New England Plant Conservation Program
Conservation and Research Plan

Neobeckia aquatica Eaton (Greene)
North American Lake Cress

Prepared by:
John D. Gabel

and

Donald H. Les
University of Connecticut
Storrs, Connecticut

For:

New England Wild Flower Society
180 Hemenway Road
Framingham, MA 01701
508/877-7630
e-mail: conserve@newfs.org ! website: www.newfs.org

Approved, Regional Advisory Council, 2000

SUMMARY

The North American lake cress, *Neobeckia aquatica* (Eaton) Greene (Brassicaceae), is listed as S1 in Vermont, SH in Massachusetts, and "SH?" in Maine.

Lake cress likely requires clear, slow-moving water. A requirement of sites is that they have regular fluctuations in water level. Sites are typically located in gently flowing riverine systems and have little or no shoreline development. Special threats include invasive plant species, eutrophication, and development of habitat.

All extant New England element occurrences of lake cress are located in Vermont at four sites. VT.002, Orwell is characterized by small population numbers (two to five plants). The site is highly eutrophic and threatened by invasive aquatic plants (*Butomus umbellatus, Lythrum salicaria,* and *Trapa natans*). VT.006, Orwell is characterized by a relatively large population (100-500 plants). The site is threatened by invasive aquatic plants (*Butomus umbellatus* , *Lythrum salicaria*, and *Trapa natans*.) VT.009, Shoreham is a highly eutrophic site with 500-1000 plants in the population. VT.010, Isle La Motte represents a population located in a pristine habitat with around 500 plants.

The conservation objectives for *Neobeckia aquatica* in New England are to:
- remove the threat of invasive plants from extant lake cress populations.
- manage current lake cress habitats in order to improve their element occurrence rankings.
- improve the status of the species by increasing numbers of individuals in extant populations and establishing new populations at historic and non-historic localities.

The specific conservation actions needed to achieve these objectives are to:
- remove invasive species from lake cress element occurrences.
- reduce eutrophication in lake cress habitats.
- protect existing element occurrences from eutrophication.
- survey states in New England with element occurrences for additional extant populations.
- conduct research on the ecology and genetics of lake cress.
- maintain metapopulation dynamics for long-term stability of lake cress within watersheds.
- reintroduce lake cress to watersheds within its historical range.

PREFACE

This document is an excerpt of a New England Plant Conservation Program (NEPCoP) Conservation and Research Plan. Full plans with complete and sensitive information are made available to conservation organizations, government agencies and individuals with responsibility for rare plant conservation. This excerpt contains general information on the species biology, ecology, and distribution of rare plant species in New England.

NEPCoP is a voluntary association of private organizations and government agencies in each of the six states of New England, interested in working together to protect from extirpation, and promote the recovery of the endangered flora of the region.

In 1996, NEPCoP published *Flora Conservanda*: New England, which listed the plants in need of conservation in the region. NEPCoP regional plant Conservation Plans recommend actions that should lead to the conservation of Flora Conservanda species. These recommendations derive from a voluntary collaboration of planning partners, and their implementation is contingent on the commitment of federal, state, local, and private conservation organizations.

NEPCoP Conservation Plans do not necessarily represent the official position or approval of all state task forces or NEPCoP member organizations; they do, however, represent a consensus of NEPCoP's Regional Advisory Council. NEPCoP Conservation Plans are subject to modification as dictated by new findings, changes in species status, and the accomplishment of conservation actions.

Completion of the NEPCoP Conservation and Research Plans was made possible by generous funding from an anonymous source, and data were provided by state Natural Heritage Programs. NEPCoP gratefully acknowledges the permission and cooperation of many private and public landowners who granted access to their land for plant monitoring and data collection. If you require additional information on the distribution of this rare plant species in your town, please contact your state's Natural Heritage Program.

This document should be cited as follows:

Gabel, John D. and Donald H. Les. 2001. *Neobeckia aquatica* (North American Lake Cress) Conservation and Research Plan. New England Plant Conservation Program, Framingham, Massachusetts, USA (http://www.newfs.org).

I. BACKGROUND

INTRODUCTION

The North American lake cress, *Neobeckia aquatica* (Eaton) Greene (Brassicaceae), is an herbaceous aquatic mustard. This monotypic species is one of only five genera of aquatic mustards. It is also one of two genera (the other being *Subularia*) of "truly aquatic" (i.e. submersed) mustards. Although lake cress has always been regarded as rare (Voss 1985), its status has remained somewhat enigmatic as indicated by its global rank of "G4?"(White 1994). Herbarium records indicate a significant decline in lake cress populations throughout the species range in the latter part of the twentieth century (Les 1994). The species is listed by most state Natural Heritage programs as S1 or S2 (White 1994). Many states with records of *Neobeckia aquatica* have only historical records or have not observed the species in the state since the 1970's. Adding to the difficulty of managing this imperiled species is the fact that, throughout its range, approximately 75% of the extant populations of *N. aquatica* occur on private land and are therefore not likely to be under direct management.

The *Flora Conservanda*: New England (Brumback and Mehrhoff *et al*. 1996) lists the species in three New England states: 1) Maine, where it is listed as of uncertain historical status (SH?); 2) Massachusetts, where the species is listed as historical (SH); 3) Vermont, where it is listed as critically imperiled (S1).

The imperilment of New England's lake cress populations is particularly distressing because of their historical association with New England. The species was first described from Berkshire County, Massachusetts in the early 19th century (Eaton 1822). At that time, Eaton described it as occurring in "wet areas" (Eaton 1822), "growing wild in water and wet places in various parts of Berkshire County, Mass." (Eaton 1829), and "manifestly indigenous" in Berkshire County (Eaton 1833). The last record of the species in MA that we could find is from Eaton's 8th edition of his Manual of Botany for North America (Eaton 1840). Recent surveys have failed to discover either specimens or living plants from the Berkshires (C.B. Hellquist, Massachusetts College of Liberal Arts, *personal communication*).

In Vermont, the magnitude of population loss is not unlike that for the rest of the United States. The United States has an average lake cress element occurrence loss of 68%. Vermont has lost 75% of its element occurrences.

This conservation plan provides a synopsis of the biology, threats, and plans for the conservation and recovery of the imperiled lake cress. This work should provide conservation professionals with additional information to direct their efforts in preserving this taxon and other biologically similar taxa.

DESCRIPTION

Neobeckia aquatica (Eaton) Greene (Brassicaceae), the North American lake cress, is a rare imperiled perennial aquatic herb. The species is usually found growing as a rosette in mucky areas, but it can have prostrate, submersed or erect stems up to four or 1.5 m long, but seldom exceeding one meter in length, when growing submerged or when in flower. Roots of lake cress plants are typically fibrous, but they can develop secondary thickening. Submersed leaves are usually deeply dissected, whereas emergent leaves are generally entire with serrate or smooth margins. Emergent leaves are often found with deep lobes that resemble the morphology of submerged leaves. The leaves of lake cress are weakly attached to their stems and are readily stripped from plants by the surface tension of the water or any slight physical disturbance. Flowers are borne in racemes up to two feet in length. Mature flowers have white, clawed petals that are 6-10 mm long, tetradynamous stamens, unilocular ovaries with 20-40 ovules, on pedicels that are 8-11 mm long. Fruits of *N. aquatica* are ellipsoid or obovoid siliques lacking or mostly lacking a central partition with a persistent style 5-12 mm long.

Lake cress is seldom found in flower. Vegetatively, the species might be confused with *Ceratophyllum* spp., *Myriophyllum* spp., *Proserpinaca palustris*, *Ranunculus* spp., *Rorippa* spp. (and other aquatic mustards), and other heterophyllous vascular hydrophytes. However, it is easy to differentiate *N. aquatica* from these taxa because it has an alternate leaf arrangement (easily distinguishing it from most milfoils and *Ceratophyllum* spp.) with dissected leaves that have their divisions further subdivided (*Proserpinaca* never has any divisions subdivided). In addition, lake cress has a definite central axis that should clearly distinguish it from aquatic *Ranunculus* and *Utricularia* spp. (Voss 1985). It is also possible to confuse this species with submerged rosettes of *Sium suave*, but the leaves of *S. suave* have sheathes. The leaves of lake cress are extremely variable. This leaf polymorphism has often been attributed to fluctuating water levels. However, plants grown terrestrially in a greenhouse can display extensive leaf variation as well; their morphology apparently changes in response to light availability and other factors (J. Gabel, *personal observation*). Thus, while water level fluctuations contribute to the heterophylly of individuals, they are not necessary to induce leaf variability.

TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

Lake cress was first described by Eaton in 1822, who named it *Cochlearia armoracia* var. *aquatica* Eaton. Since that time, the nomenclature of lake cress has undergone many changes (Al-Shehbaz and Bates 1987), being assigned variously to the following genera:

Nasturtium (*Nasturtium natans* var. *americanum* (Eaton) Gray (1835), *Nasturtium lacustre* (Eaton) Gray (1848)),
Radicula (*Radicula aquatica* (Eaton) Robinson (1908)),

Rorippa (*Rorippa aquatica* (Eaton) Palmer & Steyerm. (1938), *Rorippa americana* (Gray) Britton (1894)),
Neobeckia (*Neobeckia aquatica* (Eaton) Greene (1896)) and *Armoracia* (*Armoracia aquatica* (Eaton) Wieg.,
Armoracia americana (Eaton) Hooker & Arnott (1850), *Armoracia lacustris* (Eaton) Al-Shehbaz & Bates (1987)).

The most common nomenclature used by Natural Heritage programs to refer to the species has been *Armoracia aquatica* (Eaton) Wieg. or *A. lacustris* (Eaton) Al-Shehbaz & Bates. *Armoracia aquatica* was the name used by most conservation agencies, but '*lacustris'* is the appropriate epithet under the genus *Armoracia* for reasons described elsewhere (Al-Shehbaz and Bates 1987).

More recently, a systematic study (Les 1994) using DNA sequences of the plastid gene *rbc*L supported the nomenclature of Greene (1896) who believed that lake cress was distinct enough to merit its recognition as a monotypic genus. Greene had originally proposed the name *Neobeckia aquatica* (Eaton) Greene in honor of the botanist Lewis C. Beck. The molecular investigations of Les supported this taxonomic decision by placing *Neobeckia* clearly outside the genus *Armoracia,* but as a sister to the genus *Rorippa*. The large number of molecular differences between *Rorippa* and *Neobeckia*, as well as the many morphological differences pointed out by Greene and reexamined by Les, merited maintaining the monotypic genus *Neobeckia* and *Neobeckia aquatica* (Les 1994). Thus, lake cress represents a unique lineage within the mustard family.

SPECIES BIOLOGY

There have been few extensive investigations of lake cress reproduction. This is likely due in part to the apparent sterility of lake cress (Les 1994; Les *et al.* 1995; Muenscher 1930). Causes for the sterility of lake cress are uncertain. It is likely that the major reason for sterility is triploidy (Les *et al.* 1995). Seven populations (including all four extant Vermont populations) from northern portions of the species range have been surveyed cytologically and were all found to be triploid (Les *et al.* 1995). Other possible reasons for sterility in northern populations include: 1) ecological factors (Sculthorpe 1967); 2) paucity of self-incompatibility (SI) alleles (Les *et al*. 1991); 3) genetic load (Eckert *et al*. 1999). One aspect of lake cress reproduction that has been well studied is its vegetative reproduction (La Rue 1943).

Lake cress primarily reproduces vegetatively by several means including: 1) rhizomatous growth; 2) gemmipary (specialized buds located on the bases of leaves produce adventitious plantlets when detached from the stem); and 3) fragmentation. Fragmentation in lake cress is particularly important. Whole plants can be regenerated from root, stem and leaf fragments. As little as 0.5 mm of material can be sufficient for regeneration of an entire individual (La Rue 1943). Fragments do not require supplemental nutrients or hormones to produce new plants. Simply floating these fragments in water is sufficient for regeneration.

The most critical habitat feature for vegetative reproduction in lake cress is fluctuating water levels. Sites need to be flooded to allow leaves to be stripped from the stems of individuals. When waters later recede, the inundated muddy or silty areas act as a medium for regeneration from fragments stranded there.

Little is known about sexual reproduction in lake cress. There are anecdotal reports from state Natural Heritage botanists that suggest that natural populations in the southern portions of the lake cress range have produced viable seed (B. Summers as quoted in White 1994). No population from northern portions of the species range (including New England) have been observed to set seed. However, extensive investigations of sexual reproduction in natural lake cress populations have not been conducted. In the greenhouses of The University of Connecticut, we have begun to investigate the possibility of self-incompatibility (SI) after we observed seed production in southern lake cress populations.

Two of the most closely related genera of lake cress (*Rorippa* and *Armoracia*) have self-incompatible species. Preliminary investigations of self-incompatibility in lake cress indicate that lake cress also has sporophytic self-incompatibility (SSI). It appears from this study that individuals from southern populations can produce thousands of seeds from appropriate crosses (J. Gabel, *unpublished data*). SSI could contribute significantly to the observed sterility of lake cress populations. Predominantly asexual populations (which would have extremely low S-allele diversity) may survive, despite reduced and possibly non-existent seed production caused by the low frequency of potential mates, because they are clonal.

Other ecological factors that can affect pollination and reproduction in lake cress remain enigmatic. There is no information about pollination in lake cress. Therefore, it is not possible to evaluate the possible impacts of pollinators on populations. However, the morphology of lake cress flowers certainly suggests entomophily. Additionally there have been no investigations of physical conditions required for lake cress to flower and reproduce aside from cursory observations of habitat types.

One important observation in lake cress populations is the low occurrence of flowering. Although it is not uncommon for aquatic plants to flower infrequently (Philbrick and Les 1996, Sculthorpe 1967), the low flowering frequency could have several bases. Prolonged asexual reproduction can have serious genetic consequences, such as genetic load at sexual loci, which arise by relaxing selection on genes controlling sexual reproduction (Eckert *et al*. 1999). Thus, infrequent flowering could result from genetic causes. It is also possible that infrequent flowering results from a variety of ecological factors including nutrients, sunlight, and inundation (Sculthorpe 1967).

Genetic investigations of lake cress have not been undertaken beyond broad population surveys with molecular markers like RAPDs (Randomly Amplified Polymorphic DNAs) (Les and Gabel 1996). RAPD phenotypes demonstrate that there is substantial variation within several populations of lake cress, including those that have never been observed to flower or set seed. 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. If genetic load associated with sexual reproduction exists in lake cress it is likely to persist because of the ability of lake cress to reproduce asexually.

Presumably, lake cress depends on seed for long distance dispersal (Les *et al*. 1995, Pringle 1879). Thus, sterility greatly hampers the vagility of lake cress. Loss of vagility greatly aggravates the threat of habitat destruction because it is more difficult for less vagile species to re-colonize habitats. However, there has never been any record of seed production in New England lake cress populations. It is therefore uncertain whether seed production in lake cress has ever been a part of the natural reproductive biology for this species in this part of its range. There does not appear to be a correlation between flowering element occurrences and magnitude of element occurrence losses.

HABITAT/ECOLOGY

Lake cress habitat requirements appear to be fairly broad. The species has been found to inhabit: cypress swamps; slow streams with silty deposits; lake edges with rocky, sandy, or mucky soils; oxbows; floodplains; marl lakes; wet meadows; and other wetlands. The species appears to thrive in hard, relatively cool water. The largest specimens observed typically are found in areas with cool spring water emerging from limestone (*e.g.*, Herbarium specimen Gabel #24 CONN).

Typically associated species are *Acer* spp., *Alisma* spp., *Butomus umbellatus*, *Cardamine* spp., *Carex crus-corvi*, *Cephalanthus occidentalis*, *Ceratophyllum echinatum*, *Heteranthera dubia*, *Landoltia punctata*, *Lemna* spp., *Ludwigia* spp., *Myriophyllum* spp., *Nasturtium* spp., *Nuphar variegata*, *Nymphaea* spp., *Populus* spp., *Potamogeton* spp., *Proserpinaca palustris*, *Rorippa* spp., *Sagittaria* spp., *Samolus floribundus*, *Taxodium* spp., and *Wolffia* spp. The habitats of lake cress also support populations of three invasive species in New England, *Myriophyllum spicatum*, *Lythrum salicaria* and *Trapa natans*. It is common to visit a *Neobeckia* site and observe lake cress plants situated along the shore between *M. spicatum* in the water and *L. salicaria* on the shore advancing toward the water. Another species that has come under scrutiny as a potential threat to lake cress is *Rorippa amphibia*. This species has variable leaves like *Neobeckia*, occupies the same habitats and superficially looks like *Neobeckia* (except that *R. amphibia* has yellow flowers). *Rorippa amphibia* might threaten *Neobeckia* by competitively excluding it from appropriate habitats (Les 1993b). A problem with evaluating the threat this species may pose to lake cress is the former placement of lake cress in the genus *Armoracia* with the specific epithet "*aquatica.*" *Armoracia aquatica* is a synonym of *Rorippa amphibia.* The herbarium records of the two species are often intermixed, thereby potentially distorting the historical information for both species.

Lake cress has been found in a variety of light regimes. For example, in Tennessee, *Neobeckia* has been collected in deep shade beneath Cypress trees in flowering and vegetative (rosette) stages (Gabel # 30, CONN). In Louisiana, lake cress has been collected in flower and rosettes in open wet fields (Gabel #20, CONN). There is a need for more critical evaluations of light requirements for lake cress in order to better manage its habitat.

No investigation of water quality preferences (pH, alkalinity, etc.) of the species has been made. Lake cress populations flourish in clear springs from limestone cliffs, marl lakes, turbid cow ponds, slow moving creeks with pasture run-off, and stagnant water in roadside ditches and ponds. Thus, it is possible that lake cress has wide water quality tolerances. However, plants appear to be more robust in areas that have cold water and oligotrophic conditions. Whether this is because those habitats are more open, or because lake cress is better adapted to those conditions requires further investigation. However, these sites are almost always threatened by *Nasturtium officinale* (Gabel, *personal observation*). There are many sites where lake cress appears to do poorly in eutrophic areas (*c.f.* VT. 002, below). Eutrophication is commonly cited as a threat to the species by most state heritage programs.

Neobeckia also seems to have a broad tolerance of soils. It has been collected in mucky, sharkey, clay, silty, and sandy soils (designated SWSL, GH, MO in soil surveys). However, it is most often found in silty or mucky soils of oxbows and low areas with fluctuating water.

Lake cress populations appear healthier (larger) in habitats with rapidly changing water tables (J. Gabel, *personal observation*). This should be unsurprising to anyone who is familiar with the species' means of vegetative reproduction. Lake cress plants primarily reproduce via leaf fragments that are stripped off of their stems by the surface tension of the water (La Rue 1943, Voss 1985, McCormac 1992, Les 1994). Thus, the species is best able to recruit and maintain itself in areas that agitate the plants in a cyclical manner and allow adventitious plantlets to root in moist soils at times when water levels are lower. Two populations in Ohio best illustrate the importance of this cycle. They occur in areas that are fed by multiple creeks and backflows of fairly large riverine systems. Populations are distributed up to several miles distant. These aggregates of small waterways form floodplains that, along with the open area provided by recent clear cutting for farmland, allowed lake cress fragments free movement between areas and may be responsible for the recorded populations of 30,000+ individuals (J. Gabel, *personal observation*). This may also be the case in Reelfoot Lake, TN where there are over 14 element occurrences recorded for that locality between the Natural Heritage programs of Kentucky and Tennessee (J. Gabel, *personal observation*).

Lake cress populations are typically small (the two Ohio populations are exceptional). They typically range in size from 50-100 individuals (J. Gabel, *personal observation*).

However, exact counts of individuals are not typically reported from populations unless it is some number less than ten, owing to the inability of field botanists to find plants (see occurrence descriptions, below).

Typical habitat in New England is in slow moving water, river and creek floodplains, lakes and ponds in Vermont. These habitats are typically fairly open, and also have fluctuating water levels that allow for easier recruitment of individuals from fragments. The typical elevation of lake cress populations is less than 1000 feet.

THREATS TO TAXON

As previously stated, threats to *Neobeckia* include: 1) eutrophication from agricultural and industrial run-off; 2) invasive exotic plants; and 3) waterfront development (*e.g.*, channelization).

Many sites throughout the species range, as well as two of the New England lake cress localities, are very eutrophic. The creek and floodplain habitats usually occupied by this species are also important as agricultural lands. Inevitably there is a large amount of run-off from these areas into lake cress habitat that provides a disturbance which may attract eutrophic weeds. There is an urgent need to manage populations in these areas to reduce run-off into what would otherwise be pristine lake cress habitat.

Invasive species, especially *Lythrum salicaria*, *Trapa natans*, and *Myriophyllum spicatum*, threaten lake cress populations by overtaking and occupying portions of its suitable habitat. It is also possible, as stated above, that *Rorippa amphibia* represents another threat due to its similar habitat preference and mode of reproduction.

An additional threat is the conversion and development of suitable habitat. Habitat development can take many forms such as channelization, waterfront development, flood management, and construction of new spans across the creeks that lake cress inhabits. Construction activities destroy lake cress habitat by reducing the extent of floodplains and by destroying mudflats. For example, one historical site in Texas (Steinhagen Lake) had the parts of its shoreline where lake cress occurs converted into concrete steps or covered with granite boulders. Flood management disturbs the critical water level fluctuations necessary for optimal lake cress recruitment. Waterfront development poses a more subtle threat. Fragmentation of habitat and the disruption of corridors for dispersal between populations may pose a serious threat.

Despite the arguments of some (Judziewicz and Nekola 1997), lake cress fragments do not represent optimal dispersal units. Judziewicz and Nekola (1997) cite the observation of lake cress fragments up to 50 km from a potential (unverified) source population. However, they could not exclude the likely possibility that the fragments could have dispersed from intermediate distance sites. This is a pattern of dispersal and colonization that we might expect based upon the previous description of the Ohio and Reelfoot Lake populations. If this is a real phenomenon, then one requirement for lake cress to persist in an area may be a series of continuously distributed populations. These populations could allow rapid re-colonization of sites that are disturbed (naturally or otherwise) and allow for greater regional stability of lake cress. In other words, lake cress populations within a watershed may behave like a metapopulation (Shaffer 1987). Fragmentation of habitat between populations destroys their ability to act as a metapopulation in which small local extinctions are replaced by neighboring sites and source populations.

DISTRIBUTION AND STATUS

General status

The range of *Neobeckia aquatica* extends from eastern Texas, Louisiana and Alabama, north through the Mississippi basin to the Great Lakes and Southern Ontario, and eastward to Vermont (The Nature Conservancy and Association for Biodiversity Information 1999). It has also recently been discovered in Kansas (Figure 1). Although the range of lake cress is extensive, its frequency within its range is very low (Al-Shehbaz and Bates 1987). Most states have only between one and five extant element occurrences. Furthermore, many states have several occurrence listings for the species that are likely to represent parts of the same population, given that they are separated by less than one mile. In this report, such records from states outside New England have been recorded as part of the same element occurrence record, because they are undistinguishable on the geographical scale compared.

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 and Ohio rivers, form a very large floodplain. Lake cress appears to be well adapted to a riverine existence. Its distribution indicates a Mississippi embayment phytogeographical affinity (Stuckey 1993).

There are an estimated 50-100 records of lake cress locations in North America (Table 1). Les (1994) found records of 189 known sites that occurred before 1950 and found only 31 records of sites occurring since 1950. The Nature Conservancy currently estimates approximately 100 sites after 1970 (White 1994). Natural Heritage programs from all states that reported extant lake cress populations were contacted between 1997 and 1999. During the summers of 1997-99, fieldwork was conducted in an attempt to locate all extant sites in the United States, as well as several historical sites (J. Gabel, *personal observation*). As a result of this survey, twenty-nine populations were found throughout the species' range in the eastern United States. There was very low success rate of locating populations reported prior to 1980, and no population was located whose most recent record was prior to 1975. Since the 1997-1998 surveys, two new records have been discovered in Kansas and Texas. There has been no recent survey conducted in Canada. Most of the data available about the biology and population density of lake cress included in this report are from these recent surveys. The Nature Conservancy reports 40 records for Canada after 1970 (White 1994). Consequently, a reasonable maximum estimate of extant populations is approximately 70 populations.

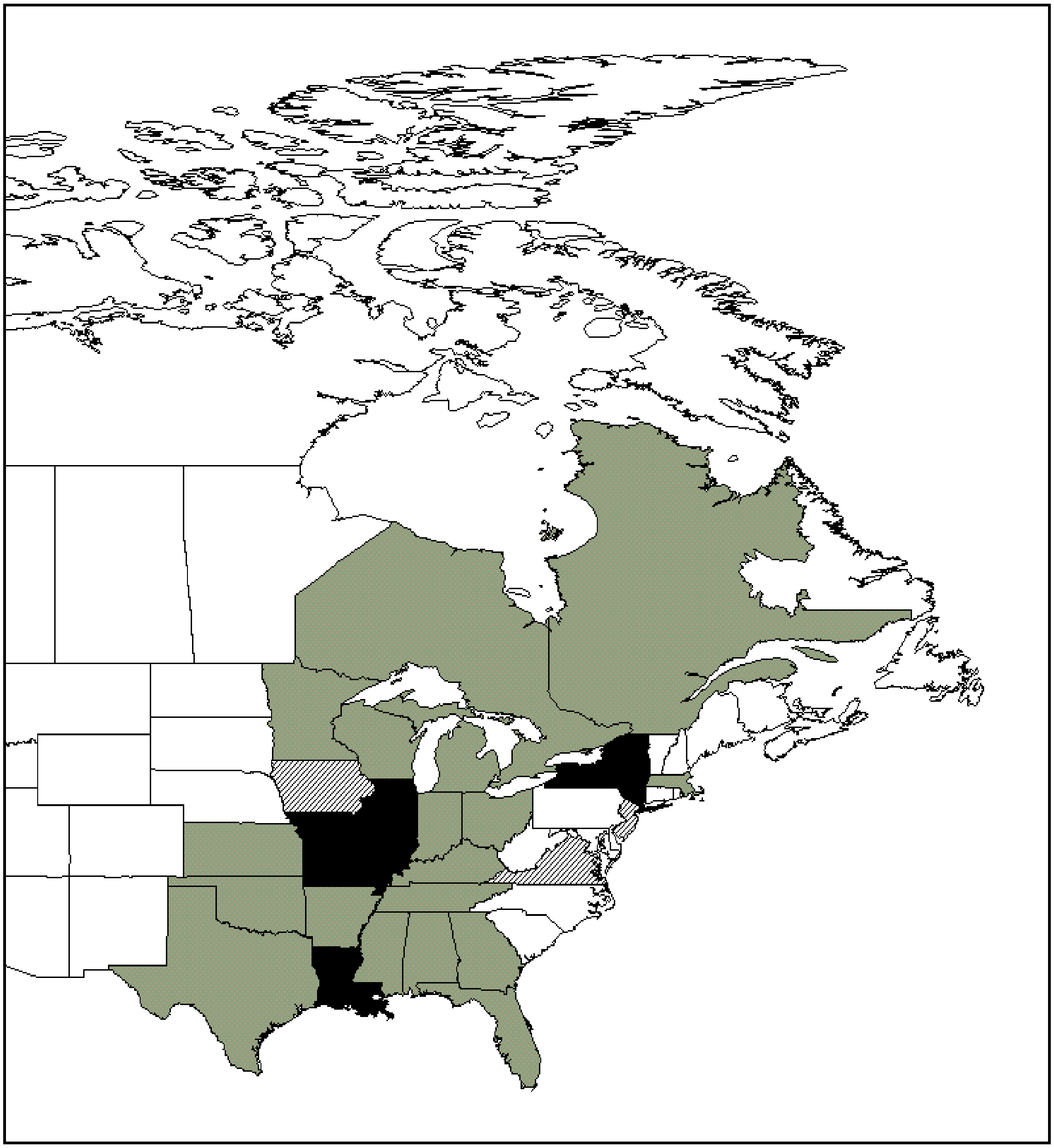

Figure 1. Occurrences of *Neobeckia aquatica* in North America. Shaded states and provinces have 1-5 extant occurrences, while those shaded in black have more than 5 occurrences. States and provinces with diagonal hatching are designated “historic” or “presumed extirpated” (see Table 1), where *Neobeckia aquatica* no longer occurs.

Table 1. Occurrence and status of *Neobeckia aquatica* in the United States and Canada based on information from Natural Heritage Programs.

OCCURS & LISTED (AS S1, S2, OR T &E)	OCCURS & NOT LISTED (AS S1, S2, OR T & E)	OCCURRENCE UNVERIFIED	HISTORIC (LIKELY EXTIRPATED)
Alabama (S1): 3 extant and 1 historic occurrences	Illinois (S3): 7 extant and 19 historic occurrences	Arkansas (SR): 1 extant and 5 historic occurrences	Iowa (SH)
Georgia (S1?): 2 historic occurrences	Ontario (S3?)	Florida (SR): 3 historic occurrences	Maine (SH): 1 historic occurrence
Indiana (S1): 2 extant and 15 historic occurrences	Pennsylvania (SU)	Louisiana (SR): 15 extant and 8 historic occurrences	New Jersey (SH): 4 historic occurrences
Kansas (S1): 1 extant occurrence recently reported	South Carolina (S?)	Minnesota (SR)	Virginia (SH): 1 historic occurrence
Kentucky (S1S2): 3 extant and 3 historic occurrences			
Massachusetts (S1/SRF): 1 historic occurrence debated			
Michigan (S2): 4 extant and 13 historic occurrences			
Mississippi (S1S2): 2 extant occurrences			
Missouri (S2): 7 extant and 7 historic occurrences			
New York (S2): 8 extant and 10 historic occurrences			
Ohio (S2): 3 extant and 8 historic occurrences			
Oklahoma (S1S3): 2 historic occurrences			
Quebec (S2)			
Tennessee (S2): 4 extant and 5 historic occurrences			
Texas (S1): 1 extant and 2 historic occurrences			
Vermont (S1): 4 extant and 7 historic occurrences			
Wisconsin (S1): 2 extant and 4 historic occurrences			

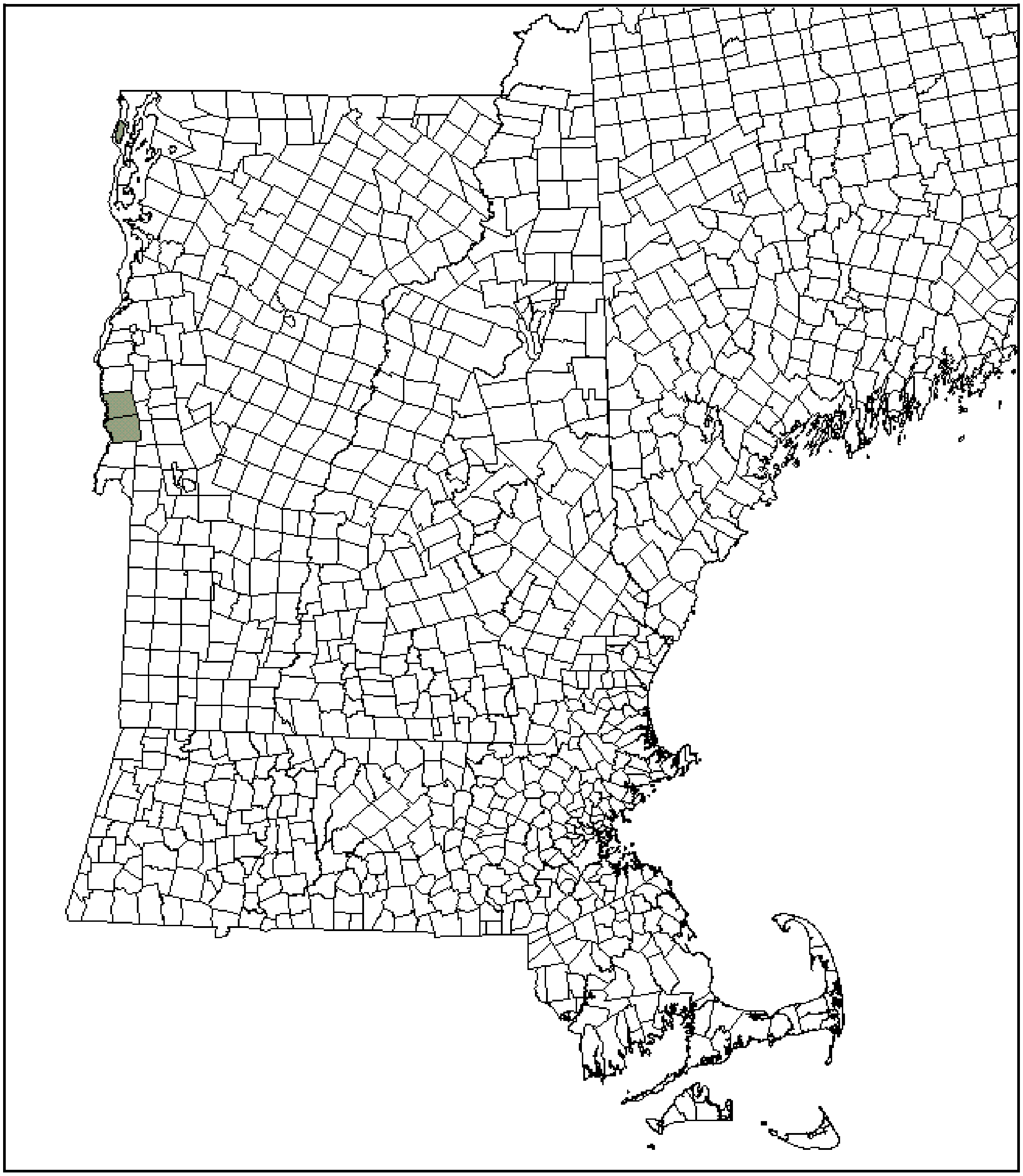

Figure 2. Extant occurrences of *Neobeckia aquatica* in New England. Town boundaries for New England states are shown. Shaded towns have 1-5 extant occurrences.

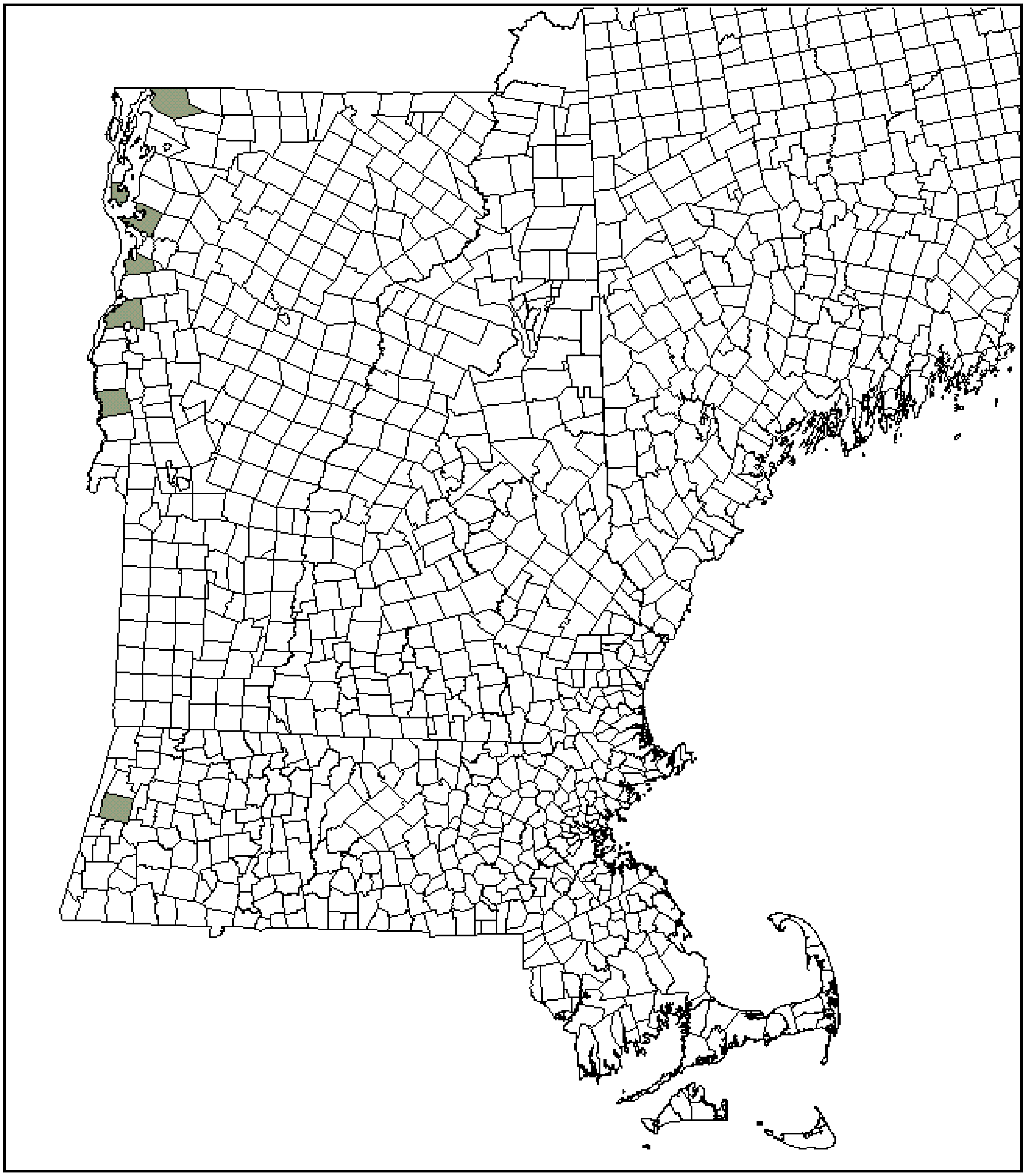

Figure 3. Historic occurrences of *Neobeckia aquatica* in New England. Town boundaries for New England are shown. Shaded towns have 1-5 historic occurrences.

Table 2. New England Occurrence Records for *Neobeckia aquatica* based on data from State Natural Heritage Programs. Shaded occurrences are considered extant.

State	EO #	County	Town
ME	None	Lincoln	Boothbay
VT	.001	Chittenden	Colchester
VT	**.002**	**Addison**	**Orwell**
VT	.003	Franklin	Highgate
VT	.004	Addison	Ferrisburg
VT	**.006**	**Addison**	**Orwell**
VT	.007	Chittenden	Shelburne
VT	.008	Addison	Ferrisburg
VT	**.009**	**Addison**	**Shoreham**
VT	**.010**	**Grand Isle**	**Isle La Motte**
VT	.011	Addison	Shoreham
VT	.012	Grand Isle	South Hero
MA	None	Berkshire	Pittsfield

II. CONSERVATION

CONSERVATION OBJECTIVES FOR THE TAXON IN NEW ENGLAND

The objectives of this recovery plan are to: 1) reduce the threat of exotic invasive species in lake cress habitat, 2) manage existing lake cress populations so that their element occurrences can be reclassified as “B” (500 to 1000 individuals) or better, 3) improve the status of the species by increasing the number of populations in VT and MA.

The first goal should be accomplished through removal of invasive plants from lake cress habitat. These sites should be treated by physical removal of invasive species from mudflats whenever practical, e.g. in small areas. Particular attention should be paid to the removal invasive species on the mudflats (e.g., *Lythrum salicaria*) because these species threaten a specific region of critical importance to reproduction of lake cress. Populations should be monitored for their size, threat from invasive species, and for drastic changes in the habitat regularly during the season until the threat of the species is removed.

The second objective will be partly satisfied by removal of exotic weeds. To fully realize this objective, habitats that are currently rated as B or lower need to be protected from eutrophication. The most plausible way to accomplish a reduction of eutrophic conditions is to enlarge the buffer zone between agricultural areas and lake cress habitat. This may be accomplished by purchases of land adjacent to the threatened areas. However, a more cost effective -- and perhaps ideal -- way to effect reduced eutrophication may be to instruct farmers about cost-effective eco-friendly farming. For example, there is considerable research on timing and amount of nitrogen fertilizer application in the literature (Matson et al. 1998). The studies illustrate that application of less fertilizer at critical times in crop development is more beneficial and cost effective than the broad application of fertilizer that is the most commonly used practice today. These studies are also of interest because they document the effect with respect to runoff and eutrophication of watersheds through nitrogen leeching. Principles illustrated by these studies may help farmers realize that less nitrogen application at the right time is better and more cost effective than using heavy doses of nitrogen.

Additionally, population monitoring should be undertaken for at least 5 subsequent years. Hopefully, these surveys will reveal that populations are not in decline. Rigorous demographic studies should be conducted on lake cress populations to allow for better management of element occurrences.

The third objective will likely be achieved after goals one and two have been met. This objective recommends that the number of occurrences in the state be increased. This should be accomplished through a combination of additional surveys in the water systems of extant populations as well as those of historical populations. In addition, re-introductions of individuals into suitable habitat can be undertaken after thorough surveying of a water system reveals no lake cress populations. There is no concrete research to guide us in recommending a specific number of populations to introduce. In addition, the absence of demographic studies illustrating what stable population sizes of lake cress should be prohibits us from recommending specific numbers of individuals to be introduced for each population. Therefore a primary focus of this goal should be to undertake demographic studies of lake cress populations to determine these parameters and develop specific guidelines for re-introductions.

Nevertheless, we can make some tentative recommendations regarding the appropriate size and number of populations that should be extant within Vermont. It is important for us to state that these are not necessarily accurate, nor are they guaranteed to bring about stable population structure in New England lake cress. From the profile of the extant lake cress populations outside of New England (Table 1 and data in Appendices) and the extant populations from Vermont (Table 2), we can infer that a population size of approximately 250 (C-rank) individuals is not unusual. The stability of populations with this many individuals is unverified, but populations of this size may be stable.

There is an average of nine records from each state within the range of lake cress (see data in Appendix). Thus, we may want to increase the number of populations in Vermont by five to a total of nine extant element occurrences. This may be accomplished through a combination of field surveys and introductions. These populations should be located on protected lands within watersheds in the historical range of the species, once these areas have been surveyed to establish that they have water fluctuations conducive to recruitment of individuals. The locations should not be eutrophic and they should also be relatively free of *Lythrum salicaria*. Introductions within watersheds should be placed in relatively close proximity to each other. This should enhance both gene flow among the populations and re-colonization after a disturbance. Initially, introduced populations should be maintained at a level of 250 individuals each. Once these populations have become established and self-maintaining, these populations should be augmented until the occurrences can be reclassified as B-ranked (500-1,000 individuals).

In Massachusetts, the third objective is particularly critical. Eaton's description of the species in MA suggests that it was common around Pittsfield. Thorough surveys of all watersheds in the area should be undertaken. If these surveys reveal no lake cress populations, then suitable habitat should be identified and re-introductions should be undertaken using appropriate source population material identified through genetic and ecological studies. It is important that this search include a thorough investigation of herbaria to find the type specimen of *Cochlearia aquatica*. This specimen may have valuable label information for relocating the species in MA. We have no records to guide us in this effort for Massachusetts, so introductions should be minimal as yet (one or two populations).

To accomplish these goals, other actions can be taken as well. Lake cress, as mentioned above, is sexually sterile in New England. It is to the advantage of any conservation program for this species to maintain a “garden of genotypes” for the species. Preliminary investigations of genetic diversity from Vermont lake cress populations suggests that there are on average ten or fewer genotypes in each population (out of twenty plants surveyed in total) (Les and Gabel 1996). These genotypes can be easily maintained in flooded pots in a greenhouse for indefinite lengths of time. Should there ever be a catastrophic event that wipes out a population, cuttings from the garden plants established from the extirpated population can be used to reintroduce the species to the site. Space requirements for each plant are small, only a four-inch pot is required for each plant that is to be maintained.

III. LITERATURE CITED

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* 68: 357-359.

Bean, R. C., A. F. Hill, and R. J. Eaton. 1961. Fourteenth report of the committee on plant distribution. *Rhodora* 63: 47-55.

Brumback, W. E., L. J. Mehrhoff, R. W. Enser, S. C. Gawler, R. G. Popp, P. Somers, D. D. Sperduto, W. D. Countryman, and C. B. Hellquist. 1996. *Flora Conservanda*: New England. The New England Plant Conservation Program (NEPCoP) list of plants in need of conservation. *Rhodora* 98: 235-361.

Countryman, W. D. 1977. An analysis of lake level influence on vegetation in lake Champlain. International Joint Commission on Lake Champlain, Burlington, Vermont, USA.

Eaton, A. 1822. *Manual of Botany for North America*. Oliver Steele, Albany, New York, USA.

Eaton, A. 1829. *Manual of Botany for North America*. Oliver Steele, Albany, New York, USA.

Eaton, A. 1833. *Manual of Botany for North America*. Oliver Steele, Albany, New York, USA.

Eaton, A. 1840. *Manual of Botany for North America*. Oliver Steele, Troy, New York, USA.

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.

Greene, E. L. 1896. *Neobeckia aquatica*. *Pittonia* 3: 95.

Judziewicz, E. J., and J. C. Nekola. 1997. Recent Wisconsin records for some interesting vascular plants in the western Great Lakes region. *Michigan Botanist* 36: 91-118.

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

Les, D. H. 1993a. An ecological assessment of lake cress (*Armoracia lacustris*, Brassicaceae) in East Creek, Addison County, Vermont. Unpublished report for The Nature Conservancy, Montpelier, Vermont, USA.

Les, D. H. 1993b. Studies of hybridization and chromosome number variation in aquatic angiosperms: evolutionary implications. *Aquatic Botany* 44: 181-228.

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: 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): 173-174.

Les, D. H., J. A. Reinartz, and E. J. Esselman. 1991. Genetic consequences of rarity in *Aster furcatus* (Asteraceae), a threatened, Self-Incompatible plant. *Evolution* 45: 1641-1650.

Matson, P. A., R. Naylor, and I. Ortiz-Monasterio. 1998. Integration of environmental, agronomic, and economic aspects of fertilizer management. *Science* 280:112-114.

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

Muenscher, W. C. 1930. VIII. Aquatic vegetation of the lake Champlain watershed. Pages 164-185 in New York Dept. Conservation (Editors), *A Biological Survey of the Champlain Watershed*, Nineteenth Annual Report, Albany, New York, USA.

Philbrick, C. T., and D. H. Les. 1996. Evolution of aquatic angiosperm reproductive systems. *BioScience* 46: 813-826.

Pringle, C. G. 1879. Leaf-propagation in *Nasturtium lacustre*. *Gr. Bot. Gaz*. 4: 2337-238.

Sculthorpe, C. D. 1967. *The Biology of Aquatic Vascular Plants*. Edward Arnold Ltd., London.

Shaffer, M. 1987. Minimum viable populations: coping with uncertainty. Pages 70-86 *in* M. E. Soulé (Editor), *Viable Populations for Conservation*. Cambridge University Press, Cambridge, UK.

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

The Nature Conservancy and Association for Biodiversity Information. 1999. Natural Heritage Central Databases. Arlington, Virginia, USA.

Voss, E. G. 1985. *Michigan Flora*, Part 2: Dicots (Saururaceae-Cornaceae). Bulletin 59 of the Cranbrook Institute of Science, Bloomfield Hills, Michigan, USA.

White, D. 1994. *Armoracia lacustris* Element Stewardship Abstract. The Nature Conservancy, Arlington, Virginia, USA.

IV. APPENDICES

1. Extant occurrences throughout the U. S. species range of *Neobeckia aquatica*

2. Summation of *Neobeckia aquatica* element occurrence and reproductive data from the United States, excluding New England records.

3. Comparison of lake cress element occurrence data with U. S. range averages.

4. An explanation of conservation ranks used by The Nature Conservancy and the Association for Biodiversity Information

Appendix 1. Extant occurrences throughout the U. S. species range of *Neobeckia aquatica.*

State	Last Observed	County	Town or Locality	Population size/Notes
AL	1973	Sumter	Livingston	-/flower, fruit, population in red clay soils
AL	1980	Greene	Mt. Hebron	-/
AL	1980	Lawrence	Red Bank	-/
AL	1997	Limestone	Triana	8/
AR	1898	Lincoln	Varner	-/flower, fruit
AR	1931	Lincoln	Grady	-/
AR	1931	Poinsett	Harrisburg	-/
AR	1953	Hempstead	Texarkana	-/
AR	1955	Monroe	Clarendon	-/
AR	1979	Jefferson	Pine Bluff	-/
FL	1957	Jackson	Mariana	-/
FL	Two more historical			from Al-Shehbaz and Bates (1987)
GA	1901	Lee		-/flower, limestone spring
GA	1947	Dougherty	Pretoria	-/flower, fruit
IL	1861	Saint Clair	McHenry	-/flower, fruit
IL	1862	Madison	St. Louis	-/flower, fruit, seed
IL	1874	Henderson	Oquawka	-/flower, fruit
IL	1883	Macoupin		-/
IL	1889	Richland	Olney	-/flower
IL	1897	Romeo	Will	-/flower, fruit
IL	19??	McHenry	Ringwood	-/
IL	1919	Alexander	Cache	-/flower
IL	1932	Wabash	Rochester Ferry	-/
IL	1940	Franklin	Christopher	-/flower, fruit
IL	1946	Saint Clair	Washington Park	-/
IL	1947	Coles	Doran	-/

State	Last Observed	County	Town or Locality	Population size/Notes
IL	1947	Cook	Orland Park	-/
IL	1948	Saint Clair	East St. Louis	-/
IL	1951	Willis	Braidwood	-/
IL	1961	Lee	Amboy	-/
IL	1968	Lawrence	Chauncey	-/
IL	1969	Johnson	Vienna	-/
IL	1986	Iroquois	Watseka	-/
IL	1992	Washington	Venedy	-/
IL	1993	Alexander	Miller City	-/
IL	1993	Jackson	Shawnee Forest	extirpated, mudflat off Big Muddy River, limestone
IL	1997	Union	Larue	80/flower, fruit, limestone spring, cold, clear water
IL	1997	Jackson	Howardton	150/flower, fruit, roadside ditch
IL	1997	Jackson	Shawnee Forest	50/flower, fruit, 2 feet of water, turbid, buttonbush swamp
IL	1997	Alexander	Miller City	60/flower, fruit, 1-2 feet of water, clean, cover in duckweeds
IN	1897	Tippecanoe		-/flower, fruit
IN	1906	Allen		-/flower
IN	1910	Saint Joseph	Notre Dame	-/flower
IN	1918	Spencer	Rockport	-/flower, fruit
IN	1918	Sullivan	Shelburn	-/seed
IN	1918	Vigo	Prairieton	-/seed
IN	1920	Lake	Griffith	-/fruit
IN	1922	Starke	North Judson	-/seed
IN	1923	Pulaski	Pulaski	-/fruit
IN	1925	Vigo	Terra Haute	-/
IN	1928	Jasper	Rensselaer	-/fruit
IN	1932	Marion		-/fruit
IN	1956	Greene	Bloomfield	-/fruits, seed

State	Last Observed	County	Town or Locality	Population size/Notes
IN	1984	Gibson	Griffin	-/
IN	1987	Dearborn	Chesterville	-/fruit, extirpated?
IA	Historic			reported in Les (1994)
KA	1998			reported in TNC database only
KY	1970	Livingston	Ledbetter	-/fruit
KY	1972	Graves		-/fruit
KY	1974	Ballard	Wildlife Area	-/
KY	1988	Trigg/Lyon	Land Between the Lakes	-/
KY	1990	Fulton	Fish Pond	-/
KY	1997	Fulton	Reelfoot Lake	80/flower
LA	1832		New Orleans	-/seed
LA	1915	Natchitoches		-/flower
LA	1970	Ouachita	Monroe	-/
LA	1971	Bienville	Bienville	-/
LA	1971	Ouachita	Monroe	-/
LA	1972	Ouachita		-/fruit
LA	1972	Grant	Aloha	-/fruit
LA	1973	Morehouse	Galion	-/
LA	1977	Morehouse	Bonita	-/
LA	1978	Morehouse	Collinston	-/seed
LA	1978	Morehouse	Jones	-/fruit
LA	1978	West Carroll	Epps	-/
LA	1980	Tensas	Saranac	-/
LA	1981	Tensas	New Light	-/
LA	1981	Richland	Alto	-/seed
LA	1984	Madison	Quimby	-/seed
LA	1984	Ouachita	Monroe	-/fruit
LA	1986	Saint Mary	Morgan City	-/flower
LA	1990	Saint Mary	Morgan City	-/fruit

State	Last Observed	County	Town or Locality	Population size/Notes
LA	1991	Saint Martin		-/
LA	1996	Assumption	Pierre Port	-/fruit
LA	1997	Iberville	Indigo Island	-/seed, cypress swamp
LA	1997	Morehouse	Monroe	-/seed, open wet field among thick sedge community
MD	1883		Near Washington D.C.	-/flower
MI	1897	Kent	Grand Rapids	-/flower
MI	1932	Cheboygen	Black Lake	-/
MI	1932	Mason	N. Hamlin Lake	-/
MI	1932	Presque Isle	Rainy River	-/
MI	1937	Cheboygen	Nigger Creek	-/flower
MI	1937	Iosco	Van Ettan Lake	-/
MI	1937	Presque Isle	Oequeve Lake	-/
MI	1938	Cheboygen		-/
MI	1948	Presque Isle	Long Lake	-/
MI	1948	Cheboygen	Sturgeon River	-/
MI	1953	Presque Isle	Rainy River	-/
MI	1970	Mackinac	Millecoguins	-/
MI	1971	Luce		-/
MI	1972	Alpena	Alpena	-/
MI	1975	Cheboygen	Alverno	-/
MI	1975	Mackinac	Engadine	-/
MI	1977	Luce	Paradise	-/
MI	1984	Alpena	Alpena	-/
MI	1997	Cheboygen	Mullet Lake	3/high number of individuals reported, Hellquist
MI	1997	Presque Isle	Sunken Lake	250/
MS	1980	Leflore	Minter City	40/flower
MS	1997	Washington	Stoneville	100/seed, sharkey clay soils in ditches of forest service road

State	Last Observed	County	Town or Locality	Population size/Notes
MO	1889	Lafayette	Alma Mills	-/flower
MO	1892	Dunklin		-/fruit
MO	1909	Jasper	Neck City	-/seed
MO	1909	Jasper	Puncell	-/
MO	1930	Dunklin	Kennett	-/seed
MO	1931	Dunklin	Campbell	-/seed
MO	1971	Butler	Poplar Bluff	-/
MO	1993	Oregon	Thomasville	6/
MO	1994	Oregon	Greer	-/"large population"
MO	1994	Wayne	Williamsville	150/
MO	1997	Christian	Ford	200/flower, cold ditch at high elevation 1250 feet
MO	1997	Howell	Mountain View	80/rosette only in cold, clear stream
MO	1997	Laclede	Morgan	250/flower, cold limestone stream, plants 8 feet long
MO	1997	Mississippi	Big Oak Park	100/fruit, turbid ditch along road entering park
MO	1998	Wayne		-/
NJ	1866		Twenty Glen	-/
NJ	1871		Newark	-/
NJ	1878	Sussex	Swartwood Park	-/
NJ	1930		Westfield	-/
NY	1831	Oneida	Oneida Lake	-/
NY	1865	Oneida	Ogdensburg	-/
NY	1871	Erie	Buffalo	-/
NY	1881	Cayuga	Moravia	-/fruit
NY	1914	St. Lawrence	Canton	-/fruit
NY	1919	Seneca	Tyre	-/flower
NY	1924	Wayne	Sodus	-/flower
NY	1927	Oneida	Three Mile Bay	-/
NY	1931	St. Lawrence	Black Lake	-/

State	Last Observed	County	Town or Locality	Population size/Notes
NY	1945	Jefferson	Watertown	-/fruit
NY	1980	Cortland	Cortlandville	-/extirpated 1983
NY	1987	Erie	Lockport	-/
NY	1988	St. Lawrence	Canton	50/
NY	1988	St. Lawrence	Hammond	fragments
NY	1988	Washington	Dresden	50/
NY	1997	Jefferson	Fort Drum	300/muddy banks of small pond
NY	1999	Onondaga	Tully	150/fruit, plants in 1 foot of water
NY	1999	Cortland	Preble	450/flower, many invasives, plants stranded several feet from water
OH		Lucas		-/historical, specimen unseen
OH		Erie		-/historical, specimen unseen
OH		Lorain		-/historical, specimen unseen
OH		Coshocton		-/historical, specimen unseen
OH		Licking		-/historical, specimen unseen
OH		Clark		-/historical, specimen unseen
OH	1914	Shelby		-/fruit
OH	1936	Pickaway		-/flower
OH	1993	Franklin	Hoover Reservoir	1/
OH	1997	Madison	Gillivan	10,000/flower, extensive floodplain, cleared area, buttonbush swamp
OH	1997	Mercer	Union	30,000/flower, extensive flooded area fed by several small creeks
OK	1949	McCurtain	Grassy Lake	-/fruit
OK	1972		Lake Eucha	-/
PA	Historic			reported by Stuckey in 1987
TN	1941	Obion	Walnut Log	-/flower
TN	1947	Lake	Tiptonville	-/
TN	1949	Montgomery	Clarksville	-/
TN	1950	Grundy	Pelham	-/

State	Last Observed	County	Town or Locality	Population size/Notes
TN	1966	Stewart	Land Between the Lakes	-/
TN	1986	Lake	Tiptonville	-/
TN	1986	Stewart	Lost Creek	-/
TN	1988	Lauderdale	Sunk Lake	-/flower
TN	1997	Lake	Reelfoot Lake	250/flower, abundant on mudflats in cypress swamp
TX	1907		Mineola	-/fruit
TX	1960	Tyler	Steinhagen Lake	-/fruit
TX	1998		Fairfield	-/flower
VA	1936	Southampton	Drewryville	-/
WS	1891	Brown	Green Bay	-/
WS	1915	Lincoln	Tomahawk	-/
WS	1921	Green Lake	Green Lake	-/
WS	1936		Door	-/
WS	1995	Bayfield	Cornucopia	-/
WS	1993	Marinette	Peshtigo Flowage	-/
WS	1991	Ashland	Oak Island	-/fragments
WS	1992	Bayfield	Stockton Island	-/fragments
WS	1994	Bayfield	Raspberry Bay	-/fragments
WS	1995	Bayfield	Siskiwit Bay	-/fragments
WS	1995	Bayfield	Bark Bay	-/fragments
WS	1995	Bayfield	Sand River	-/fragments
WS	1995	Bayfield	Sand River	-/fragments

Appendix 2: Summation of *Neobeckia aquatica* element occurrence (E.O.) data from the United States, excluding New England records.

State	Total (extant and Historic)	Total Extant only (e.g. 1975-present)	# counties in the state with extant E.O.'s	% E.O.'s flowering (extant and historic)	% E.O.'s with seed (extant and historic)	% E.O. loss
AL[1]	4	3	3	25%	0%	25%
AR	6	1	1	16%	0%	83%
FL	3	0	0	0%	0%	100%
GA	2	0	0	100%	0%	100%
IL	26	7	6	39%	4%	73%
IN	15	2	2	80%	27%	87%
KA[2]	1	1	1	-	-	-
KY	6	3	3	50%	0%	50%
LA	23	15	10	61%	26%	35%
MI	17	4	4	12%	0%	77%
MO	14	7	6	64%	22%	50%
MS[1]	2	2	2	100%	50%	0%
NJ	4	0	0	25%	0%	100%
NY	18	8	6	39%	0%	56%
OH[3]	11	3	3	36%	0%	73%
OK	2	0	0	50%	0%	100%
TN	9	4	4	33%	0%	56%
TX	3	1	1	100%	0%	66%
VA	1	0	0	0%	0%	100%
WS	6	2	2	0%	0%	66%

[1]Recently reported, no specimen seen, unknown number of populations, not used for calculations.
[2]Unseen historical records. Not used for calculations.
[3]Several records unseen. Not used for calculations.

Appendix 3. Comparison of lake cress element occurrence data with U. S. range averages. Alternative values to the mean are used in some instances in an attempt to circumvent bias from collections (*e.g.*, the tendency to collect only specimens in flower). Figure for U.S. averages was derived from data in Appendix 1.

Region	**Total (extant and historic)**	**Total extant (1975 to present)**	**Number of counties in state with occurrences**	**Percent of occurrences flowering (extant and historic)**	**Percent of occurrences with seed (extant and historic)**	**Percent population loss**
U.S.	9	3	2	44% (median=39%)	6.8% (median=0%)	68%
MA	1	0	0	-	-	-
VT	12	4	2	25%	0%	75%

Appendix 4. An explanation of conservation ranks used by The Nature Conservancy and the Association for Biodiversity Information

The conservation rank of an element known or assumed to exist within a jurisdiction is designated by a whole number from 1 to 5, preceded by a G (Global), N (National), or S (Subnational) as appropriate. The numbers have the following meaning:

1 = critically imperiled
2 = imperiled
3 = vulnerable to extirpation or extinction
4 = apparently secure
5 = demonstrably widespread, abundant, and secure.

G1, for example, indicates critical imperilment on a range-wide basis—that is, a great risk of extinction. S1 indicates critical imperilment within a particular state, province, or other subnational jurisdiction—i.e., a great risk of extirpation of the element from that subnation, regardless of its status elsewhere. Species known in an area only from historical records are ranked as either H (possibly extirpated/possibly extinct) or X (presumed extirpated/presumed extinct). Certain other codes, rank variants, and qualifiers are also allowed in order to add information about the element or indicate uncertainty.

Elements that are imperiled or vulnerable everywhere they occur will have a global rank of G1, G2, or G3 and equally high or higher national and subnational ranks. (The lower the number, the "higher" the rank, and therefore the conservation priority.) On the other hand, it is possible for an element to be rarer or more vulnerable in a given nation or subnation than it is range-wide. In that case, it might be ranked N1, N2, or N3, or S1, S2, or S3 even though its global rank is G4 or G5. The three levels of the ranking system give a more complete picture of the conservation status of a species or community than either a range-wide or local rank by itself. They also make it easier to set appropriate conservation priorities in different places and at different geographic levels. In an effort to balance global and local conservation concerns, global as well as national and subnational (provincial or state) ranks are used to select the elements that should receive priority for research and conservation in a jurisdiction.

Use of standard ranking criteria and definitions makes Natural Heritage ranks comparable across element groups—thus G1 has the same basic meaning whether applied to a salamander, a moss, or a forest community. Standardization also makes ranks comparable across jurisdictions, which in turn allows scientists to use the national and subnational ranks assigned by local data centers to determine and refine or reaffirm global ranks.

Ranking is a qualitative process: it takes into account several factors, including total number, range, and condition of element occurrences, population size, range extent and area of occupancy, short- and long-term trends in the foregoing factors, threats, environmental specificity, and fragility. These factors function as guidelines rather than arithmetic rules, and the relative weight given to the factors may differ among taxa. In some states, the taxon may receive a rank of SR (where the element is reported but has not yet been reviewed locally) or SRF (where a false, erroneous report exists and persists in the literature). A rank of S? denotes an uncertain or inexact numeric rank for the taxon at the state level.

Within states, individual occurrences of a taxon are sometimes assigned element occurrence ranks. Element occurrence (EO) ranks, which are an average of four separate evaluations of quality (size and productivity), condition, viability, and defensibility, are included in site descriptions to provide a general indication of site quality. Ranks range from: A (excellent) to D (poor); a rank of E is provided for element occurrences that are extant, but for which information is inadequate to provide a qualitative score. An EO rank of H is provided for sites for which no observations have made for more than 20 years. An X rank is utilized for sites that known to be extirpated. Not all EO's have received such ranks in all states, and ranks are not necessarily consistent among states as yet.