Rorippa aquatica (Eaton) *E.J. Palmer & Steyermark*
(lake cress)

USDA Forest Service, Eastern Region
Hiawatha National Forest
May 2005

This Conservation Assessment was prepared to compile the published and unpublished information on *Rorippa aquatica* (Eaton) E.J. Palmer & Steyermark. This report provides information to serve as a Conservation Assessment for the Eastern Region of the Forest Service. It is an administrative study only and does not represent a management decision by the U.S. Forest Service. Although the best scientific information available was used and subject experts were consulted in preparation of this document and its review, it is expected that new information will arise. In the spirit of continuous learning and adaptive management, if the reader has any information that will assist in conserving this species, please contact the Eastern Region of the Forest Service – Threatened and Endangered Species Program at 310 Wisconsin Avenue, Suite 580 Milwaukee, Wisconsin 53203.

Acknowledgments

Outside Reviewers: We would like to thank our academic reviewers and agency reviewers outside of the United States Forest Service for their helpful comments on this manuscript.
Ihsan A. Al-Shehbaz, Department of Asian Botany Head, Missouri Botanical Garden St.

National Forest Reviewers: We also thank our internal National Forest reviewers for their suggestions and corrections and for providing element occurrences for their National Forests.
Eric Ulaszek, Midewin National Forest, Illinois (Forest Horticulturist)

Herbarium and Heritage Data: We appreciate the sharing of occurrence information for this species from Heritage personnel both in the United States and Canada, along with the helpful assistance of Herbarium personnel. See Contacts section at end of report for a complete list.

Editorial Committee
We thank Jan Schultz, of the Hiawatha National Forest, for her suggestions and patience through numerous revisions.

Also appreciated was the editorial assistance of the following contract employees working with the Hiawatha National Forest:

Literature Search
We thank Laura Hutchinson of the North Central Research Library for performing initial species inquires and sending us relevant research articles.

We thank Jan Schultz, of the Hiawatha National Forest, for use of the extensive library of materials to begin to compile background information on this species.

We also thank Beverly Braden, a contract botanist, for additional literature searches at Northern Michigan University in Marquette, Michigan State University in East Lansing, and the University of Michigan in Ann Arbor.

Initial Draft: We are grateful to Beverly Braden, a contract botanist, for her efforts in providing us with an original draft for this Conservation Assessment.

Table of Contents

Introduction/objectives

The National Forest Management Act and USDA Forest Service policy require that National Forest Service lands be managed to maintain viable populations of all native plant and animal species. A viable population is one that has established populations and a distribution of reproductive individuals sufficient to ensure the continued existence of the species throughout its range within a given planning area. In addition to those species listed as Endangered or Threatened under the Endangered Species Act, or Species of Concern by the U.S. Fish and Wildlife Service, the Forest Service lists species that are sensitive within each region – Regional Forester Sensitive Species (RFSS). A designation of "sensitive" affords some additional regulatory protection.

Rorippa aquatica (Eaton) E.J. Palmer & Steyermark is a Regional Forester Sensitive Species (RFSS) in the Eastern Region of the National Forests. It is listed as an Regional (Region 9) Forester Sensitive Species (RFSS) on the Hiawatha National Forest and the Huron-Manistee National Forest both in Michigan. It also occurs without risk on the Shawnee National Forest (B. Shimp pers. comm. 2003) and the Midewin Tallgrass Prairie (E. Ulaszek pers. comm. 2003) both in Illinois. It was previously listed as occurring at Finger Lakes National Forest in New York, but it has been determined that the known location occurs outside the proclamation boundary (D. Burbank pers. comm. 2003).

The objectives of this document are to:

1. Provide an overview of current scientific knowledge for this species.
2. Provide a summary of the distribution and status of this species, both rangewide and within the Eastern Region of the National Forests.
3. Provide the available background information needed to prepare a subsequent Conservation Approach.

Executive Summary

Prior to 1950, *Rorippa aquatica* was known from much of the eastern United States. Currently, in contrast, five states have only historical element occurrences, and many other states such as New York, Indiana, and Ohio have fewer recent element occurrences compared to historical occurrences. It is presumed that many occurrences were lost due to pollutants, especially agricultural runoff. Lake cress appears to prefer slow waters such as old oxbows. In the Midwest many streams have been channelized to facilitate agricultural drainage. Most of these altered streams are no longer suitable habitat for this aquatic plant since the current is too swift and their muddy riverine flats are no longer exposed periodically due to increased volumes of water. In the northern portion of its range, lake cress rarely sets seed. Lake cress relies heavily on vegetative reproduction primarily by developing new shoots from leaves that become detached from the stem due to abscission layers at the base of the leaves (LaRue 1943). While vegetative reproduction may enable the plant to flourish at a site, its ability to populate new sites on

another body of water are greatly hampered. Many states list this species as either state endangered (e.g. Wisconsin) or state threatened (e.g. Michigan).

Nomenclature and Taxonomy:

Order: Capparales
Family: Brassicaceae (Cruciferae)
Scientific name: *Rorippa aquatica* (Eaton) E.J. Palmer & Steyermark
USDA NRCS Plant Code: NEAQ2
Common names: lake cress
Synonyns: (Al-Shehbaz & Bates 1987, USDA NRCS 2003, Wisconsin State Herbarium 2003)
Cochlearia armoracia L. var. *aquatica* Eaton
Cochlearia aquatica (Eaton) Eaton
Nasturtium natans var. *americanum* A. Gray
Armoracia americana (A. Gray) Britton
Neobeckia aquatica (Eaton) Green
Radicula aquatica (Eaton) Robinson
Armoracia aquatica (Eat.) Wiegand
Armoracia lacustris (Gray) Al-Shehbaz & Bates
Nasturtium lacustre A. Gray
Rorippa americana (Gray) Britton

Taxonomy discussion:

The nomenclature of lake cress has been confused at both the specific and generic ranks, although it has always been assigned to the mustard (Brassicaceae) family. Eaton (1822) originally described it as a variety of horseradish (*Cochlearia armoricia* L.) but later (1829) recognized it as a distinct species of *Cochlearia*. Various authors have treated it as a species of *Nasturtium* (water cress), *Rorippa* (yellow cress), or as *Neobeckia* a monotypic genus.

Bateman (1955 *cf*. Les 1994) maintained that attempts at phylogenetic classification of the Brassicaceae have been complicated because many characters of possible systematic importance vary independently; this is especially true among the aquatic cress genera. Rollins (1993) reasoned that the weak differentiation among all mustard genera was due to the family's recent evolutionary history.

Lake cress and horseradish affinities
The superficial similarity of *Neobeckia* and horseradish (*Armoracia*) led Eaton (1822, refer to synomyns) to describe lake cress as a variety of horseradish. Wiegand (1925) also included *Neobeckia* within *Armoracia* noting its resemblance in stature, flower size, fruit shape, and dissected submerged leaves to horseradish. Wiegand (1925) further stated that the elongated style and partial or complete absence of the septum in lake cress

did not seem sufficient to warrant its separation as a separate genus and that *Armoracia* is the correct genus. Several recent taxonomic treatments (Voss 1985, Al-Shehbaz & Bates 1987, Gleason & Cronquist 1991) have adopted the placement of *Neobeckia* in the genus *Armoracia* because of its apparent similarity.

Les (1994) noted that both *Amoracia* (horseradish) and *Neobeckia* (lake cress) have similar features. Although cultivated horseradish is not perceived as aquatic, all species of *Armoracia* are typically marsh plants. Horseradish is heterophyllous and will produce pinnately dissected lower leaves if grown under submersed conditions (Jennings & Avinoff 1953 *cf.* Les 1994). MacDougal (1914 *cf.* Les 1994) noted that when grown under terrestrial conditions lake cress plants produce thicker roots (up to 1 cm) that are comparable to radishes in texture and taste.

In mustards, an encircling, thick, rib known as the replum is the placental tissue resulting from the union zone of the two carpels. The fruits of many aquatic mustards (*Cardamine, Nasturtium,* and *Rorippa*) possess both a replum and a complete septum. Both lake cress and horseradish are one-celled from the incomplete partition, but imprecise descriptions of fruit structure have confused efforts to assess the relationship of lake cress to horseradish. Les (1994) examined herbarium specimens and found horseradish fruits to possess a septum that was 60-90% complete. In lake cress the septum was less than 10% complete. Les (1994) was unsure if this difference was of taxonomic significance and thought the abnormal septa might be due to a recent parallelism. Al-Shehbaz (pers. comm. 2005) believes that this difference has no taxonomic value because it occurs sporadically and independently throughout the mustard family.

Neobeckia and _Rorippa_ affinities

The similarity of *Neobeckia* to species of *Rorippa* is striking and provides a rationale for merging these genera (Muenscher 1944 *cf*. Les 1994). Both genera exhibit heterophylly and gemmipary (Les 1994). A well-developed system of vegetative reproduction occurs in *Rorippa*. Norton (1933 *cf*. Les 1994) observed the production of plantlets from submersed stems and branches of *Rorippa amphibia*; it also produced adventitious plants on dislodged leaves, particularly following water level drops (Stodola 1967). *Rorippa amphibia* and *Neobeckia* are similar and are difficult to distinguish in the absence of fruit and flowers. Specimens of *Neobeckia aquatica* have been mistaken for *Rorippa amphibia* on several occasions (Marie-Victorin 1930 *cf*. Les 1994). Les (1994) concluded that based on phylogenetic position *Neobeckia* (lake cress) is a genetically distinct sister genus to *Rorippa* with a recent common ancestry. A combination of taxonomic features (white petals, submersed habit, and vestigial fruit septum) was used to separate *Neobeckia* and *Rorippa* rather than merge them together into the genus *Rorippa* (Les 1994). Later, Appel & Al-Shehbaz (2003) in their worldwide monograph of the Brassicaceae reduced *Neobeckia* to a synonym of *Rorippa*.

Nomenclature issue

In the genus *Armoracia*, lake cress was known for many years as *Armoracia aquatica* (Eaton) Wiegand. However, this conflicts with a synonym for *Rorippa amphibia* (L.)

Besser. Therefore, the specific epithet *aquatica* cannot be used under the genus *Armoracia*. A new combination based on *Nasturtium lacustre* A Gray was proposed; therefore, the correct name should be *Armoracia lacustris* (A. Gray) Al-Shehbaz & Bates (1987). This remains the most common nomenclature used by Natural Heritage programs.

More recently, a systematic study (Les 1994) using DNA sequences supported the nomenclature of Greene (1896) who believed that lake cress was distinct enough to merit its recognition as a monotypic genus. The molecular investigations of Les (1994) support the decision of placing *Neobeckia* clearly outside the genus *Armoracia*, but as a sister to the genus *Rorippa*. Les felt that both the large number of molecular differences as well as many morphological differences merited maintaining *Neobeckia aquatica* as a monotypic genus. Returning to the scientific name of *Neobeckia aquatica* (Eaton) Greene is also an older classification so use of this scientific name causes some confusion.

Les sampled only a small number of species in *Rorippa*, a genus of over 75 species that grows on all continents except Antarctica; therefore Les's above conclusions can only be considered preliminary (Al-Shehbaz, pers. comm. 2005). In a more comprehensive review, Appel & Al-Shehbaz (2003) in their worldwide monograph of the Brassicaceae reduced *Neobeckia* to a synonym of *Rorippa*.

Species Description

Rorippa aquatica is a fibrous-rooted aquatic perennial with lax, submersed or prostrate stems. Submersed leaves are pinnately compound and dissected into thread-like divisions which often fall from the stem due to surface water tension when removed from the water. Above the water level, leaves are lance-shaped and toothed. Flowers are white. The fruit rarely matures and most reproduction is asexual with the leaf segments taking root and forming new plants (TNC 1995).

Species Characteristics: Material compiled from Chadde 1998, Chadde 1999, Crow & Hellquist 2000, Godfrey and Wooten 1981, Newmaster *et al*. 1997, and Voss 1985.

Habit: Aquatic perennial herb, usually somewhat submerged; sometimes alternating between submersed and emersed as water levels fluctuate.

Height: Up to 3 feet central stem, lax when submersed.

Roots: Fibrous-rooted herb, anchored to lake or stream bottom.

Stem: Central axis with alternating leaves, commonly submersed, flaccid or prostrate.

Leaves: Quite variable in relation to whether submerged or emersed

Submersed leaves: Pinnately dissected into many threadlike segments
Emersed leaves: Lance-shaped, 3-7 cm long, finely to coarsely toothed margins; might not have any emersed leaves.

Inflorescence: Floral racemes of variable lengths up to 1.5 dm long, weak, often curved, spreading elongated heads held above the water surface. Flowers bloom from June to August.

Flower: Each flower is at the end of a spreading stalk 6-8 mm long; sepals 3-4 mm long elliptic to spatuate; petals 4-merous white.

Fruit: Ellipsoidal 1 chambered pod (5-8mm long), tipped by a persistent slender style 2-4 mm long (style length about half as long as the body of the fruit). Rarely maturing in northern portion of its range. Seeds, when mature, are in 2 rows in each locule.

Similar Aquatic Species:

The alternate leaves of *Rorippa aquatica* will distinguish this species from *Ceratophyllum dermersum* (coontail), *Megalodonta beckii* (water marigold), and most *Myriophyllum* spp. (water milfoils). The presence of a central leaf axis distinguishes lake cress from *Ranunculus longirostris* (curly white water crowfoot) and *Utricularia* spp. (bladderworts) (Voss 1985). Another common wetland mustard is the marsh yellow cress (*Rorippa palustris*); it has bright yellow flowers, leaves cut into deeply cut lobes, a taproot. *Rorippa palustris* is also more variable in habitat, it grows in deciduous swamps, ditches and wet shores (Wisconsin Lakes Partnership 1997). *Proserpinaca palustris* (mermaidweed) and some rare water milfoils (*Myriophyllum spp.*) have alternate leaves with a central axis, but their leaves are not as divided (Voss 1985). Also *R. aquatica* leaves are likely to drop off if this plant is removed from the water, a feature not observed in other similar looking plants (Voss 1985, Newmaster 1997).

Lake cress was previously assigned the same genus as horseradish (*A. rusticana*). Horseradish, introduced from Europe, is an escape from cultivation. It is a coarse plant of wet ditches and shores with mostly simple leaves to sometimes once-pinnatified leaves growing from a thick taproot (Voss 1985).

Life History

Lake-cress is a perennial species, blooming in mid-summer and producing scant quantities of fruit in August and September (Crispin *et al*. 1985). Particularly in the northern latitudes very little fruit matures. For example, in the vicinity of Cheboygan, Michigan few fruits formed; it appeared that these plants did not have sufficient time to ripen before early frosts killed them (LaRue 1943).

Rorippa aquatica overwinters by hardy rootstalks. The stem bases of mature plants remain alive in the muck over the winter, after the upper parts have died and rotted. In spring, side buds grow from the old stem and produce a rosette of leaves. The plant may remain entirely submersed, or portions of the stem may reach the surface and trail on the water (Wisconsin Lakes Partnership 1997).

Most reproduction occurs vegetatively. Lake cress can reproduce vegetatively by several means including: 1) rhizomatous growth, 2) gemmipary (specialized buds located on the bases of leaves that produce adventitious plantlets when detached from the stem, and 3) fragmentation (Gabel & Hes 2000). Microscopic sections show abscission layers at the bases of the leaves. Nearly all leaves except the very young are soon broken off. If one pulls a plant up from the muck usually only the youngest entire leaves at the tip of the stem and the rosette of leaves at its base remain attached (LaRue 1943). Sections of leaves and stems break off and float to new locations, and leaf fragments can generate new plantlets. The floating propagules can be produced in vast quantities which cover the water's surface; many float down stream and out into lakes where they are lost since they fail to find suitable exposed substrate to take root. Some root on mucky banks and others sink to the bottom to overwinter, then rise again in the spring and continue dispersing (LaRue 1943). Buds form more rapidly on leaves that are floating on water, but roots form more readily on leaves that are resting upon a substrate. Damaged or mutilated leaf fragments as well as stem fragments are capable of regenerating buds, but only in the presence of light. When the bases of the leaf were removed (all preformed buds removed) roots normally formed within eight days (LaRue 1943). Arching stems can also take root in the sediment and send up new shoots (Wisconsin Lakes Partnership 1997).

Pringle (1879) described the vegetative reproduction with the lowest, most dissected leaves casting off first and progressing upward along the stem. The leaves are not withered or aged, but still green and gorged with growth material having attained their fullest development. When a leaf lands on the soft mud it puts forth a young plant from the leaf bud, and the young plant develops stem and leaves simultaneously with the roots. The stored nutrients in the leaf enable the new plant to become established within a short time (Pringle 1879). Once established lake cress appears to flourish locally and can become abundant (La Rue 1943), yet this species has never become common. The local abundance of lake cress has been ascribed to its efficient vegetative reproduction (La Rue 1943), and its tolerance of a wide range of environmental conditions.

The most critical habitat feature for vegetative reproduction in lake cress is fluctuating water levels. Sites need to be flooded to facilitate leaves being stripped from the stems of individual plants. When waters later recede, the previously inundated muddy or silty shores or riverbanks act as a medium for regeneration (Gabel & Hes 2000).

Many plants never flower, and thus do not develop mature seeds. Lake cress is known to be highly sterile (La Rue 1943) although seeds are on occasion produced. The condition

of sterility is particularly true for the northern portion of its range; anecdotal reports from state Natural Heritage botanists suggest that natural populations in the southern portion of its range have produced viable seed (TNC 1995). La Rue (1943) suggested that the rarity of lake cress might be directly related to its poor seed production which reduces the potential for long-distance dispersal. The lack of seed production greatly compromises the ability of the species to disperse beyond local distances. Also the brittle nature of the leaves of lake cress limits its ability to get tangled up with other aquatics and be carried away.

Geographic Distribution

The historic range has included 26 states in the United States, but in recent years it has disappeared from many sites (Les 1994). *Rorippa aquatica* is considered rare south of Missouri in the western portion of its range and south of New York in the east (Hotchkiss 1972).

Range-wide Distribution

Rorippa aquatica occurs from Quebec west to Minnesota, south along the eastern coast with scattered occurrences to Florida; in the west it follows the Mississippi drainage basin from Illinois south to Louisiana and Texas (Al-Shehbaz & Bates 1987). It has never been common within its range, and in most areas of the country there has been a distinct drop in occurrences from historic records. The dot map by Al-Shehbaz & Bates (1987) gives a good picture of the historic distribution for lake cress (Also see table in Appendix contrasting Pre-1950 and After-1950 element occurrences).

The highest density of lake cress populations is in the central Midwest region where the Mississippi and Ohio rivers meet. This area is characterized by many smaller riverine systems that together with the Mississippi River and Ohio River, form a very large floodplain. Lake cress appears to be well adapted to a riverine existence (Gabel & Hes 2000). Its distribution indicates a Mississippi embayment phytogeographical affinity (Stuckey 1993).

The number of occurrences were historically highest for Illinois with 41 pre-1950 occurrences and 2 occurrences known in 1987; since then eight occurrences were found on and near Shawnee National Forest in 1991 (B. Shimp pers. comm. 2003). New York had 28 pre-1950 occurrences and 3 current occurrences by 1987. Other states with more than 10 historic occurrences were Indiana (14), Michigan (13), Missouri (12) and Ohio (11); the number of known occurrences for these states currently averages about 3 occurrences (Al-Shehbaz & Bates 1987).

Les (1994) found records for 189 known sites that occurred before 1950 and only 31 records for sites occurring after 1950. During the summers of 1997-99 additional field work was performed (J. Gabel); 29 populations were found in the eastern United States.

Two additional populations were located in Michigan in Cheboygen and Presque Isle counties; in New York 3 new populations were found ranging in size from 150-450 plants; in Missouri five new populations of 80-250 plants many in flower or fruit were documented; large populations (10,000 and 30,000 individuals) were documented for Ohio. Since these surveys, single populations have been reported for Kansas and Texas (Gabel & Hes 2000).

Scoggan (1978) reports lake-cress occurring in lakes and quiet streams from Ontario (north to the Ottawa district) to southwest Quebec. There have been no recent surveys conducted in Canada. The Nature Conservancy reports 40 records for Canada after 1970 (TNC 1995). Therefore the maximum extent of extant populations in North America is estimated at approximately 70 populations (Gabel & Hes 2000, TNC 1995).

Great-Lakes Distribution

Rorippa aquatica is only known from a few scattered locations in eastern and northern Wisconsin, including sites within Lake Superior estuaries (Wisconsin Lakes Partnership 1997). Historically it was known from Brown, Green Lake, Lincoln, and Waukesha counties. Recent occurrences are known for Ashland, Bayfield, Marinette, and Winnebago counties (Wisconsin State Herbarium 2003). It is known from the Apostle Islands, but it is considered rare occurring in wet sand in shallow water in a lagoon (Judziewicz & Koch 1993). In Minnesota, it is reported from the extreme southeastern portion in Houston County but no herbarium specimen was obtained (Al-Shehbaz & Bates 1987).

In the Great Lakes Region, lake cress has diminished in number of occurrences particularly in Illinois. Prior to 1950 it was known throughout the state (Al-Shehbaz & Bates 1987) and now it occurs primarily in northeastern Illinois (Chadde 1998). Indiana has twelve populations that are assumed extirpated and another six historic records whose status is unknown along with two extant populations in southern Indiana in Dearborn and Gibson counties (Hedge *et al.* 1991). Ohio had eleven historic occurrences (Al-Shehbaz & Bates 1987) from five counties in central Ohio and three northern counties along the Ohio River (McCormac 1992). In 1991, six separate populations were discovered along a stretch of the St. Mary's River, a tributary of the Maumee River in northwestern Ohio (McCormac 1992). Prior to 1950, Michigan had several occurrences in the following southern counties: Macomb, Gratiot, Mason, Muskegon and Ionia. Currently lake cress is known from several northern Lower Peninsula counties: Alpena, Cheboygan, Iosco, and Presque Isle. It is also known from Mackinac, Luce, and Marquette counties in the Upper Peninsula (MNFI 2003). In 1995, a healthy population was found on the Hiawatha National Forest in Alger County (M. Jaunzems Element Occurrence).

Illinois, Indiana, Ohio, and southern Michigan are all agricultural areas. Presumably many occurrences in the Great Lakes Region were lost either due to river channelization or due to agricultural runoff polluting adjacent streams. Upper Michigan has

considerable land under State or Federal Forest Systems. For the Great Lakes States of Michigan, Wisconsin, and Minnesota this includes about 49 million acres of forest in either government or private ownership (Frelich & Reich 1996). Often timber harvest practices allow for a riparian buffer so an aquatic plant such as lake cress would be afforded some minimal protection on public lands in forested areas.

Habitat and Ecology

The habitat for *R. aquatica* is quite varied. It includes quiet water, springs, bays of lakes, sluggish streams, muddy shores, rocky shores of lakes, marl ponds in kettle holes, floodplains and oxbows along rivers, small streams, brooks, and bald cypress swamps (TNC 1995).

Rorippa aquatica does best in clear non-polluted waters (TNC 1995). Lake cress appears to thrive in hard, relatively cool water. The healthiest specimens are found in areas with cool spring water emerging from limestone (Gabel #24 CONN). Many element occurrences list either muddy or mucky soils in shallow slow moving waters (See Appendix for element occurrences). Michigan Floristic Assessment (Herman *et al*. 1996) scored lake cress as an 8 out of 10 (highest rating) as a coefficient of conservation. This is an estimate of how likely this plant is to occur in presettlement conditions. An 8 indicates that only 20% of the time would we expect to see *R. aquatica* remaining in polluted waters or fast currents, in the majority of cases we would find it in non-polluted waters.

Lake cress appears to be healthier and occurs in larger populations in habitats with rapidly changing water tables (J. Gabel, personal observation). The species is best able to maintain itself in areas that agitate the plants enough to strip off the leaves and then expose muddy flats for the adventitious plants to root during low water periods. Two populations in Ohio illustrate the importance of this cycle. The populations are fed by multiple creeks and backflows of a fairly large riverine system; these populations are distributed over several miles (Gabel & Hes 2000).

Lake cress populations are typically small, less than 100 individuals. However exact counts are rarely reported unless the number is less than ten. The aquatic habit of lake cress makes it difficult to estimate a population size unless it is found in flower or fruit since the flower head is typically held above the water's surface (Gabel & Hes 2000).

Midwest region

Rorippa aquatica can be found in quiet fresh waters of lakes or slow streams or along moist muddy shorelines. It will grow in water up to several meters deep (Wisconsin Lakes Partnership 1997), and seems to prefer cold or spring-fed waters (Newmaster *et al*. 1997). In Michigan, LaRue (1943) found streams of four to six feet deep with mucky bottoms to be the favored habitat. In Wisconsin, habitat varies from a sandy-bottomed

stream flowing through a bog-embayment along Lake Superior to a nearly dry streambed within deciduous woods (Wisconsin Lake Partnership 1997).

In Michigan, its distribution is limited to the central and eastern Upper Peninsula and the northern Lower Peninsula. Its habitat includes quiet shallow backwaters, silty or sandy lake margins and slow creeks or rivers usually in just 1 to 2 feet of water. Lake cress can also occur as a rare plant associate of the wooded dune and swale complex community type (Albert & Comer 1999). Associated species in Michigan include *Scirpus validus* (softstem bulrush), *Glyceria* spp. (manna-grass), *Sparganium americanum* (bur-reed), *Alisma plantago-aquatica* (water-plantain), *Sagittaria latifolia* (arrowhead), *Equisetum fluviatile* (water-horsetail), *Ludwigia palustris* (purslane), *Polygonum amphibium* (water smartweed), *Typha latifolia* (common cat-tail), and *Nuphar variegata* (yellow water-lily) (Chadde 1998). Other associates in Michigan include *Myriophyllum* spp. (water milfoil), *Nasturtium officinale* (watercress), and *Spirodela polyrhiza* (great duckweed) (Crispin *et al.* 1985).

There is one occurrence of *R. aquatica* on the Hiawatha National Forest (Munising District) growing in a backwater swale of the AuTrain River (Jaunzems EO 1995). Two locations also occur in the vicinity of the Hiawatha National Forest, one in northeastern Luce County (Bodi Lake, 1971) and the other in western Mackinac County (Milleconquin Lake, 1975) (Crispin *et al*. 1985).

Habitat within other mid-west states is frequently floodplains and old oxbows. In Indiana, populations were known from floodplain oxbows along the Wabash River in sandy silt substrates within an abandoned channel (TNC 1995). Ditches and bayous with either stagnant or slowly moving water were typical historic habitat. The two extant populations in Indiana are found in a rocky pool of an old stream channel, and along the border of a wooded slough (Hedge *et al*. 1991).

Recently in Ohio (McCormac 1991) populations were found growing in wet soil in seasonally inundated, disassociated channels of the St. Mary's River, a tributary of the Maumee River. By mid-June surface water was no longer present in these oxbows and *R.. aquatica* was growing in soft, muddy substrate along the edge of each oxbow (McCormac 1991). The Ohio oxbows are semi-open riparian woodlands dominated by *Acer saccharinum* (sugar maple) and *Fraxinus pennsylvanica* (red ash). *Cephalanthus occidentalis* (buttonbush) occurs in the wetter sections. Typical *Carex* species associates include *Carex crus-corvi, C. lupulina, C. muskingumensis,* and *C. tribuloides.* Other associates include the grasses *Leersia lenticularis* and *Leersia oryzoides.* Herbaceous associates include *Ludwigia palustris* (water purslane), *Polygonum hydropiperoides* (smartweed), *Proserpinaca palustris* (mermaid-weed), *Rorippa sessiliflora* (yellow cress), *Samolus floribundus* (water-pimpernel), and *Saururus cernuus* (water-dragon) (McCormac 1991).

In Illinois lake cress is found in swamps and quiet streams (TNC 1995). Populations of *R.. aquatica* have been found in densely forested floodplains, forested oxbows, river terraces and swamps. In northern Illinois, lake cress grows in quiet waters with *Alisma*

subcordatum (southern water-plantain), *Glyceria septentrionalis* (eastern mannagrass), *Leersia oryzoides* (rice cut-grass), *Ludwigia palustris* (common water-purslane), *Mimulus ringens* (Allegheny monkey-flower), *Penthorum sedoides* (ditch-stonecrop), *Polygonum spp.* (smartweed), *Rumex verticillatus* (water-dock), *Sium suave* (water parsnip), *Sparganium eurycarpum* (giant bur-reed), and *Typha latifolia* (common cattail). Because of habitat degradation this species is now much rarer in Illinois (Swink & Wilhelm 1994).

Southern states

In Mississippi, *Rorippa aquatica* was found growing in open areas in calcareous soil subjected to periodic flooding. It has also been found in delta bottomland hardwood forests. In Louisiana, lake cress is found in bottomland forests and cypress lakes. Dominant tree species in these habitats include *Carya aquatica* (water hickory), *Gleditsia aquatica* (water locust), *Quercus nuttallii* (Nuttall's oak) and *Taxodium distichum* (bald cypress) (TNC 1995).

In Missouri, habitat includes bald cypress swamps, other wooded swamps, sloughs, slow streams, springs, shallow or still water, muddy shores of rivers and ponds. Associated plant species include *Alisma triviale* (water plantain), *Bidens americana* (Devil's beggar-ticks), *Cyperus* sp. (bullrush), *Eleocharis* sp. (spikerush), *Justicia americana* (water-willow), *Lobelia cardinalis* (cardinal flower), *Ludwigia palustris* (water purslane), *Mentha* sp. (mint), *Mimulus alatus* (sharpwing monkey-flower), *Potamogeton* spp. (pondweeds), *Samolus parviflorus* (water pimpernel), *Sium suave* (water parsnip), and *Utricularia gibba* (creeping bladderwort) (Summers 1993 *cf.* TNC 1995).

Eastern states

In New York the habitat is muddy shores of large ponds and lakes, and marl ponds derived from glacial kettle holes. Associated plant species include *Cardamine pensylvanica* (bitter-cress), *Lindernia dubia* (false pimpernut), *Polygonum leersia* (smartweed), *Potamogeton* spp. (pondweeds), *Sagittaria* sp. (arrow-head), *Sparganium americanum* (bur-reed), and *Trapa natans* (water-chestnut) (Young 1992 *cf.* TNC 1995).

Vermont habitat includes lake floodplain forests with slow moving waters, and fluctuating water levels due to spring flooding. Lake cress is found in low floodplain forests near river, stream, or creeks, and ponds (TNC 1995). These habitats are fairly open. The typical elevation for lake cress populations in New England is less than 1000 feet (Gabel & Hes 2000).

Typical associated species in Vermont are *Alisma* spp. (water plantain), *Butomus umbellatus* (flowering rush), *Cardamine* spp. (bitter-cress), *Carex crus-corvi, Cephalanthus occidentalis* (buttonbush), *Lemna* spp. (duckweed), *Ludwigia* spp.(water-primrose), *Myriophyllum* spp. (water milfoil), the waterlilies *Nuphar variegata and Nymphaea* spp., *Potamogeton* spp.(pondweed), *Proserpinaca palustris* (mermaid-weed), *Rorippa* spp. (yellow-cress), *Sagittaria* spp. (arrow-head), *Samolus floribundus* (water-pimpernel), and *Wolffia* spp. (water-meal) (Gabel & Hes 2000).

National Forests
Rorippa aquatica is R9 Sensitive on the Hiawatha National Forest (MI) and the Huron Manistee National Forest (MI). The Huron Manistee National Forest site was documented in 1932 and is now considered extirpated; previously lake cress occurred at this site in 1 – 1.5 m of water in an artificially flooded area with a pulpy peat bottom (MNFI 2003).

On the Hiawatha National Forest, a large population estimated at between 1500 to 3000 plants was found in a few square meter area within a slow current backwater slough in deep muck. Vegetative reproduction was evident, and 80% of the plants had flowers in bud. Water depth ranged from 1-5 feet and muck depth was estimated at several feet. The ecological integrity of the entire area, but especially the riparian zone, was high shown by the high diversity of aquatic and wetland communities within close proximity. Other aquatic species consisting of about 60% coverage in the backwater were: *Ranunculus longirostris* (white water-crowfoot), *Elodea canadensis* (common water-weed), *Sagittaria cuneata* (northern arrow-head), *Ceratophyllum demersum* (coontail), *Vallisneria americana* (water celery), *Potomogeton robbinsii* (fern pondweed), *and Nuphar variegata* (yellow water-lily). Emergent vegetation (10% cover) within the back slough consisted of *Scirpus validus* (softstem bulrush), *Acorus calamus* (sweet flag), *Equisetum fluviatile* (water horsetail), and *Sagittaria latifolia* (common arrow-head) (M. Jaunzems EO 1995).

Finger Lakes National Forest in New York no longer lists *Rorippa aquatica* as occurring on the Forest; it occurs outside of the NF proclamation boundary at Seneca Lake (D. Burbank pers. comm. 2003).

Rorippa aquatica is not threatened in Illinois. Populations have not been specifically surveyed on the Midewin Tallgrass Prairie; prairie potholes that contain several hundred individuals appear to be thriving and increasing in number (E. Ulaszek pers. comm. 2003). The Shawnee National Forest in southern Illinois has eight element occurrences, they were found during the 1991 field season. Two element occurrences (EOs) were located just outside the Forest boundary along a roadside ditch. Other habitat within the Forest are a spring, riparian levee, and a bald cypress swamp. The number of flowering plants varied from 20 to almost 500 with the largest populations occurring in the bald cypress swamp and along the roadside ditch (B. Shimp EO 2003).

Rangewide Protection Status (NatureServe)

Currently, the official status for *Rorippa aquatica* with respect to federal, state, and private agencies is:

U.S Fish and Wildlife Service: Not listed. It was proposed as a candidate for federal listing in 1990, but it was downlisted in 1991 due to its abundance in Louisiana (was S4 but now is SR).

Global Heritage Status Rank: G4
U.S National Heritage Status Rank: N4
Canada Heritage Status Rank: N?

U.S. Forest Service: Region 9 Sensitive on Hiawatha (MI), and the Huron-Manistee National Forests (MI). It also occurs on Midewin (IL), and Shawnee (IL) National Forests where statewide populations appear stable. It is known to occur just outside the proclamation boundary of the Finger Lakes National Forest (NY).

The Regional Forester has identified it as a species for which viability is a concern on Hiawatha National Forest as evidenced by being an aquatic species sensitive to eutrophication and requiring quiet waters; its numbers are decreasing, presumably due to poor water quality. The population on the Hiawatha National Forest is the largest known population in Michigan (USDA FS Viability 2003).

With a global rank of G4 an a U.S. National rank of N4, The Nature Conservancy defines these rankings as:

N4: Nationally widespread or secure, but with cause for long-term concern.
G4: Widespread, but apparently rare to uncommon throughout its range. The status of this species is poorly known in several southeastern States. Seed production is poor at many sites. Exotic species may also pose a threat.

N?: Status not determined at present

United States (NatureServe 2003, USDA NRCS 2003 for state protection status)

Alabama	S1	(3 extant)	Mississippi	S1S2	(2 extant)
Arkansas	SR	(1 extant)	Missouri	S2	(7 extant)
Florida	SR	(historic?)	New Jersey	SH	Historic
Georgia	S1?	(2 historic)	New York	S2	Threatened
Illinois	S3	Considered secure	Ohio	S2	Threatened
Indiana	S1	Endangered	Oklahoma	S1S3	Introduced ?*
Iowa	SH	Historic	Pennsylvania	SU	Not tracked
Kansas	S1	(1 extant)	South Carolina	S?	Not tracked
Kentucky	S1S2	Threatened	Tennessee	S2	Special Concern
Louisiana	SR	(15 extant)	Texas	S1	(1 extant)
Maine	SH	Extirpated	Vermont	S1	Threatened
Maryland	S1	Endangered	Virginia	SH	Historic
Michigan	S2	Threatened	Wisconsin	S1	Endangered
Minnesota	SR	(unverified)			

* TNC 1995, Gabel & Hes 2000 list as 2 historic occurrences; Information in parenthesis from Gabel & Hes 2000

Canada (NatureServe 2003)

Ontario	S3?	Quebec	S2

Definitions (NatureServe)
S1: Extremely rare; typically 5 or fewer known occurrences in the state; or only a few remaining individuals; may be especially vulnerable to extirpation.

S2: Very rare; typically between 6 and 20 known occurrences; may be susceptible to becoming extirpated.

S3: Rare to uncommon; typically 21 to 50 known occurrences; S3 ranked species are not yet susceptible to becoming extirpated in the state but may be if additional populations are destroyed.

S?: The species is either unranked or it is not tracked.
SR: Reported from state, but not assessed
SU: Status unknown, insufficient data to assign a ranking
SH: Possibly extirpated

Population Biology and Viability

Although the range of lake cress is extensive, frequency within its range is very low (Al-Shehbaz & Bates 1987). Lake cress populations are typically small ranging in size from 50 to 100 individuals (J. Gabel, personal observation). Many occurrences do not mention population size since its aquatic nature makes this difficult to estimate. Several Illinois element occurrences list from 50-150 plants in flower and fruit. Only one Michigan site (Presque Isle County) estimated size at 250 stalks. Missouri lists population sizes between 80-250 plants. New York has populations ranging from 50-150 with one population estimated at 300. The largest populations are reported from Ohio with 10,000 in one floodplain and 30,000 in an extensive area fed by several small creeks (Gabel & Hes 2000).

Lake cress is known to be highly sterile (La Rue 1943, Godfrey & Wooten 1981, Al-Shehbaz & Bates 1987, Gleason & Cronquist 1991, and McCormac 1992). Although seeds are produced on occasion (Rollins 1993) their viability has never been demonstrated. Prolonged asexual reproduction can have serious genetic consequences such as genetic load at sexual loci (Eckert *et al.* 1999).

La Rue (1943) suggested that the rarity of lake cress might be directly related to its poor seed production which reduces its potential for long-distance dispersal. The lack of seed production greatly compromises the ability of the species to disperse beyond local distances. Also the brittle nature of the leaves of lake cress limits its ability to get tangled

up with other aquatics and be carried away by dispersal agents such as waterfowl or aquatic mammals.

Stuckey (1972) hypothesized that the genera *Armoracia, Cardamine, Nasturtium,* and *Rorippa* represented the closest relatives of *Neobeckia,* a conclusion that was consistent with a molecular study of aquatic mustards (Les 1994). A base number of $x = 8$ characterizes all genera (*Armoracia, Cardamine, Nasturtium, Rorippa*) that are putatively allied with lake cress. In the tribe *Arabideae* in which all these genera occur the most common base number is x = 8 (Harberd 1976 *cf.* Les *et al.* 1995). Examination of lake cress populations (from Michigan, Ohio, Vermont, and Wisconsin) reviewed 2n counts of 23-26 chromosomes. Les (1995) was convinced that the actual chromosome number for lake cress is 2n = 24, and that stained particles in the nucleolus region made the counts difficult. The 2n = 24 chromosome number of *Rorippa aquatica* indicates that the species is triploid, at least in the northern populations studied.

The origin of triploidy in lake cress remains uncertain. We do not know if the species represents an intraspecific hybrid or an interspecific hybrid resulting from a cross between diploids, tetraploids, or possibly a diploid and tetraploid (Les *et al*. 1995).

The number 2n = 24 is rare in the tribe *Arabideae* and is associated with tripoid hybrids when it does occur (Les *et al*. 1995). In *Rorippa*, spontaneous triploids (2n = 32), for example, *R. amphibia* and *R. palustris* (Howard 1947 *cf.* Les *et al*. 1995). The triploid hybrids are sterile whereas tetraploid hybrids are fertile (Les *et al*. 1995).

It is possible that in the southern portions of its range there could be diploid or tetraploid populations of lake cress. This can only be ascertained by further cytological examination of populations throughout the range. A comprehensive survey of lake cress populations, especially at its southern range, is highly recommended because the discovery of fertile plants could significantly influence conservation strategies for this species (Les *et al.* 1995).

Even with asexual reproduction there is substantial variation within several populations of lake cress, including those populations that have never been observed to flower. Most of the variation within asexual populations of lake cress has been attributed to somatic mutation (Les and Gabel 1996). However, there are currently no data to evaluate whether there is genetic load associated with sterility in lake cress populations (Gabel & Hes 2000).

Sterility in the related horseradish (*Armoracia rusticana* L.) has been attributed to interspecific hybrid origin (Weber 1949 *cf.* Les *et al.* 1995) along with self-incompatibility, and accumulation of deleterious mutations from prolonged vegetative propagation (Stokes 1955). Self-incompatibility has also been implicated in the low seed production of several clonal, perennial *Rorippa* (Jonsell 1968 *cf.* Les *et al.* 1995). Preliminary investigations of self-incompatibility in lake cress (Gabel, unpublished data) indicate that it also has sporophytic self-incompatibility (SSI) (Gabel & Hes 2000).

Potential Threats

Construction activities that may impact *Rorippa aquatica* populations include stream channelization, flood management, and waterfront development. Construction activities destroy lake cress habitat by reducing the extent of floodplains and by destroying mudflats. Flood management disturbs the critical water level fluctuations necessary for optimal lake cress recruitment. Waterfront development results in fragmentation of habitat and the disruption of corridors for dispersal between populations (Gabel & Hes 2000).

In New England, the principle threats to *R. aquatica* include: 1) eutrophication from agricultural and industrial run-off, 2) invasive exotic aquatic plants 3) waterfront development and stream channelization (Gabel & Hes 2000).

Two New England lake cress localities are very eutrophic. The creek and floodplain habitats usually occupied by this species are also important agricultural lands. Inevitably there is a large amount of run-off from these areas, which not only degrades the habitat but also attracts invasive weeds (Gabel & Hes 2000). Invasive species such as *Lythrum salicaria* (purple loosestrife), *Trapa natans* (water-chestnut), and *Myriophyllum spicatum* (Eurasian milfoil) threaten lake cress populations by overtaking portions of potential habitat. In New England, it is common to observe lake cress situated along the shore between *Myriophyllum spicatum* in the water and *Lythrum salicaria* on shore. It is also possible that *Rorippa amphibia* represents an additional threat due to its similar habitat preference and mode of reproduction (Gabel & Hes 2000).

Myriophyllum spicatum (Eurasian watermilfoil), *Rorripa amphibia* (marsh cress), *Trapa natans* (water chestnut) and other aquatic exotic plants are of concern as they decrease habitat quality and reduce or eliminate populations (TNC 1995). A historic occurrence in New Jersey was possibly lost due to the application of herbicides used to control *Myriophyllum spicatum*. At this site, all aquatic plant species with similar dissected leaves were lost including *Bidens beckii, Myriophyllum sibiricum, Ranunculus aquatilis,* and *R. longirostris* (Synder 1993 *cf.* TNC 1995).

Recently (Adirondack Council 2002) there was a debate whether to approve the chemical herbicide fluridone for use in Lake George in the Adirondack Park, New York. *Rorippa aquatica* has been found at the West Tongue Mountain Bay; therefore, the Adirondack Council recommended that fluridone not be used to control Eurasian milfoil at this site. The current proposal is for use of 2000 pounds of the chemical at four sites in Lake George. The proposed chemical (brand name 'Sonar') kills all underwater plants in an area by destroying the plant's ability to photosynthesize (Adirondack Council 2002).

Alteration of habitat through stream channelization is a significant threat, especially in agricultural areas. In Florida, the creation of impoundments (farm ponds) is a significant threat (TNC 1995). Any changes in the hydrological regime of an area is a threat to this

species. Increased water levels may flood existing habitat, while decreasing water levels will lead to the loss of suitable habitat (TNC 1995).

Summary of Existing Habitat Protection

Because *R. aquatica* grows in aquatic habitats such as stream edges or old ox bows it is greatly affected by conditions outside of a preserve area. Working with adjacent landowners within watersheds is critical. Up stream pollution is especially degrading for this species and its habitat. Stream channelization causes a faster current that is often detrimental as *R. aquatica* seems to thrive in slow moving waters (TNC 1995).

Stewardship of lakes and streams normally involves numerous agencies across an entire watershed; therefore, establishing the necessary partnerships to protect these resources can be quite involved and take many years.

In Indiana, the two extant populations appear to be secure for the present. However, their occurrence on private land makes the assessment of threats uncertain for these sites, and in fact one site had been heavily grazed so it might be negatively impacted (Hedge *et al.* 1991).

One Michigan locality lies within a private natural area in Marquette County, another occurs within Lake Superior State Forest in Luce County (Crispin *et al*. 1985). A recent (M. Jaunzems 1995) occurrence was found on the Hiawatha National Forest in Alger County; this element occurrence is the largest population in the Upper Peninsula (USDA FS Viability 2003). The Manistee National Forest location is presumed extripated (A. Cleveland pers. comm. 2003).

Management and Conservation Issues

Management of habitats suitable for *R. aquatica* should include protection from agricultural activities and possible degradation by organic and industrial pollutants, chemical run-off, siltation, and herbicides (TNC 1995). High water quality and natural hydrology are particularly important for the health of this species (Crispin *et al.* 1985). Activities that should be discouraged are shoreline improvements and construction, and destructive recreational activities. Additional threats include hydrological perturbations such as channelization or artificial flooding, and competition from exotic plant species (TNC 1995).

Maintaining the hydrological integrity of *R. aquatica* is of utmost importance for the perpetuation of this species. Prevention of stream channelization and maintenance of water quality are key components. Waters need to be protected from eutrophication. Eliminating threats from siltation due to agricultural or timber harvesting activities is necessary. Herbicides, pesticides, and other chemical pollution pose a major threat. Water quality needs to be monitored periodically (TNC 1995). The most practical way to accomplish a reduction of eutrophic conditions is to enlarge the buffer zone between agricultural areas and lake cress habitat. The most cost-effective method is to instruct farmers about cost-effective eco-friendly agriculture. Studies by Matson *et al*. (1998) illustrate that application of less fertilizer at critical times is more beneficial and cost effective than broad application of fertilizer, and it also results in less runoff and nitrogen leeching.

Efforts to control exotic aquatic species such as *Myriophyllum spicatum* (Eurasian milfoil) are needed. The most effective practice is to prevent Eurasian milfoil's spread by removing all plant fragments from boats and trailers, and draining water from the boat's live well before leaving the lake. Where possible boaters should avoid traveling through heavily invested areas (Ottawa National Forest 2002). Once established, care must be taken to ensure that eradication or control efforts (hand-pulling, suction harvesting, mechanical harvesting, or herbicide application) does not negatively impact *R. aquatica* populations (Adriondack Aquatic Institute 1997). A population of lake cress was lost in New Jersey when herbicide was used to control Eurasian milfoil in one lake; all species with dissected leaves were lost (TNC 1995). In New England, *Lythrum salicaria* (purple loosestrife) is a particular concern since it inhabits the mudflats where lake cress could potentially take root. Physical removal is suggested for small areas (Gabel & Hes 2000).

It has long been known that vegetatively reproducing mustard crops such as horseradish and watercress can be severely damaged by fungal and viral pathogens (Crisp 1976 *cf* Les 1995). Such threats are particularly serious for clonal plants like lake cress since seed production and adaptation can not be relied on to develop resistance to these pathogens (Les *et al*. 1995).

It is unlikely that vegetative propagules alone can adequately maintain dispersal among the remaining fragmented lake cress habitats. Without human intervention, sites that have experienced local exterminations due to population crashes are likely to remain devoid of the species (Les *et al*. 1995). This could ultimately lead to fewer and fewer populations that would be very susceptible to habitat loss or a catastrophic event. To supplement remaining habitat protection, Les (1995) recommends the implementation of artificial establishment techniques to overcome the dispersal limitations of lake cress.

Restoration Potential

Rorippa aquatica might be relatively easy to introduce into suitable habitats. Experiments by McCormac (1992) have shown that plants will grow from cauline leaf cuttings placed in potting soil. The survivorship of rosettes in natural systems is poorly

understood. Restoration efforts need to be undertaken to assess the feasibility of controlled introductions of leaf cuttings.

There is an absence of demographic studies illustrating what stable lake cress population sizes should be, but from extant populations in Vermont it appears that a population size of 250 individuals is not unusual. The stability of populations with this many individuals is unverified, but populations of this size may be stable since they remain as extant populations (Gabel & Hes 2000). Re-introductions should be located on protected lands within watersheds in the historic range of this species. Areas of reintroduction need to have water fluctuations conducive to recruitment of individuals and be free of *Lythrum salicaria*. Also re-introductions should be placed in relatively close proximity to each other; this practice enhances both gene flow among populations and recolonization after a disturbance. Initially it is recommended that populations be maintained at 250 individuals or more (Gabel & Hes 2000).

Les and Gabel (1996) recommend maintaining a "garden of genotypes". In preliminary investigations, they found on average ten or fewer genotypes for each population. These genotypes could be easily maintained in flooded pots in the greenhouse for indefinite lengths of time. If a catastrophic event wipes out a population, cuttings from garden plants may be used to reintroduce the species to the site (Gabel & Hes 2000).

It is possible that excessive shading contributes to a diminishing population at a site. In some areas, selective timbering might open up the canopy and perhaps increase flowering and fruiting of these populations (TNC 1995).

Research and Monitoring

The determination of population status, trends, reproductive success, and an assessment of habitat quality and threats is needed. Surveys should be made to locate additional extant populations and to relocate historic occurrences. Populations should be surveyed repeatedly to see if they are decreasing or flourishing. Where are the sites of highest quality across the range of this species, what are the effects of soils, light, and flucuating water levels. Research is needed to study reproductive and population biology of this species, investigate plant response to lowering water levels, and determine the effects of competing aquatic plant species (TNC 1995).

Many questions could be researched with regards to *R. aquatica* such as causes for low flower, fruit and viable seed production. Do low rates of seed production exist over all its range, or only in the northern states and Canada? It is unclear how lake cress successfully disperses since propagules are rarely transported during flood episodes. Nor has anyone determined the percentage of rosettes that survive and develop to maturity in natural systems. An understanding of how well lake cress competes with other aquatic species is lacking as well (TNC 1995).

Another question to be considered is the effect of water level. For instance as water level decreases the lower dissected leaves (which were once submerged) wither and drop, while the plant produces new broad leaves. Does the greater leaf surface aid the plant in sunlight utilization; is there a change in photosynthesis? Is a change in water table helpful for sexual functioning in terms of flower and fruit production? (TNC 1995).

Summary

Rorippa aquatica is considered rare over much of its range. Michigan is central on a east to west range, and with element occurrences in Ontario, Michigan is not at the far northern limit of its range (USDA FS Viability 2003). Many populations have disappeared throughout the United States since pre-settlement conditions. It is considered extiripated from Iowa, Maine, New Jersey, Virginia, and Texas. In Michigan, only 5 of 22 occurrences have been confirmed since 1980 (MNFI 2003, HNF EO 1995). Lake cress is sensitive to pollution and appears to favor slow moving waters. Often either muddy shores or muck is mentioned as the substrate. Channelization of rivers upstream have caused faster currents downstream thus making these rivers unsuitable habitat.

At the same time, lake cress is probably somewhat under-reported. Aquatic species are not as easily recognized by all field botanists. Some botanists may find their study cumbersome as surveying for aquatics may require the use of a canoe or row-boat. Also aquatic species tend to become entangled with each other by wave action which makes them more difficult to inventory. The Alger County site on the HNF was located from a canoe (M. Jaunzems EO 1995). In Michigan, over ten sites were found in the 1970s which would have coincided with the extra survey work that was done for the Michigan Flora project and Voss' first volume (Monocots and aquatic key). Since 1980 only five additional EOs were documented (MNFI 2003, HNF EO 1995). The Hiawatha National Forest has not had funds allocated to specifically focus on aquatic surveys (Viability Evaluation 2003). At Pictured Rocks National Lakeshore vegetative surveys have been done for several years, but rarely has staff attempted to do aquatic vegetative surveys; and what surveying effort that was done focused primarily on the suitability of fish habitat (W. Loope pers. comm. 2001).

In Wisconsin, more extensive field work focused on rare aquatic plants was done between 1991 to 1995. Emmet Judziewicz located five element occurrences in Bayfield County and Ashland County, and in 1998 three additional EOs were located by B. Johnson in Marinette County (Wisconsin State Herbarium 2003). During the summer of 1991 extensive field work on the Shawnee National Forest in Illinois lead to the discovery of six sites on the Forest and two adjacent to the Forest (B. Shimp EO). Six new sites were discovered in Ohio in 1992 along the St. Mary's River (McCormac 1992).

Although *R. aquatica* remains rare, in states where extensive surveys are being performed it is being found in limited numbers.

Another reason *R. aquatica* might be under-reported is that it often loses its leaves when lifted out of the water which means it is likely to be under-represented in herbariums; therefore, a site might not be reported to the state's Natural Heritage Program. In addition, this species confusing taxonomic history, and the need to check under numerous synonyms to research lake cress could lead to the misplacement of a several specimens which, therefore, might not ever be reflected on state distribution dot maps or listed in Natural Heritage Programs.

References

Adirondack Aquatic Institute. 1997. Eurasian milfoil information. Adirondack Aquatic Institute at Paul Smith's College, NY. p 1-2.

Adirondack Council. 2002. News release: Another state-protected plant found in Lake George where chemical herbicide treatment is proposed. (Adirondack Council is an 18,000 member, privately funded not-for-profit organization). Accessed 11/26/2003, Available at: http://www.adirondackcouncil.org/sonar3pr.html

Albert, D.A. and P.J. Comer. 1999. Natural community abstract for wooded dune and swale complex. Michigan Natural Features Inventory. Lansing, MI. p. 1-6.

Al-Shehbaz, I.A. and V. Bates. 1987. *Armoracia lacustris* (Brassicaceae), the correct name for the North American lake cress. Journal of the Arnold Arboretum. Vol. 68 p. 357-359.

Appel, O. & A. Al-Shehbaz. 2003. Cruciferae. K. Kubitzki (ed.), Families and genera of vascular plants. Vol. 5. Springer Verlag, Berlin. Pp. 75-174.

Chadde, S.W. 1998. A Great Lakes Wetland Flora. Pocketflora Press. Calumet, Michigan. P. 122.

Chadde, S.W. 1999. A Forester's Field Guide to Endangered and Threatened Plants of Michigan's Upper Peninsula. Pocketflora Press. Calumet, Michigan. P. 85.

Crispin, S.R., L.A. Wilsmann, K.A. Chapman, S.J. Ouwinga. 1985. An overview of endangered and threatened species in the Hiawatha National Forest, Michigan. Summary for *Armorica aquatica*. Michigan Natural Features Inventory. P. 80-81.

Crow, G.E. and C. B. Hellquist. 2000. Aquatic and Wetland Plants of Northeastern North America. The University of Wisconsin Press. p. 148-149.

Eckert, C.G., M.E. Dorken, and S.A. Mitchell. 1999. Loss of sex in clonal populations of a flowering plant, *Decodon verticillatus* (Lythraceae). Evolution 53: 1079-1092.

Frelich, L.E., and P.B. Reich. 1996. Old Growth in the Great Lakes Region *in* Eastern Old-Growth Forests.(Ed. M.B. Davis). Island Press. Washington, D. C. p. 144-160.

Gabel and Hes, J.D. 2000. *Neobeckia aquatica* Eaton (Greene). New England Plant Conservation Program, Conservation and Research Plan. P. 1-31.

Gleason, H.A. and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. The New York Botanical Garden. Bronx, New York. p. 187.

Godfrey, R.K. and J.W. Wooten. 1981. Aquatic and Wetland Plants of Southeastern United States. University of Georgia Press. Athens, Georgia. P. 174-175.

Hedge, C.L., M. Homoya, and C. Baker. 1991. Report on the status of *Armoracia aquatica* (lake cress) in Indiana. Dept. of Natural Resources. Indianapolis, IN.

Herman, K.D, L.A. Masters, M.R. Penskar, A.A. Reznicek, G.S. Wilhelm, and W.W. Brodowicz. 1996. Floristic quality assessment with wetland categories for the State of Michigan. Appendix C.

Hotchkiss, N. 1972. Common marsh, underwater and floating-leaved plants of the United States and Canada. Dover Publications, Inc. New York. p.57.

Jaunzems, M. 1995. Hiawatha Plant Survey Form (Element Occurrence), Hiawatha National Forest, Michigan.

Judziewicz, E.J. and R.G. Koch. 1993. Flora and vegetation of the Apostle Islands National Lakeshore and Madeline Island, Ashland and Bayfield counties, Wisconsin. The Michigan Botanist. Vol. 32 (March) P. 43-189.

LaRue, C.D. 1943. Regeneration in *Radicula aquatica*. Michigan Academician 28: 51-61.

Les, D.H. 1994. Molecular systematics and taxonomy of lake cress (*Neobeckia aquatica*; Brassicaceae), an imperiled aquatic mustard. Aquatic Botany 49: 149-165.

Les, D.H., G.J. Anderson, and M.A. Cleland. 1995. Sterility in the North American lake cress *Neobeckia aquatica* (Brassicaceae): Inferences from chromosome number. Rhodora 97(891) P. 185-200.

Les, D.H. and J.D. Gabel. 1996. Genetic variation among and within populations of *Neobeckia aquatica* (Eaton) Greene (lake cress), a sexually sterile, clonal triploid. American Journal of Botany 83 (supplement) p. 173-174.

McCormac, J.S. 1992. *Armoracia lacustris* (Brassicaceae) rediscovered in Ohio. Rhodora. Vol. 94 (880) P. 387-390.

Michigan Natural Features Inventory (MNFI). 2003. Online database. Accessed 04/30/2003 and 10/22/2003. Found at http://web4.msue.msu.edu/mnfi/search/

Newmaster, S.G., A.H. Harris, and L.J. Kershaw. 1997. Wetland Plants of Ontario. Lone Pine Publishing. Edmonton, Canada. P. 185.

Ottawa National Forest (USDA Forest Service). 2002. Exotic Species Alert. p. 1-2.

Pringle, C.G. 1879. Leaf propagation of *Nasturtium lacustre*. Botanical Gazette. Vol. 4 (12) p. 237-238.

Rollins, R.C. 1993. The Cruciferae of Continental North America. Stanford, California. P 87-89, 210-213.

Scoggan, H.J. 1978. The Flora of Canada. Part 3. National Museum of Natural Sciences. Ottawa, Canada. p. 798.

Shimp, B. 1991. Shawnee National Forest biological conservation datasystem Element Occurrence (EO) report form. Shawnee National Forest, Illinois.

Stuckey, R. L. 1993. Phytogeographical outline of aquatic and wetland angiosperms in continental eastern North America. Aquatic Botany. 44: 259-301.

Swink, F. and G. Wilhelm. 1994. Plants of the Chicago Region. Morton Arboretum. Lisle, Illinois. P. 124.

The Nature Conservancy (TNC). 1995. Element Stewardship Abstract for *Armoracia lacustris.* Arlington, Virginia p. 1-14.

USDA Forest Service. 2003. Regional Forester Sensitive Plants. P. 1-21.

USDA Forest Service (FS Viability). 2003. Species Viability Evaluation Documentation. Panel of Hiawatha National Forest Botanists. Escanaba, MI. p. 68-70.

USDA NRCS. 2003. Plants Database (*Neobeckia aquatica*) Accessed 02/06/2003 Found at http://plants.usda.gov

Voss, E.G. 1985. Michigan Flora. Vol. 2. Cranbrook Institute of Science Bulletin 59 and the University of Michigan Herbarium. Ann Arbor, Michigan. P-280-292.

Wisconsin Lakes Partnership. 1997. *Armoracia lacustris in* Through the Looking Glass, a field guide to aquatic plants. Reindl Printing, Inc. Merrill, WI. p. 204-205.

Wisconsin State Herbarium. 2003. Wisconsin vascular plants – *Armoracia lacustris*. Found at: www.botany.wisc.edu/herbarium Accessed: 11/04/2003

Contacts mentioned in TNC Element Stewardship Abstract

Synder, D.B. 1993. Botanist, New Jersey Natural Heritage Program. Personal communication: ESA questionnaire for *Armoracia lacustris*. 4 pp.

Summers, B. 1993. Botanist, Missouri Botanical Garden. Personal communication with The Nature Conservancy.

Young, S. 1992. Botanist, New York Natural Heritage Program, Department of Environment Conservation. Personal communication: ESA questionnaire for *Armoracia lacustris*. 4pp.

Cited from Les (1994 & 1995)

Bateman, A.J. 1955. Self-incompatibility systems in angiosperms. Cruciferae. Heredity 9:52-68.

Crisp, P., 1976. Trends in the breeding and cultivation of cruciferous crops. In J.G. Vaughan, A.J. Macleod and B.B.G. Jones (Editors), The Biology and Chemistry of the Cruciferae, Academy Press, New York, pp. 69-118.

Harberd, D.J. 1976. Cytotaxonomy of Brassica In: J.G. Vaughan, A.J. Macleod and B.B. G. Jones (eds) The Biology and Chemistry of the Cruciferae. Academic Press. N.Y. p. 47-68.

Howard, H.W. 1947. Chromosome numbers of British species of the genus *Rorippa* Scop. (part of the genus *Nasturtium* R. Br. Nature 159: 66-67.

Jennings, O.E. and Avinoff, A. 1953. Wild flowers of western Pennsylvania and the Upper Basin. Vol. 1. University of Pittsburgh Press, Pittsburgh. 575pp.

MacDougal, D.T. 1914. The determinative action of environmental factors upon *Neobeckia aquatica*. Greene. Flora. 106:264-280.

Marie-Victorin, F., 1930. Le genre *Rorippa* dans le Quebec. Lab. Bot. Univ. Montreal. Vol. 17: 1-17.

Muenscher, W.C. 1944. Aquatic Plants of the United States. Cornell University Press, Ithaca, N.Y. 374 pp.

Norton, A.H. 1933. *Rorippa amphibia* in Androdscoggin County, Maine. Rhodora. 35:262.

Stuckey, R.L. 1987. *Armoracia aquatica* disappeared from central portion of its range. In Aquatic Plants Reference Manual. Compiled Publication Series, No. 3. Columbus, OH p. 231.

USDA Forest Service and other agencies Contacts

Hiawatha National Forest, MI: Jan Schultz (Forest Plant Ecologist) (906)-228-8491 jschultz@fs.fed.us
Hiawatha National Forest, MI: Deb LeBlanc (West side Ecologist) (906)-387-2512 dleblanc2@fs.fed.us
Hiawatha National Forest, MI: Mark Jaunzems (East side seasonal botanist) (906)-643-7900 mjaunzems@fs.fed.us
Finger Lake National Forest, VT: Diane Burbank (Forest Ecologist) (802)-388-4362 dburbank@fs.fed.us
Midewin National Forest, IL: Eric Ulaszek (Forest Horticulturist) (815) 423-6371
Shawnee National Forest, IL: Beth Shimp (Forest Botanist) (618) 253-1053
Huron Manistee National Forest, MI: Alex Cleveland (Forest Plant Ecologist) (231)-775-2421 acleveland@fs.fed.us
US. Geological Service at Pictured Rocks National Lakeshore, MI: Walt Loope (Geologist) (906)-387-3116
Library Services, MN: Laura Hutchinson lhutchinson@fs.fed.us

Outside Reviewer:

Missouri Botanical Garden, St. Louis, Missouri: Ihsan A. Al-Shehbaz, Department Head of Asian Botany (314)-577-9556

Appendix for *Neobeckia aquatica*

National Forest Service Occurrences

National Forest	Location/Remarks	Date Observed	Resource
Hiawatha (MI)	Alger Co., AuTrain NE	1995	M. Jaunzems
Huron Manistee (MI)	Mason Co., Hamlin Lk.	Considered extirpated	A. Cleveland
Finger Lakes (NY)	Seneca Lake, occurs outside boundary	No longer listed on FL Nat. Forest	D. Burbank (2003)
Midewin (IL)	Marsh habitat, unmanaged but increasing (a few hundred individuals)	Pers. comm. 2003	E. Ulaszek
Shawnee NF (IL) Adj. Land owned by State – IDOT	Jackson Co., Route 3 Ditch	7 Jun 1991 (37 flowering plants)	E.L. Shimp
Shawnee NF (IL) Adj. Land owned by State – IDOT	Jackson Co., Route 3 Ditch	7 Jun 1991 (488 flowering plants)	E.L. Shimp
Shawnee NF (IL)	Union Co., Water Cress Springs	7 Jun 1991 (41 flowering plants)	E.L. Shimp
Shawnee NF (IL)	Jackson Co., Oakwood Bottoms Levee	10 Jun 1991 (26 plants)	K. Nash
Shawnee NF (IL)	Alexander Co., Clear Creek Swamp	13 Jun 1991 (180^{+} flowering plants)	K. Nash
Shawnee NF (IL)	Alexander Co., Clear Creek Swamp	17 Jun 1991 (425 flowering plants)	K. Nash
Shawnee NF (IL)	Alexander Co., Clear Creek Swamp	21 Mar 1991	R. Smith
Shawnee NF (IL)	Jackson Co., wet roadside ditch	6 Jun 1991	R. Smith

Michigan Historical occurrences prior to 1954 (MNFI 2003)

Location / County	Date observed	Remarks
Clinton River, Macomb County	1848-06-22	Abundant in creek, but no fertile plants
Clinton River, Macomb County	Pre-1900	Flowing water
Ionia County	1889	A mill pond
Alma, Gratiot Co.	1889-07-23	
Muskegon Co.	1898-07-23	Critical dune area
Mason Co., Hamlin Lk	1932	Manistee National Forest, A pulpy peat

		bottom in 1 to 1.5m of water
Alpena Co. Long Lk	1939-06-14	1 to 2 feet of water; gravel bottom
Presque Isle, Long Lk	1939-06-14	1 to 2 feet of water; gravel bottom
Presque Isle Co.	1937-08-12	A river in several feet of water
Cheboygan Co.	1953-08-12	Quiet shallow backwaters
Cheboygan Co.	1951-07-16	
Cheboygan Co.	1953-07-20	A river

Michigan occurrences after 1969 (MNFI 2003)

County	Date observed	Remarks
Cheboygan	1970-07-29	Mouth of Black River – 8 occurrences
Marquette	1976	Huron Mountain Club
Iosco	1981	Sandy bottom lake in 2 ft. of water
Cheboygan	1981-07-13	Silty margin of a lake; assoc. with emergent sedges
Cheboygan	1984	Silty, muddy bank of a small creek
Cheboygan*	1997	High number of individuals (Hellquist)
Alpena*	1997	250 individuals
Alpena	1984	
Alpena	1972-07-28	
Presque Isle	1981-07-06	An acidic brownwater river near lake outlet
Mackinac	1975-07-07	Shallow, turbid water of a lake
Luce	1971-08-05	Sandy lake bottom in 2 ft. of water

* Reported by Gabel and Hes (2000)

Wisconsin occurrences (Wisconsin State Herbarium 2003, Gabel & Hes 2000)

County (Town)	Date observed	Collector
Waukesha		U. Rowlatt
Brown	1891	J.H. Schuette
Lincoln	1915	
Green Lake	1921	H.W. Rickett
Marinette	1993	At Peshtigo Flowage
Marinette	7/28/1998	B. Johnson
Marinette	7/28/1998	B. Johnson
Marinette	7/28/1998	B. Johnson
Bayfield (Cornucopia)	6/15/1995	E.J. Judziewicz
Bayfield (Siskiwit Bay)	6/20/1995	E.J. Judziewicz
Bayfield (Bark Bay)	6/21/1995	E.J. Judziewicz
Ashland	8/18/1992	E.J. Judziewicz
Ashland (Oak Island)	8/18/1991	E.J. Judziewicz

Bayfield (Sand River)	7/22/1980	W.S. Alverson
Bayfield	7/22/1980	W.S. Alverson
Bayfield	7/22/1980	W.S. Alverson
Winnebago	8/05/1980	W.S. Alverson

Mississippi-Ohio River Basins (extant element occurrences) (Gabel & Hes 2000)

State	Last Observed	County	Town/Locality	Notes
IL	1986	Iroquois	Watseka	
IL	1992	Washington	Venedy	
IL	1993	Alexander	Miller City	
IL	1993	Jackson	Shawnee National Forest	Mudflat off Big Muddy River
IL	1997	Union	Larue	80 flower & fruit; cold, clear water, limestone spring
IL	1997	Jackson	Howardton	150 flower & fruit; roadside ditch
IL	1997	Jackson	Shawnee National Forest	50 flower & fruit; 2 feet of water, turbid, buttonbush swamp
IL	1997	Alexander	Miller City	60 flower & fruit; 2 feet of water
LA	1990	Saint Mary	Morgan City	Fruit
LA	1991	Saint Martin		
LA	1996	Assumption	Pierre Port	Fruit
LA	1997	Iberville	Indigo Island	Cypress swamp; in seed
LA	1997	Morehouse	Monroe	Open wet sedge community; in seed
MO	1993	Oregon	Thomasville	6 plants
MO	1994	Wayne	Williamsville	150 plants
MO	1994	Oregon	Greer	Large population
MO	1997	Christian	Ford	200 in flower; cold ditch at 1250 feet
MO	1997	Howell	Mountain View	80 rosettes; cold, clear water
MO	1997	Laclede	Morgan	250 flower; cold limestone spring; plants up to 8 foot long
MO	1997	Mississippi	Big Oak Park	100 fruit; turbid ditch along road
MO	1998	Wayne		

OH	1993	Franklin	Hoover Resv.	
OH	1997	Madison	Gillivan	10,000 in flower; extensive floodplain and buttonbush swamp
OH	1997	Mercer	Union	30,000 in flower; extensive flooded area fed by several small creeks

New York and Vermont (extant occurrences) (Gabel & Hes 2000)

State	Last Observed	County	Town/Locality	Notes
NY	1987	Erie	Lockport	
NY	1988	St. Lawrence	Canton	50 plants
NY	1988	St. Lawrence	Hammond	fragments
NY	1988	Washington	Dresden	50 plants
NY	1997	Jefferson	Fort Drum	300 plants; muddy banks of small pond
NY	1999	Onondaga	Tully	150 in fruit; 1 foot of water
NY	1999	Cortland	Preble	450 in flower; many invasives
VT	1997	Addison	Orwell	2-5 plants; threatened by invasive plants
VT	1997	Addison	Orwell	100-500 plants
VT	1998	Addison	Shoreham	Highly eutrophic site with 500-1000 plants
VT	1998	Grand Isle	Isle La Motte	Pristine habitat with 500 plants

Table of Pre-1950 versus After-1950

Reported in Les 1994, based primarily on Stuckey 1987. Updated Information from various sources.

State/province	Pre-1950 sites	After 1950 sites	Updated info
Alabama	2	0	3 extant (Gabel & Hes 2000)
Arkansas	8	0	2 additional counties (NRCS)
Florida	3	1	2 counties[1]
Georgia	2	0	
Illinois	41	2	7 extant and 19 historic occurrences (Gabel & Hes 2000)

			populations less than 1 mile apart were considered same EO
Indiana	14	0	11 counties extirpated, 6 unknown historic, 2 counties recent records[2]
Iowa	3	0	Pre-1900s 3 counties (TNC 95)
Kansas		1	Recently reported (Gabel & Hes 2000)
Kentucky	5	5	14 EOs from 5 counties[3]
Louisiana	6	3	15 extant and 8 historic (Gabel & Hes 2000)
Massachusetts	1	0	Historic site reported around Pittsfield (Gabel & Hes 2000)
Maryland	1	0	Historic (TNC 1995)
Michigan	13	5	7 counties with 13 occurrences after 1950[4]
Minnesota		1	Houston Co.; extreme SE[5]
Mississippi	3	1	5 occurrences (TNC 1995)
Missouri	12	0	8 extant and 7 historic (Gabel & Hes 2000)
New Jersey	4	0	
New York	28	3	8 extant and 10 historic occurrences (Gabel & Hes 2000) populations less than 1 mile apart were considered same EO
North Carolina	?	0	Not tracked (TNC 1995)
Ohio	11	3	8 pre-1937 counties; 6 populations in 3 counties in St. Mary's River 1991[6]
Oklahoma	3	1	Occurs in eastern ¼ of state; may be introduced (TNC 1995)
Pennsylvania	1	0	
South Carolina	?	0	
Tennessee	5	2	6 counties (NRCS 2003); 30 EOs 24 since 1981[7]
Texas	2	1	TNC (1995) one extant pop.
Vermont	8	4	3 counties[8], 4 EOs (TNC 1995)
Virginia	1	0	1 historic (TNC 1995)
Wisconsin	4	1	7 counties, 14 records; 12 verified after 1980[9]
Canada			
Ontario	9	3	
Quebec	1	0	12 historic; extant pop unknown (TNC 1995)

Footnotes

1. Florida – Atlas of Florida Vascular Plants (2003)
2. Indiana – Report on the Status of *Armoracia aquatica* in Indiana (Hedge *et al*. 1991)
3. Kentucky – (KY NHP 1992 *cf*. TNC 1995)
4. Michigan – MNFI electronic database (2003)
5. Minnesota – Vascular Plants of Minnesota (Ownbey & Morley 1991); Chadde 1998
6. Ohio – *Armoracia lacustris* rediscovered in Ohio (McCormac 1992)
7. Tennessee – Tennessee Valley Authority Regional Heritage (TVA RH 1992)
8. Vermont – Flora of the Northeast (Magee & Ahles 1999)
9. Wisconsin – Wisconsin State Herbarium (2003)

Habitat Summary

from Element Stewardship Abstract for lake cress (TNC 1995)

State/ Province	Habitat
Florida	Spring runs in panhandle region
Illinois	Swamps and quiet streams
Indiana	Floodplain oxbows in sandy silt substrates
Iowa	Historically inhabited quiet water with muddy shores
Kentucky	Roadside sloughs, swampy woodland, floodplains, slow water, and open marshes
Louisiana	Bottomland forests and cypress lakes
Michigan	Quiet, shallow water along lake margins or backwaters of slow-moving streams (particularly cold spring-fed waters) (Voss 1985)
Mississippi	Calcareous soil which is subject to periodic flooding; also delta bottomland hardwood forests
Missouri	Bald cypress swamps, sloughs, slow streams, springs, shallow or still water and muddy shores of rivers and ponds
New Jersey	Historic, lakes within limestone belt
New York	Muddy shores of ponds and lakes; marl ponds
Ohio	Seasonally inundated river channels, densely forested floodplains, river terraces, buttonbush swamps
Tennessee	Still open water of natural lakes or sloughs, ponds, canals, ditches and swamps
Texas	Historic occurrence in mud on lakeshore
Vermont	Lake floodplain forests, swamp forests, slow streams
Virginia	Historically found in wet creek depressions and alluvial bottomlands
Wisconsin	Cold, clear, sandy-bottomed stream flowing through a bog-embayment along Lake Superior
Canada	
Ontario	Edges of lakes, small streams and brooks

Quebec	Lakes, rivers, and small brooks