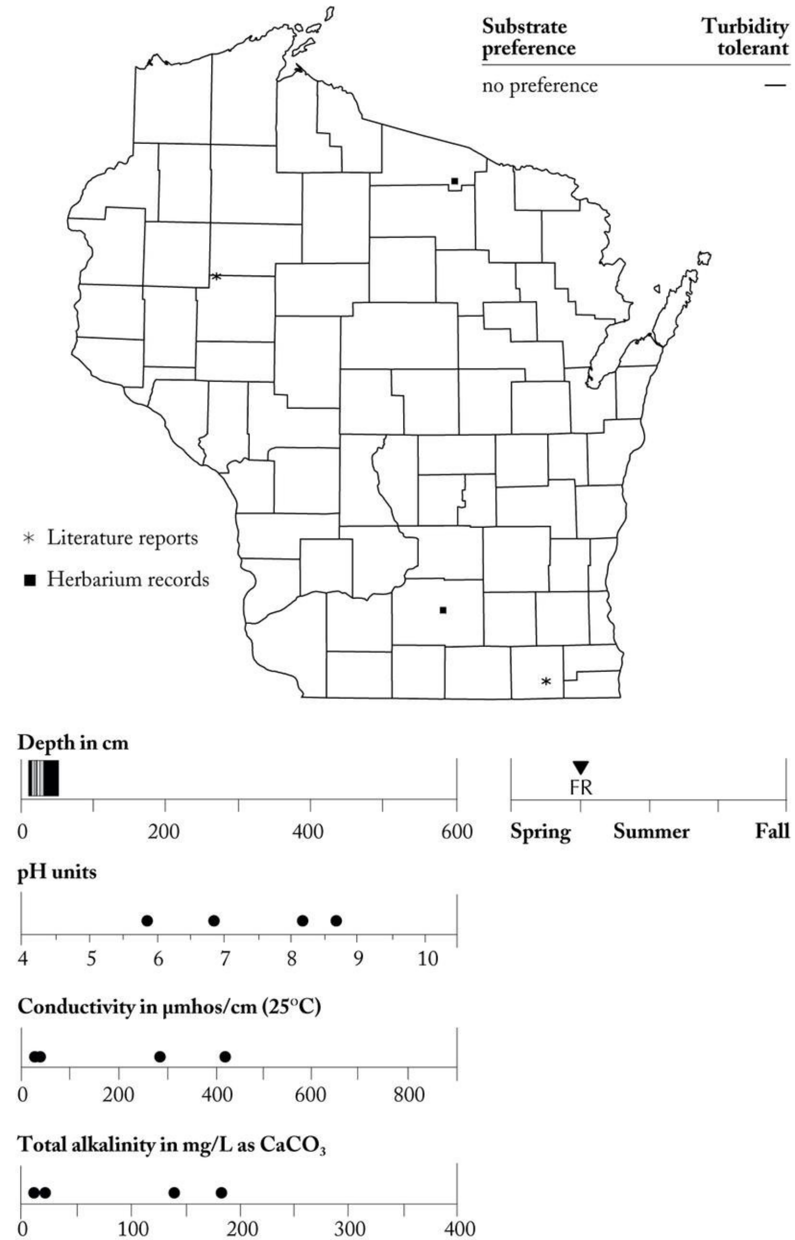
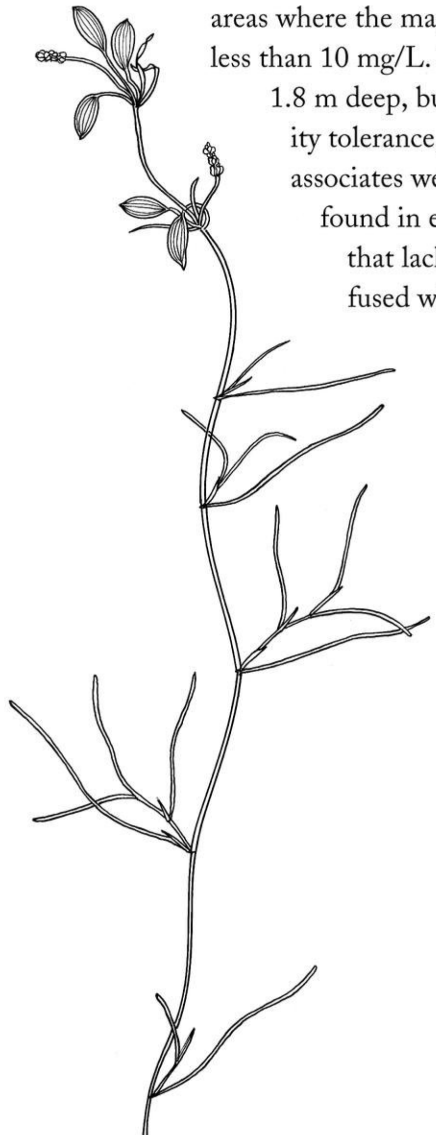
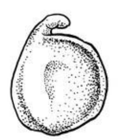


Figure 79. Distribution and habitat characteristics of *Potamogeton vaginatus* Turcz.

An annual plant, rare in Wisconsin (fig. 80). It is found primarily in low alkalinity, low conductivity water, but over a moderate pH range. No distribution points were in the Southeastern Wisconsin Till Plain Ecoregion and all points were in areas where the magnesium concentration was less than 10 mg/L. It is found in water less than 1.8 m deep, but substrate preference, turbidity tolerance, flowering date, and common associates were not determined. Fruits are found in early summer. Sterile plants that lack floating leaves may be confused with *P. pusillus* (Fassett, 1969).





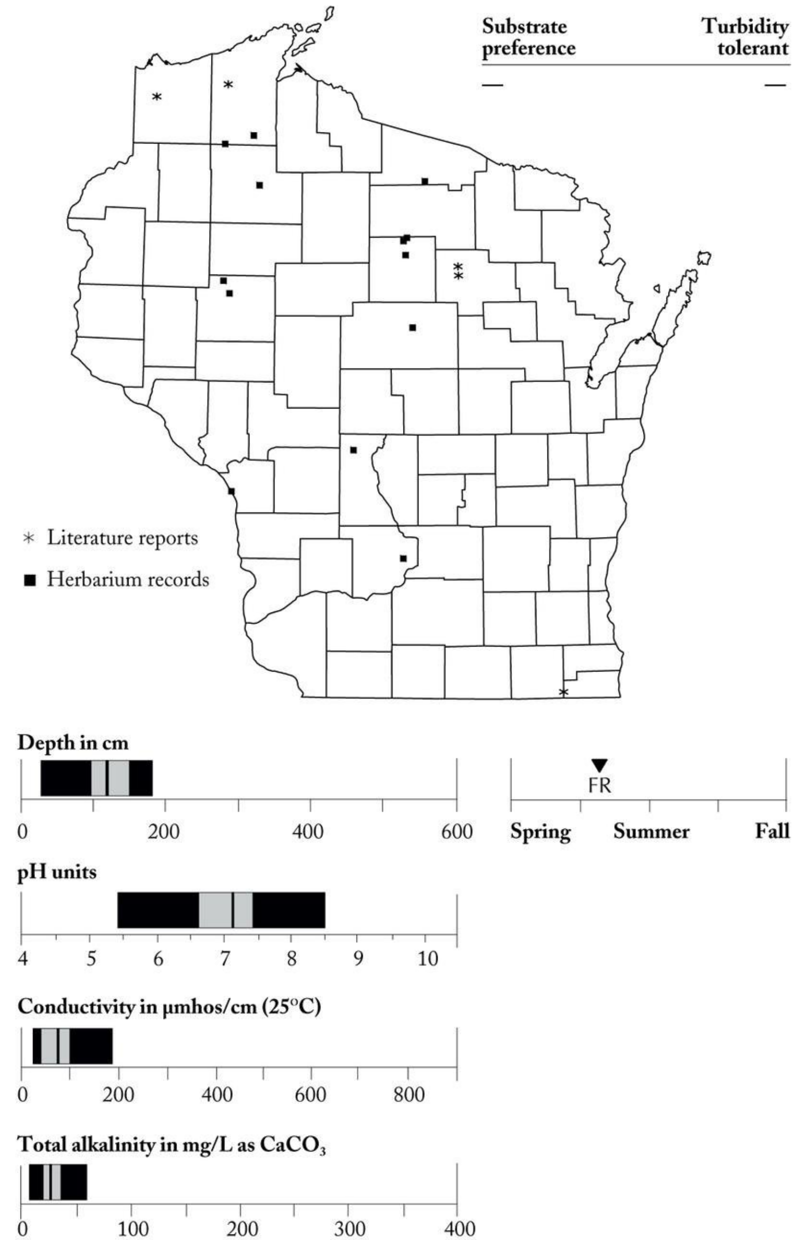
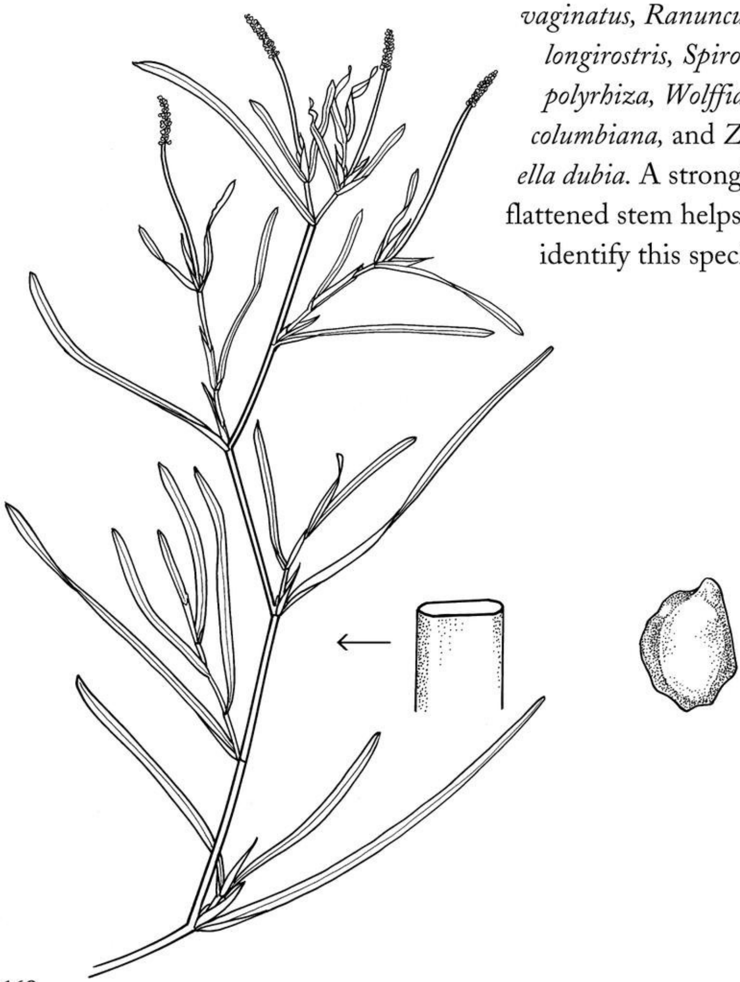
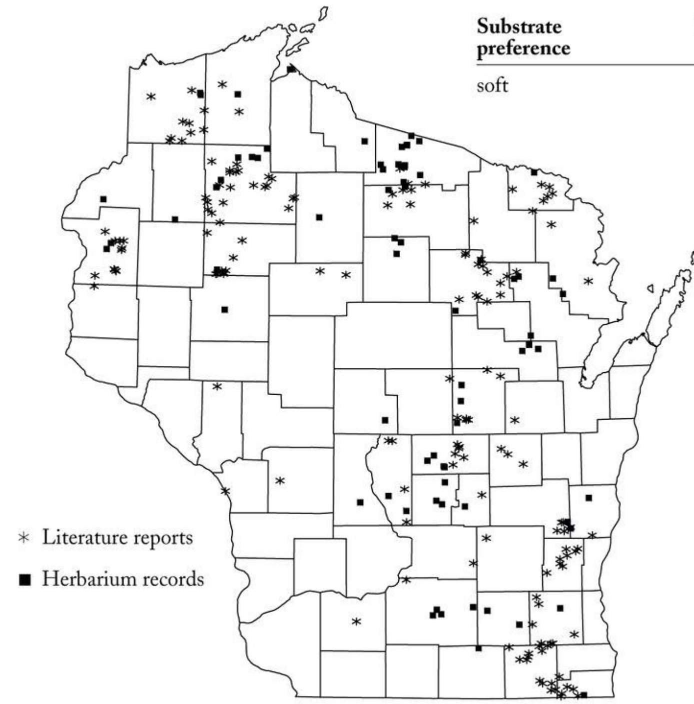


Figure 80. Distribution and habitat characteristics of *Potamogeton vaseyi* Robbins.

An abundant species, found statewide in water depths to 4 m (fig. 81). It prefers soft substrate, but it is not turbidity tolerant. It is found over broad alkalinity and pH ranges and a moderate conductivity range. Flowering occurs in early summer, and fruits appear by midsummer. Common associates are *Bidens beckii, Ceratophyllum demersum, Lemna minor, L. trisulca, Myriophyllum heterophyllum, M. verticillatum, Potamogeton diversifolius, P. natans, P. praelongus, P. vaginatus, Ranunculus longirostris, Spirodela polyrhiza, Wolffia columbiana*, and *Zosterella dubia*. A strongly flattened stem helps identify this species.



Substrate preference	Turbidity tolerant
soft	no



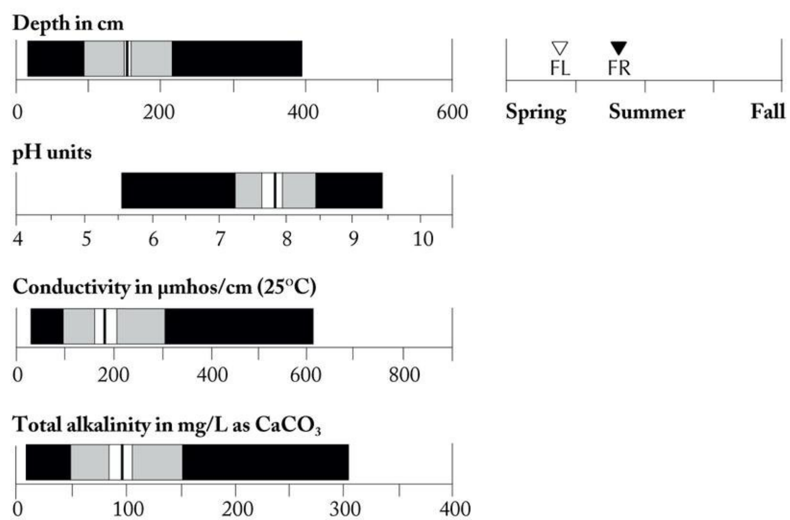


Figure 81. Distribution and habitat characteristics of *Potamogeton zosteriformis* Fern.

Potentilla palustris (L.) Scop.

A common species, found where bog mats meet shorelines, mostly in northern Wisconsin lakes (fig. 82). Stems can trail on the water and root at the nodes. Flowering occurs in early summer. *Potentilla palustris* is found over a moderate pH range, but a limited range of conductivity and alkalinity. Substrate preference and turbidity tolerance are unknown. Common associates were not determined, but are likely to be other bog species.

marsh cinquefoil

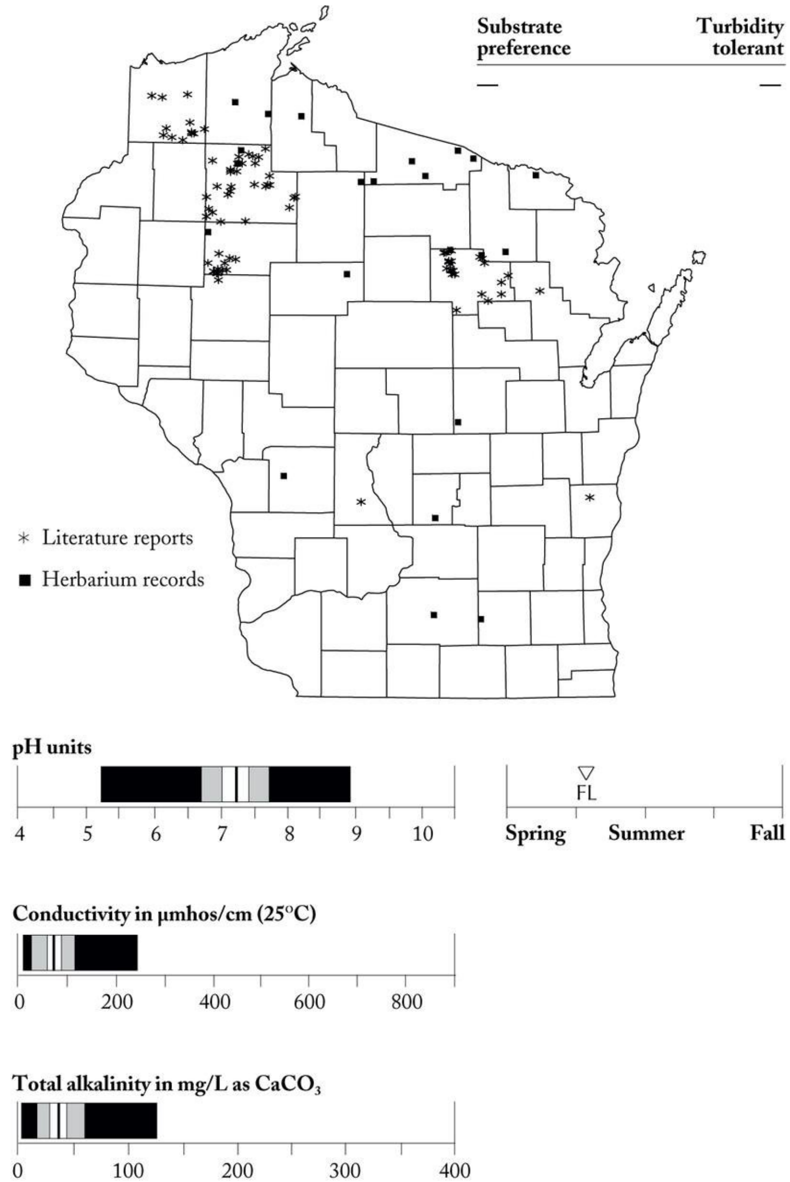
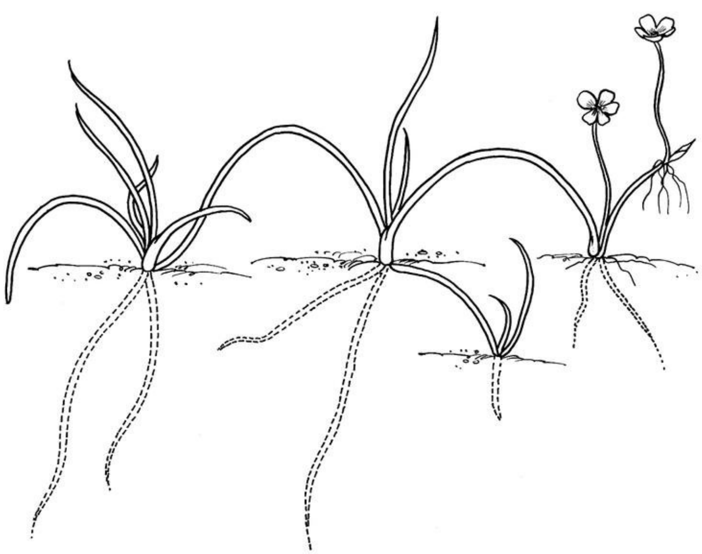


Figure 82. Distribution and habitat characteristics of *Potentilla palustris* (L.) Scop.

A rare species, found over narrow and low conductivity and alkalinity ranges and a moderate pH range (fig. 83). All but two distribution points were in the Northern Lakes and Forests Ecoregion; all points were in areas where the sulfate concentration was less than 10 mg/L and chloride concentration, less than 3 mg/L. This plant is found in water depths to 3.3 m and prefers hard substrates. Flowering and fruiting occur in midsummer. The plant spreads vegetatively by means of arching green stolons. Terrestrial forms with broad leaves (approximately 5 mm) can be found (Voss, 1985). Turbidity tolerance was not determined, and no common associates were found.



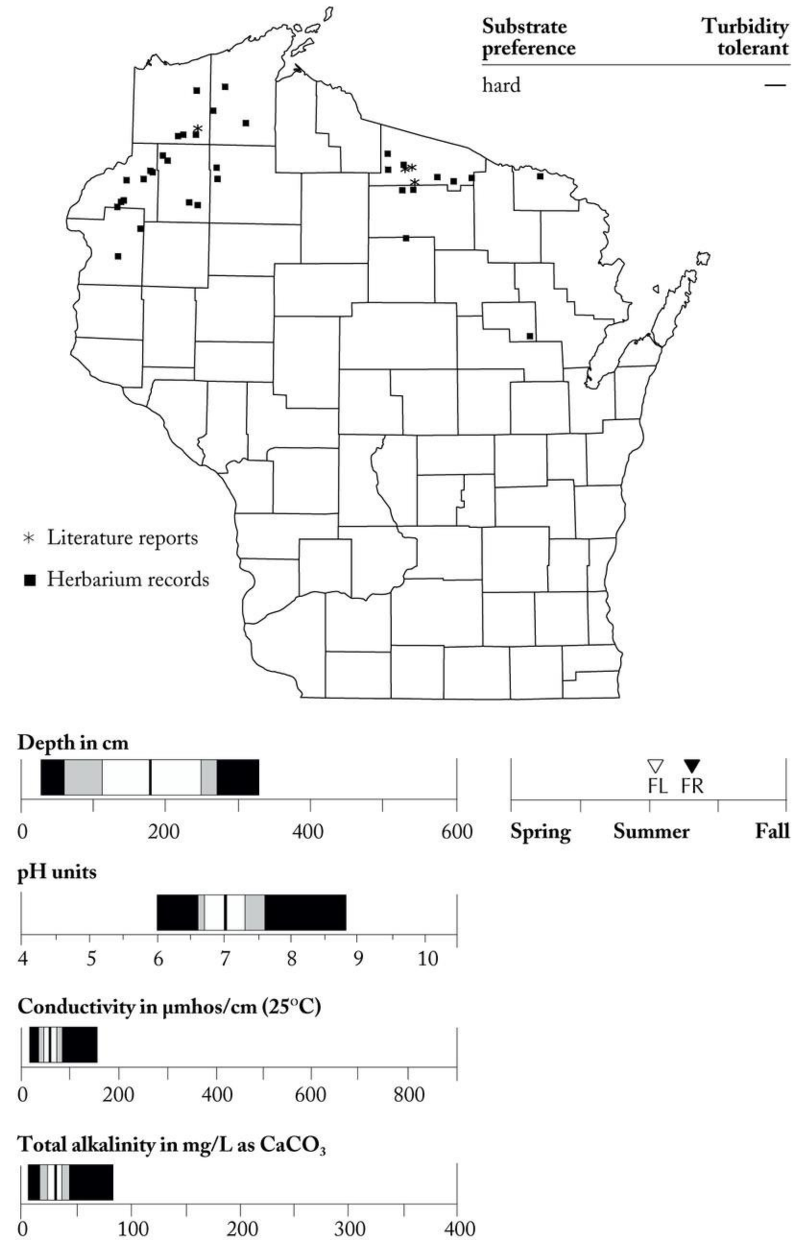
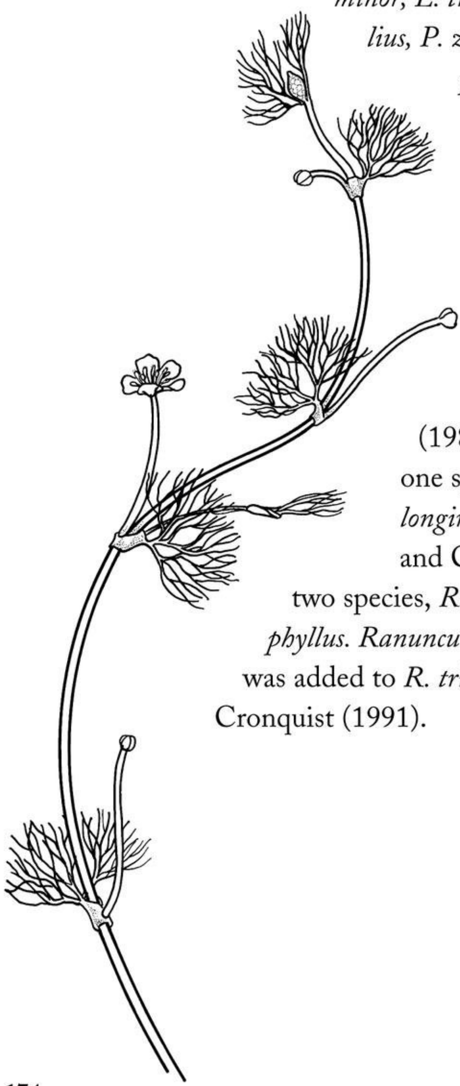


Figure 83. Distribution and habitat characteristics of *Ranunculus flammula* L.

Ranunculus longirostris Godron

May be more common in streams than in lakes. It is found over moderate ranges of alkalinity, pH, and conductivity and in water depths less than 2 m (fig. 84). It shows no turbidity or substrate preference, and it flowers and fruits in early summer. Common associates include *Ceratophyllum demersum, Lemna minor, L. trisulca, Potamogeton diversifolius, P. zosteriformis, Spirodela polyrhiza,* and *Wolffia columbiana.* Voss (1985) and Gleason and Cronquist (1991) should be consulted for a discussion of the taxonomic differences between *R. longirostris, R. trichophyllus* Chaix, and *R. aquatilis* L. Voss (1985) considered this group as one species, which he called *R. longirostris* for Michigan. Gleason and Cronquist (1991) recognized two species, *R. longisrostris* and *R. trichophyllus. Ranunculus aquatilis* var. *capillaceous* was added to *R. trichophyllus* by Gleason and Cronquist (1991).



white water crowfoot

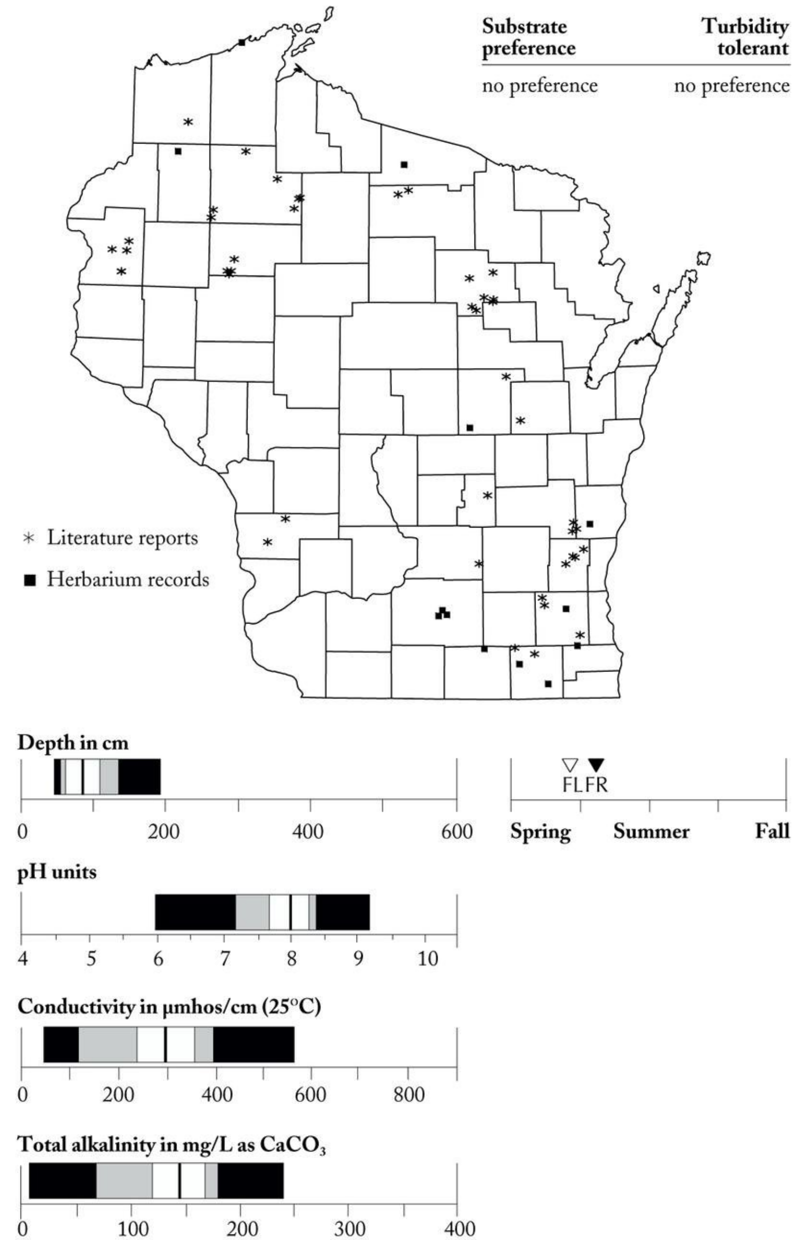
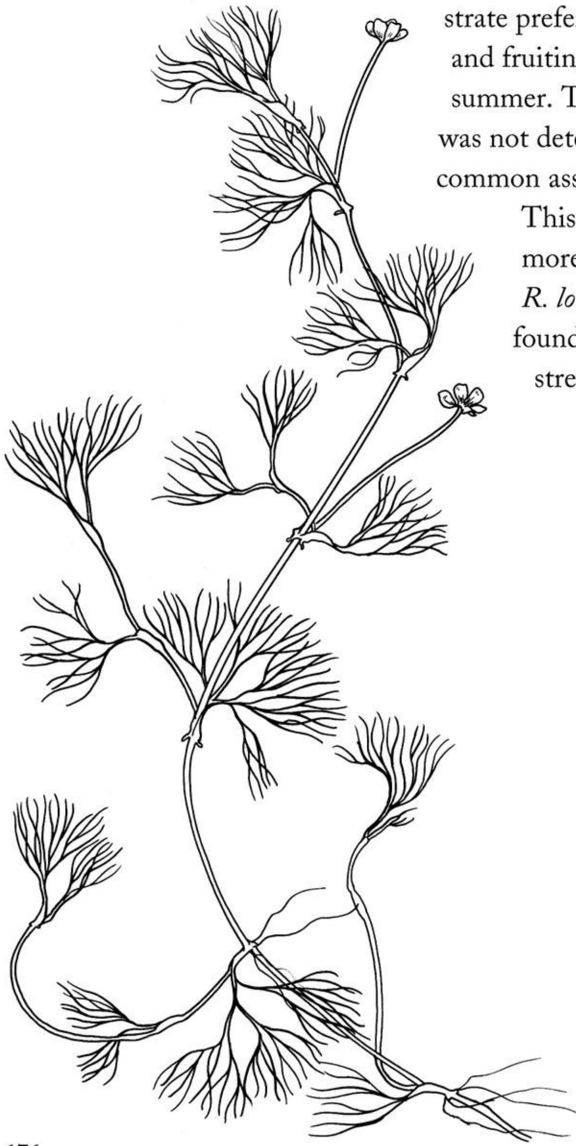


Figure 84. Distribution and habitat characteristics of *Ranunculus longirostris* Godron.

An infrequent species, found over broad alkalinity and conductivity ranges and a limited and mostly alkaline pH range (fig. 85). It is scattered widely in Wisconsin. It is found in water depths less than 2.1 m, and it shows no substrate preference. Flowering and fruiting occur in early summer. Turbidity tolerance was not determined and no common associates were found. This species may be more common than *R. longirostris* and is also found in slow-moving streams.



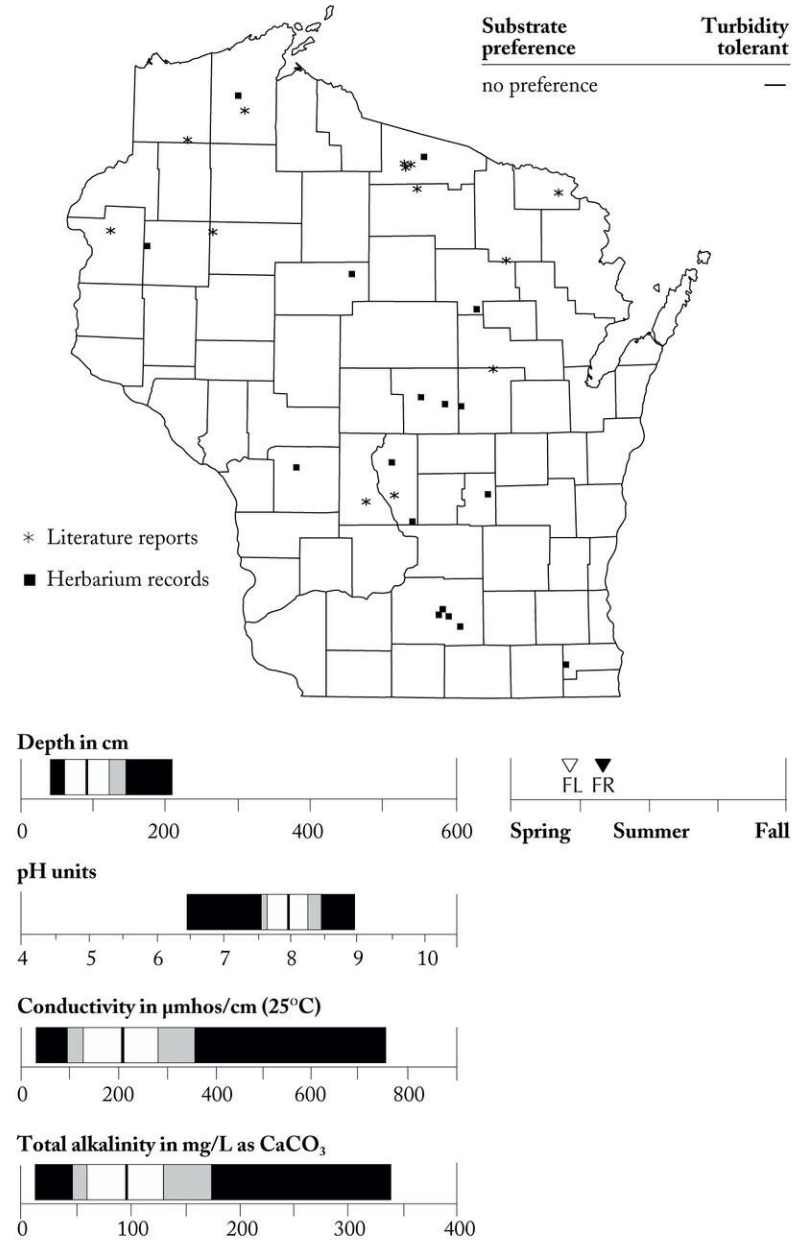
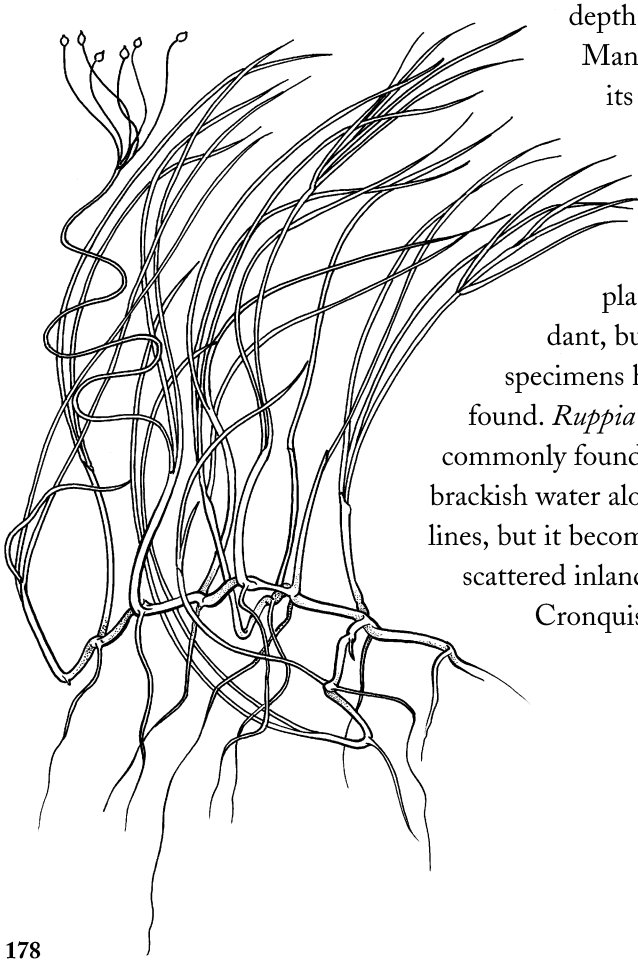


Figure 85. Distribution and habitat characteristics of *Ranunculus trichophyllus* Chaix.

Ruppia maritima L.

widgeon grass

A rare species, found in a few high alkalinity, high conductivity, high pH lakes in the Southeastern Wisconsin Till Plain Ecoregion (fig. 86). All distribution points were in areas where alkalinity was greater than 30 mg/L as $CaCO_3$ and where chloride concentration was greater than 10 mg/L. All but two distribution points were in an area where sulfate concentration was greater than 40 mg/L. Depth distribution, substrate preference, flowering and fruiting dates, and common associates were not determined. Voss (1972) stated it is found in water depths to 2.5 m in Manistique Lake, its only known occurrence in Michigan. There, flowering plants are abundant, but fruiting specimens have not been found. *Ruppia maritima* is commonly found in saline or brackish water along both coastlines, but it becomes much more scattered inland (Gleason and Cronquist, 1991).



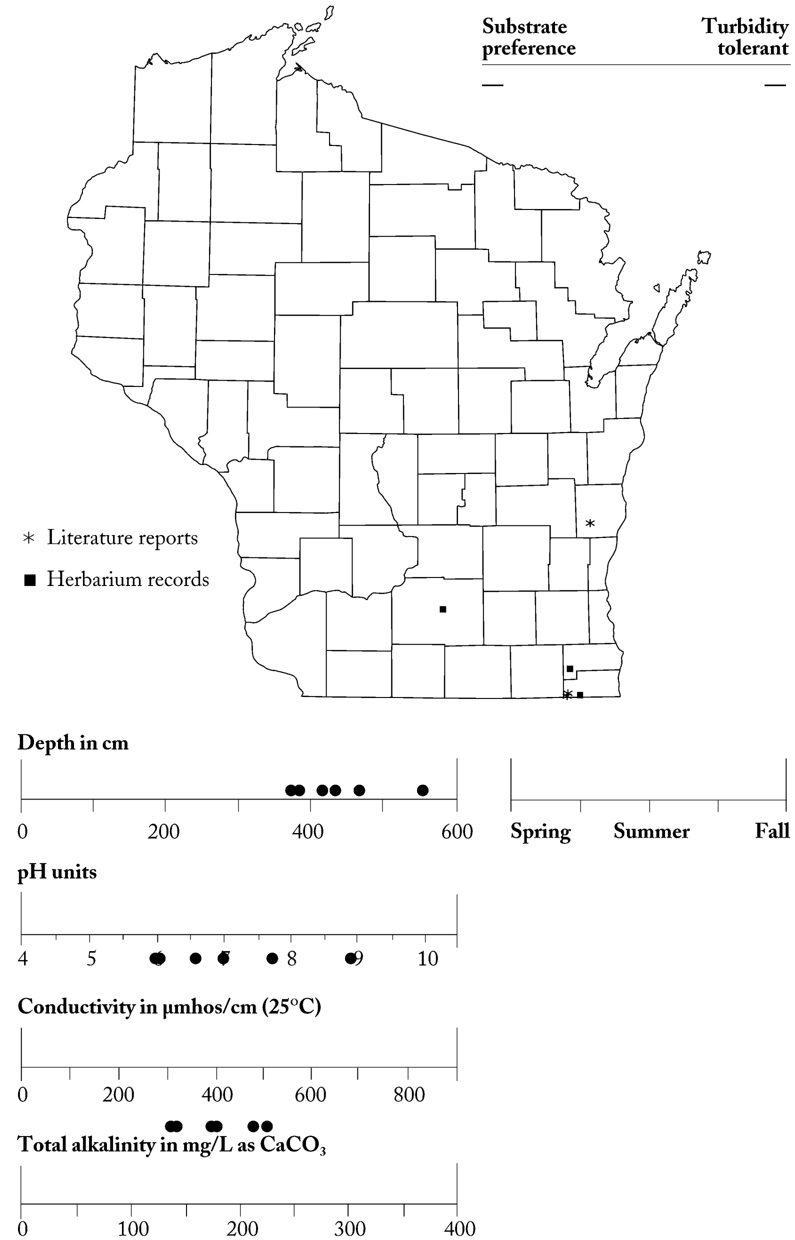
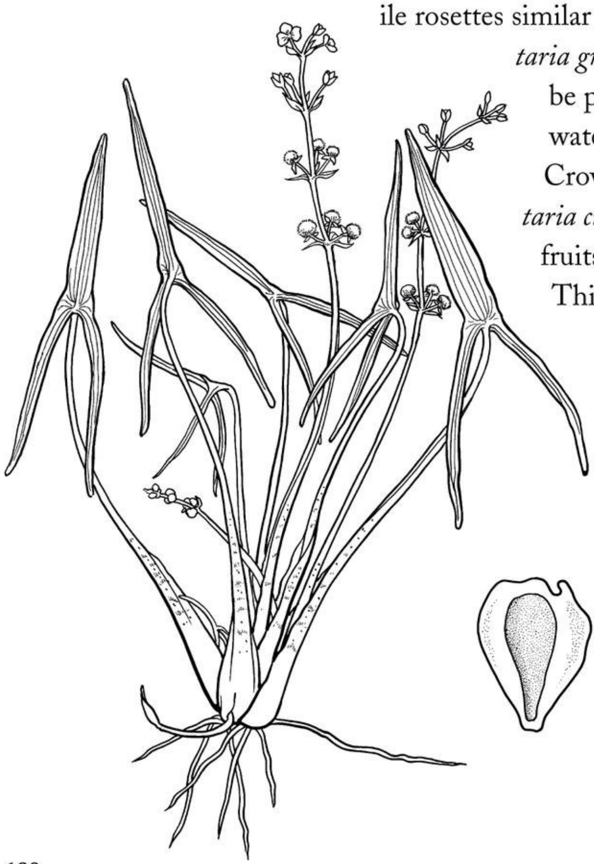


Figure 86. Distribution and habitat characteristics of *Ruppia maritima* L.

An infrequent species, found primarily in northern Wisconsin (fig. 87). Fassett (1929) reported it in southern Wisconsin and in sandy bottomed areas of the Mississippi and Wisconsin Rivers. It is generally found in low conductivity, low alkalinity water, but over a broad and circumneutral pH range. Not enough information was available to describe its depth distribution, substrate preference, turbidity tolerance, or common associates. According to Voss (1972), it is usually found in shallow water or on wet shores in Michigan. In deep water and in rivers, flat linear leaves, similar to those of *Vallisneria americana* are formed (Voss, 1972; Hellquist and Crow, 1981). Sterile rosettes similar to those of *Sagittaria graminea* may also be produced in deep water (Hellquist and Crow, 1981). *Sagittaria cuneata* flowers and fruits in midsummer. This species produces large, edible tubers.



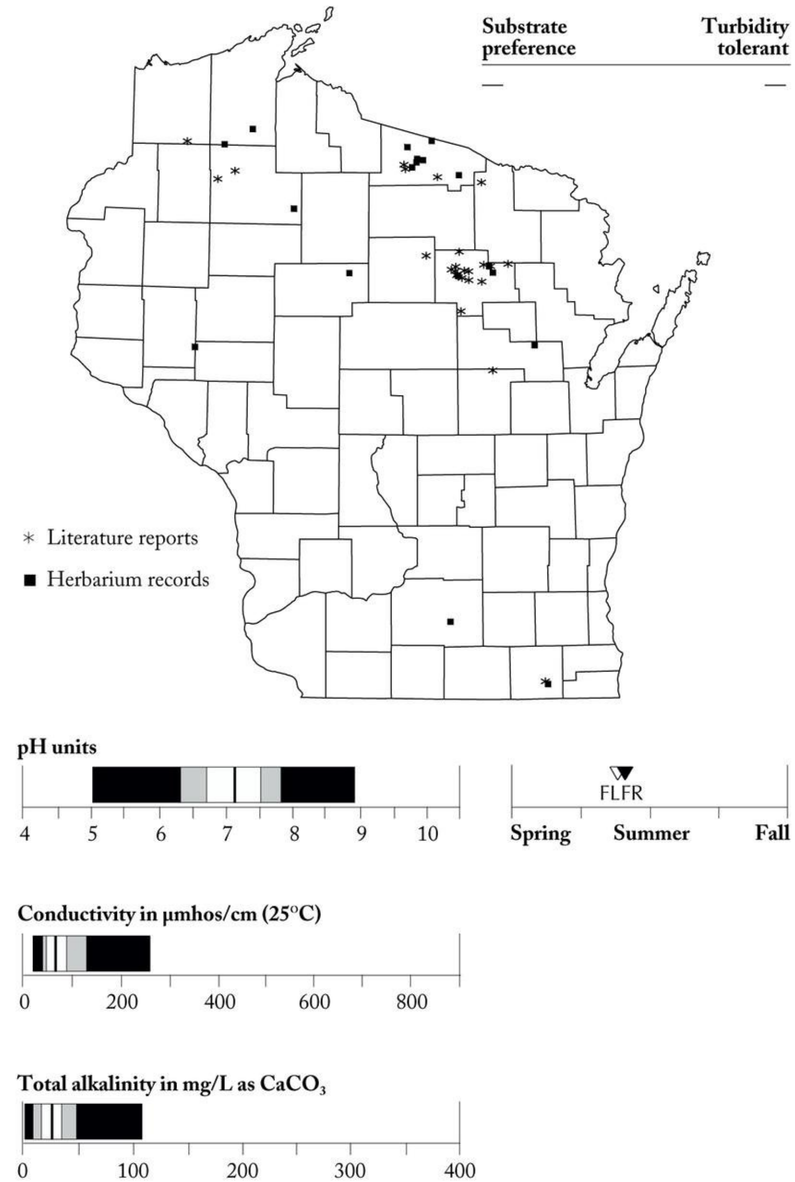
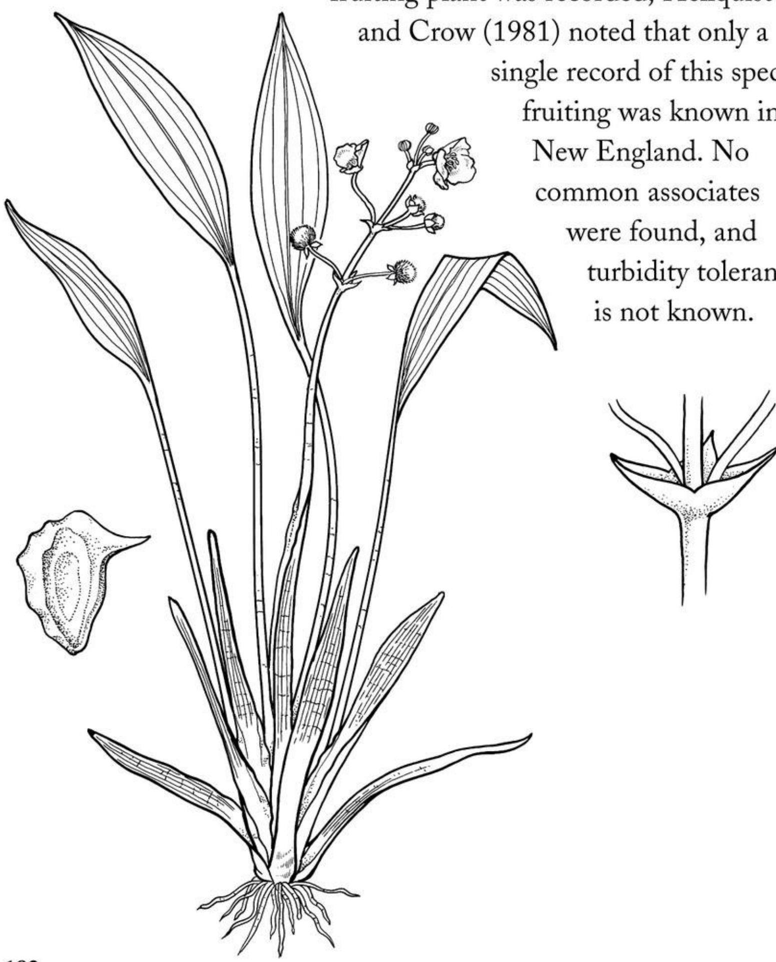


Figure 87. Distribution and habitat characteristics of *Sagittaria cuneata* Sheldon.

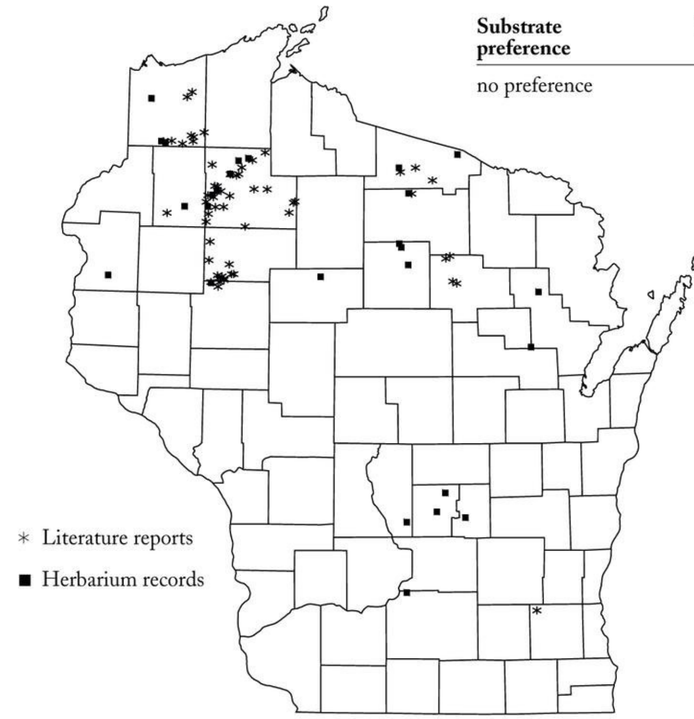
Sagittaria graminea Michx.

An infrequent species, found primarily in northern Wisconsin (fig. 88). It grows in low conductivity, low alkalinity water, and at circumneutral pH. It shows no substrate preference and grows in water depths up to 1.8 m. In Michigan it grows along exposed shorelines (Voss, 1972). It frequently produces rosettes of stiff, blade-like underwater leaves (Voss, 1972; Hellquist and Crow, 1981). Flowering occurs in midsummer. Fruiting plants are difficult to find. Only one late summer fruiting plant was recorded; Hellquist and Crow (1981) noted that only a single record of this species fruiting was known in New England. No common associates were found, and turbidity tolerance is not known.



grassy arrowhead

Substrate preference	Turbidity tolerant
no preference	—



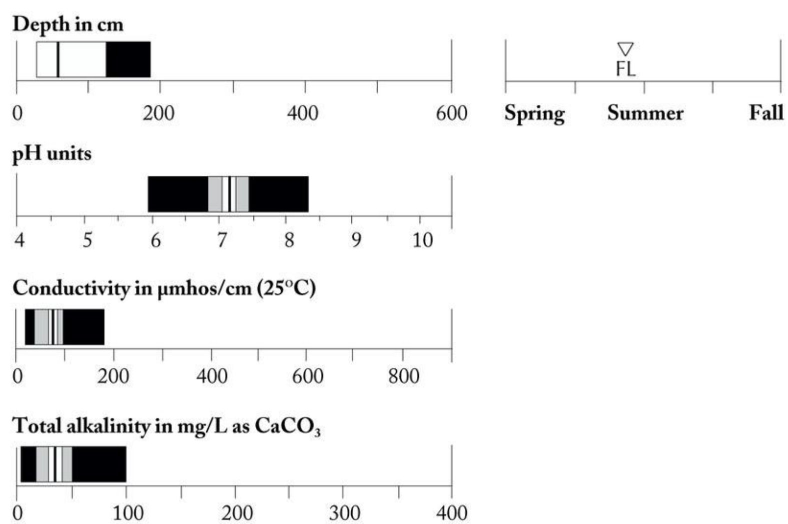
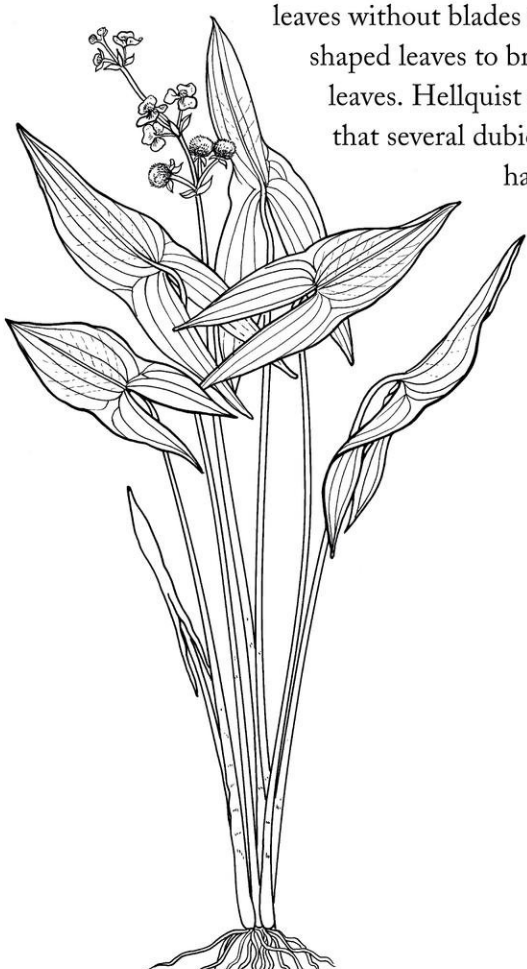
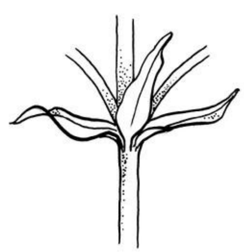


Figure 88. Distribution and habitat characteristics of *Sagittaria graminea* Michx.

Sagittaria latifolia Willd.

An abundant species, found statewide. It grows in water depths to 1.2 m and shows no substrate or turbidity preference (fig. 89). It is found over broad pH and alkalinity ranges and a moderate conductivity range. Flowering and fruiting occur in middle to late summer. Common associates include *Elodea candensis, Lemna minor, Nymphaea odorata, Potamogeton crispus, P. foliosus, P. vaginatus,* and *Typha latifolia.* The erect leaves on this species are extremely variable, ranging from narrow leaves without blades to narrow arrowhead-shaped leaves to broad arrowhead-shaped leaves. Hellquist and Crow (1981) noted that several dubious varieties and forms have been based on leaf shape, but all these leaves can be found on the same plant.





common arrowhead

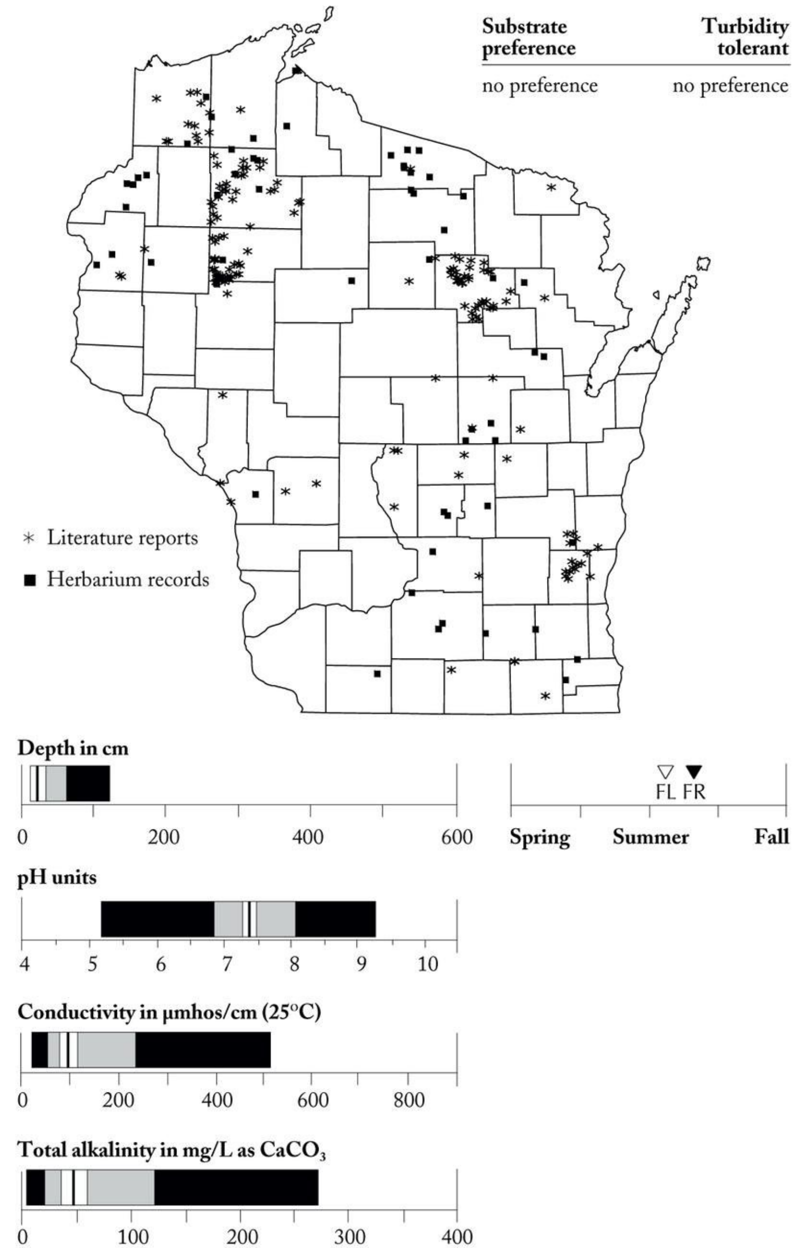
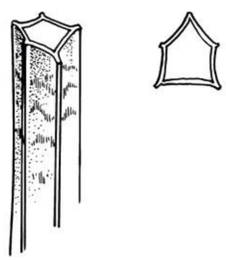


Figure 89. Distribution and habitat characteristics of *Sagittaria latifolia* Willd.

Sagittaria rigida Pursh

An infrequent species, found most commonly in northern Wisconsin (fig. 90). It grows in water depths up to 1.8 m deep, prefers soft substrate, and is turbidity tolerant. It is found over a moderate pH range and over limited conductivity and alkalinity ranges. It flowers in midsummer. The only two fruiting plants were found in late summer. Common associates include *Brasenia schreberi*, *Ceratophyllum echinatum*, *Dulichium arundinaceum*, *Lemna minor*, *Nymphaea odorata*, *Polygonum amphibium*, *Sparganium chlorocarpum*, and *Utricularia vulgaris.*



stiff arrowhead

Substrate preference	Turbidity tolerant
soft	yes

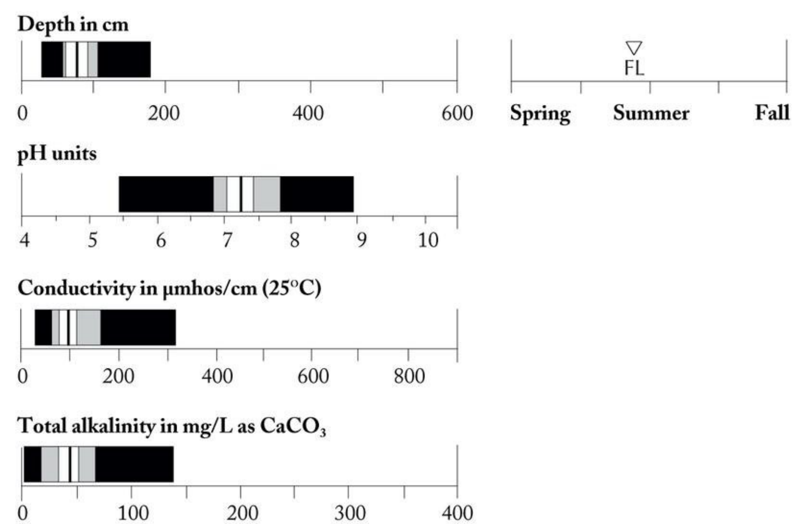
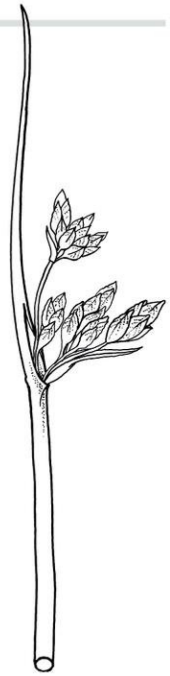


Figure 90. Distribution and habitat characteristics of *Sagittaria rigida* Pursh.

Scirpus acutus Muhl.

hardstem bulrush



A common species, found in northern and eastern Wisconsin lakes (fig. 91). It may be confused with *S. validus,* but a pinch on the stem to test whether it is hard stemmed (*S. acutus)* or soft stemmed (*S. validus*) is useful to separate the two species. Intermediate hybrids can be found in areas where the two species grow together. *Scirpus acutus*, not as common as *S. validus*, is found over narrower pH, alkalinity, and conductivity ranges; its median pH, alkalinity, and conductivity are also lower than those of *S. validus. Scirpus acutus* produces fruit by midsummer. Depth distribution, substrate preference, common associates, and flowering time are unknown. Voss (1972) reported that it usually grows in water to about 1.5 m, but culms as long as 4.3 m have been collected in deep water. This plant can be found growing on sand, gravel, marl, or peat, and it may grow in pure stands or with other emergent species such as *Phragmites australis*, *S. americanus, S. validus,* and *Typha* spp. Tolerance of alkali conditions (Gleason and Cronquist, 1991) could not be confirmed by the Wisconsin distribution.

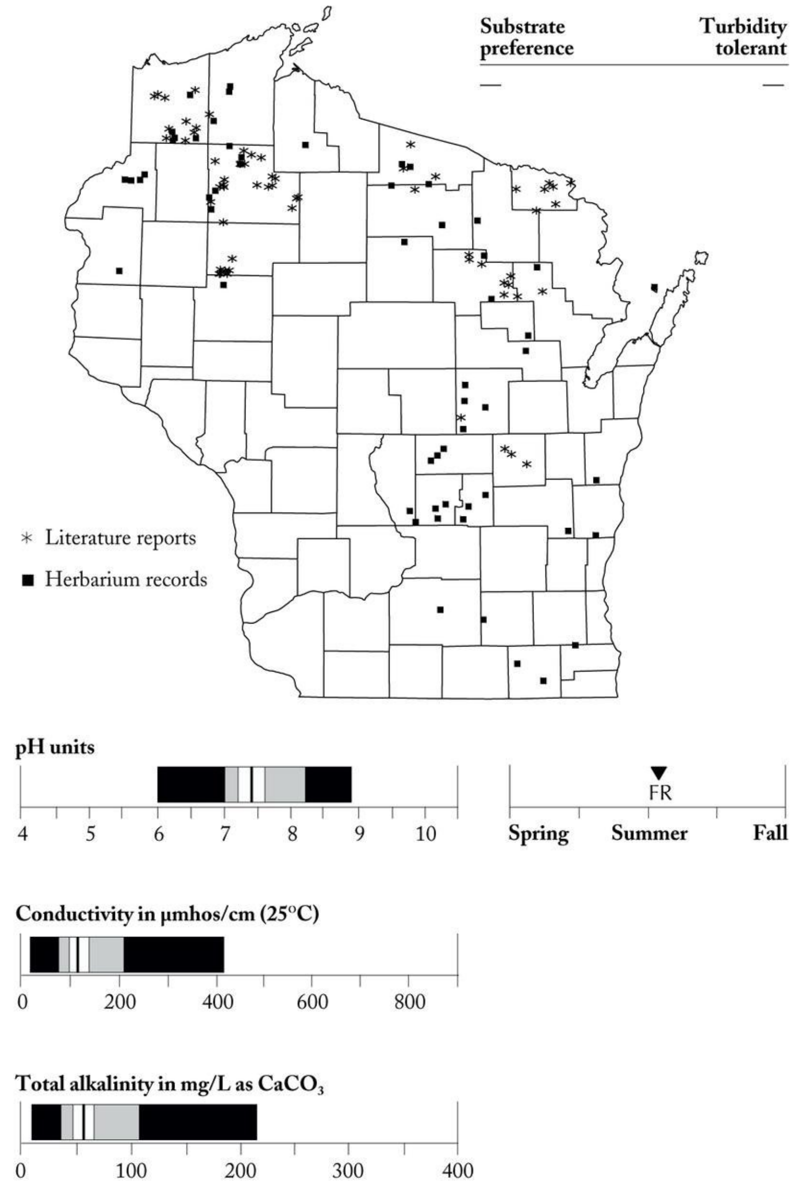
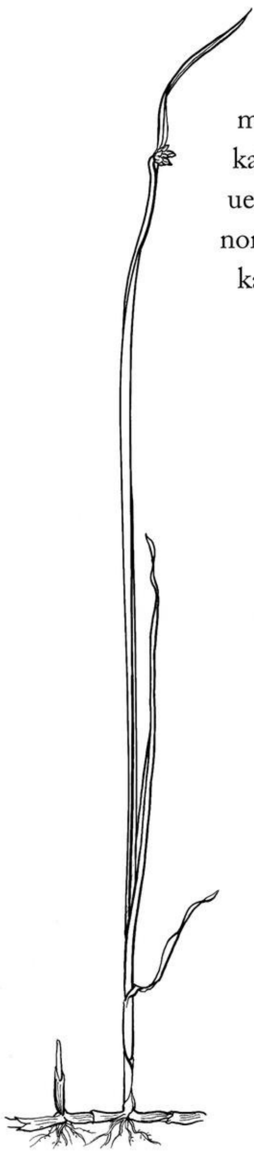
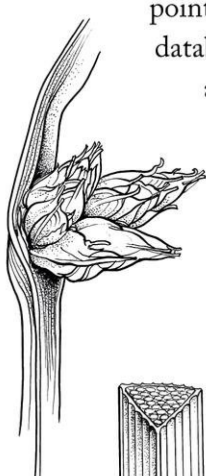
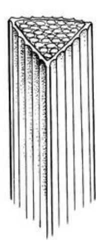


Figure 91. Distribution and habitat characteristics of *Scirpus acutus* Muhl.

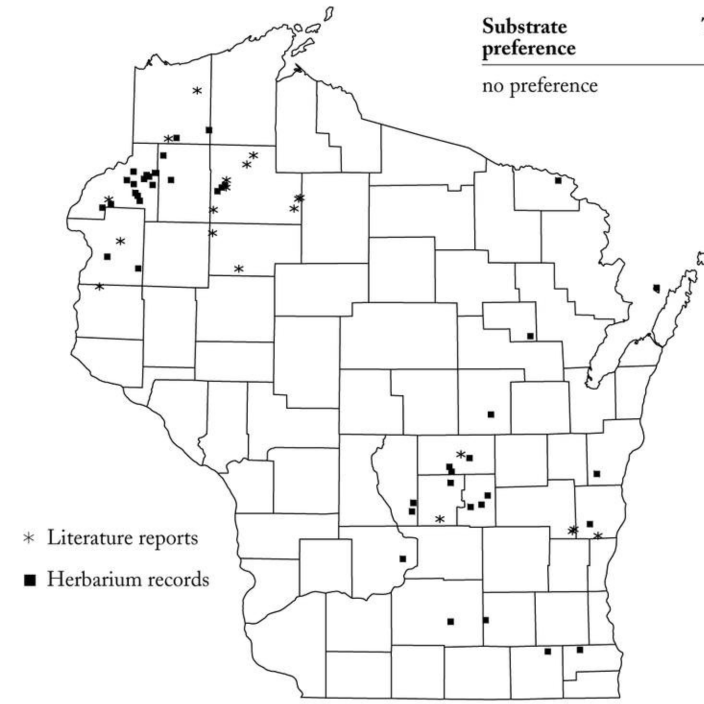
An infrequent species, found in southeastern and northwestern Wisconsin, but not reported in north-central Wisconsin (fig. 92). A similar distribution was found by Greene (1953), who reported this species grew in hard-water lakes. The median pH of the lakes in which *S. americanus* was found is higher than for many other species, but the conductivity and alkalinity ranges is only moderate and median values are not high. Some distribution points in northwestern Wisconsin were in areas where alkalinity was less than 15 mg/L as $CaCO_3$ and calcium and magnesium concentrations were low. However, only two points, both from the literature database, were found that showed all three parameters were low. *Scirpus americanus* is found in water depths to 1.8 m, shows no substrate preference, is found more often in clear water lakes, and flowers in midsummer. No common associates were found. This species may be undercollected in the state or may be more common than its occurrence in lakes indicates—Voss (1972) believed it to be one of the most common bulrushes in Michigan.







Substrate preference	Turbidity tolerant
no preference	no



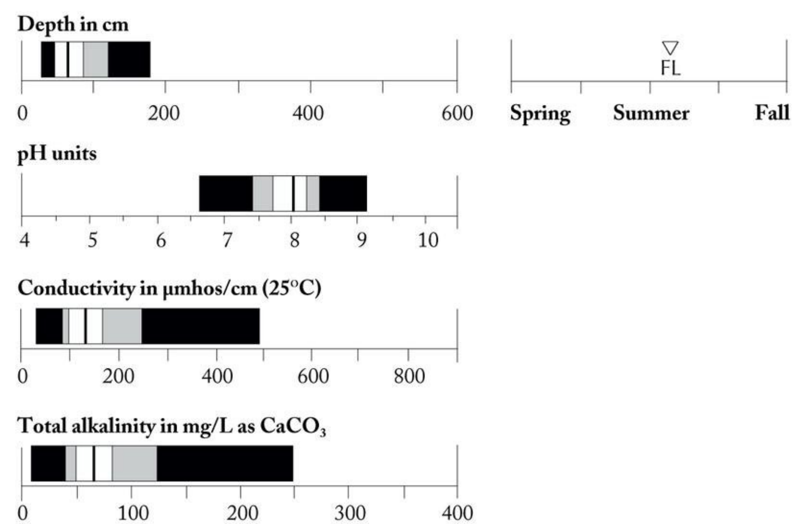
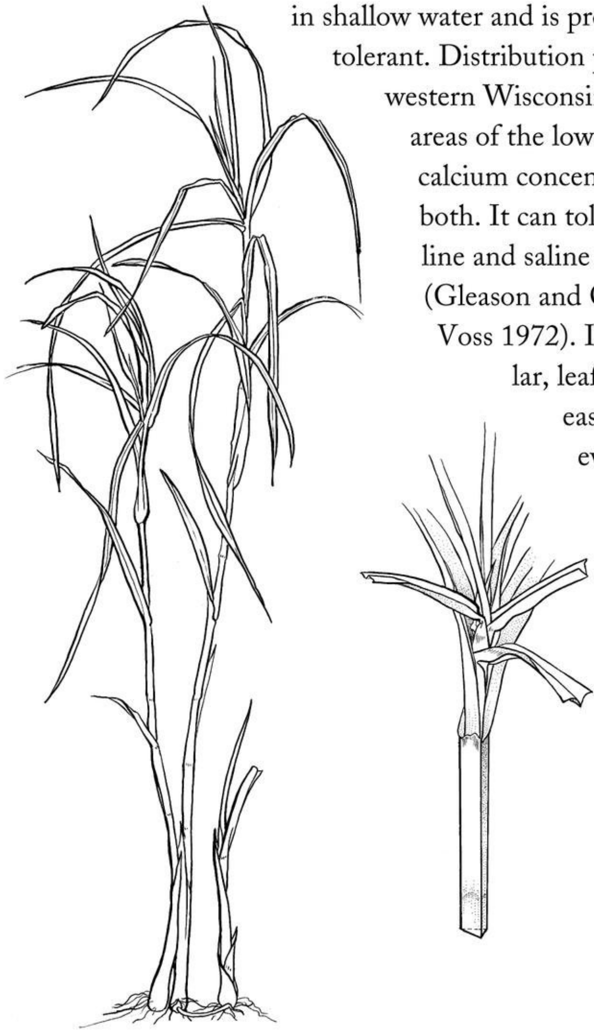


Figure 92. Distribution and habitat characteristics of *Scirpus americanus* Pers.

Scirpus fluviatilis (Torr.) A. Gray

An infrequent species, generally found in southern and western Wisconsin (fig. 93). It grows over a broad alkalinity range and moderate conductivity and pH ranges. It flowers in midsummer. Depth distribution, substrate preference, turbidity tolerance, fruiting date, and common associates were not determined. Because it is an emergent, it is found in shallow water and is probably turbidity tolerant. Distribution points in northwestern Wisconsin were found in areas of the lowest alkalinity or calcium concentrations, but not both. It can tolerate highly alkaline and saline conditions (Gleason and Cronquist, 1991; Voss 1972). Its sharply triangular, leafy stem makes it easily recognizable, even when it is sterile.



river bulrush

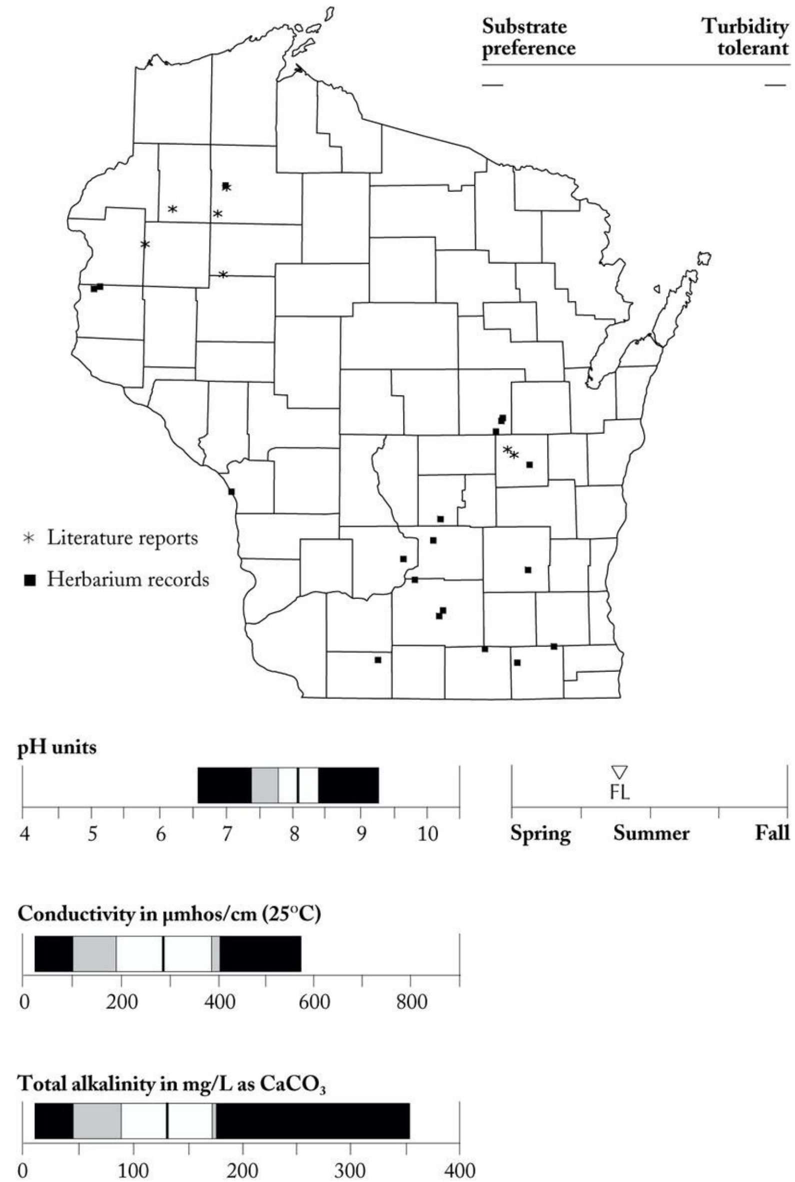
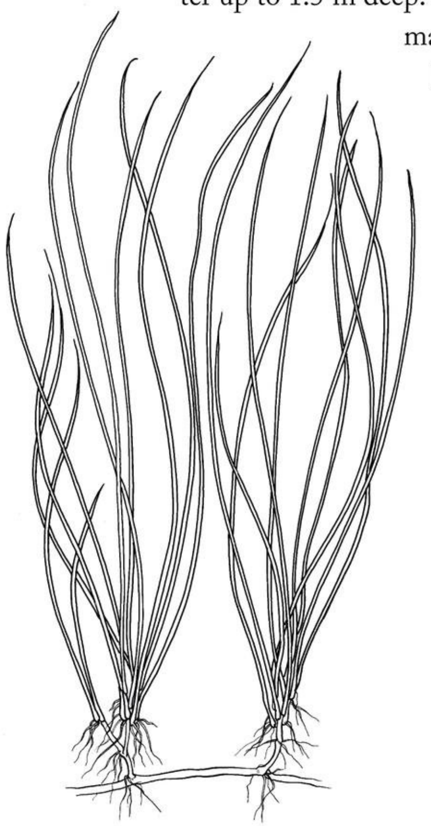
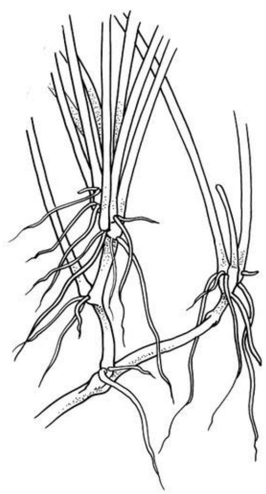


Figure 93. Distribution and habitat characteristics of *Scirpus fluviatilis* (Torr.) A. Gray.

Scirpus subterminalis Torr.

An infrequent species, found in northwestern and eastern Wisconsin (fig. 94). It has not been reported in the northeast region of Vilas, Oneida, Florence, and Forest Counties, where calcium concentration and alkalinity are the lowest in the state. It is found over a moderate range of pH, conductivity, and alkalinity conditions. Depth distribution, substrate preference, turbidity tolerance, common associates, and flowering and fruiting dates are unknown. Voss (1972) reported that it is usually submersed, except for the tip of the fertile culm in water up to 1.5 m deep. It is found growing on sand, marl, muck, or peat, and the hair-like submersed leaves can form grass-like beds. It may grow in the same places as *Eleocharis robbinsii.*





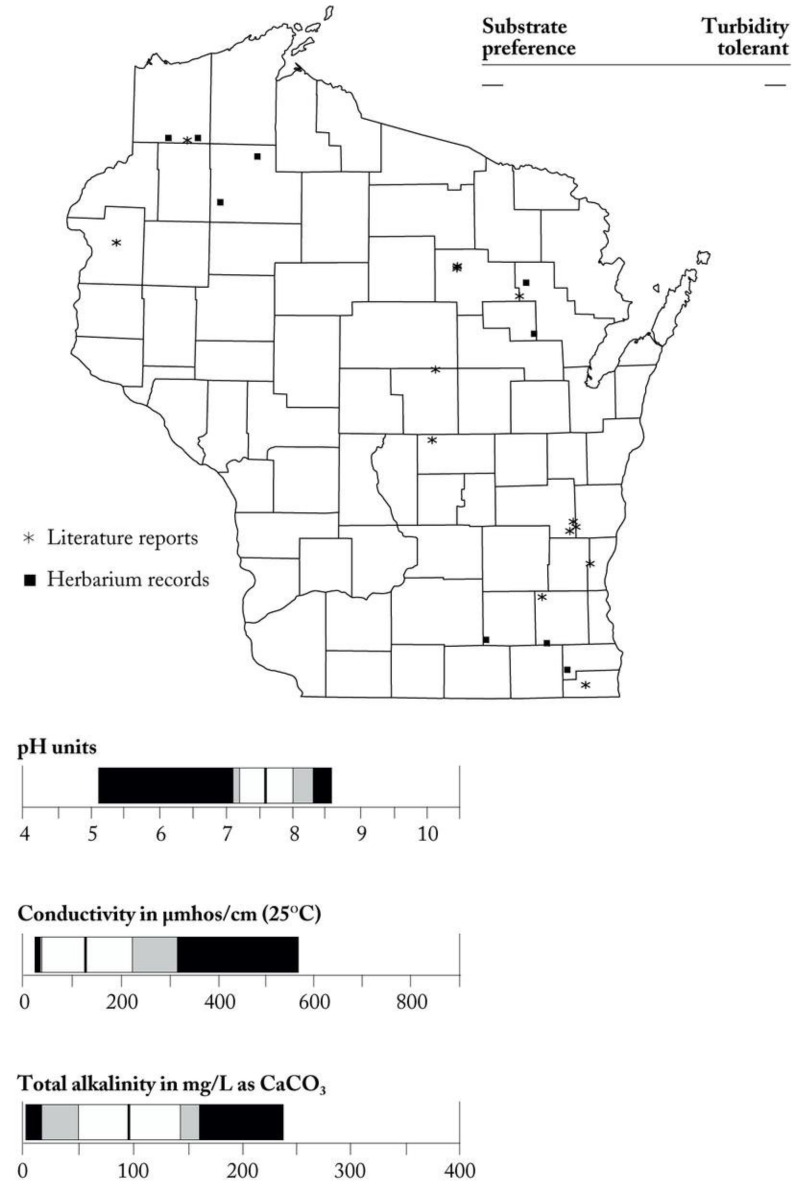
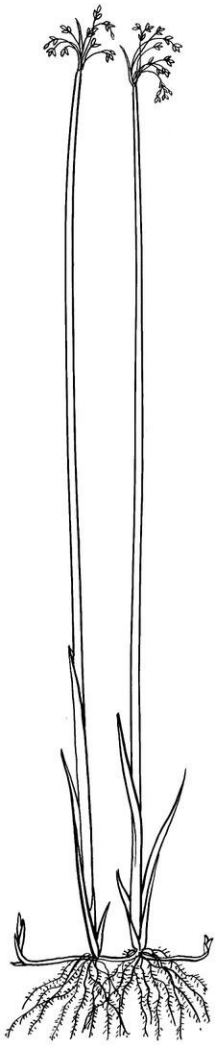
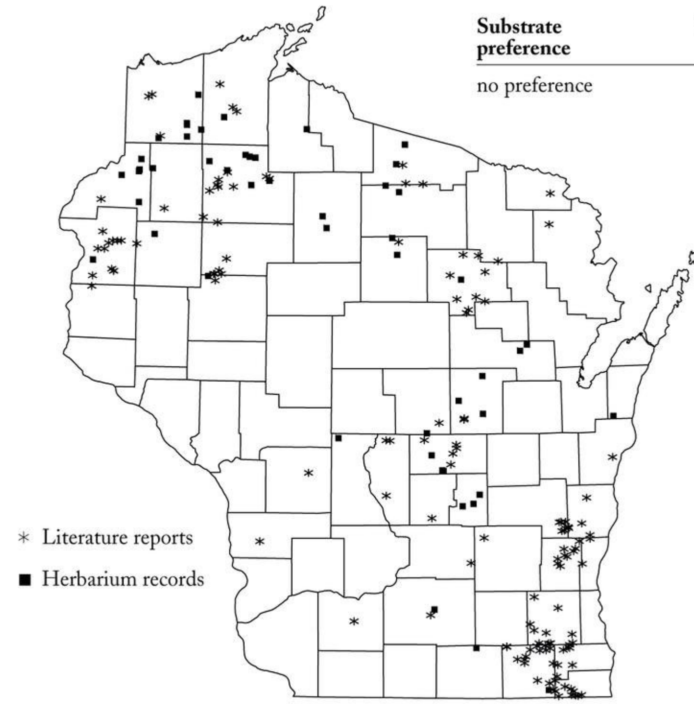


Figure 94. Distribution and habitat characteristics of *Scirpus subterminalis* Torr.

A common species statewide, found over a broad range of pH, conductivity, and alkalinity conditions (fig. 95). It is found in water to 1.5 m deep, shows no substrate preference, and does not commonly grow in turbid water. Flowering occurs in mid-summer. *Scirpus validus* is usually associated with *Chara* spp. and showed strong negative association with *Ceratophyllum demersum, Elodea canadensis, Myriophyllum sibiricum, Potamogeton praelongus, P. robbinsii, P. zosteriformis,* and *Vallisneria americana.* It may form large, monospecific stands. See *S. acutus* for a discussion of the similarities and differences between the two species.



Substrate preference	Turbidity tolerant
no preference	no



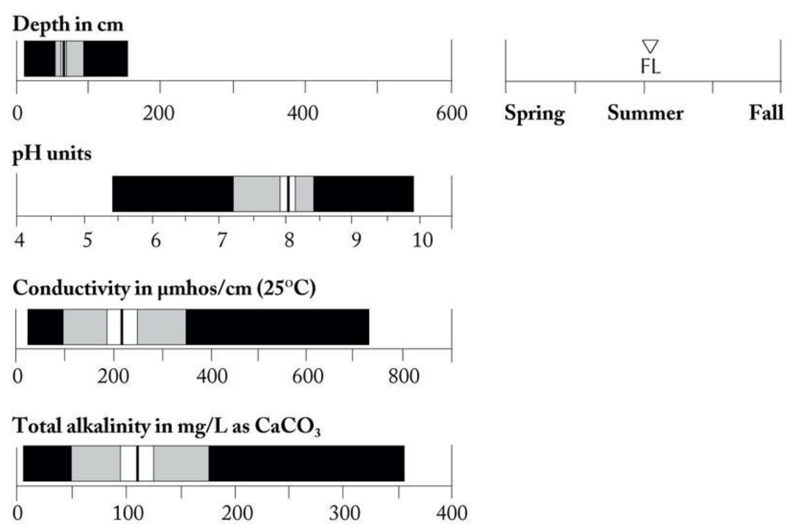
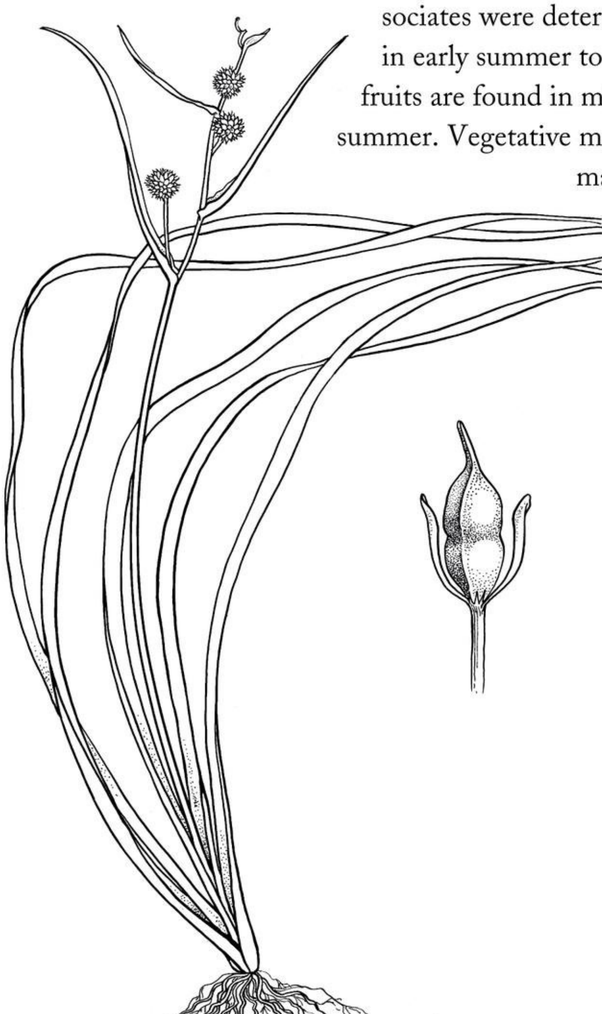


Figure 95. Distribution and habitat characteristics of *Scirpus validus* Vahl.

An infrequent species, found in low conductivity, low alkalinity water in the Northern Lakes and Forests Ecoregion (fig. 96). It is usually found in water less than 1.5 m deep, over a broad pH range, and in the areas of the lowest chloride and sulfate concentrations. All distribution points but one were in an area where magnesium concentration was less than 10 mg/L. No substrate preference, turbidity tolerance, or common associates were determined. It flowers in early summer to midsummer, and fruits are found in middle to late summer. Vegetative material is normally easily recognized by its long, very narrow floating leaves (Voss, 1972).



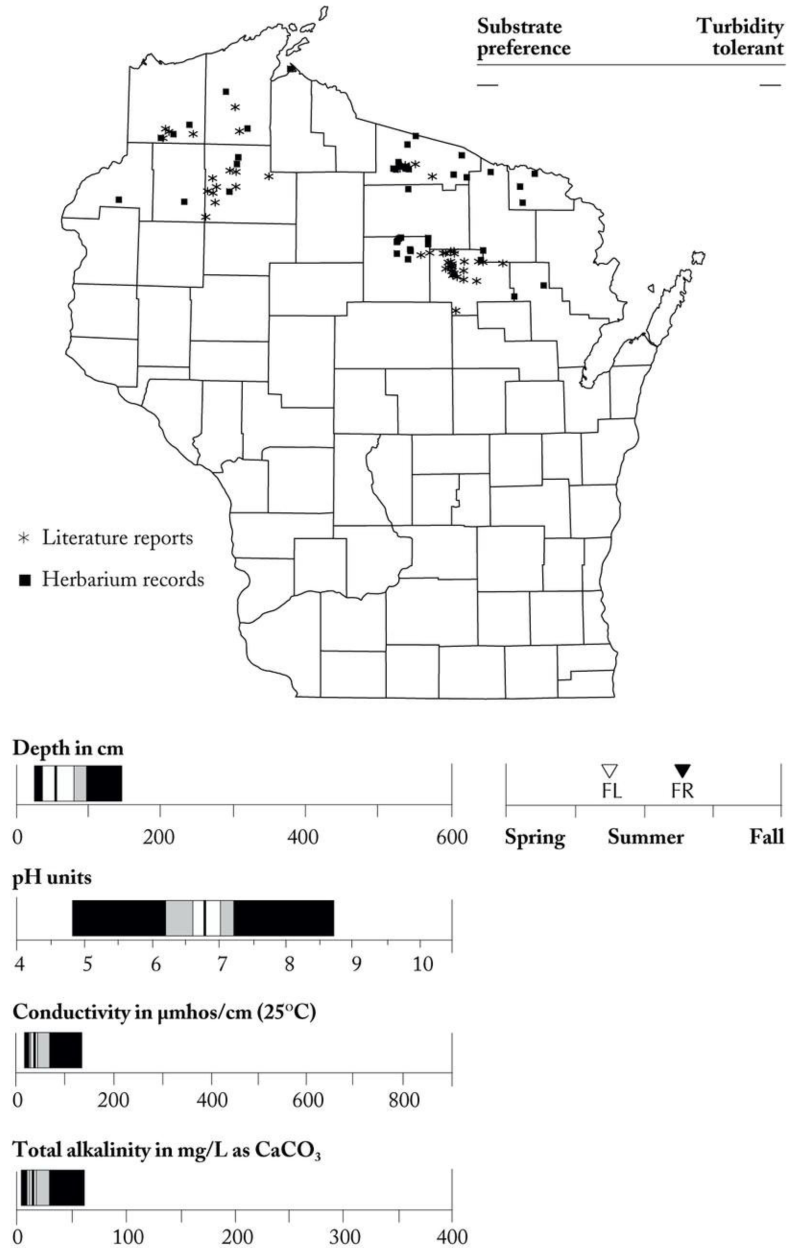
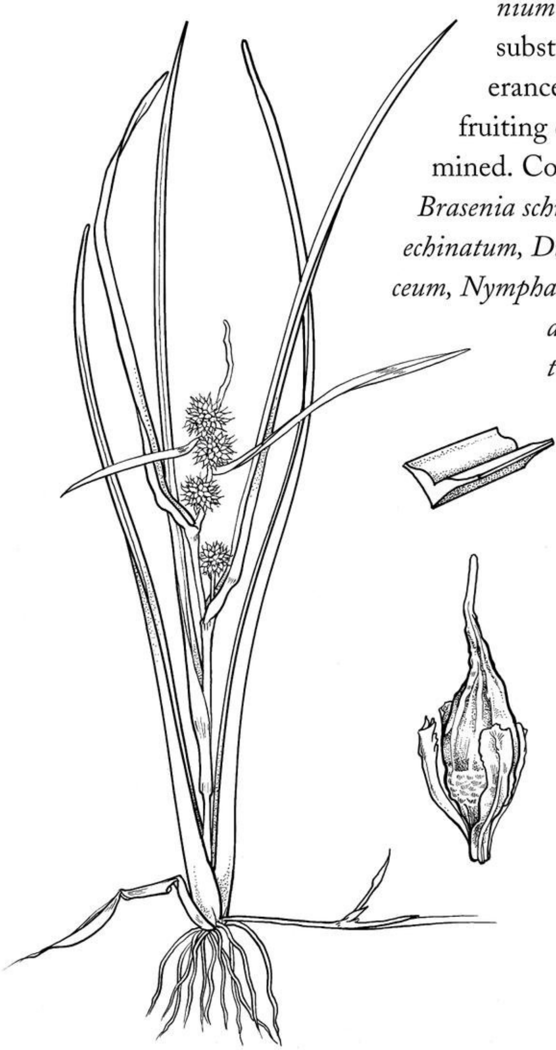


Figure 96. Distribution and habitat characteristics of *Sparganium angustifolium* Michx.

Sparganium chlorocarpum Rydb.

An infrequent species, primarily in the Northern Lakes and Forests Ecoregion (fig. 97). It is found over a broader alkalinity and conductivity range than *S. fluctuans* or *S. angustifolium,* but not as broad as *S. eurycarpum.* It generally grows in the areas of the lowest magnesium and sulfate concentrations. It can also be found in deeper water than any of the other three *Sparganium* species. It prefers soft substrate, but turbidity tolerance and flowering and fruiting dates were not determined. Common associates are *Brasenia schreberi, Ceratophyllum echinatum, Dulichium arundinaceum, Nymphaea odorata, Polygonum amphibium, Potamogeton natans, P. pusillus, Sagittaria rigida,* and *Utricularia vulgaris.* Floating plants are often confused with *S. angustifolium* (Crow and Hellquist, 1981). The strongly two-ranked leaves can aid field identification (Voss, 1972).



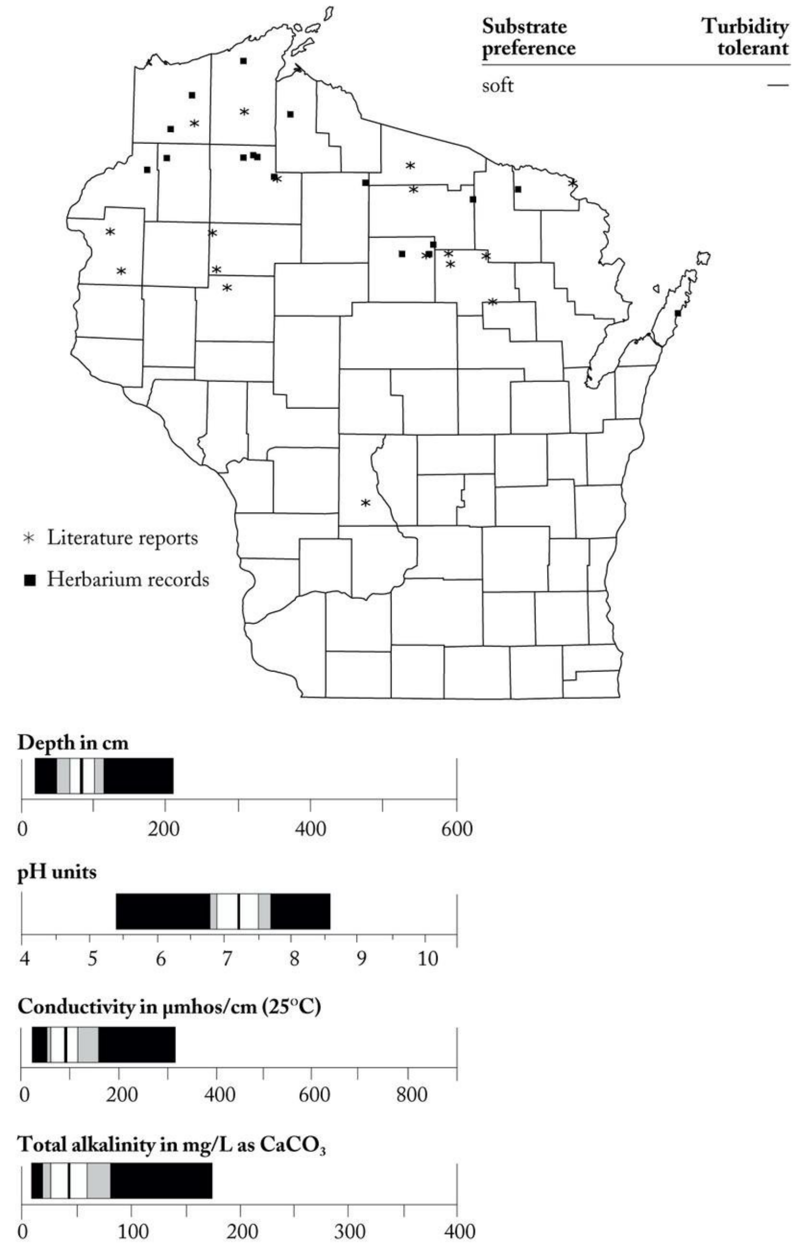


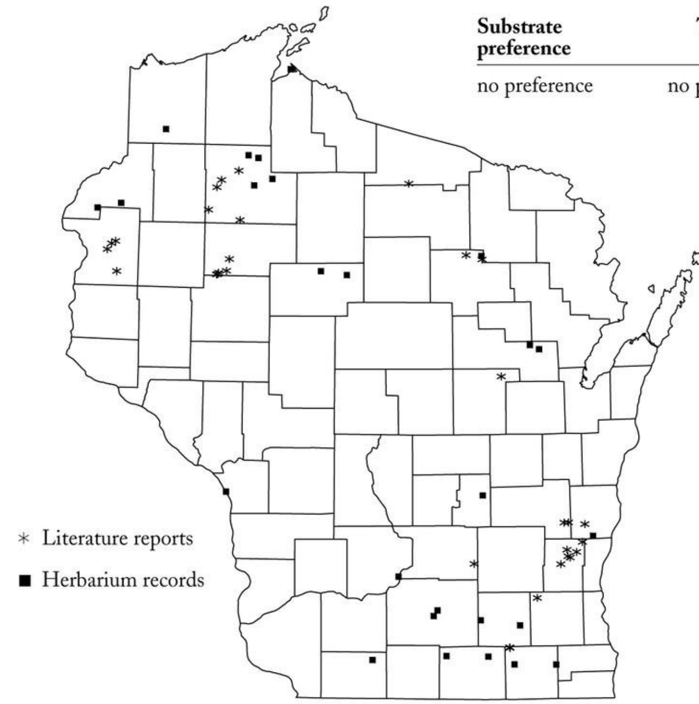
Figure 97. Distribution and habitat characteristics of *Sparganium chlorocarpum* Rydb.

Sparganium eurycarpum Engelm.

The most common bur-reed in the state (fig. 98), but found infrequently in shallow water around the state. In contrast to other *Sparganium* species, it is found over broad and high conductivity and alkalinity ranges. Its pH range is moderate. It shows no substrate or turbidity preference. Flowering and fruiting dates and associated species were not established.

common bur-reed

Substrate preference	Turbidity tolerant
no preference	no preference



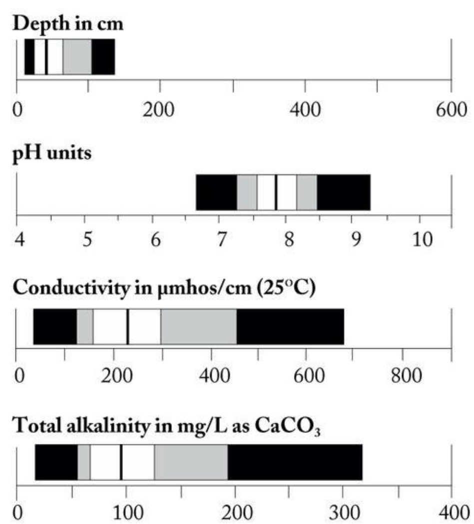


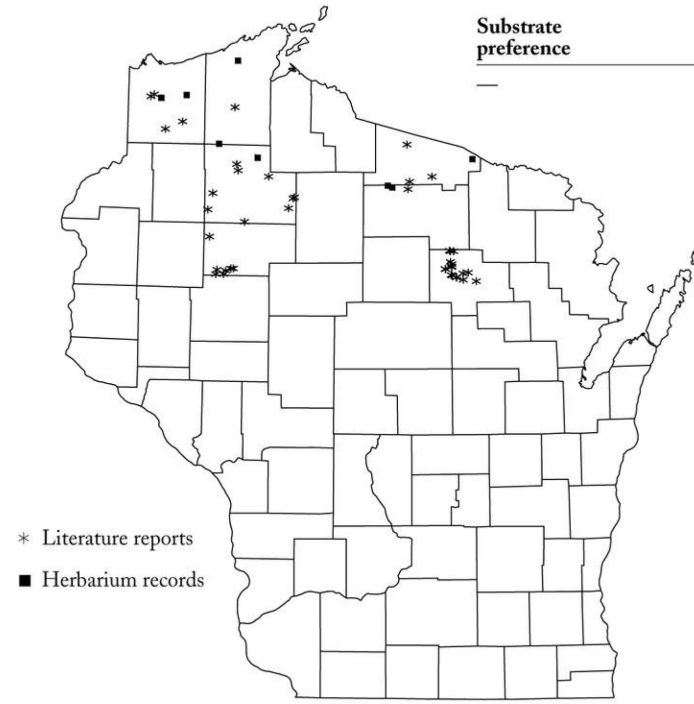
Figure 98. Distribution and habitat characteristics of *Sparganium eurycarpum* Engelm.

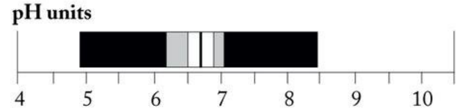
Sparganium fluctuans (Morong) Robinson

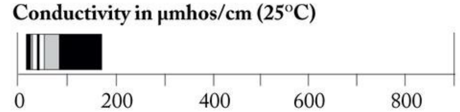
Found infrequently in low alkalinity, low conductivity water in the Northern Lakes and Forests Ecoregion (fig. 99). It grows in the areas where chloride, sulfate, and magnesium concentrations are the lowest. Voss (1972) reported that it is usually found in water approximately 0.5 m deep in Michigan. No depth distribution, flowering and fruiting dates, substrate preference, turbidity tolerance, or common associates were established. Vegetative material can sometimes be separated from that of other *Sparganium* species by the relatively wide, floating leaves (Voss, 1972).

small-leaf bur-reed

Substrate preference	Turbidity tolerant
—	—







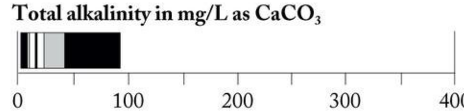
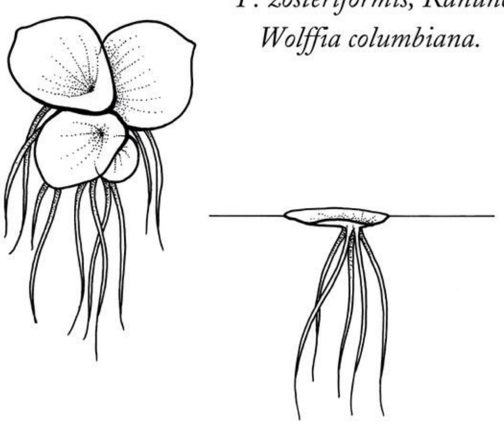


Figure 99. Distribution and habitat characteristics of *Sparganium fluctuans* (Morong) Robinson.

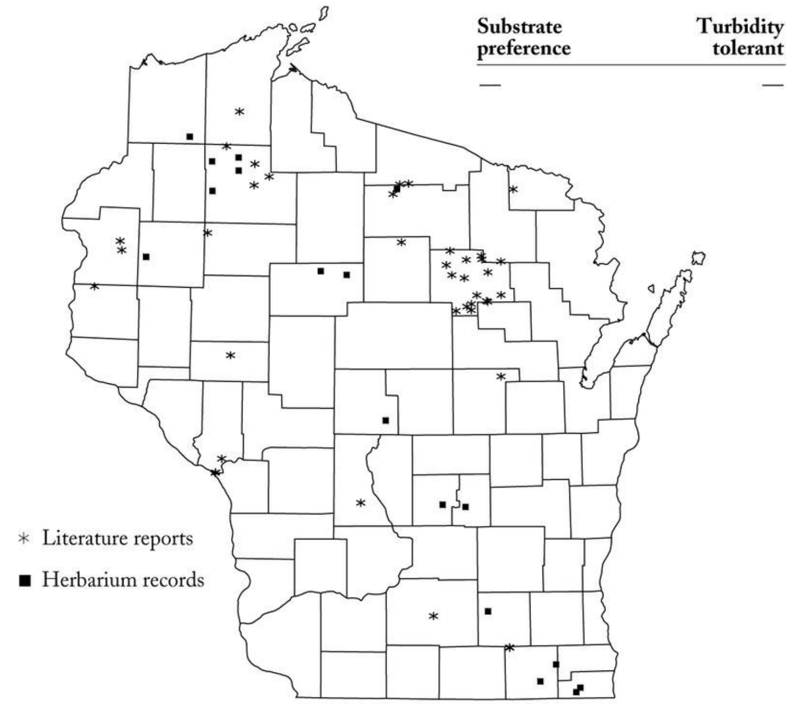
Spirodela polyrhiza (L.) Schleiden

Found statewide (fig. 100). Its small size has probably resulted in its being under-reported and undercollected. Because it is free floating, discussion of depth distribution and substrate preference is not appropriate. It is probably not greatly influenced by turbid water. It is found over moderate ranges of pH and conductivity and a broad range of alkalinity conditions. No flowering or fruiting dates were determined, and none of the material examined had flowers or fruits. Common associates are *Ceratophyllum demersum, Elodea canadensis, Lemna minor, L. trisulca, Nymphaea odorata, Potamogeton diversifolius, P. zosteriformis, Ranunculus longirostris,* and *Wolffia columbiana.*



ACTUAL SIZE

great duckweed



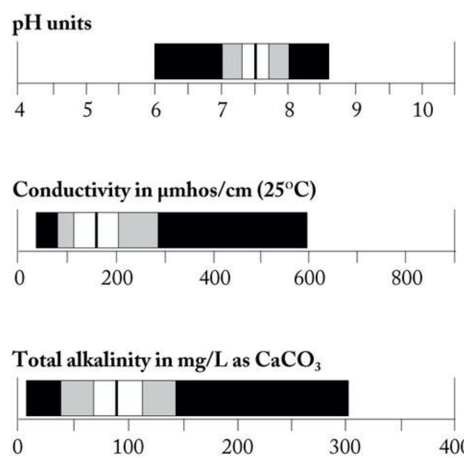
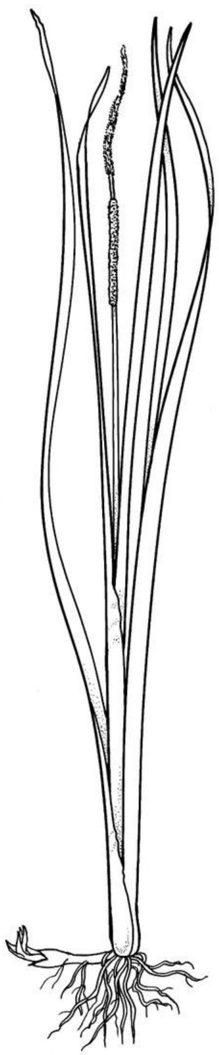


Figure 100. Distribution and habitat characteristics of *Spirodela polyrhiza* (L.) Schleiden.

Typha angustifolia L.

An infrequent species, scattered across the state (fig. 101). Fassett (1930a) first reported this introduced species in Wingra Marsh, Dane County. It is found in water depths to 0.8 m over broad alkalinity and pH ranges and a moderate conductivity range. Its substrate preference and turbidity tolerance were not determined; because it is an emergent, it is probably turbidity tolerant. Flowering and fruiting dates were not calculated, but flowering occurs in early summer. Common associates are unknown. This species is more tolerant of salt and alkali than is *T. latifolia* (Gleason and Cronquist, 1991) and may be spreading in the state.



narrow-leaf cattail

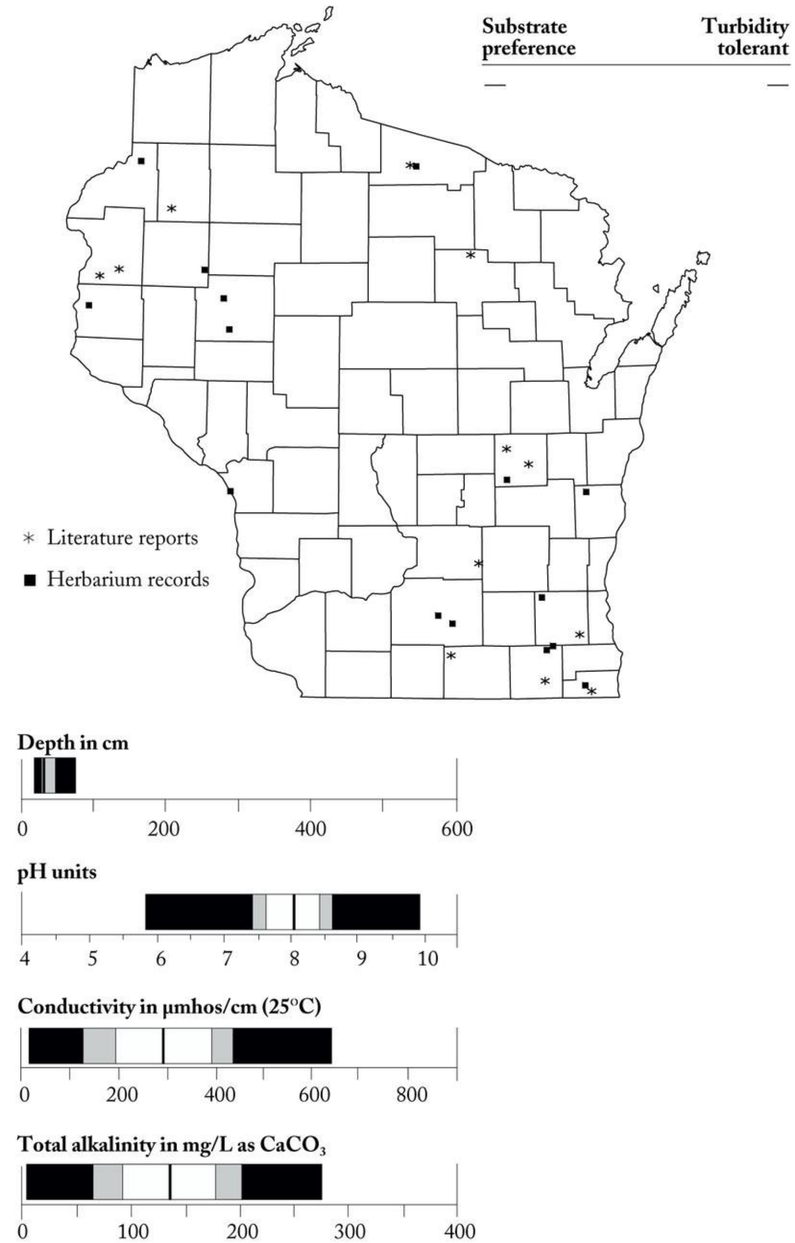
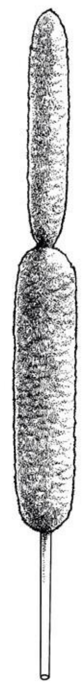
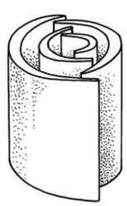


Figure 101. Distribution and habitat characteristics of *Typha angustifolia* L.

Typha latifolia L.

A common species, found statewide in Wisconsin lakes (fig. 102). It can grow over a broad pH range, a moderate alkalinity range, and a limited conductivity range. Its maximum growth depth is about 1.2 m, and it shows no substrate preference. Even though it is emergent, it prefers clear water (Gleason and Cronquist, 1991) and is not turbidity tolerant. Flowering occurs in early summer; fruiting, by midsummer. Common associates include *Elodea canadensis, Lemna minor, Potamogeton crispus, P. foliosus, P. vaginatus,* and *Sagittaria latifolia.* A hybrid between *T. latifolia* and *T. angustifolia,* called *T.* x *glauca* Godr., is also reported in Wisconsin (Fassett, 1930a).





broad-leaf cattail

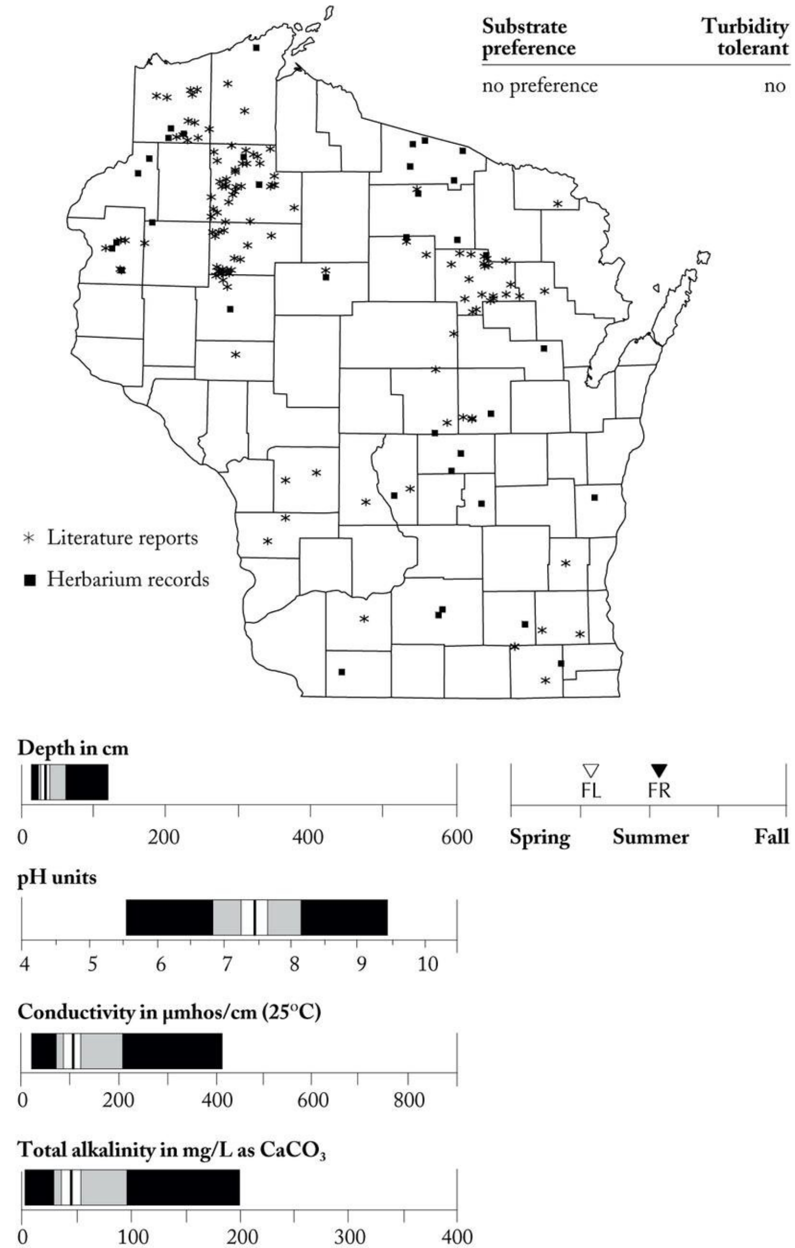
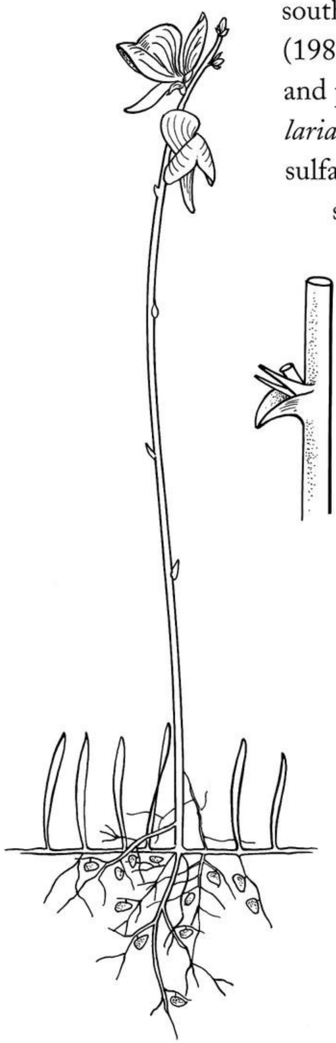


Figure 102. Distribution and habitat characteristics of *Typha latifolia* L.

Utricularia cornuta Michx.

A rare species, but possibly undercollected. It is primarily found in low alkalinity, low conductivity, circumneutral lakes in the Northern Lakes and Forests Ecoregion (fig. 103). Thomson (1940) reported it as common in northern Wisconsin and down the Lake Michigan shoreline. Tans (1987) found this species in calcareous fens and marl flats in southeastern Wisconsin. Crow and Hellquist (1985) reported that it is found along sandy and peaty shores in New England. *Utricularia cornuta* prefers the areas of the lowest sulfate concentration of the region. No substrate preference, turbidity tolerance, depth distribution, or common associates were determined. It is inconspicuous except when flowering, which occurs mainly in August (Tans, 1987); this species does not produce winter buds.



horned bladderwort

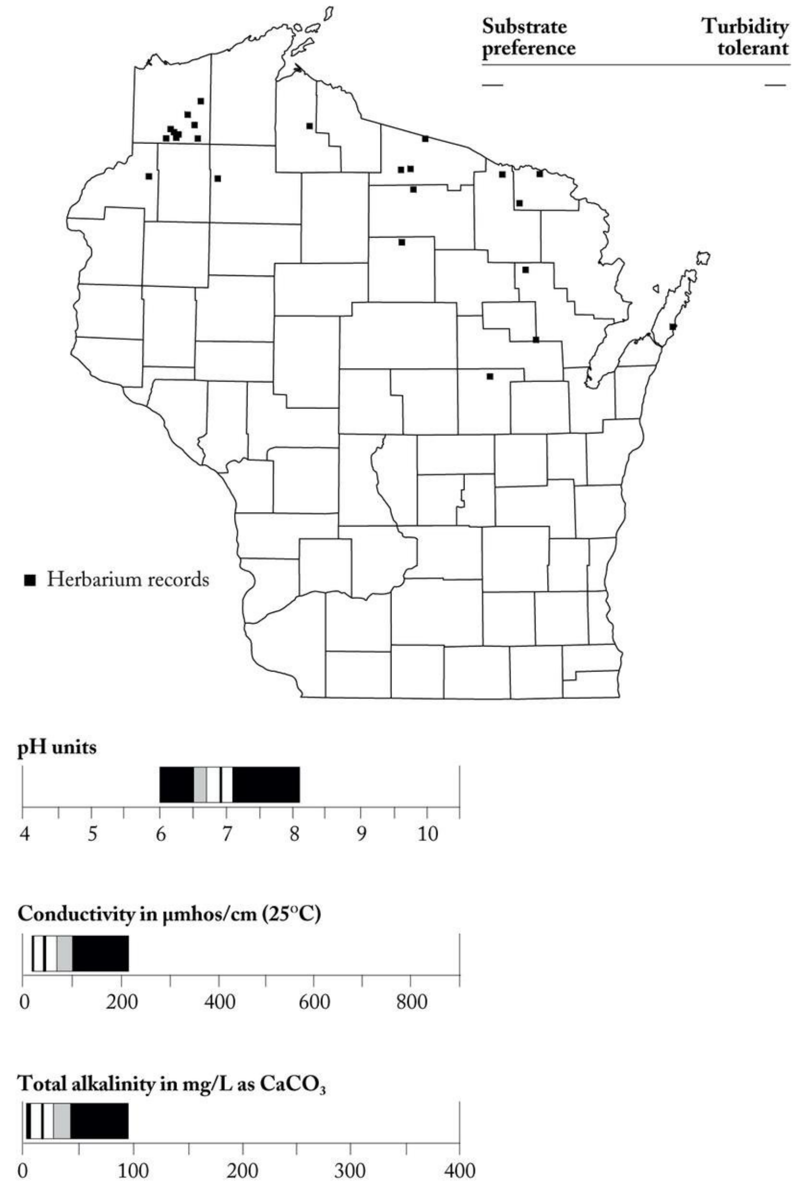
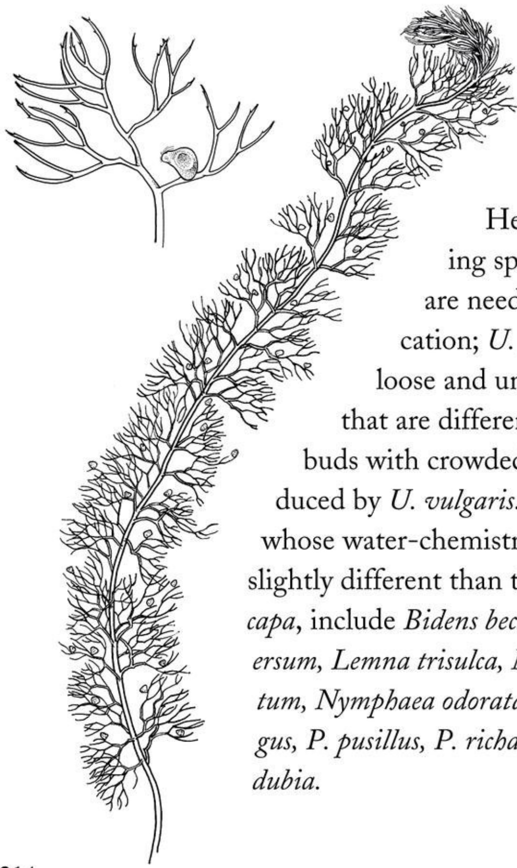


Figure 103. Distribution and habitat characteristics of Utricularia *cornuta* Michx.

Utricularia geminiscapa Benj.

mixed bladderwort

A rare species (fig. 104). Interestingly, except for two points, the distribution of this species follows a band of low sulfate concentration water through the center of the state. Generally, it prefers low alkalinity, low conductivity, and circumneutral pH water, but it is also found over moderate ranges of all three parameters. However, it was collected from Lake Wingra, Dane County, which does not fit this chemistry description, and from calcareous swales in Door County (Tans, 1987). It grows at a median depth of 1.2 m and prefers soft substrate. Flowering and fruiting dates and turbidity tolerance were not determined. This species may be undercollected because it is easily mistaken for a diminutive *U. vulgaris* (Crow and Hellquist, 1985). Flowering specimens, rarely found, are needed for accurate identification; *U. geminiscapa* produces loose and unspecialized winter buds that are different than the tight winter buds with crowded leaf-like branches produced by *U. vulgaris.* Common associates, whose water-chemistry requirements are slightly different than those of *U. geminiscapa*, include *Bidens beckii, Ceratophyllum demersum, Lemna trisulca, Myriophyllum verticillatum, Nymphaea odorata, Potamogeton praelongus, P. pusillus, P. richardsonii,* and *Zosterella dubia.*



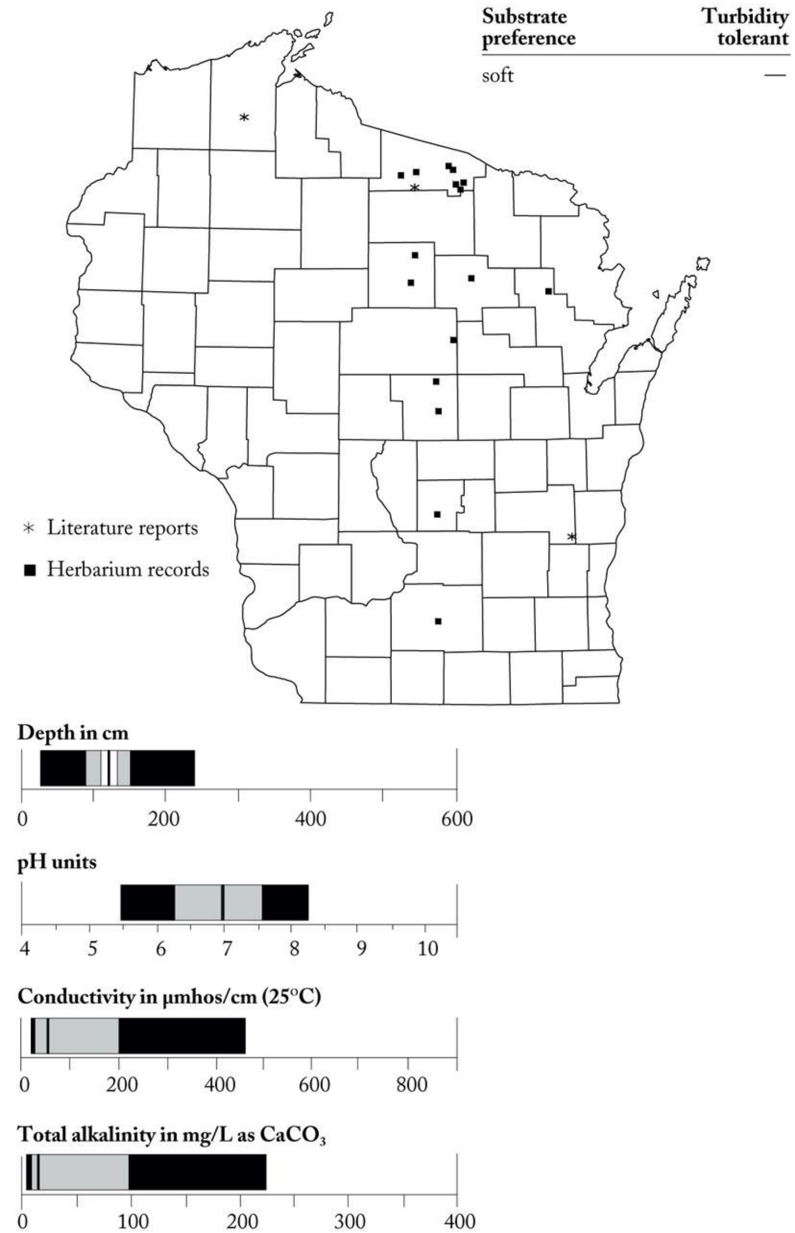
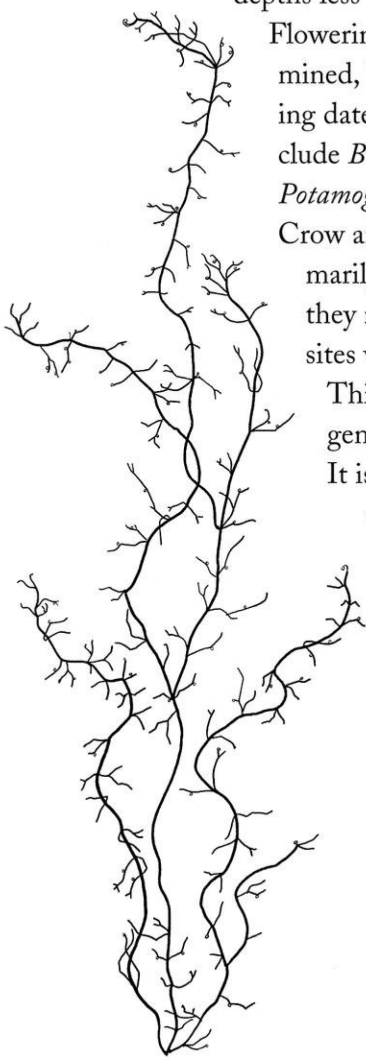
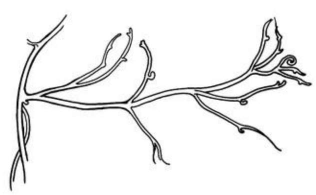


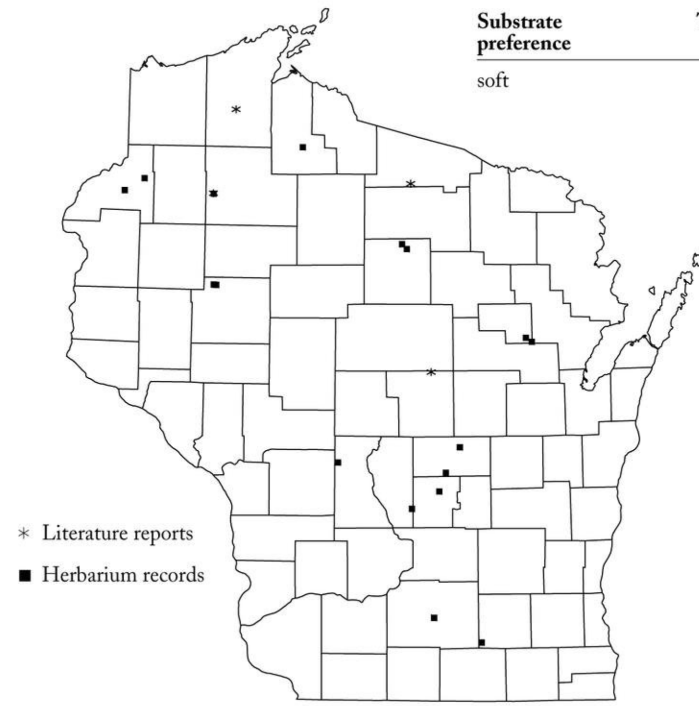
Figure 104. Distribution and habitat characteristics of *Utricularia geminiscapa* Benj.

A rare species, scattered statewide over a moderate pH range, a limited alkalinity range, and a narrow conductivity range (fig. 105). All but two distribution points were in the lowest chloride areas of the state and all but three were in the lowest sulfate areas of the state. *Utricularia gibba* is found in water depths less than 3.8 m and prefers soft substrate. Flowering and fruiting dates were not determined, but Tans (1987) reported most flowering dates in August. Common associates include *Brasenia schreberi, Myriophyllum farwellii, Potamogeton oakesianus,* and *U. intermedia.* Crow and Hellquist (1985) found *U. gibba* primarily on acidic sites in New England, but they noted that it can be found on marly sites westward as well as on sandy shores. This species appears to display this divergence of habitat preference in Wisconsin. It is the most widespread *Utricularia* species found in Wisconsin. *Utricularia gibba* is found in North America, South America, and tropical Africa; one subspecies is known from Spain, Portugal, most of Africa, tropical Asia, and Australia.





Substrate preference	Turbidity tolerant
soft	—



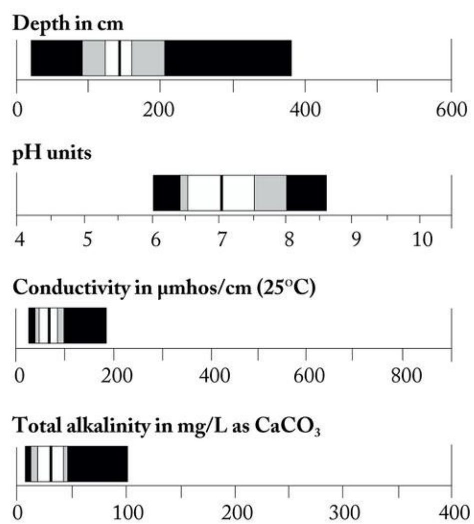
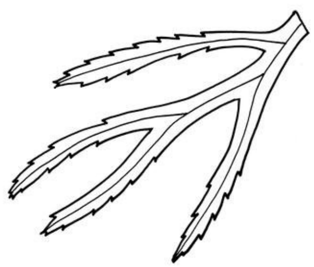


Figure 105. Distribution and habitat characteristics of *Utricularia gibba* L.

Utricularia intermedia Hayne

A rare species, according to lake-occurrence data (fig. 106). However, Thomson (1940) and herbarium specimens indicated it may be more common; Tans (1987) considered it the second most frequent bladderwort in the state. It is found to a depth of 3 m. All but two distribution points were in the low sulfate region of northern and central Wisconsin. *Utricularia intermedia* grows over moderate pH and alkalinity ranges and a limited conductivity range. It prefers soft substrate. Turbidity tolerance and common associates were not established. Tans (1987) reported that flowering was about equally distributed over June, July, and August. This species can overwinter under the ice as a free-floating winter bud.



flat-leaf bladderwort

Substrate preference	Turbidity tolerant
soft	—

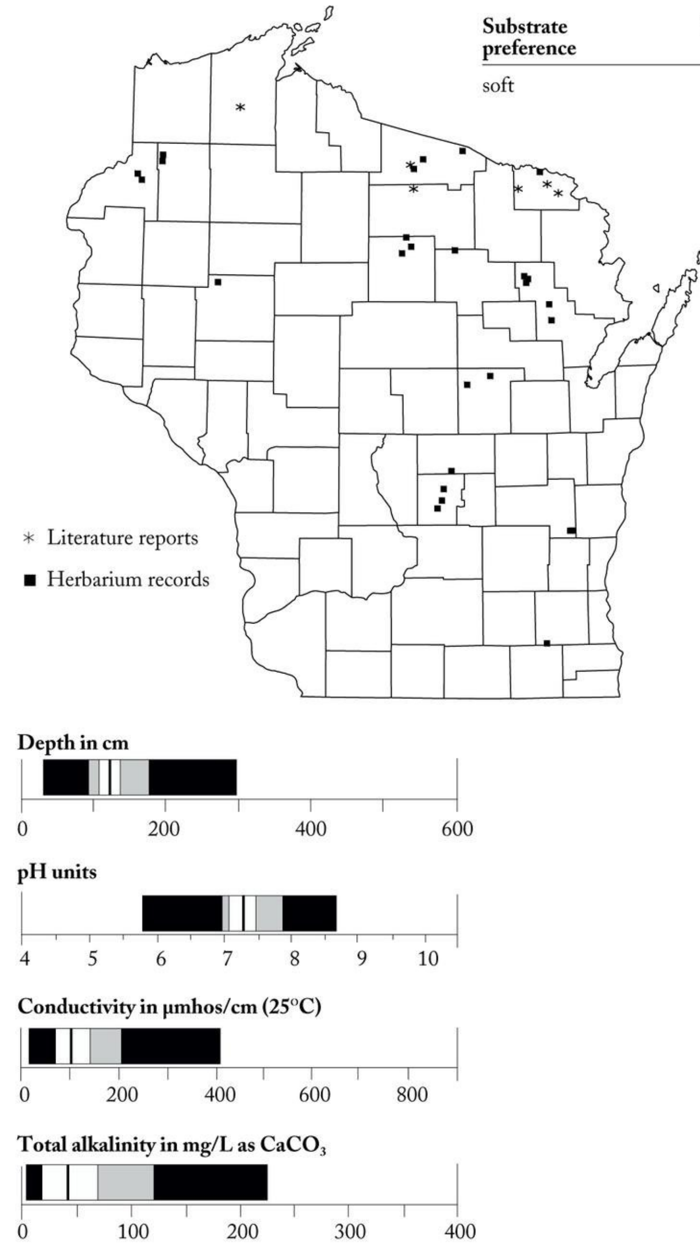
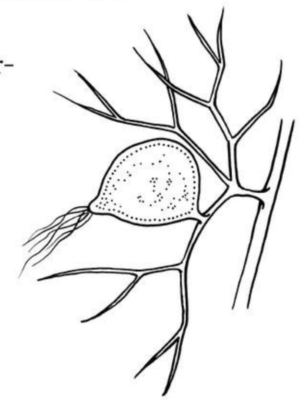


Figure 106. Distribution and habitat characteristics of *Utricularia intermedia* Hayne.

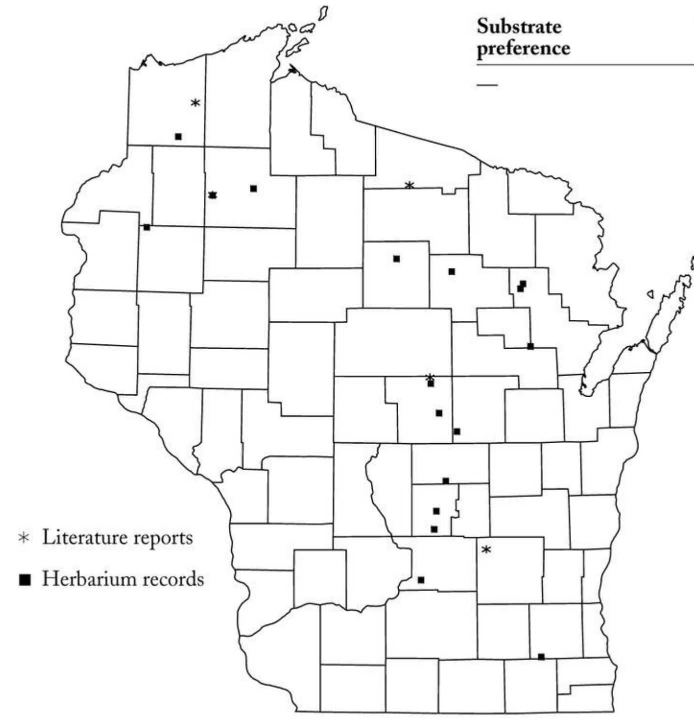
Utricularia minor L.

A rare species, found at scattered locations in Wisconsin lakes (fig. 107). Like some other *Utricularia* species, most distribution points were within the low sulfate water of northern and central Wisconsin. It grows over a limited conductivity range and moderate alkalinity and pH ranges. Tans (1987) also found it in calcareous fens, cold spring seeps, sedge and tamarack bogs, and Great Lakes beach pools and swales in southeastern Wisconsin and in Door County. Depth distribution was not determined, but it is apparently a shallow-water species (Fassett, 1969; Gleason and Cronquist, 1991). Turbidity tolerance, substrate preference, and common associates were also not determined. Tans (1987) found the majority of its flowering dates equally distributed in June, July, and August. It overwinters under the ice as free-floating winter buds. It is easily distinguished from vegetative material by its flattened stem.



small bladderwort

Substrate preference	Turbidity tolerant
—	—



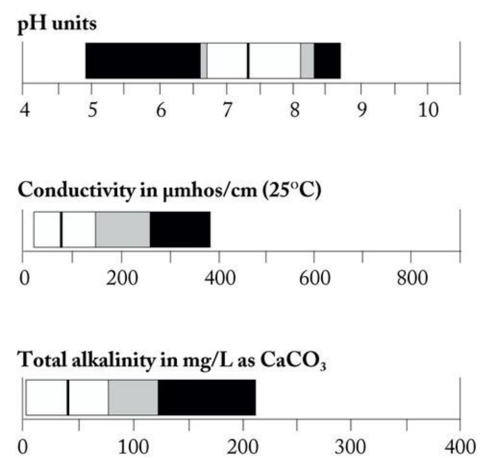
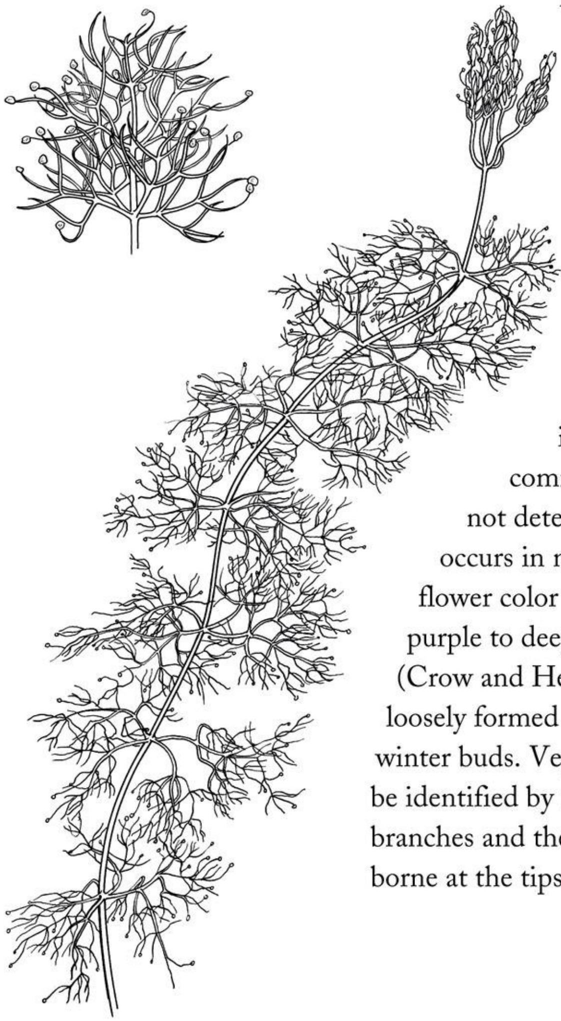


Figure 107. Distribution and habitat characteristics of *Utricularia minor* L.

A rare species, found at scattered locations within the low sulfate water of northern and central Wisconsin (fig. 108). It is found in low alkalinity, low conductivity, and generally low pH lakes in Wisconsin, but it also grows in moderately alkaline water in New England (Crow and Hellquist, 1985). It is probably more common than collection records indicate because it is often sterile and inconspicuous and few botanists venture into the many small bog lakes where it is likely to grow (Tans, 1987). Depth distribution, substrate preference, turbidity tolerance, and common associates were not determined. Flowering occurs in midsummer, and flower color can range from purple to deep pink to white (Crow and Hellquist, 1985). It has loosely formed and unspecialized winter buds. Vegetative material can be identified by the whorled, leaf-like branches and the bladders that are borne at the tips of the branches.



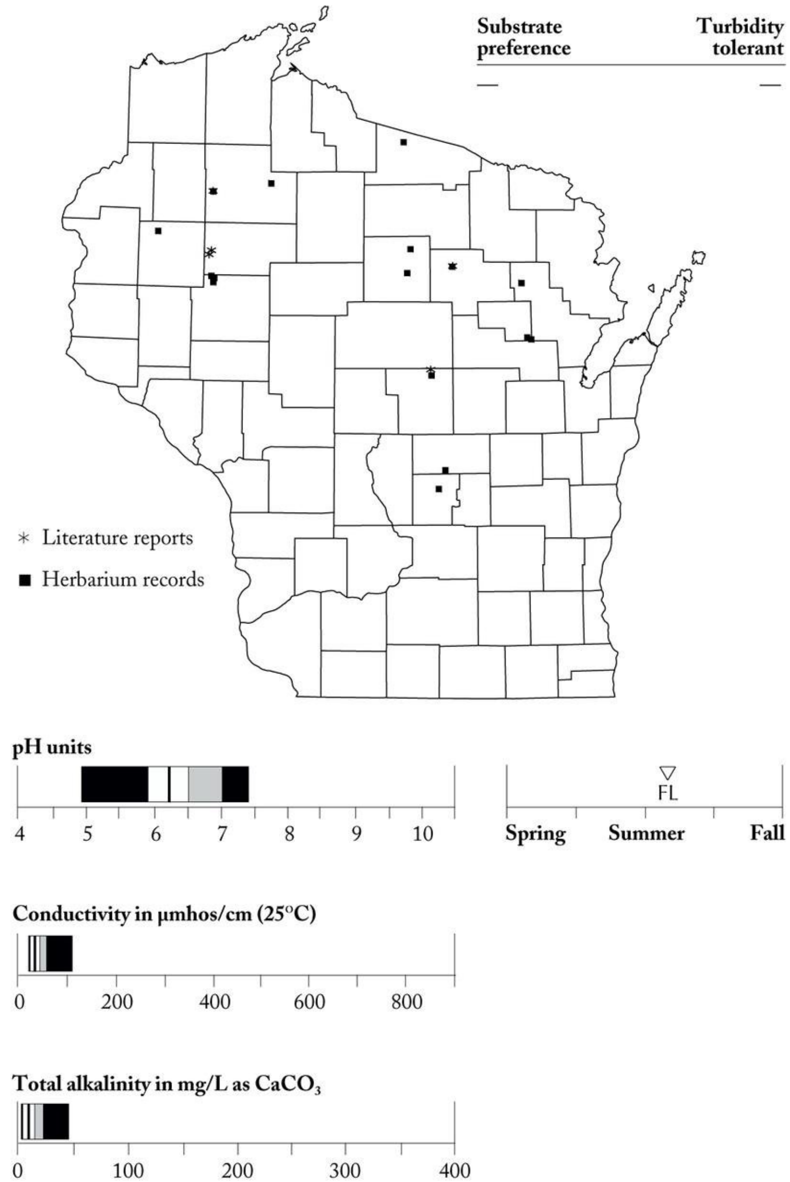
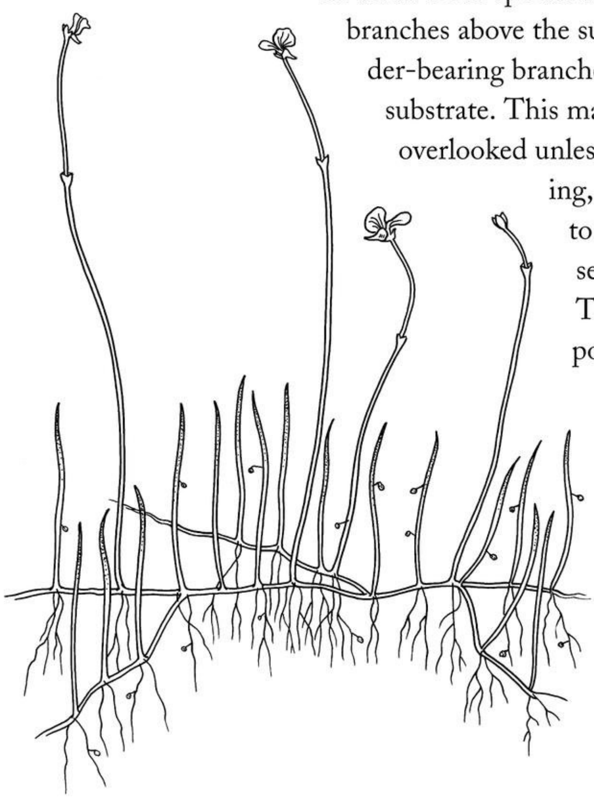


Figure 108. Distribution and habitat characteristics of *Utricularia purpurea* Walter.

Utricularia resupinata B.D. Greene

A rare species, scattered over the state (fig. 109). It is found in low alkalinity, low conductivity water and over a moderate but acid pH range. All distribution points were in areas where chloride concentration was less than 3 mg/L, and all points but one were in areas where the sulfate concentration was less than 10 mg/L. Substrate preference, depth distribution, turbidity tolerance, common associates, and flowering and fruiting dates were not determined. Tans (1987) described the habitat for this species as sandy lake shores, in many cases in water up to 15 cm deep. Vegetatively, this species looks very similar to *U. cornuta* and, similar to *U. cornuta,* it does not produce winter buds. Both species have grass-like branches above the substrate and bladder-bearing branches buried in the substrate. This makes them easily overlooked unless they are flowering, which, according to the records I searched, is seldom. Tans (1987) reported that most flowering and fruiting occurs in July and August. This species is probably undercollected.



small purple bladderwort

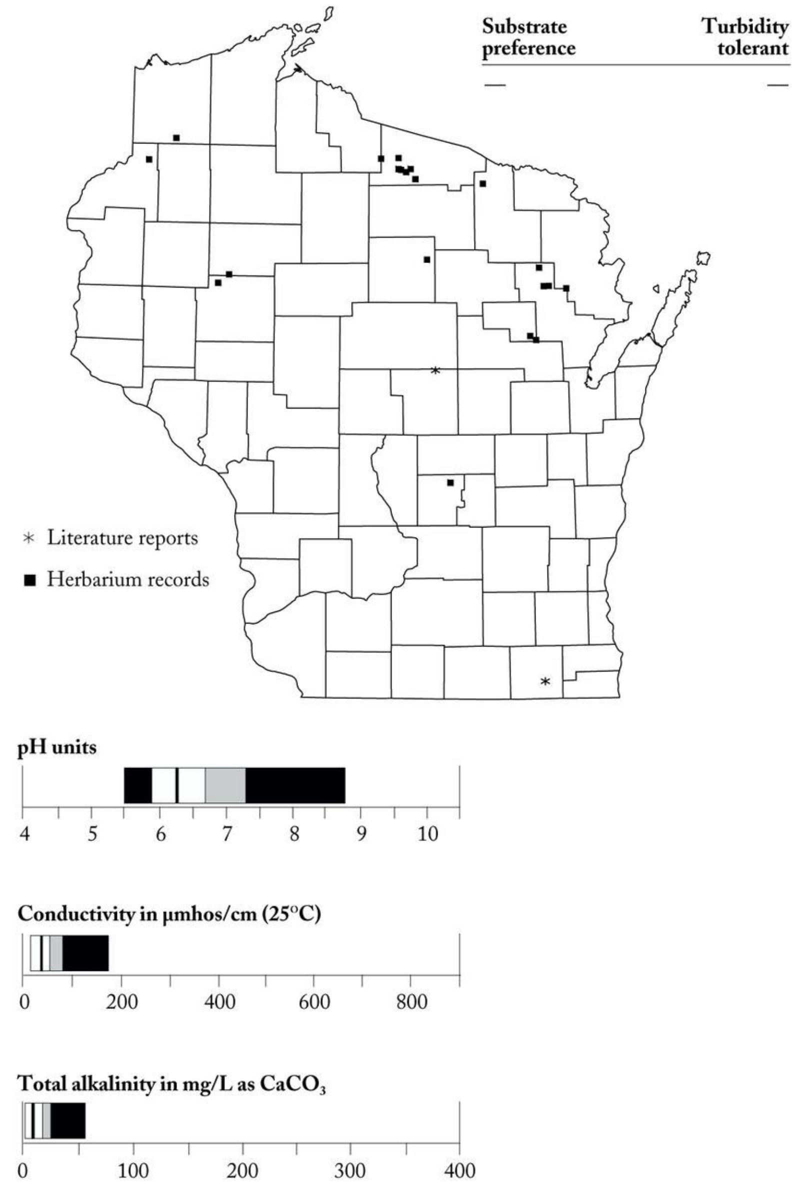
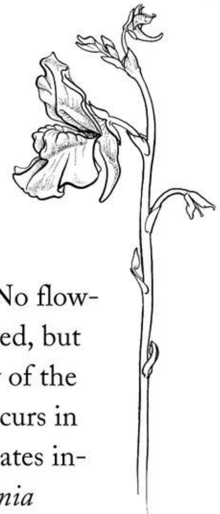
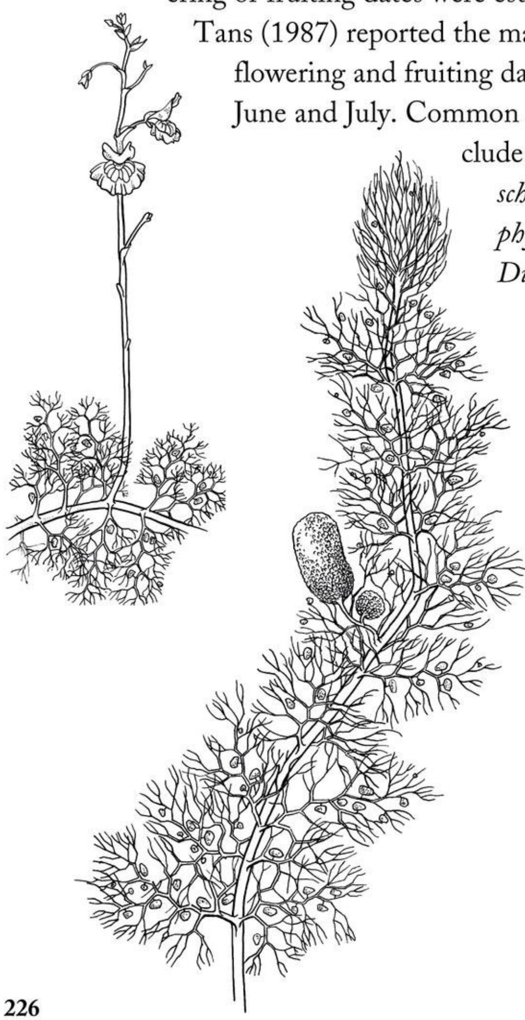


Figure 109. Distribution and habitat characteristics of *Utricularia resupinata* B.D. Greene.

Utricularia vulgaris L.

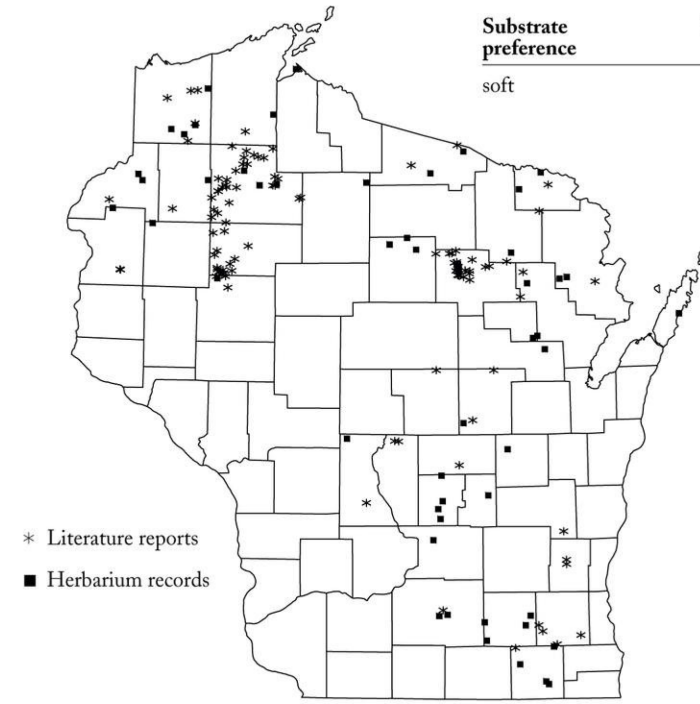


The most common bladderwort, found statewide (fig. 110). It prefers soft substrate, tolerates turbid water, and grows in water depths to 2.4 m. It is found over a broad pH range, including some acid water with a pH of less than 5. Its alkalinity range is moderate and conductivity range is limited. No flowering or fruiting dates were established, but Tans (1987) reported the majority of the flowering and fruiting dates occurs in June and July. Common associates include *Brasenia schreberi*, *Ceratophyllum echinatum*, *Dulichium arundinaceum*, *Nymphaea odorata*, *Polygonum amphibium*, *Potamogeton natans*, *P. pusillus*, *Sagittaria rigida*, and *Sparganium chlorocarpum*. *Utricularia vulgaris* produces free-floating winter buds.



great bladderwort

Substrate preference	Turbidity tolerant
soft	yes



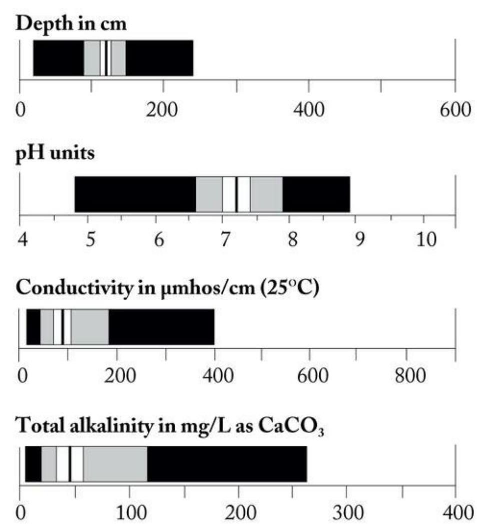
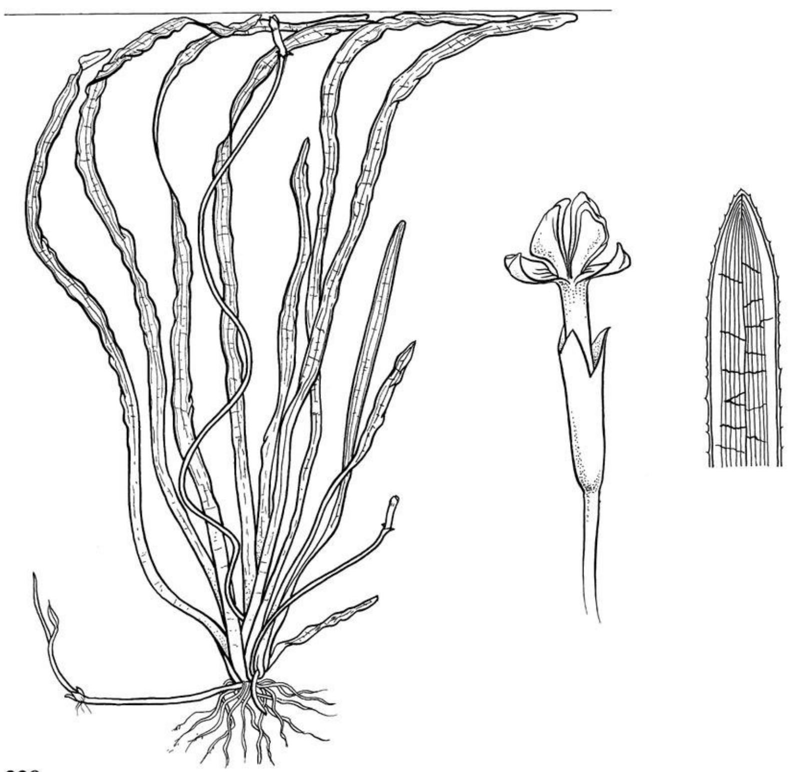


Figure 110. Distribution and habitat characteristics of *Utricularia vulgaris* L.

Vallisneria americana L.

A common plant, found statewide (fig. 111). This species prefers hard substrate, is turbidity tolerant, and grows in water depths to 3.2 m. It is found over broad pH and alkalinity ranges and a moderate conductivity range. Flowering occurs in late summer. The flowers are probably pistillate flowers. Staminate flowers are released underwater and float upon the water surface until they encounter the pistillate flower and pollinate it (Sculthorpe, 1967). The length of the long, spiraled stalk that bears the pistillate flower seems unrelated to the water depth where the plant grows (Sculthorpe, 1967). It spreads from rhizomes with tuberous tips that, along with the fruits, are relished by waterfowl (Voss, 1972). Common associates are *Najas flexilis, Potamogeton pusillus, P. gramineus,* and *P. nodosus.*



eel grass or wild celery

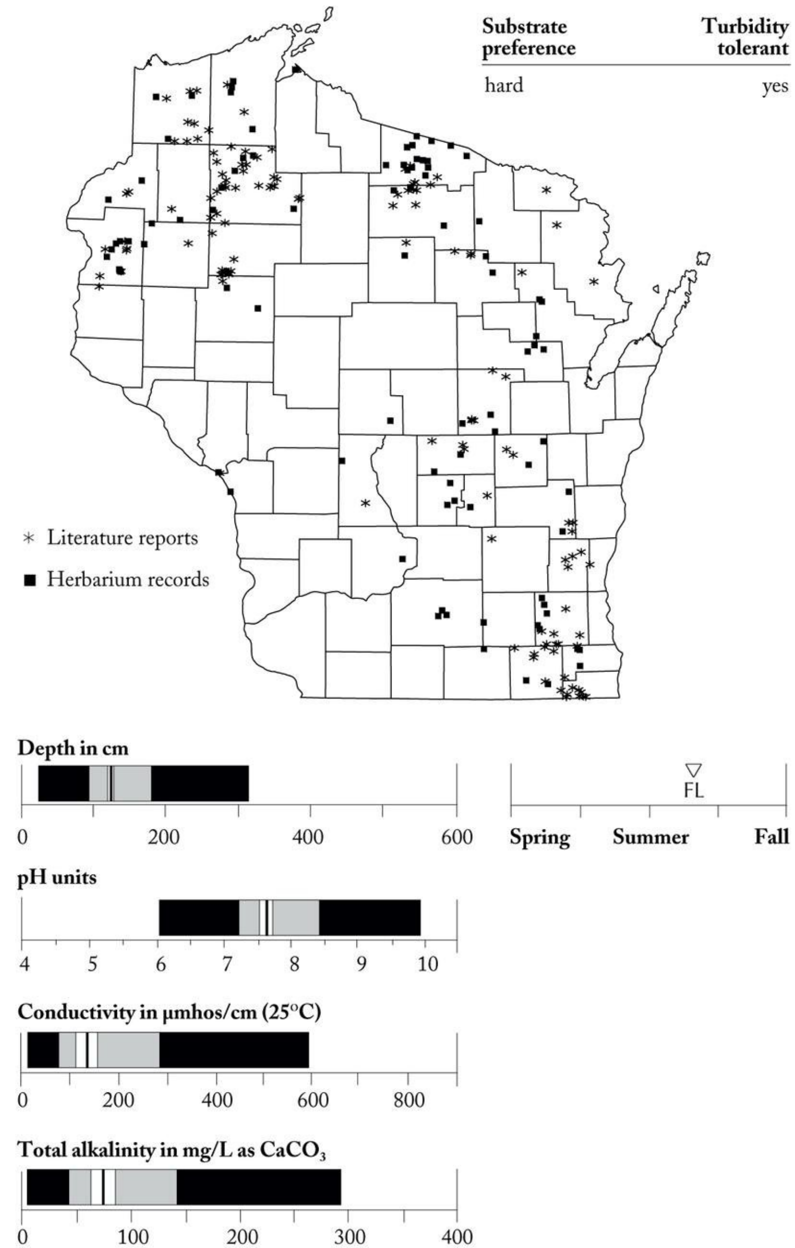
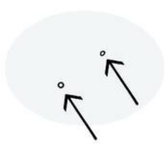


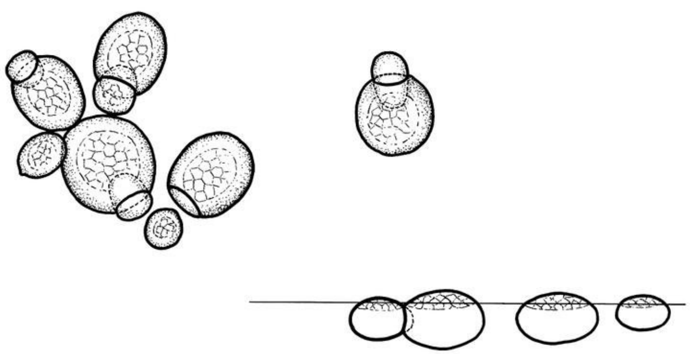
Figure 111. Distribution and habitat characteristics of *Vallisneria americana* L.

Wolffia columbiana Karsten

An infrequently found species (fig. 112). However, it is probably more common than its infrequent status indicates because it is often overlooked in plant surveys because of its small size. It is found over moderate alkalinity and conductivity ranges and a limited pH range. No distribution points were found in the Northern Lakes and Forests Ecoregion or in an area where alkalinity was less than 15 mg/L as $CaCO_3$; only one point was in an area where calcium concentration was less than 10 mg/L. It is a free-floating plant; therefore, description of depth distribution, substrate preference, and turbidity tolerance is inappropriate. The plant is seldom, if ever, found flowering (Voss, 1972). Common associates include *Ceratophyllum demersum, Lemna minor, L. trisulca, Nymphaea odorata, Potamogeton diversifolius, P. nodosus, P. praelongus, P. zosteriformis, Ranunculus longirostris,* and *Spirodela polyrhiza.*



ACTUAL SIZE



common watermeal

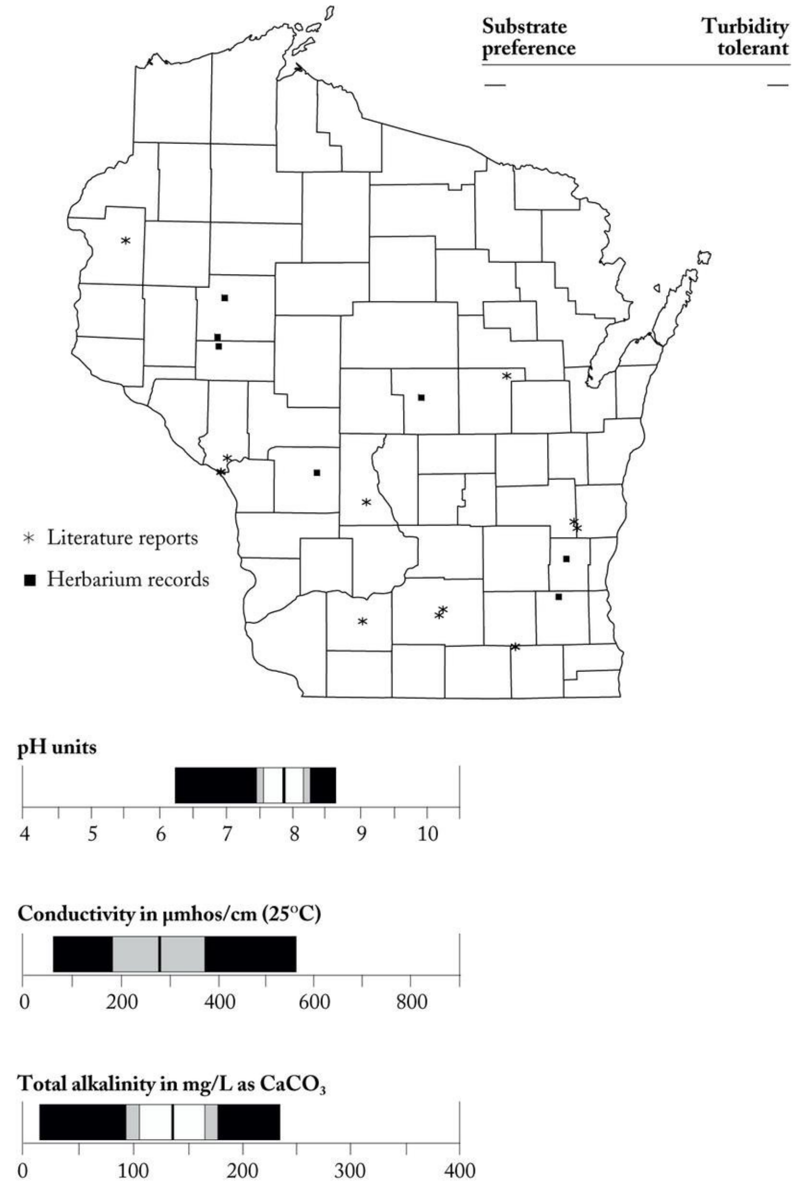
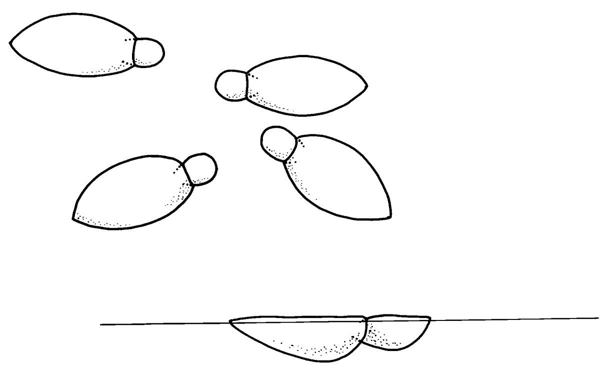


Figure 112. Distribution and habitat characteristics of *Wolffia columbiana* Karsten.

Wolffia punctata Griseb.

Listed as rare, but probably much more common (fig. 113). *Wolffia* spp. in general are overlooked; when they are noted, *W. punctata* is seldom separated from *W. columbiana* in lake surveys. It often grows with *W. columbiana* (Voss, 1972), and it may be as common as that plant. None of the few distribution points was located in the Northern Lakes and Forests Ecoregion. It is a free-floating plant, similar to *W. columbiana*; no flowering specimens have been reported. The two species can sometimes be separated by an interesting growth characteristic: *Wolffia punctata* grows in a single layer on the water surface; *W. columbiana* will grow in more than one layer, and some plants are wholly submersed (Gleason and Cronquist, 1991). *Wolffia punctata* plants are oblong, pointed at both ends, and flat on top. *Wolffia columbiana* plants are spherical and rounded on top.



dotted watermeal

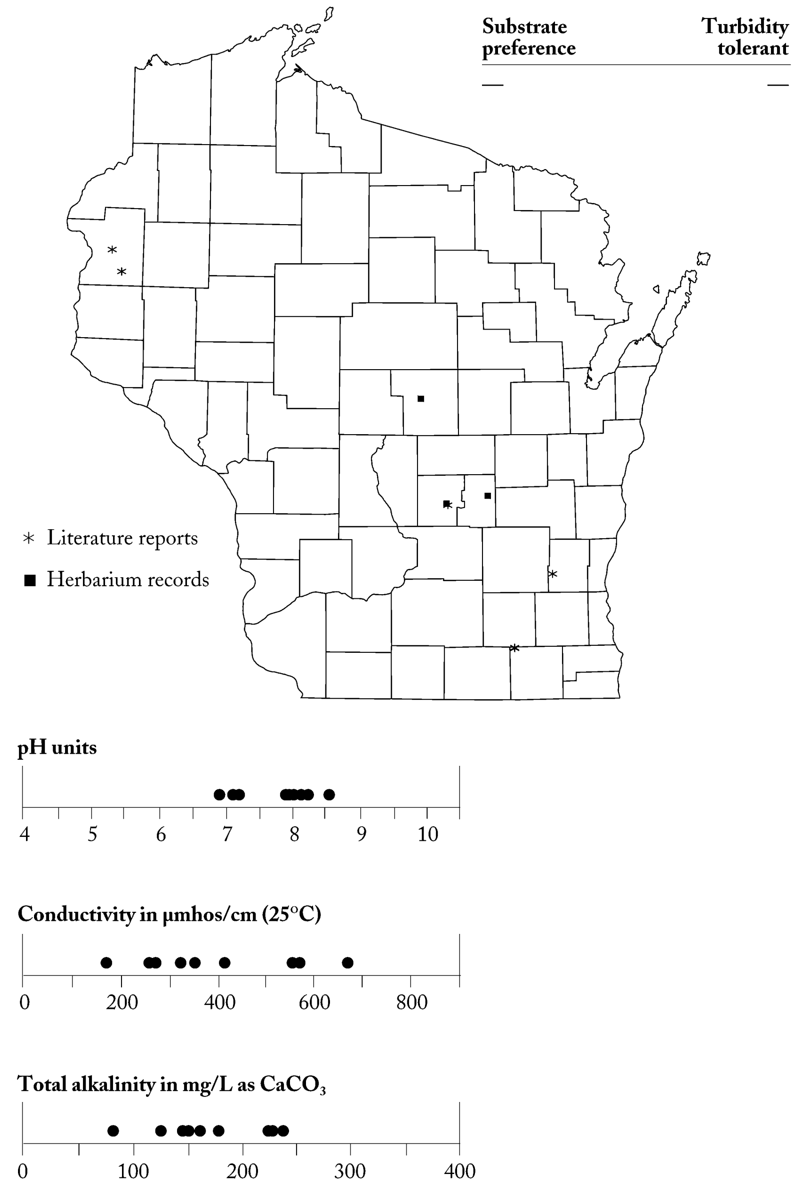


Figure 113. Distribution and habitat characteristics of *Wolffia punctata* Griseb.

Zannichellia palustris L.

An infrequent species, distributed primarily in the southern two-thirds of the state (fig. 114). Only one distribution point was in the Northern Lakes and Forests Ecoregion; it was in an area where alkalinity was less than 30 mg/L as $CaCO_3$. This species is found in high alkalinity, high pH, and high conductivity water. It is turbidity tolerant and prefers hard substrate, although Voss (1972) noted that it is found on muddy bottoms. No flowering date could be determined, but it fruits by midsummer. It is commonly found in water less than 3.6 m deep. No common associates were determined. This plant is easily overlooked, especially when found in tangled masses of vegetation. Its pattern of opposite branching helps to differentiate its vegetative material from that of *Potamogeton* spp.

horned pondweed

Substrate preference	Turbidity tolerant
hard	yes

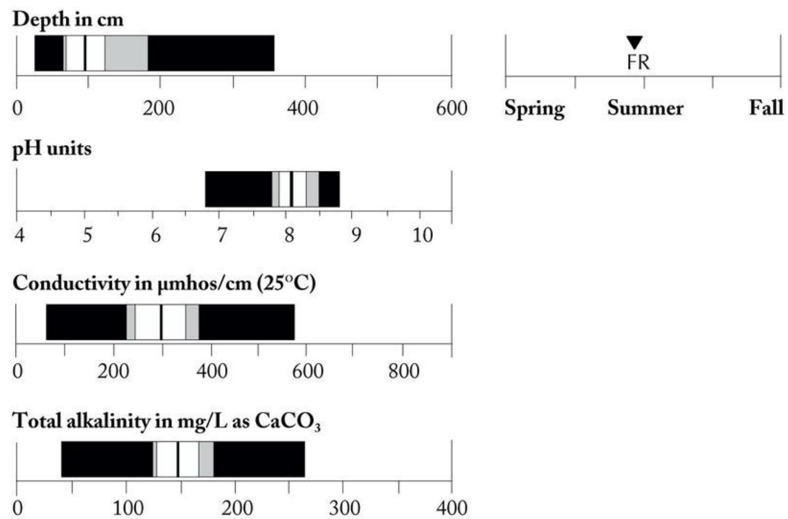
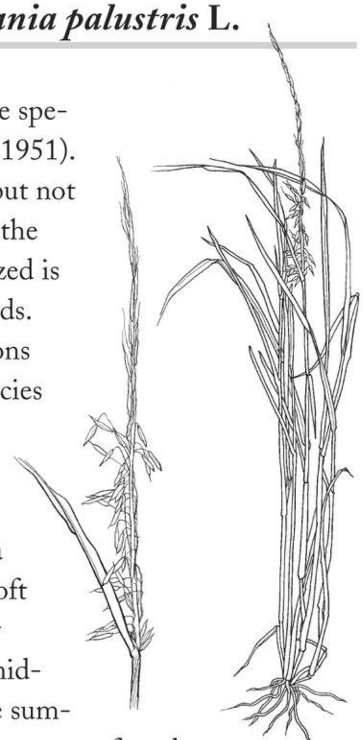
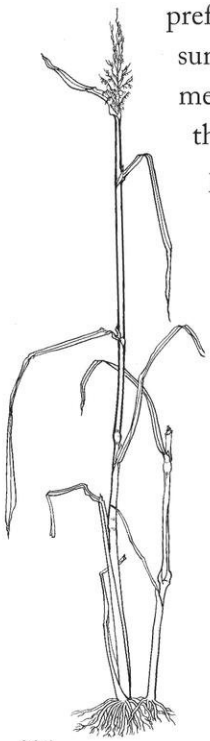


Figure 114. Distribution and habitat characteristics of *Zannichellia palustris* L.

Until recently, considered a single species with three varieties (Fassett, 1951). Plant surveys noted the species, but not the varieties; therefore, mapping the two species that are now recognized is not possible from historical records. The map and chemical descriptions presented here combine both species (fig. 115). Wild-rice grows over a broad alkalinity range, a moderate conductivity range, and a limited pH range. It is found at a median depth of 0.9 m, prefers soft substrate, and shows no turbidity preference. It flowers in midsummer and fruits in late summer. No common associates were found; the plant generally does not withstand competition very well (Voss, 1972). *Zizania palustris* is the smaller and probably the more common of the two species. It is found primarily in northern Wisconsin (Fassett, 1951) and, because of its large grains, it forms the base of the edible wild-rice industry. It has been spread to many waters by Native Americans, wildlife managers, and others. *Zizania aquatica* is a robust species found primarily in the southern half of Wisconsin; it may be becoming rare as a result of continued human encroachment on its habitat.





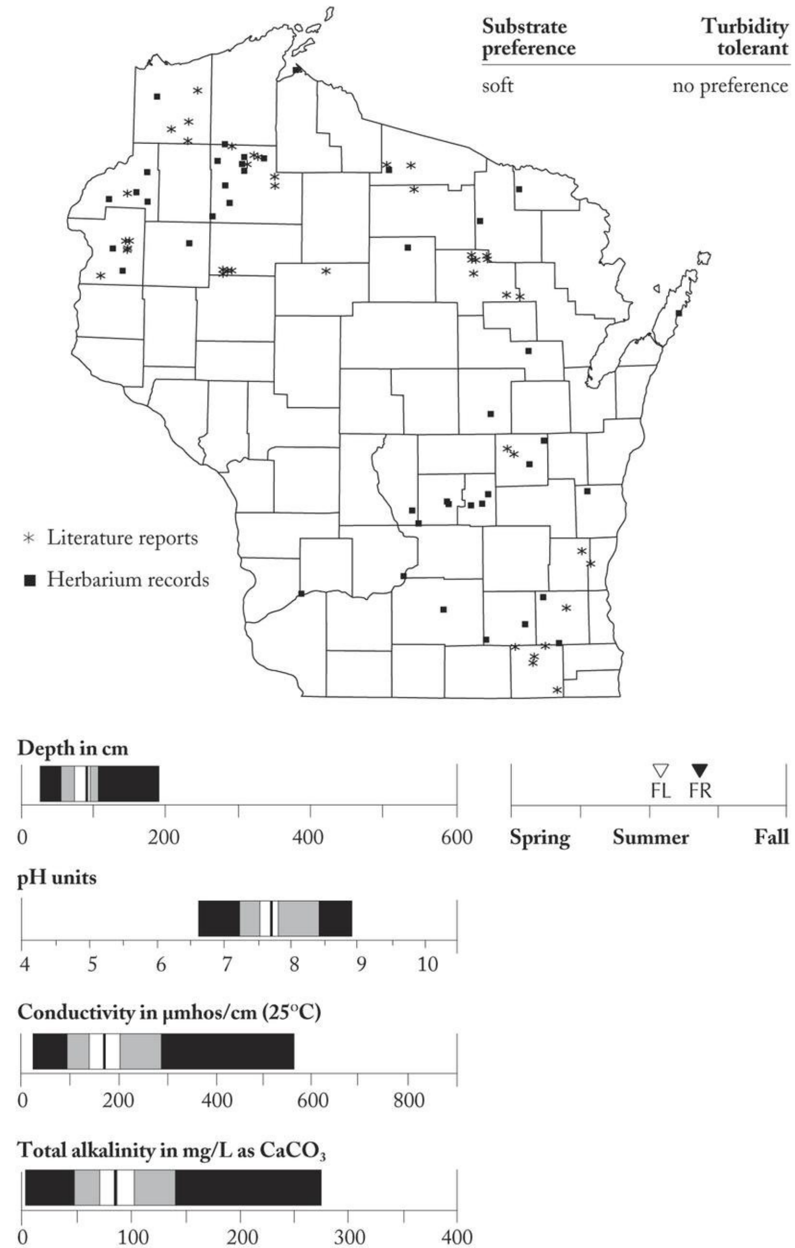


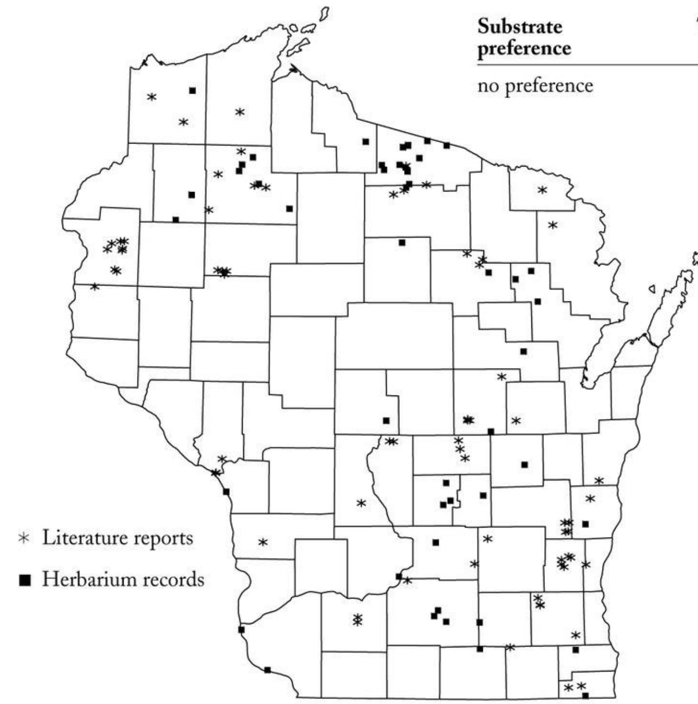
Figure 115. Distribution and habitat characteristics of *Zizania aquatica* L. and *Zizania palustris* L.

Zosterella dubia (Jacq.) Small

A common plant statewide (fig. 116). It is found in water depths to 3.1 m, shows no substrate preference, and is turbidity tolerant. Most submersed plants are sterile (Voss, 1972), so flowering and fruiting dates were not established. The few flowering or fruiting plants noted were collected in middle to late summer. *Zosterella dubia* is distributed over a moderate, somewhat alkaline pH range and moderate conductivity and alkalinity ranges. Common associates are *Bidens beckii, Ceratophyllum demersum, Lemna trisulca, Myriophyllum verticillatum, Nymphaea odorata, Potamogeton nodosus, P. zosteriformis,* and *Utricularia geminiscapa.* Lack of a prominent midrib in the leaf makes it easy to differentiate this species from similar-looking *Potamogeton* spp.

water star-grass

Substrate preference	Turbidity tolerant
no preference	yes



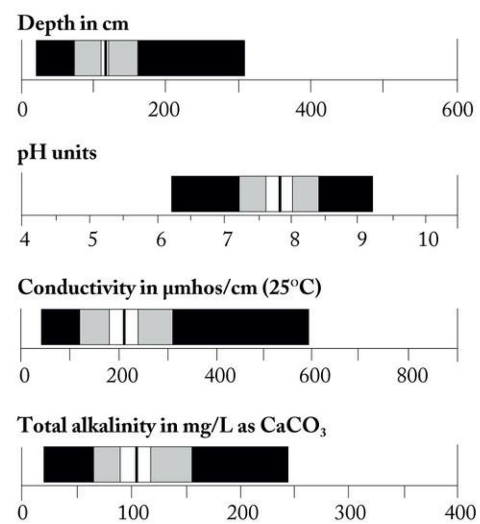


Figure 116. Distribution and habitat characteristics of *Zosterella dubia* (Jacq.) Small.

Gradients of Lake-Plant Characteristics

Figures 117–120 present alkalinity, conductivity, pH, and depth distribution data in gradients of increasing median values, which makes it easier to compare multiple species ranges and preferences. Flowering and fruiting dates (fig. 121) are presented in gradients of increasing average value. It is easy to see, for example, that *Littorella uniflora* and *Najas marina* are not likely to be found in the same lakes because their alkalinity ranges do not overlap. These charts also provide a quick visualization of the breadth of the ranges the species occupy. Again, using alkalinity as an example, it is easily seen that *Utricularia geminiscapa* occupies a much broader range than *Eriocaulon aquaticum,* even though their median values are the same.

It is evident from these charts that alkalinity, conductivity, and depth distributions are skewed toward low values. The minimum values of the distribution ranges are much more similar to each other than the maximum values are to each other. A major difference between species is the extent to which they grow in deep water or high alkalinity and conductivity water.

The ranges of pH values do not display this skewed distribution. Some species extend into highly acidic conditions, others into highly alkaline conditions, and still others have broad ranges that span acidic and alkaline conditions. Some species that have a broad pH range have a median pH near neutral.

Flowering and fruiting gradients have management and ecological implications. Species that share the same habitat may reduce interspecific competition by flowering and fruiting at different times. Growth for many species starts to decline after flowering and fruiting. The times during which a species grows and dies can have profound effects on internal nutrient cycling in a lake's littoral zone (Carpenter, 1983). It also has

important implications for the timing of management activities. *Potamogeton crispus,* for example, usually dies by midsummer; after that, it no longer creates nuisance conditions. Nutrients released from decaying *P. crispus* plants, however, often stimulate late summer algae blooms. Management considerations and nutrient cycling are considerably different in a *P. crispus* bed than in a *Vallisneria americana* bed, in which growth often does not peak until middle to late summer.

Habitat Similarities

The habitat of a lake plant is defined by the interaction of physical, chemical, and biological factors. In this section, I define the physical–chemical habitat and use multivariate analysis to compare habitats on the basis of turbidity tolerance, substrate preference, and distributions of alkalinity, conductivity, pH, and depth.

Methods

To compare the habitat requirements of plant species, the coefficient 2W/A+B (Cox, 1967) was used to calculate the similarity of the habitat ranges of each species pair. The parameters compared are turbidity tolerance, substrate preference, and distributions of alkalinity, conductivity, pH, and depth. The whole distribution range for each parameter was used. The factor 2W is twice the sum of the ranges two species have in common; A and B are the ranges of each species. The parameter values were relativized by changing them to a percentage of the total range for all species. Alkalinity, conductivity, and pH distributions were available for all species, except those having less than 10 occurrences, which were not considered. Substrate preference, turbidity tolerance, and depth distribution were not known or were not appropriate for some species (for example, depth distribution of *Lemna* spp.); in those areas, similarity was calculated from the data available. In total, 102 species were compared.

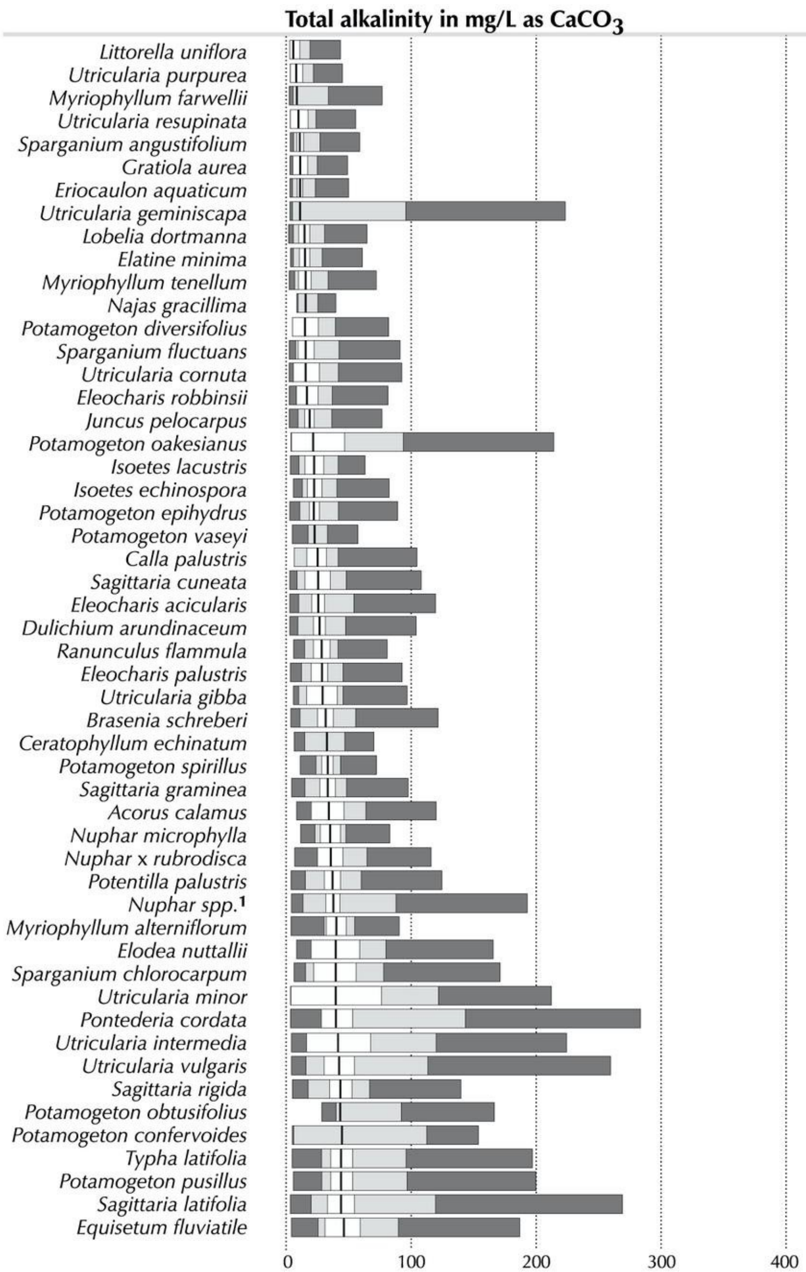
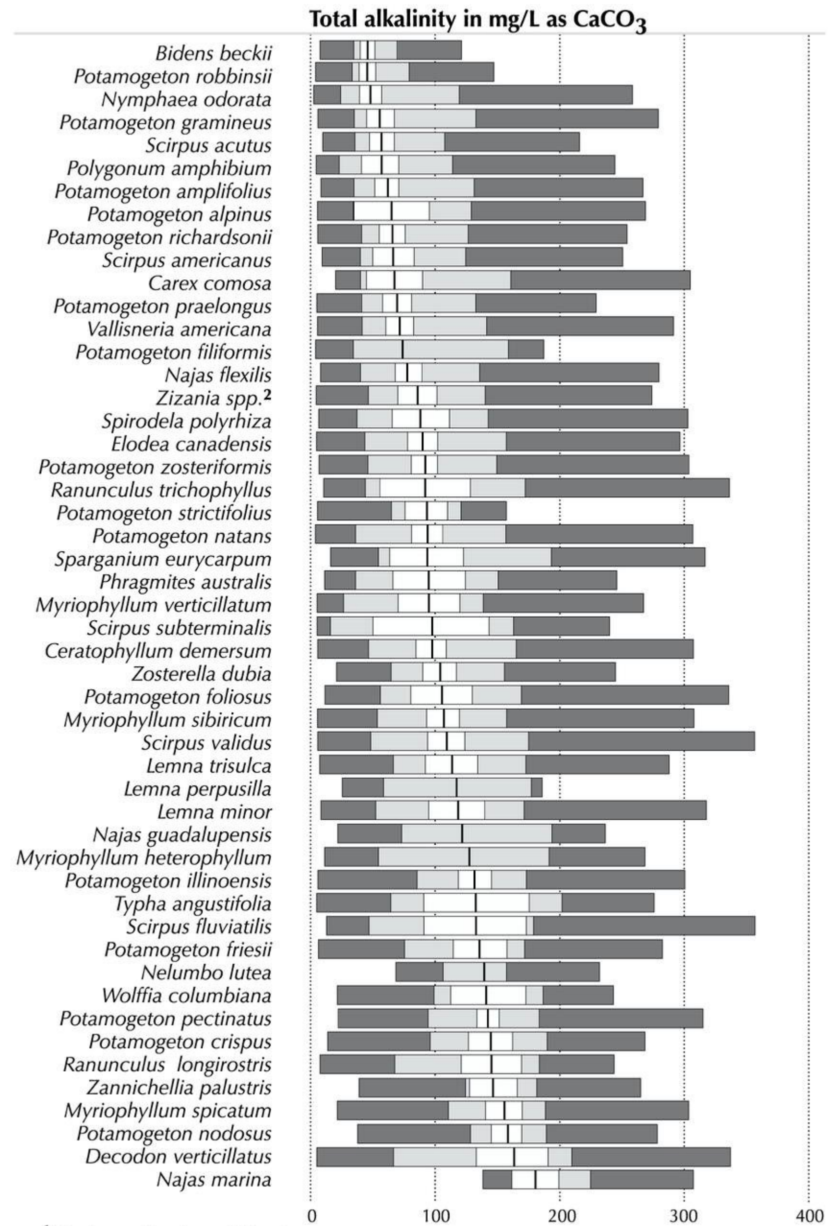


Figure 117. Comparison of species alkalinity distributions, arranged by increasing median values.



[1]*Nuphar variegata* and *N. advena*
[2]*Zizania aquatica* and *Z. palustris*

Figure 117. *Continued*

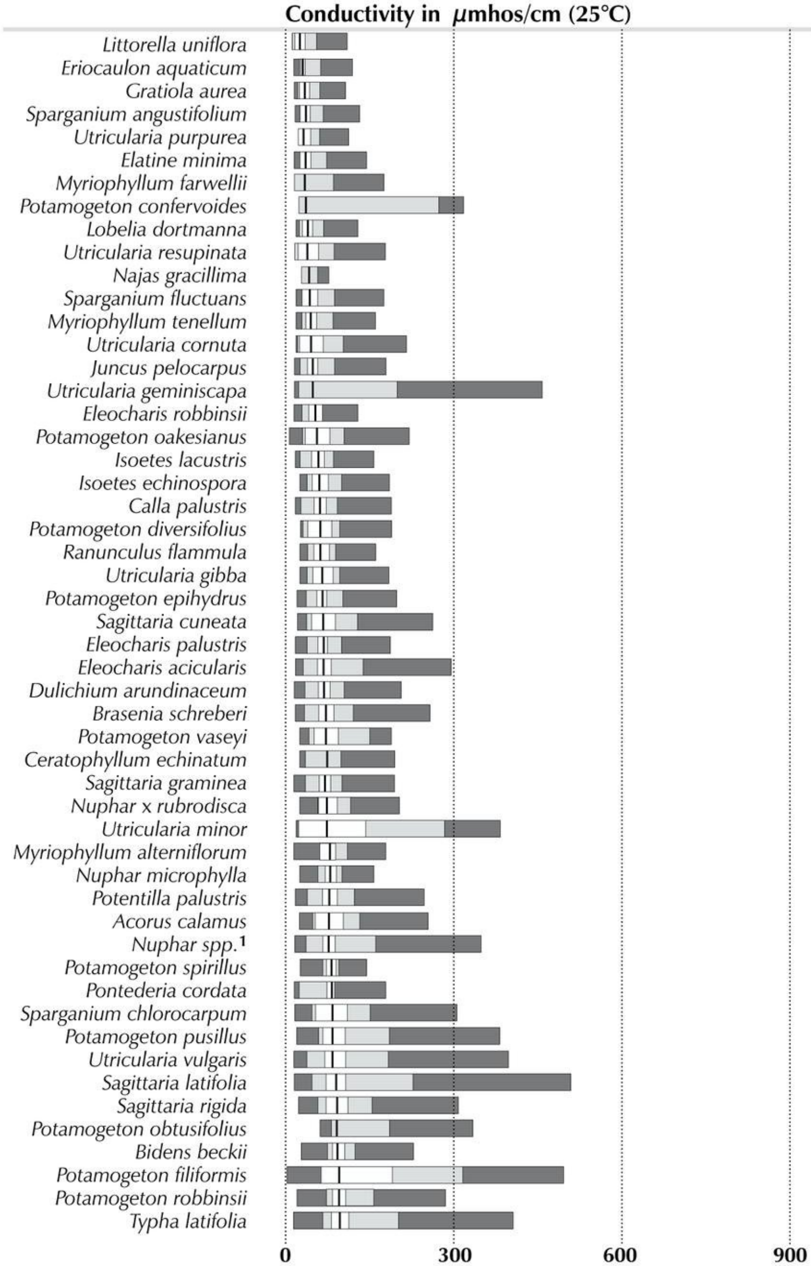
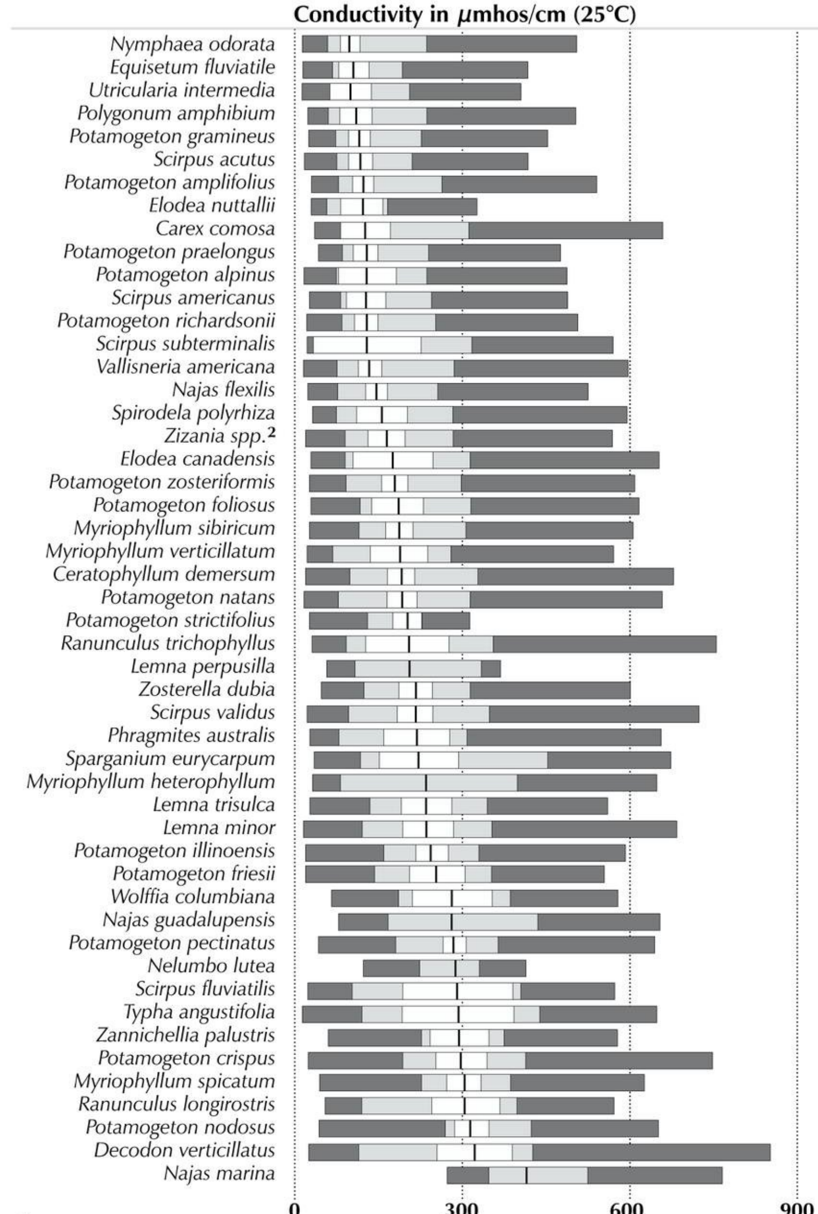


Figure 118. Comparison of species conductivity distributions, arranged by increasing median values.



[1] *Nuphar variegata* and *N. advena*

[2] *Zizania aquatica* and *Z. palustris*

Figure 118. *Continued*

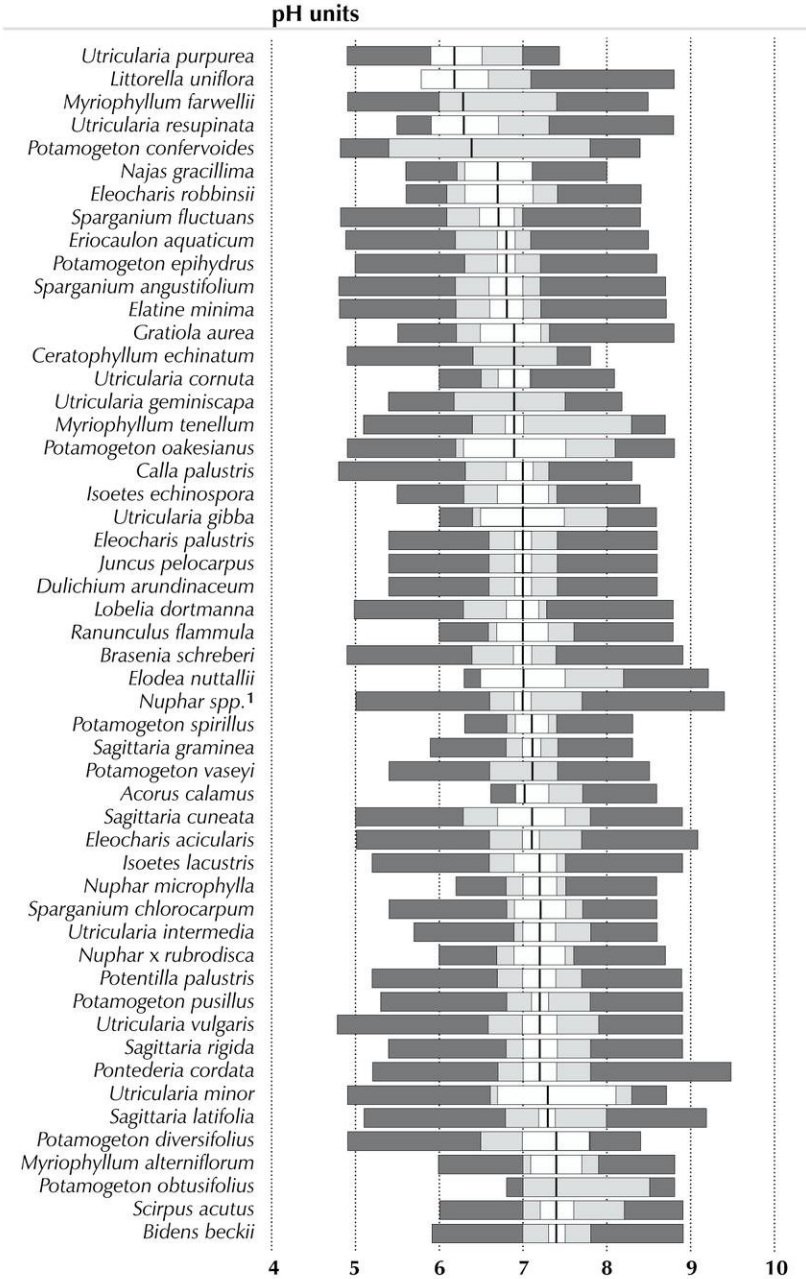
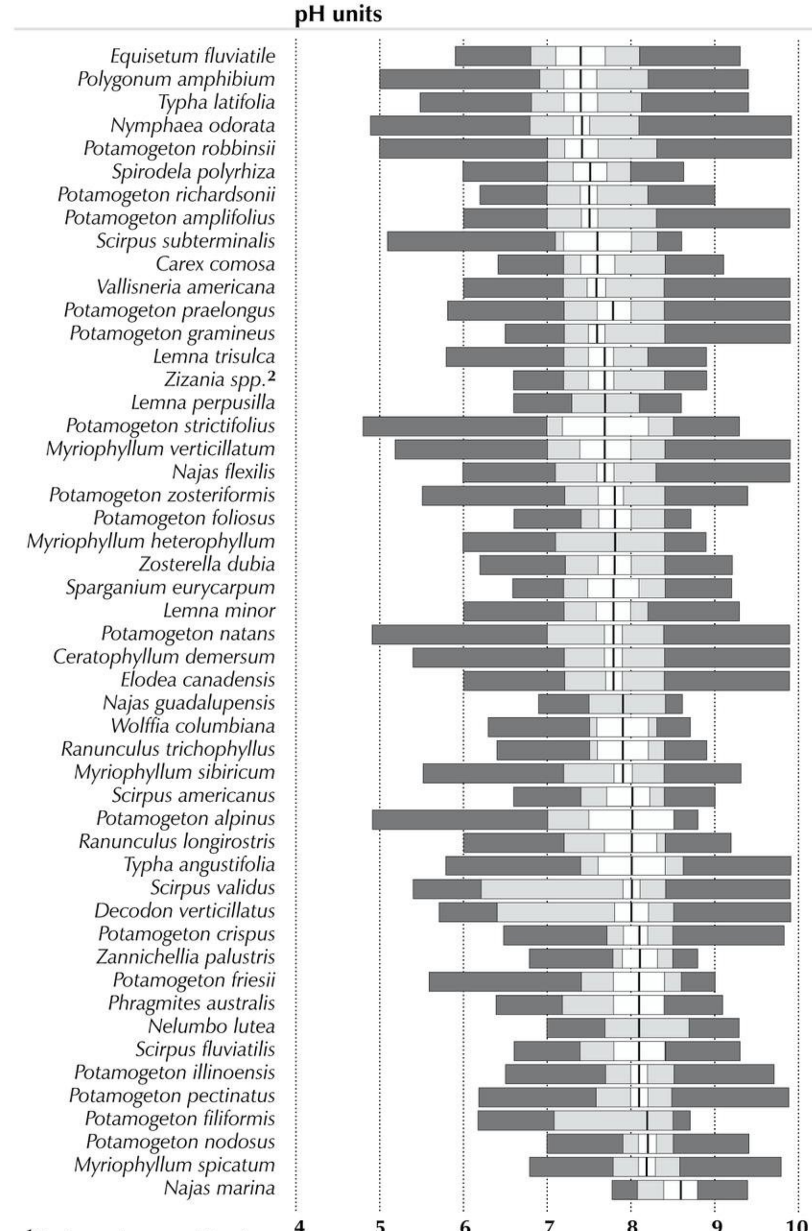


Figure 119. Comparison of species pH distributions, arranged by increasing median values.



[1]*Nuphar variegata* and *N. advena*
[2]*Zizania aquatica* and *Z. palustris*

Figure 119. *Continued*

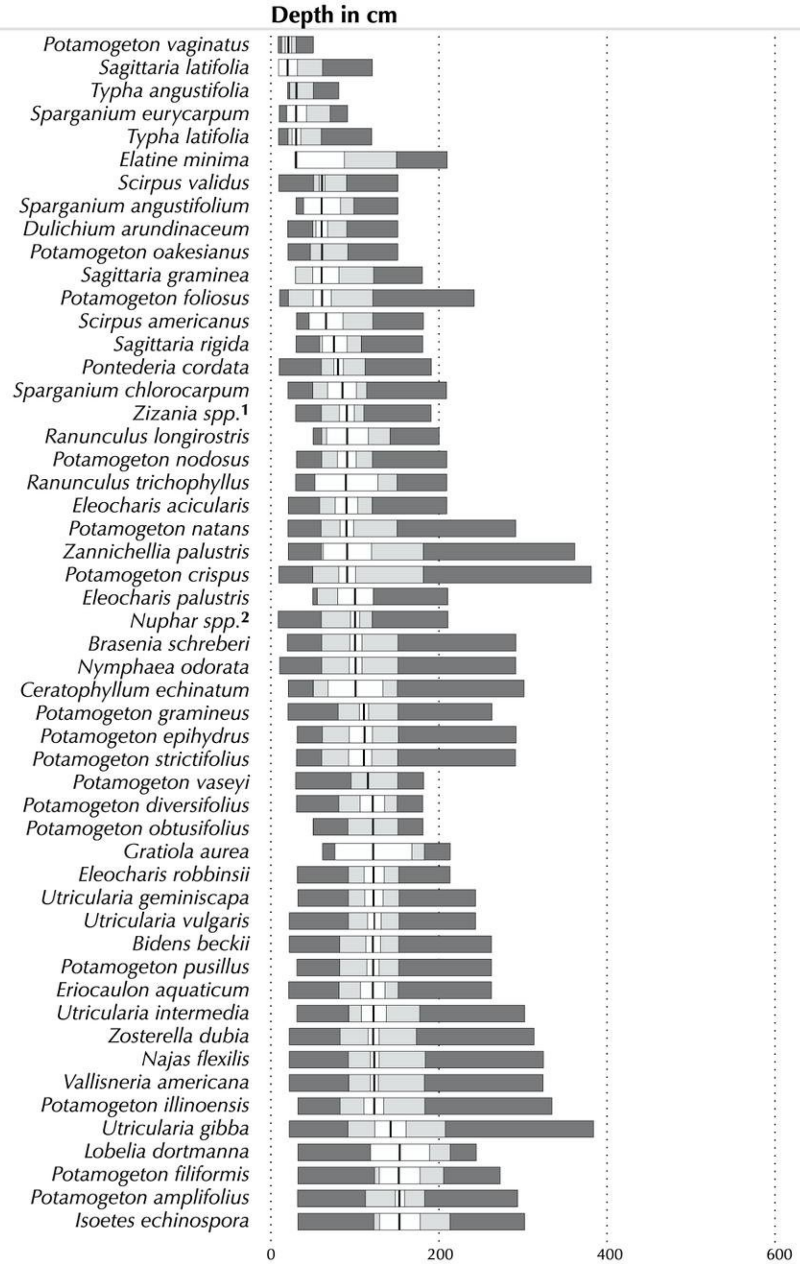
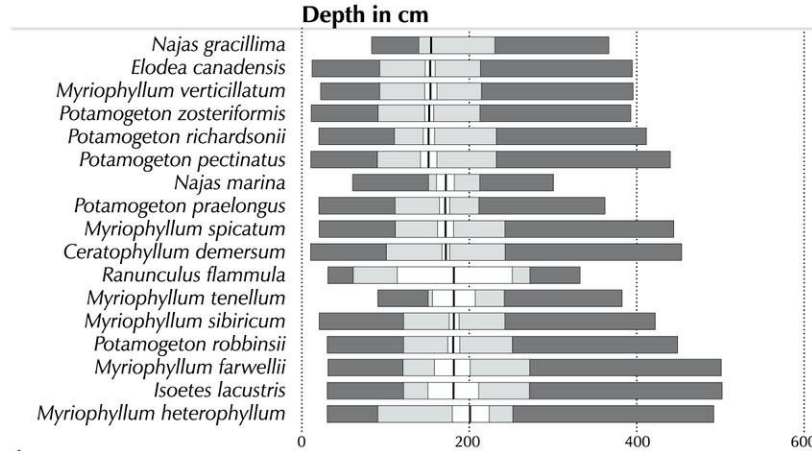


Figure 120. Comparison of species depth distributions, arranged by increasing median values.



[1] *Zizania aquatica* and *Z. palustris*
[2] *Nuphar variegata* and *N. advena*

Figure 120. *Continued*

Because substrate preference and turbidity tolerance are not expressed as ranges, special rules were devised to compare values and express the results as a percentage of total range. If a species preferred hard or soft substrate, it could occupy 50 percent of the total range. If a species showed no substrate preference, it could occupy 100 percent of the total range. For example, if two hard- or soft-preferring species were compared, they scored 50 percent of the total range in common. A hard- or soft-substrate species compared to a no-preference species also scored 50 percent. If a hard-substrate species was compared to a soft substrate species, they scored zero; if two no preference species were compared, they scored 100 percent of the total range.

Because there is probably no reason why turbidity-tolerant plants cannot thrive in clear water, the rules for comparing turbidity tolerance were slightly different. If a plant was turbidity tolerant or showed no turbidity preference, it occupied 100 percent of the turbidity range; turbidity-intolerant plants occupied 50 percent. A score of 100 percent was given when two turbidity-tolerant or no-preference species were compared; a score of 50 percent was achieved when a turbidity-in-

Table 2. Examples of calculating similarity coefficients (2W/A+B)[1] with a full dataset and with missing data.

Full-data example

	Ceratophyllum demersum			*Elodea canadensis*			In common		
	Min.	Max.	Range (%)	Min.	Max.	Range (%)	Min.	Max.	Range (%)
Akalinity	4	305	85	3	295	82	4	295	82
Conductivity	17	675	77	24	645	73	24	645	73
pH	5.4	9.9	88	6	9.9	76	6	9.9	76
Depth	0.1	4.5	90	0.1	3.9	78	0.1	3.9	78
Substrate	soft		50	soft		50	soft	soft	50
Turbidity tolerance	yes		100	yes		100	yes	yes	100
TOTAL			A=490			B=460			W= 459
2W/A+B = 0.97									

Limited-data example

	Ceratophyllum demersum			*Lemna minor*			In common		
	Min.	Max.	Range (%)	Min.	Max.	Range (%)	Min.	Max.	Range (%)
Akalinity	4	305	85	6	315	88	6	305	85
Conductivity	17	675	77	16	680	78	17	675	77
pH	5.4	9.9	88	6	9.3	65	6	9.3	65
Depth	0.1	4.5	not compared	—	—	not compared	—	—	not compared
Substrate	soft		not compared	—	—	not compared	—	—	not compared
Turbidity tolerance	yes		100	yes		100	yes	yes	100
TOTAL			A=350			B=331			W=327
2W/A+B = 0.96									

[1] after Cox (1967)

tolerant plant was compared to any other turbidity type, including another turbidity-intolerant plant.

Table 2 illustrates how similarity coefficients were calculated for a case with a full set of data and a case with missing data. Similarity coefficients were changed to dissimilarity coefficients by subtracting the similarity coefficient from 1. Ward's minimum variance cluster analysis (SAS, 1989) was used to arrange species using the dissimilarity value as the distance measure for clustering.

Results

The result of Ward's clustering is a dendrogram (fig. 122) that illustrates the habitat similarity between species. Those species that are close together on the list at the left of the diagram and are connected by short branches and few forks are found in the most similar habitats. Species that are close together, but are attached by longer branches and more forks, have more dissimilar habitats. Species that are widely separated on the list and are connected by many forks and long branches have the least amount of habitat in common. For example, *Acorus calamus* and *Utricularia intermedia* probably share little habitat in common. They are at the far ends of the dendrogram and are connected only by long branches and many forks. *Ceratophyllum demersum, Elodea canadensis,* and *Potamogeton crispus,* however, show a great habitat similarity: They are close together and are connected by short branches and few forks. Care must be taken when comparing species like *Carex comosa* and *Potamogeton spirillus.* Although they are close to each other on the species list, they are connected by a labyrinth of forks and long branches, which indicates that their habitats are not very similar.

Statistical techniques can be used to suggest species groups formed by cluster analysis, but ultimately the groupings are made subjectively. For ecological interpretation and management purposes, comparison of small groups of species is probably most interesting. Examining the length of branches and number of forks allows the determination of species groupings at multiple levels along a continuum of species or groups that have a similar habitat to others with a more dissimilar habitat to species or groups that have different habitats. Because each reader's interest is likely to be different, I do not make subjective judgments about species groups. The reader's examination of the patterns of species relationships to answer specific questions is a more productive approach.

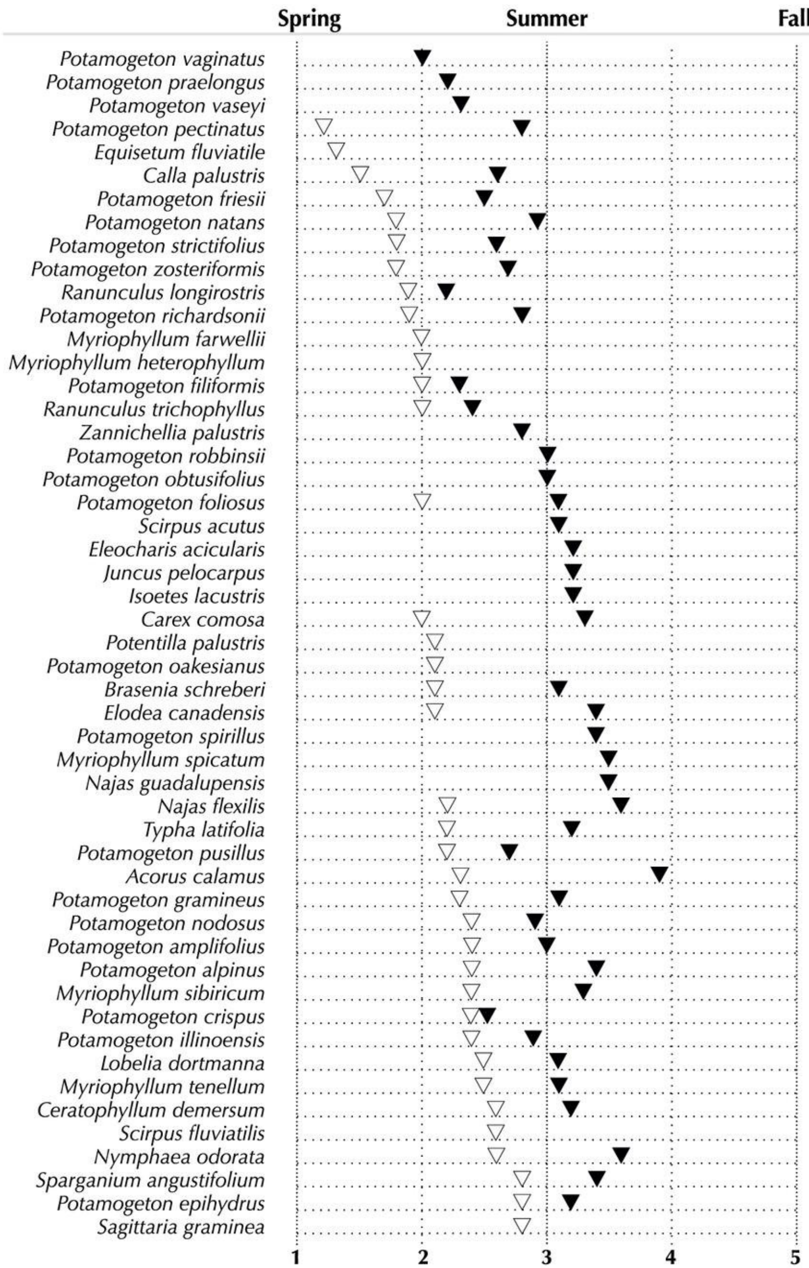


Figure 121. Comparison of species flowering and fruiting dates, arranged primarily by early to late flowering, where information was available.

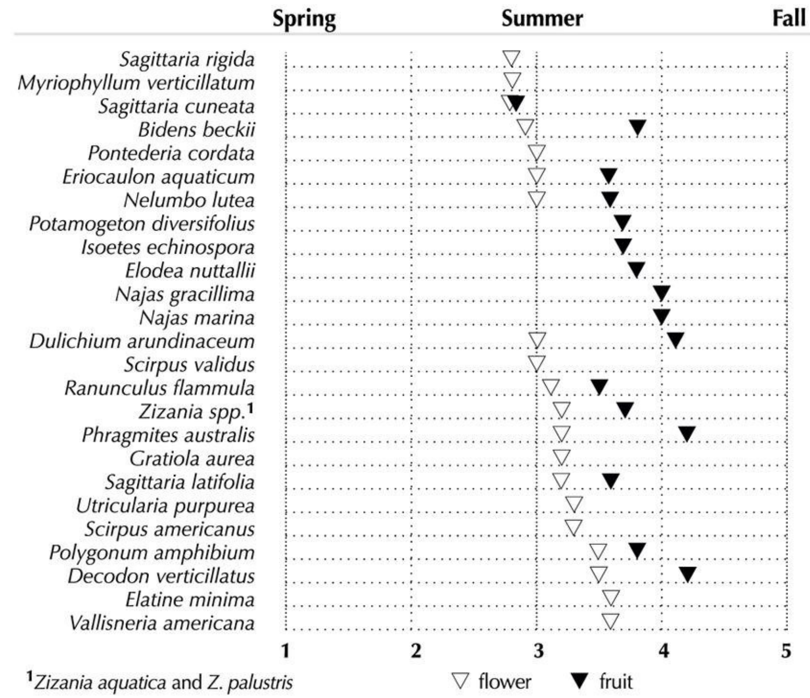


Figure 121. *Continued*

It should also be remembered that widths of habitat ranges are being compared. It is possible that a broad range species nearly overlaps the range of a narrow range species, but the similarity coefficient is not high because of the narrow overlap of ranges compared to the total range of all species.

Discussion

Association with ecoregions

The lack of lake-plant diversity in the Driftless Area Ecoregion is most likely due to the lack of lakes in the region. However, this is probably not the only explanation. Ninety percent (Lillie and Mason, 1983) of the lakes in this region are impoundments that are a maximum of 150 years old, but many are much younger. They are also small, shallow, have high ionic concentrations, and poor water quality. These conditions

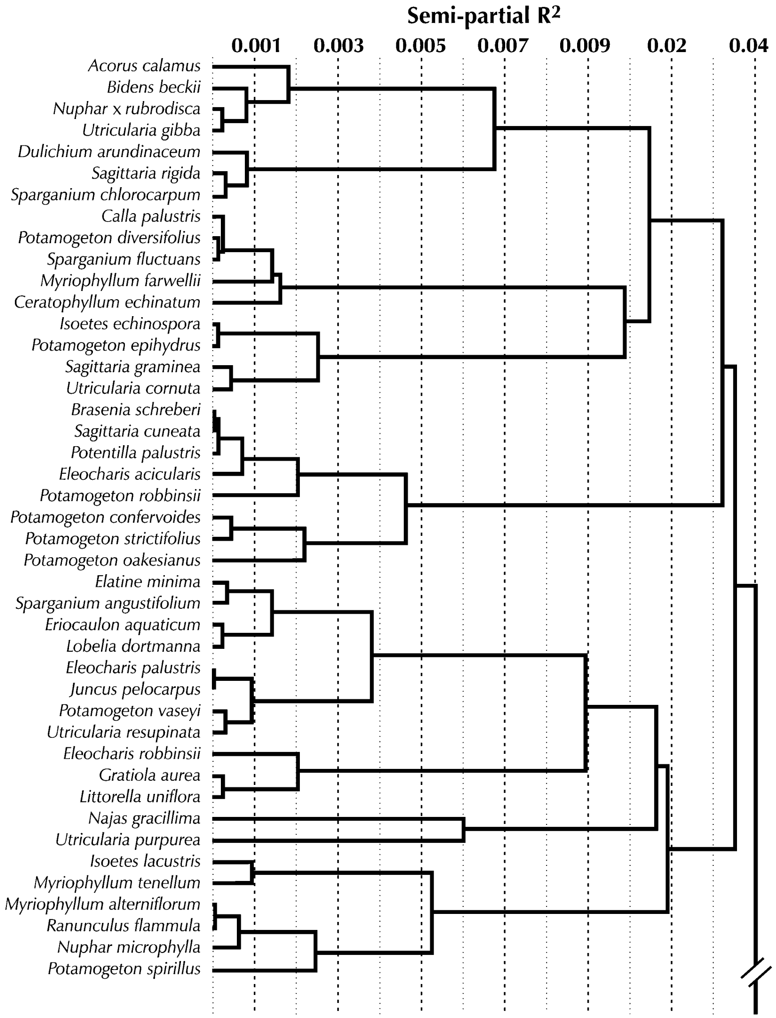
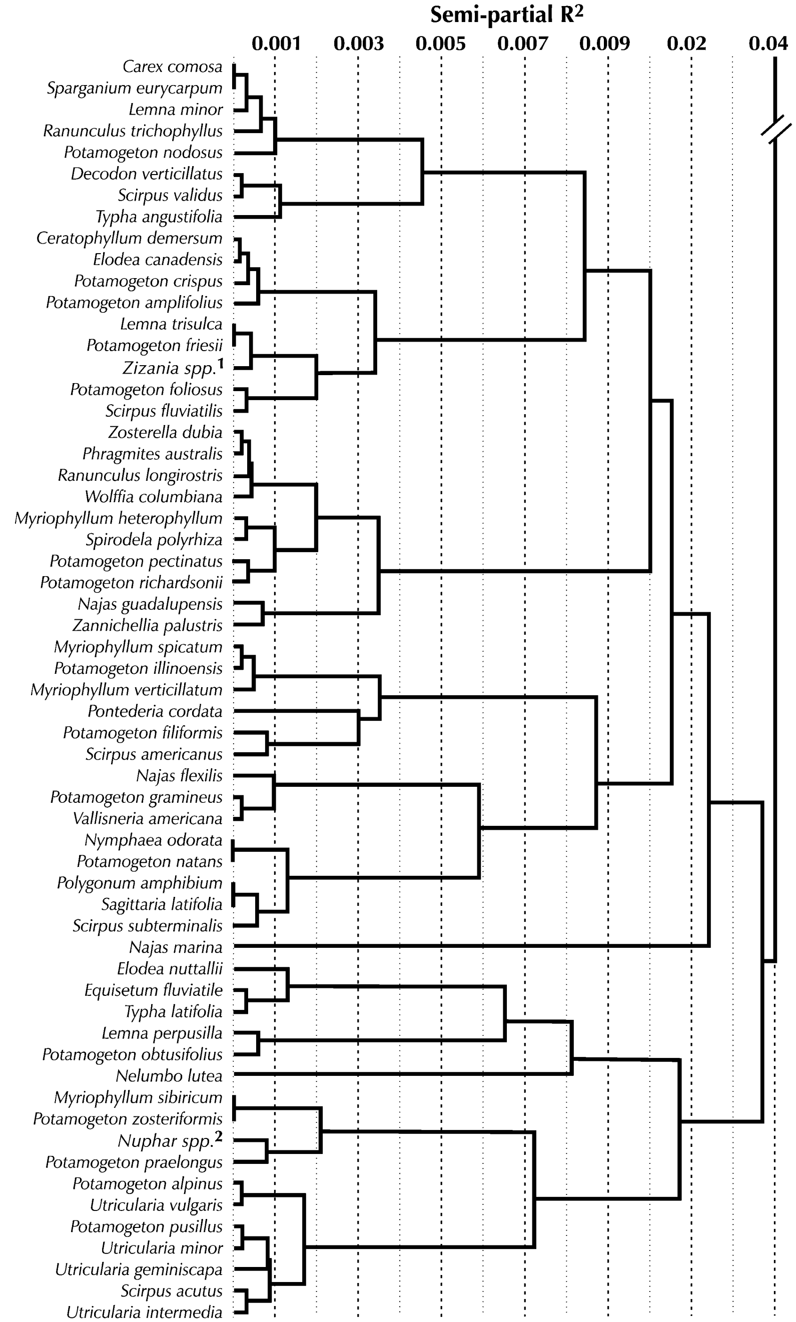


Figure 122. Ward's clustering diagram illustrating multivariate habitat similarity between species.

eliminate species that migrate slowly, are not tolerant of turbid conditions, and prefer low ionic conditions.

Many species are wholly confined or have the majority of their distribution within the Northern Lakes and Forests Ecoregion. These are generally species that have narrow or limited distribution ranges and prefer low ionic conditions.



[1] *Zizania aquatica* and *Z. palustris*
[2] *Nuphar variegata* and *N. advena*

Figure 122. *Continued*

Some species that have a northern distribution range find their southerly range limits in northern Wisconsin. A few species that have southerly distributions or those that prefer high ionic concentrations are not found in this region.

A few species are found only in the Southeastern Wisconsin Till Plain Ecoregion. These species can tolerate high ionic concentrations and are generally more common in coastal or alkali water areas of the United States. No species are unique to the North Central Hardwood Forests Ecoregion.

Correspondence with regional water-chemistry patterns

Some species found entirely within the Northern Lakes and Forests Ecoregion grow only in areas where alkalinity, calcium, magnesium, sulfate, and chloride are low. Other species in the same ecoregion were not found in areas where all ions are low. These examples show how regional water-chemistry patterns more clearly refine ecoregional patterns. All the above water-chemistry distributions must be viewed for this particular pattern to be evident.

Some species found primarily in the Northern Lakes and Forests Ecoregion are also found in other areas of the state where alkalinity, calcium, magnesium, sulfate, or chloride concentrations are low. The most significant patterns may be those that relate to chloride and sulfate because species sensitive to high chloride or sulfate concentrations could be at risk in lakes where concentrations increase. The increase in chloride concentration in some lakes is well documented and there is potential but no documentation for increased sulfate concentration (Lillie and Mason, 1983).

Although volumes have been written about the relationship between phosphorus and productivity in lakes, no pattern between summer phosphorus concentration and macrophyte distribution was evident.

Points that do not fit general habitat-distribution patterns could be caused by error; ways to minimize error were previously discussed. An error, however, should not be assumed only because a distribution point is an outlier. Water-quality conditions in a single lake can vary dramatically from regional conditions. Some plant-distribution data are based on historical records. A species may have been extirpated from a region of the state since the collection was made. The historic range of the species may have been greater than the present range. The Madison area lakes, for example, have lost about one-third of their flora since 1900 (Nichols and Lathrop, 1994).

Boxplots

The boxplots in this report show depth and water-chemistry distribution for species in Wisconsin. Extreme care must be exercised when making ecological interpretations or when making comparisons to regions other than Wisconsin. If the range of the parameter for a species is small (narrow- or limited-range species) compared to the total range of the parameter, it is safe to assume that the species is living in its preferred habitat. This is especially true in Wisconsin for species that prefer low conductivity and low alkalinity because Wisconsin has an abundance of low alkalinity, low conductivity habitats. As the distribution range for a specific parameter of the species increases, it may more closely reflect the distribution of habitat available to the plant. Depth, alkalinity, and conductivity distributions are strongly skewed toward low values (figs. 117–120). The median alkalinity of a species in Wisconsin could be considerably different than the median alkalinity in, for instance, New England merely because the distribution of water chemistries in New England might be different than those of Wisconsin water. An extreme case in point is *Najas guadalupensis* distribution in relation to chloride. In New England the mean value for *N. guadalupensis* chloride distribution was 414 mg/L (Hellquist and Crow, 1980); in Wisconsin

Table 3. Number of species in commonness versus breadth-of-range categories.

	Commonness			
Range	Rare	Infrequent	Common	Abundant
Narrow	2	1	0	0
Limited	11	21	8	0
Moderate	6	24	11	4
Broad	0	5	2	7

the maximum chloride value in the Lillie and Mason (1983) random lakes dataset was only 57 mg/L. Many Wisconsin species are found over broad geographical ranges—some nearly worldwide. To define areas where a species prospers, distribution over broad ranges of habitat variables, broader than those found in Wisconsin, needs to be studied.

Even depth distribution may be influenced by the skewed distribution of potential habitat. The mean depth of more than 50 percent of Wisconsin lakes is less than 3 m, well within the depth range of many species. The probability of finding habitable shallow water is much greater than finding habitable deep water.

Species commonness and breadth of habitat

The average of the percent of range values for alkalinity, conductivity, and pH was used to define the breadth of habitat. A species with an average of 75 percent or more was classified as a broad-habitat species; 50 to 74 percent, a moderate-habitat species; 25 to 49 percent, a limited-habitat species; and less than 25 percent, a narrow-habitat species. These classifications were compared to species abundances (table 3; Nichols and Vennie, 1991). As expected, most values fell on the diagonal from the upper left to the lower right of the matrix. That is, most narrow habitat species were rare and most broad habitat species were abundant. Most species were in the middle of the matrix—they were infrequent to common and had a limited to moderate habitat range.

The matrix can be used to aid management decisions and to help formulate ecological questions. Species that have narrow- or limited-habitat ranges and rare or infrequent abundance are most in need of protection; species that are abundant or common and have moderate to broad habitat ranges are likely to spread rapidly into new areas and could cause aquatic plant-management concerns. Species that are rare and have broad habitat ranges may be undercollected, and the estimate of their abundance may not be accurate. They could be species that are recent invaders and are still expanding their geographic range, or they may be species that have slow migration mechanisms and they do not expand their range rapidly. They could also be poor competitors, and may not grow in a location even though they may have the physiological ability to grow there. The abundance of these species could also be limited by an unknown factor. No species were found in the upper right corner of table 3 (narrow–common, narrow–abundant, and limited–abundant), where species that might spread more quickly or be better competitors than would be expected from habitat information would be found.

Species association and similarity of habitat

Because two species have similar habitat preferences or requirements does not mean they will be found growing together, and vice-versa. They may not be growing together even though their habitats are similar because resources in that habitat may be limited and competition for resources is high. For example, many of the isoetid species do not grow near other species. Some species, such as *Zizania* spp., do not appear to be good competitors. Certain habitat parameters may be much more influential in determining where a plant will grow, and these key factors could be different from species to species.

The habitat parameters studied also vary in scale. Water chemistry, for example, varies primarily between lakes; depth and substrate can vary tremendously within a lake. Plants with similar water-chemistry requirements might not be found growing near each other because they prefer different substrates. The habitat similarities shown in figure 122 are not good predictors of which species associate with each other (Nichols, 1990). This probably is not surprising considering the multiplicity of factors needed to define a species habitat and our limited ability to measure them.

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