New England Plant Conservation Program

Floerkea proserpinacoides Willdenow
False Mermaid-weed

Conservation and Research Plan
for New England

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SUMMARY

Floerkea proserpinacoides Willdenow, false mermaid-weed, is an herbaceous annual and the only member of the Limnanthaceae in New England. The species has a disjunct but widespread range throughout North America, with eastern and western segregates separated by the Great Plains. In the east, it ranges from Nova Scotia south to Louisiana and west to Minnesota and Missouri. In the west, it ranges from British Columbia to California, east to Utah and Colorado. Although regarded as Globally Secure (G5), national ranks of N? in Canada and the United States indicate some uncertainly about its true conservation status in North America. It is listed as rare (S1 or S2) in 20% of the states and provinces in which it occurs. *Floerkea* is known from only 11 sites total in New England: three historic sites in Vermont (where it is ranked SH), one historic population in Massachusetts (where it is ranked SX), and four extant and three historic localities in Connecticut (where it is ranked S1, Endangered). The *Flora Conservanda:* New England ranks it as a Division 2 (Regionally Rare) taxon.

Floerkea inhabits open or forested floodplains, riverside seeps, and limestone cliffs in New England, and more generally moist alluvial soils, mesic forests, springy woods, and streamside meadows throughout its range. New England sites occur on calcareous substrates underlain by marble, slate, or trap rock. *Floerkea* is among the very earliest species to emerge in the growing season. Its seeds germinate in winter and seedlings are visible in late March to early April. Plants primarily self-pollinate; pollinators appear to be very few for this species. Plants live only 60-70 days, maturing an average of 4-12 seeds per individual and senescing by mid-June. The majority of seeds do not persist in the soil for longer than a year. Seeds disperse by gravity mainly over short distances, but water dispersal may allow infrequent, long-distance colonization of new sites. Potential threats to the species in New England include invasive species (*Aegopodium podagraria, Alliaria petiolata, Ranunculus ficaria* and others), trampling by dirt bikes and all-terrain vehicles, non-point-source pollution, hydrological change, and disturbance from construction of a greenway park. Two of the occurrences are on protected land, and others may be protected from habitat conversion by state wetlands legislation. Its unusual life history, as a non-seedbanking, autogamous annual with high fidelity to sites (some of which are disturbance-prone), may make this species vulnerable to local extinction.

The conservation objective for *Floerkea* in New England is to maintain the four extant populations in Connecticut at a mean annual size of 1,000 to 100,000 stems, occupying at least several 100 m^2 each. A secondary objective is to survey for populations in each of the states from which it was known historically, with an ultimate goal of locating and maintaining a total of eight populations of at least 1,000 stems each in three separate watersheds. This number reflects the historic distribution of known sites and acknowledges significant temporal variability in population size. Conservation actions to achieve these objectives include: concerted searches at historical and new sites; biennial, quantitative monitoring; assessments of threats from invasive species; notification of park designers of the species' existence; and *ex-situ* seedbanking and germination trials.

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.

The New England Plant Conservation Program (NEPCoP) of the New England Wild Flower Society 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.

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I. BACKGROUND

INTRODUCTION

Floerkea proserpinacoides Willdenow, false mermaid-weed (Limnanthaceae), is an herbaceous, autogamous annual of calcareous floodplains, limestone cliffs, wet meadows, and mature, mesic forests. The genus *Floerkea* is monotypic, and *Floerkea proserpinacoides* is the only member of the Limnanthaceae in New England. *Floerkea proserpinacoides* is widespread in North America, with eastern and western segregates separated by the Great Plains. The species is regarded as Globally Secure (G5), but it is listed as rare (S1 or S2) in 20% of the states and provinces in which it occurs. In New England, *Floerkea* is known from only 11 sites total in New England: three historic sites in Vermont (where it is ranked "Historic"), one historic population in Massachusetts (where it is ranked "Extirpated"), and four extant and three historic localities in Connecticut (where it is ranked S1, Endangered). The *Flora Conservanda:* New England recognizes *Floerkea* as a Division 2 (Regionally Rare) taxon (Brumback and Mehrhoff et al. 1996).

Floerkea proserpinacoides has been the focus of several detailed studies, so aspects of its life history are well-known. It is a very early spring ephemeral; its seeds germinate in winter and seedlings emerge in late March-early April. Self-pollination is the primary reproductive mode for this species; flower visitors are almost never seen. Plants complete their life cycle in 60-70 days, maturing an average of three seeds per plant, and senescing by mid-June. Most seeds do not persist in the soil seed bank for longer than a year. Dispersal occurs by gravity mainly over short distances, but water may disperse a few seeds (or seedlings), permitting infrequent, long-distance colonization of new sites.

Actual threats to the species in New England are largely unknown, but may include invasive species (which are prevalent at at least three of the extant sites), trampling by dirt bikes and all-terrain vehicles, non-point-source pollution, and possible disturbance from construction of a greenway park. Two of the occurrences are encompassed wholly or in part by nature preserves, and wetlands legislation may protect the others from wholesale habitat conversion. *Floerkea* has an unusual life history; it is an autogamous annual with very low fecundity and minimal seedbanking capacity that appears to move and reestablish only sporadically among sites. These features make individual populations especially vulnerable to disturbance.

This Conservation and Research plan reviews in detail the conservation status of *Floerkea proserpinacoides*, its biology, its biogeography, and the actions that are necessary to ensure its persistence in New England. These actions, including concerted searches at historical and new sites; biannual, quantitative monitoring; assessments of threats from invasive species; notification of park designers of the species' existence; and *ex-situ* seedbanking and germination trials, are designed to achieve the following overall conservation objective: to protect and maintain four populations of a mean annual size of

1,000 to 100,000 stems, occupying at least several 100 m^2 each. A secondary objective is, through concerted survey, to relocate and maintain at least two populations in each of the states from which it was known historically (Vermont, Massachusetts, and Connecticut). These objectives reflect the known historic distribution of the taxon and acknowledge significant temporal variability in population size.

DESCRIPTION

The following description is based on the species description in Gleason and Cronquist (1991), with modifications based on examination of live plants and herbarium specimens, Smith (1981), McKenna and Houle (2000a), and others as noted. *Floerkea proserpinacoides* is a glabrous, alternate-budding, weak-stemmed, dicotyledonous, annual spring ephemeral. It has a decumbent or suberect growth habit and characteristically forms prostrate patches with densities as high as 1500 plants/m^2. At maturity, plants may range in length from 3 cm (at 2700 m in western U. S.) to ca. 60 cm (the late-season extreme observed by Moorhead at extant Connecticut sites and on herbarium specimens). In Connecticut, the maximum length commonly reached is 30-35 cm (personal observation). The plant may grow erect until it is 15-20 cm tall, but becomes prostrate as it grows longer.

The cotyledons of *Floerkea* remain underground. The first aboveground portion of the plant to appear is a trifoliate leaf, which fully expands before the second trifoliate leaf unfurls. Soon after the first trifoliate leaves appear, the apex of the lengthening stem emerges above-ground, looking minutely bushy with several ranks of tiny, expanding 5-parted leaves and flower buds crowded together before the internodes lengthen. The leaves continue to grow during the life of the plant and the wider leaflets may reach about 4 or 5 mm in width before they begin to senesce. The trifoliate first leaves are the first part of the plant to senesce. *Floerkea* has 3- to 7-parted compound leaves with leaflets that are mostly entire, but not infrequently 2- to 3-lobed, and occasionally 5-lobed. Nearly all leaves above the first 1 to 2 trifoliate leaves are pinnately compound and mostly 5-parted (Theiret 1989). The leaflets are 0.5 to 2 cm long according to Gleason and Cronquist (1991); the longest leaflets measured *in situ* by Moorhead were 3 cm. There are no stipules at the bases of the petioles. The leaflets of the first several ranks of leaves are typically elliptic or oblanceolate, about 2 times as long as wide when first fully expanded (personal observation); later leaves are linear (Gleason and Cronquist 1991). Each leaflet of the trifoliate first leaf and first five-parted leaf is bluntly rounded to the ends, where there is a tiny, barely expressed cusp. Leaf petioles are usually 2 to 6 cm long; petioles of the lowest leaves may reach about 10 cm. The two lateral leaflets of the trifoliate first leaves are opposite and sessile, and the terminal leaflet of at least the first trifoliate leaf is nearly sessile, hence the palmate pattern. The three leaflets tend most often to assume a "T" orientation; less often, the 3 leaflets will approach an equi-angular orientation.

The stem of *Floerkea* may be simple or may branch at the first to third nodes. Axillary flowers tend to be produced instead of branches at the upper nodes (Smith

1984). Plasticity in branching versus flower production at nodes may have evolved as a response to competition in dense stands of this plant, as it enables reproduction when plants are small and crowded (Smith 1984; Brent Smith, Earlham College, personal communication).

Floerkea has radially symmetric, perfect, trimerous (very rarely 4-merous) flowers. The flowers have no bracts and arise singly from the axils of the leaves on flexuous pedicels that lengthen over the life of the plant and eventually may exceed the length of the subtending leaf. The calyx consists of three green lance-ovate, valvate sepals that are 2.5-3 mm at anthesis, but grow to about 6 mm at maturity. The corolla is much shorter, consisting of 3 tiny white oblanceolate petals, 1-2 mm long, that alternate with the sepals. The flowers are hypogynous and/or slightly perigynous (Fernald 1950) and the ovary is divided into 2 to 3 globular carpels that are joined near the base by a single gynobasic style. Each carpel contains a single erect ovule. The ovary is initially whitish, with tiny bumps on the surface. The styles are smooth, erect, curved, translucent processes much shorter than the height of the ovary, capped by a knoblike stigma with a roughened surface. There are 3-6 distinct stamens, alternating with the petals, one or two to an interval. At the opening of the flower, the stamens are about the same height as the stigmas and curved inward such that the anthers are close to or in contact with the stigmas. Several of the anthers may abort and not produce pollen (personal observation). Other Limnanthaceae species produce an adnate nectar gland at the base of each stamen filament (Gleason and Cronquist 1991, Link 1992), but it is not clear that *Floerkea* does. Brent Smith (personal communication) detected no nectar production and never observed a flower visitation by an insect over hundreds of hours of *in situ* observation of *Floerkea* plants in Wisconsin and Indiana.

The first flowers open when the plant is 5-10 cm tall. Flowers open when their pedicels are less than 1 cm long (flower buds appear sessile), the pedicels continue to lengthen until they are over 5 cm long by the time the fruit matures (McKenna and Houle 2000a). The lowest pedicels on the stem are the longest, while upper ones may be less than 1 cm long. The flowers soon become hanging and bell-like because the pedicel smoothly recurves as it lengthens. Flowers are often upward-facing and clustered tightly at the apex when first open (personal observation).

The fruit is a lobed schizocarp, which is divided into 2-3 ovoid-globose mericarps joined only near their bases; the mericarps become the seeds. Smith (personal communication) estimates that seed production averages 4-12 seeds per plant. These egg-shaped seeds are at first green and somewhat fleshy, and have numerous small yellowish, semi-translucent, resinous-looking bumps, more concentrated toward the distal end of the seed. The seeds are easily detachable from the receptacle by bumping or picking while still green, but many remain attached and become paler and less green over time. Smith (1981) reported that the seeds are green when first abscised from the flower, and within a few weeks turn red-brown. Seeds that are picked while still green and air-dried soon become blackish and appeared minutely spiny or warty (personal observation). The seeds are variously reported to be 2.5 mm in diameter (Gleason and Cronquist 1991), 2.5-3 mm in diameter (Smith 1983b), and 1-2 mm x 2-3 mm (Houle et

al. 2001). Green seeds from Connecticut plants were 3 x 4 mm (personal observation). Many seeds remain attached to the plant as it senesces and dies, and seeds may turn dark-colored while still attached to the plant (Penni Sharp, Consulting Botanist, personal communication). In summary, the following characters are most useful for distinguishing *Floerkea* in the field:

Very early phenology. *Floerkea* appears between late March and late April in Connecticut, and completely disappears from mid-late June in northeast North America.

Trifoliate first leaves. Co-emerging annual and perennial species bear no resemblance to *Floerkea,* with the possible exception of *Trifolium* (clover) spp. However, *Trifolium* leaflets are serrate, nearly as wide as long, and have a pronounced fold down the midrib. *Floerkea* leaflets are entire, several times as long as wide, and are flat or slightly upwardly convex, with an obscure midrib.

Alternate, pinnately compound five-parted leaves with sub-linear leaflets. *Floerkea* may be the only trailing herb in New England with pinnately compound, once-divided leaves that normally have no more than 5 leaflets. *Cardamine pensylvanica* and *Cardamine pratensis* leaf out early and the latter, especially, could co-occur and be confused with *Floerkea* when plants are very young. However, both *Cardamine* species are truly erect, have terminal inflorescences with 4-merous flowers, and later leaves have many more than 5 leaflets.

Bright, light green or yellow-green color. Herbs appearing with *Floerkea* in the early spring are more anthocyanic (reddish or purplish) or darker green. One exception is *Galium aparine*, a trailing herb with similarly bright green leaves and early phenology. However, *G. aparine* is easily distinguished by its whorled, simple leaves.

Prostrate, mat-forming habit and high stem density. Among the other species that may occur with this habit in similar habitats are *G. aparine, Ludwigia palustris*, *Chrysosplenium americanum*, and *Lysimachia nummularia*, but their leaves are all distinct from *Floerkea*.

Tiny trimerous flowers on slender flexuous pedicels solitary in the axils of most leaves. Very rarely, *Floerkea* may be found with 4-merous flowers as a mutation (Mason 1952; Smith, personal communication), but in general, no species in New England has these characters in combination with compound leaves. Some Caryophyllaceae that might occur with *Floerkea* (e.g., *Stellaria borealis*, in seeps) have tiny flowers on flexuous axillary pedicels, but all of these have opposite, entire leaves, and the flowers are 4- or 5-merous.

Affinity for bare soil and microsites with thin or patchy leaf litter. It can be productive *during early season surveys* to search out mesic (but not very wet)

microsites where the leaf litter is thin, patchy, or non-existent and the soil is warmed by sunlight.

TAXONOMIC RELATIONSHIPS, HISTORY, AND SYNONYMY

The species *Floerkea proserpinacoides* and the genus *Floerkea* together were named by the German botanist C. L. Willdenow in 1801. The genus was named in honor of another German botanist, Gustav Heinrich Flörke (Floerke in the English alphabet). The specific epithet means "like *Proserpinaca.*" Willdenow was under the impression that *Floerkea* was an aquatic plant, and saw a resemblance between the compound leaves of *Floerkea* and the submersed leaves of *Proserpinaca*, a genus of emergent aquatic plant (Theiret 1989). *Proserpinaca* itself is named for Proserpine (in Roman mythology adopted from Greek), who spent half of the year above-ground with her mother Ceres (Goddess of Agriculture), and the other half in the underworld with Pluto (God of the Underworld). The emergent aquatic plant *Proserpinaca* is like Proserpine, a being of two worlds, in that the lower part of the plant is typically submersed and the upper part emersed in the air, and the two parts are morphologically different. The common name of *Proserpinaca*, "mermaid-weed," also alludes to this dimorphism. Since *Floerkea proserpinacoides* is not aquatic and it does not exhibit such dimorphism, the specific epithet "*proserpinacoides*" is something of a misnomer, as pointed out by Theiret (1989). In fairness to Willdenow, *Floerkea* is also known from seeps, marshes, and wet meadows, in some parts of its range, and it displays a dimorphism between the trifoliate first leaf and the five-parted later leaves (however, this is unrelated to submersion).

Floerkea is a monotypic genus, with *Floerkea proserpinacoides* the only currently recognized species (but see below). It belongs to the small family Limnanthaceae (the meadow foam family), which is endemic to temperate North America, and is comprised of only two recognized genera with eight currently recognized species (NatureServe 2002). The relationship of Limnanthaceae to other families has been disputed since the family was first proposed in 1836, and has not yet been resolved. Cronquist ascribed the Limnanthaceae to the Geraniales, with Oxalidaceae, the Geraniaceae, and the Balsaminaceae as its closest relatives— a view that has been revised in recent years. Members of the Limnanthaceae produce "mustard oil," a family of aromatic oils (isothiocynates). This unusual characteristic is shared with the members of the Brassicales, namely the Tropaeolaceae, the Brassicaceae, and the Caricaceae (Fahey et al. 2001). In addition, recent molecular DNA-sequencing research supports the view that these families may be closely related, but places the Setchellanthaceae and the Koeberliniaceae most closely to the Limnanthaceae (Stevens 2001, Tree of Life 2003; *cf* Spichiger and Savolainen 1997, Reveal 1999 for data on anatomical, floral, ovary, and embryological characters).

The sister genus of *Floerkea* is *Limnanthes* (meadowfoam), which is comprised of seven species (NatureServe 2002). All the species of *Limnanthes* are endemic to California, Oregon, or British Columbia. By contrast, the range of *Floerkea* spans the continent. *Floerkea* and *Limnanthes* were recognized as different genera on the basis of

only two characters. *Floerkea* has hypogeous cotyledons (i.e., that remain hidden underground, unless exposed by erosion) and 3-merous flowers, whereas *Limnanthes* has epigeous cotyledons (i.e., they are brought above-ground) and 4- or 5-merous flowers (Ornduff and Crovello 1968). In their taxonomic study of Limnanthaceae, Ornduff and Crovello (1968) concluded that *Floerkea* could be interpreted as a highly reduced, autogamous phylogenetic derivative of *Limnanthes*, the species being farthest along a trend toward the reduction in number of floral parts associated with autogamy that was evident to a lesser degree in some other species in *Limnanthes*. In addition, all species in both genera are annual spring ephemerals, and both occupy vernally wet sites that are dry or mesic later in the growing season. Although these similarities and shared derived characters might argue for subsuming *Floerkea* under *Limnanthes,* studies of flavonoid profiles uphold a clear separation of the genera (Parker and Bohm 1979).

The following are synonyms for *Floerkea proserpinacoides* according to Rydberg (1910):

- *Floerkea lacustris* Pers. *Syn Pl*. 1: 393. 1805.
- *Nectris pinnata* Pursh. *Fl. Am.* Sept. 239. 1814.
- *Floerkea uliginosa* Muhl. *Cat*. 36. 1813.
- *Floerkea palustris* Nutt. *Gen*. 1: 229. 1818.
- (?) *Cabomba pinnata* R.& S. *Syst. Veg*. 7: 1379. 1830.

Taxonomists have disagreed as to whether the *Floerkea* plants west of the Great Plains represented a separate species, *F. occidentalis* Rydb. (*Memoirs of the New York Botanical Garden* 1: 268 [1900]). Rydberg (1910) recognized *Floerkea occidentalis* as a separate species, which was distinguished from *F. proserpinacoides* by its smaller size, "much shorter petioles and shorter leaflets, comparatively longer pedicels, broader sepals, and sharper tubercled fruit" (Rydberg 1910: 268). Russell (1919) interpreted *Floerkea occidentalis* as a "condensed form" or "probably a starved, or feeble form of *F. proserpinacoides* of varietal rank," because of its "resembling *Floerkea proserpinacoides* in all essentials, differing from it by a slight reduction in size of its parts" (Russell 1919, p. 404-405). Russell presented Rydberg's (1910) separation of the taxa as based on a single weak character, i.e. "pedicels longer than the petioles" in *F. occidentalis*, versus "pedicels rarely equaling the petioles" in *F. proserpinacoides* (Russell 1919, p. 414). Emphasizing the dubiousness of the distinction, Russell argued that plants exhibiting either condition had been collected from the vicinity of Philadelphia, where only *F. proserpinacoides* should occur (plants in Connecticut also exhibit both states, personal observation). Russell evidently carried the day by the second half of the century, because western plants are called simply *Floerkea proserpinacoides* in most works published after 1950. Though Russell recognized a var. *occidentalis* of *F. proserpinacoides*, she acknowledged that some taxonomists regarded it as identical to *F. proserpinacoides*; today, the *occidentalis* taxon does not even have varietal status (NatureServe 2002). The question of a taxonomic distinction between western and eastern *Floerkea* was not mentioned in Ornduff's and Crovello's (1968) numerical taxonomic study of Limnanthaceae, which suggests that it was considered by then a settled question.

Based on the large collection of eastern and western North American *Floerkea* specimens at the New York Botanical Garden herbarium (NYBG), it is clear at least that western *Floerkea* plants only rarely reach the overall dimensions commonly reached by eastern plants (Moorhead, unpublished data). Also, the comparative length of the fruiting pedicel and subtending leaf can separate most (but not all) western *Floerkea* from all eastern *Floerkea*. To the authors' knowledge, the question of one versus two *Floerkea* species has not been revisited using modern techniques of molecular systematics, nor have hybridization studies been conducted. Given the large range gap at the Great Plains, a study of the taxonomic affinities of the western and eastern *Floerkea* would be of general interest to confirm or debunk the single-species concept, to determine how long the western and eastern segregates have been genetically isolated, and to clarify the global distribution and conservation status of the taxon.

SPECIES BIOLOGY

The life history of *Floerkea proserpinacoides* is atypical for an annual plant (McKenna and Houle 2000b). In many parts of its range east of the Great Plains, the species occurs in great abundance in a few restricted localities, but is inexplicably missing from vast areas of seemingly identical habitat that is nearby or connected via streams. It is an annual that occurs in mature deciduous forest through much of its range (though not always in New England), a habitat in which few other annuals occur. Because it does not seedbank (unlike many other annual species), and has exceptionally low per-individual fecundity for an annual, it would be expected to be erratic and to "come and go" at particular sites. Instead, it has been documented to persist for 100 years in restricted localities, showing high site fidelity and infrequent dispersal. Thus, while much is known about its basic biology, the behavior of *Floerkea* remains an ecological conundrum and presents challenges for its conservation.

Seed Germination and Seedling Establishment

The seeds of *Floerkea proserpinacoides* remain dormant during summer and fall; they germinate in winter, but the embryonic axis does not tend to elongate until the soil warms up in March (Smith 1983c). Baskin et al. (1988) determined that seeds of *Floerkea* in the southern part of its range (Ohio) germinate in early to mid-winter (December through February). A minimum temperature of 5º C and a period of cold stratification is required for germination. Seed germination rate was significantly enhanced in their studies, attaining levels in excess of 90%, by application of both a cold and a warm (e.g., 12 weeks at $30^{o}/15\ ^{o}C$) stratification pretreatment. A similar early- to mid-winter germination timing is reported for plants in southern Wisconsin (Smith 1981) and in Quebec, where winter germination has been documented at 0º and under deep snow (Houle et al. 2001). In Connecticut, Moorhead found a living, germinated seedling of *Floerkea* in soil collected on February 5, 2003, which greened up rapidly upon warming and exposure to light. Seeds generally occupy only the upper 2 cm of the soil surface (Houle et al. 2001), and thus are likely to be highly sensitive to minute

temperature increases in the winter. Observations of field populations have noted naturally high germination rates that are density-independent (Smith 1983c, Houle et al. 2001). Soil drying, as might occur during a late-season drought, reduces germination rates but not overall germination percentages (Houle et al. 2001).

Floerkea embryos are large, highly provisioned, and fully-developed upon seed dehiscence (Martin 1946), characteristics that favor rapid germination. Studies following the fate of bagged seeds suggest that a small proportion of seeds enter dormancy and that such dormancy would be short-lived (Smith 1983c). Dormancy rates varied from approximately 10% in 1979 to 2% in 1980 and seeds dormant in one year generally germinated in the next. Although dormancy may allow a small proportion of seeds to "bet-hedge" against environmental variation, seeds generally do not remain viable in the soil seed bank for longer than one year (Smith 1983c) and there is little overlap of the seed bank from year to year (Houle et al. 1998, 2001).

About 40% of germinating seeds successfully establish as seedlings (Smith 1983c). Experimental manipulations of litter depth demonstrate that seedling establishment is hindered by a deep litter layer from canopy leaf-fall (Smith 1983c, Houle et al. 2001). Species composition of the leaf litter (e.g., *Quercus rubra* versus *Acer saccharum*), however, had no discernible influence on seedling success (Smith 1983c).

Phenology

Floerkea proserpinacoides is a spring ephemeral with an above-ground lifespan of 60-70 days, all of which is completed by early summer (Smith 1981, McKenna and Houle 2000b, Houle et al. 2001). In central Ohio, flowering dates from 10 April to 2 June have been observed (Hendricks and Matz 1999; Gregory Payton, Dawes Arboretum, personal communication). At the other extreme, plants in Nova Scotia apparently exhibit a later phenology: in the year of its discovery (1948), a population was found on 29 May mostly in flower, and the same population was found in fruiting condition at the end of June (Roland and Smith 1969). Spring warm-up and the vegetation response is much later in the maritime provinces than in southern Quebec (Sean Blaney, Atlantic Canada Conservation Data Centre, personal communication).

The phenology of *Floerkea* in New England, based on Moorhead's observations over 12 years in Connecticut, and the life stage of dated herbarium specimens, is presented in Table 1 (below). Plants with fully-developed first leaves have been observed in Connecticut as early as 19 March in a year with an unusually warm early spring (2002). In 2003, a year with an exceptionally cold winter and cold early spring, plants first emerged at one site on 20 March, after about a week of milder weather. These observations suggest that *Floerkea* may first emerge in some years before mid-March, and probably by late March in most years. The earliest date that *Floerkea* has been documented in flower in Connecticut is 22 April, at the northernmost Connecticut occurrence.

In Vermont, the only specimens that have dates are from Chittenden County (the northernmost of the historic sites in Vermont). These several specimens are dated 13 May to 19 May and they have either immature fruit (13 and 15 May of different years) or mature fruit (19 May of a single year) (Arthur Haines, New England Wild Flower Society Herbarium Recovery Project, unpublished data). In Massachusetts, one collection represents the only clue to the local phenology of *Floerkea*. Fernald's 30 May 1915 collection is in fruit (Haines, unpublished data). Dates on the Vermont and Massachusetts specimens indicate that *Floerkea* phenology in those states are likely somewhere between that of Connecticut and southern Quebec. Thus, one might reasonably expect first emergence in Massachusetts and Vermont to be in early to mid-April, and flowering to begin in early to mid-May.

Table 1. Phenology of *Floerkea proserpinacoides* in New England documented by *in situ* observations and inspection of herbarium specimens.

Life stage	CT	MA	VT
First emergent leaf	19 March – 14 April	no data	no data
Unopened flower buds	6 April - 23 April (6 May[3])	no data	no data
In flower (no obvious fruit)	22 April – 3 May	no data	no data
Earliest date with obvious immature fruit	5 May	no data	13 May
Earliest date with mature fruit	12 May	30 May[1]	19 May[1]
Earliest observation of senescence (excluding senescence of trifoliate leaves)[2]	18 May;[3] 22 May	no data	no data
Latest date plants observed	12 June	no data	no data

[1]Single observation/specimen
[2]Based on *in situ* observations only, because hard to judge in pressed specimens
[3] observation not by authors

Onset of senescence coincides closely with the completion of forest leaf-out (Smith 1981), and timing is correlated with decreases in photosynthetically active radiation as the canopy closes and air temperatures increase, especially at night (McKenna and Houle 2000a). In Connecticut, plants begin to senesce in mid- to late May, die in early June, and have disappeared entirely by early to late-June (unpublished data and Sharp, personal communication). Houle et al. (2001) note some polymorphism in Quebec populations for germination timing, with the majority of seedlings emerging before the end of April and a "substantial proportion" of seeds germinating later. However, these later cohorts apparently did not have time to mature their own seeds before the onset of early, synchronized senescence, indicating a potential disadvantage to late germination in most years.

Growth

Intraspecific competition may be a significant ecological force structuring populations of *Floerkea*. Demographic studies by Smith (1983b) showed that growth rates of individual plants (expressed as production of branch nodes, leaflets, and buds) decline at higher densities and that plants died sooner in high density stands. The resource axes along which plants are competing (e.g., water, nutrients, light) remain largely unknown, but Smith (1983b) suggested that light may be the limiting factor. However, the autogamous populations of *Floerkea* are most likely composed of individuals that share a high proportion of alleles; thus, self-thinning of these dense stands does not imply competition among genotypes in the conventional sense. However, density-dependent growth and mortality, together with low dispersal rates, have important implications for the maximum size (and carrying capacity) that *Floerkea* populations can maintain.

Reproduction

The flowers of *Floerkea* are autogamous, or self-fertilizing (McKenna and Houle 2000a). This does not mean that the flowers are incapable of cross-pollination, but Ornduff and Crovello (1968) considered *Floerkea* to be almost exclusively autogamous. *Floerkea* has many of the characteristics associated with self-pollination including relatively few flowers per plant, small and inconspicuous flowers, very small petals, reduction in number of floral parts (3-merous flowers are extremely uncommon among dicots), calyx and corolla funnelform at anthesis, wide distribution, low pollen production, odorless flowers, and little, if any, nectar production (Smith 1983b and personal communication). Neither Smith nor Houle have observed insect visitation during their long-term studies of *Floerkea* in Wisconsin, Indiana, and Quebec (Smith, personal communication; Gilles Houle, Université Laval, personal communication). Over the course of several cumulative hours of observation on different dates in 2003, Moorhead observed only one very brief visit to a *Floerkea* flower, by a Syrphid fly (a "hoverfly"). The fly touched the face of an upward-facing flower with its proboscis, in the vicinity of an anther, for a fraction of a second, before flying away.

Houle (2002) tested the hypothesis that *Floerkea* may exhibit trade-offs between growth and flowering activity, particularly because its lifespan is very brief. Manipulating the timing of reproduction by removing flowers throughout most of the growing season, Houle found that delayed-flowering plants took one week longer to senesce, which allowed them time to mature as many seeds as control plants; this may be evidence that senescence is cued by hormonal changes associated with seed ripening (Smith, personal communication). Since senescence is also strongly correlated with light availability, however, delayed flowering can result in reduced plant fitness during years with early canopy leaf-out. Houle (2002) also suggested that green sepals may contribute photosynthetically to flower maintenance, thus reducing the potential costs to growth of early flowering. Likewise, Houle and McKenna (2000b) noted that *Floerkea* plants performed better in terms of growth and reproductive output when grown under the

higher temperatures characteristic of the late spring, but only as long as water and light availability are not limiting. Therefore, the species has a very narrow phenological window in which to complete its life cycle, which is risky for an annual plant (McKenna and Houle 2000b).

The fecundity of individual *Floerkea* plants is inversely proportional to plant density, principally because densely growing plants tend to be smaller (Smith 1983b). At all densities, *Floerkea* has exceptionally low fecundity compared with other forest annuals. Struik and Curtis (1962) reported a mean production of 4.3 seeds per plant and Houle et al. reported mean plant fecundities at their southern Quebec sites varying from 0.5 to 3.5 seeds/plant. (both of which Smith [personal communication] views as underestimates due to the challenges of counting seeds correctly). Smith (1983b) reported averages of 4-12 seeds per plant over a density range of 100-1550 plants/m^2 at his study site in Wisconsin. Because *Floerkea* plants can attain high densities in natural populations, area-based seed yields can be quite high. Seed yields at the end of the growing season commonly exceeded 5000 seeds/m^2 in southern Wisconsin (Smith 1983b). Houle et al. (2001) reported seedling densities of 839-6900 seedlings/m^2 at two sites in southern Quebec.

Seed Dispersal

Smith (1983) and Houle et al. (2001) have concluded that the primary dispersal mechanism for *Floerkea* seeds is barochory (dispersal by their own weight, falling under the parent plant). This has been inferred from the seeds' lack of accessory structures (i.e., wings, hooks, elaiosomes) that promote dispersal by other agents. In feeding trials in Wisconsin, Smith (1983c) found that ants rejected the seeds and that predation by mammals does not occur, possibly due to the toxic flavonol glycosides produced by the plants. Smith (1983c) and Houle et al. (2001) have demonstrated that the majority of seeds germinate near the parent plant. The seeds of *Floerkea* are notably large (mean dry weight 6.7 mg) for such a diminutive plant and would not be disposed to move far without assistance from water or animals.

Hydrochory (dispersal by water) could be an alternate dispersal mechanism (Gauthier and Rousseau 1973); *Floerkea* seeds are buoyant under experimental conditions. In experimental trials, seed buoyancy lasted for a shorter period in agitated water than in still water, and seeds differed in duration of floating (Houle et al. 2001). Given the fact that all of the known New England occurrences of *Floerkea* are on floodplains or near streams, hydrochory is a plausible dispersal route. However, given the extremely patchy distribution of *Floerkea*, even in riparian corridors with ample available habitat, it appears that hydrochory is an infrequent event, perhaps only taking place during years in which high floods dislodge and transport seeds or seedlings, then quickly dissipate, exposing suitable habitat for early establishment.

Since the majority of *Floerkea* seeds remain at or very near the soil surface, they could be carried on the treads of shoes and tires, and on the feet or hooves of larger

animals such as deer. Dispersal over perhaps hundreds of meters may be occurring at a portion of CT .004 (North Haven/Wallingford), where there is heavy all-terrain vehicle (ATV) and dirt bike use in and around occupied *Floerkea* habitat; several small patches are scattered along one ATV path. Longer-distance anthropogenic dispersal could occur through excavation, transportation, and deposition of fill. Plants at CT .005 (Meriden) are most abundant on an abandoned fill road, for example.

HABITAT/ECOLOGY

Several botanical manuals addressing northeastern North America describe *Floerkea* habitat as follows: "Damp woods in rich soil" (Gleason and Cronquist 1991); "Rich low or alluvial woods or wet calcareous rocks" (Fernald 1950); "In marshes and along rivers" (Britton and Brown 1913). A table of habitats occupied by *Floerkea proserpinacoides* throughout its transcontinental range is presented as Appendix 2. *Floerkea* shows considerable ecological amplitude with respect to certain habitat parameters, as might be suspected of a plant that can occur in Louisiana, Nevada, British Columbia, and Nova Scotia.

There appears to be at least one unifying ecological common denominator for the species across its range: a requirement for moist or wet soil conditions and intolerance of dry or xeric conditions. *Floerkea* is listed as a facultative to obligate wetland plant throughout its range in the northeast, southeast, North Central, Intermountain, and California regions (USDA, NRCS 2003). East of the Great Plains, at least, it is consistently found on sites of higher fertility as well. In the mountains of western North America, and at the northern limits of its range, in southern Canada, it is often found in open-canopy seasonal seeps and wet meadows, while throughout most of its range in the midwestern and eastern U. S., it is a species of rich, moist, deciduous forests. *Floerkea* is almost exclusively riparian in the eastern coastal states and provinces (see below), while in the Midwest, it occurs both on floodplains and in rich, mesic old-growth forests far from any stream (Smith, personal communication). It is known to occur in forested seeps or otherwise seasonally wet forested sites, such as in wet depressions in undulating clay-soil forests bordering Lake Erie in Ontario (Blaney, personal communication).

Plant species associated with *Floerkea* in many parts of its range are presented with the habitat information in Appendix 2, and associate species recorded at the extant New England occurrences are presented in Appendix 4. *Acer saccharum* (sugar maple) frequently dominates the canopy over *Floerkea* throughout the eastern sector of its range. *Acer saccharum* is recorded at all extant New England occurrences.

An apparent large range discontinuity at the Great Plains strongly suggests that the tall grass and short grass prairie ecoregions/biomes offer little potential habitat for *Floerkea*. This is interesting, considering that prairie soils can be quite rich, and that seasonally wet habitats that dry out later in the growing season occur in these ecoregions/biomes.

Russell (1919) noted that *Floerkea* is also curiously absent from the Coastal Plain physiographic province. The largest New England occurrence, CT .004 (North Haven/Wallingford), is arguably an exception to this rule. It occurs in large part in a zone that has been designated as the "Eastern Coastal ecoregion" ...of Connecticut with... "a strong southeastern Coastal Plain influence on the flora" (Dowhan and Craig 1976: 40). This occurrence inhabits the floodplain of a stream that meanders across a large glaciofluvial sand plain supporting characteristic coastal plain species (e.g., *Pityopsis falcata* and *Polygonella articulata* [Mehrhoff 1996]). However, no occurrences of *Floerkea* are known in New England from the areas with the largest and best-developed occurrences of Coastal Plain geomorphology and vegetation.

While only one occurrence of *Floerkea* in New England (VT .001 [Shelburne]) is known to have been closely associated with basic bedrock, most extant and historic occurrences of *Floerkea* in New England are noted from places where the soil is likely to be derived to some degree from high-base bedrock types. This accords with Gauthier and Rousseau's (1973) characterization in Quebec. Five of the seven Connecticut occurrences are/were along streams that drain traprock (basalt and/or dolerite [= diabase]) uplands (3 occurrences), or uplands that are just downstream, in terms of glacial ice movement, of large exposed traprock formations. One historic Connecticut occurrence was on alluvium of the Housatonic River, a large portion of whose drainage area has calcareous marble bedrock geology, and a small portion of which has traprock bedrock. CT .001 (Greenwich) is along a stream immediately downstream of amphibolite and shistose marble bedrock formations (Rodgers 1985). The two Vermont occurrences from Castleton (VT .002) and Fair Haven (VT .003) likely occurred in areas underlain by slate bedrock. This bedrock may, in fact, be acidic (Elizabeth Thompson, Consulting Botanist, personal communication), but calcareous influences are evident in the composition of the surrounding vegetation communities. Finally, MA .001 (Greenfield) appears likely to have occurred on or in close association with deposits of rich clay that border the Green River floodplain along much of its course. Much of the bedrock in this area is calcareous, and associated vegetation indicates calcareous influences.

Two of the extant Connecticut occurrences are on the active floodplains of large streams; that is, the entire known occurrences are flooded at frequencies as high as several times per year and not lower than 1 in 10 years. The individual populations, or suboccurrences, are on sites where flooding is dynamic, and soils are reworked by flood currents that scour and deposit alluvium. Although *Floerkea* is documented from floodplains throughout its range (see Appendix 2), this may represent an unusual level of disturbance for the species relative to its typical habitats outside of New England. Given that *Floerkea* is an annual and only minimally seedbanks, one would expect that populations at CT .003 (Southbury) and CT .004 (North Haven/Wallingford) would be subject to catastrophic mortality and local extirpations. This has not been documented specifically for *Floerkea* at these sites; however, at CT .004 (North Haven/Wallingford), no plants could be found during a visit by Moorhead in June, soon after a flood event in 1999. Nevertheless, plants were observed in abundance in the same area in subsequent years. Since there are several other subpopulations upstream of this one, this population

could have recovered by way of its own seeds or seeds from upstream populations. Infrequent local extirpations and establishment of new populations of varying longevity may occur in these habitats; however, with low fecundity and dispersal rates, *Floerkea* numbers will be reduced by frequent disturbances (Smith, personal communication). *Floerkea* appears to be more likely to persist long-term in the less flood-prone areas in floodplains, swales, and upper terraces; hence, its apparent affinity for more flood-prone areas in northeastern North America remains a puzzle.

THREATS TO TAXON

Several threats that impinge on riparian habitats can pose a challenge to *Floerkea proserpinacoides* populations. Few immediate external hazards face *Floerkea* at its extant sites in Connecticut, but the plant's curious life history as an annual spring ephemeral makes it vulnerable to sudden changes in habitat quality. The following threats are discussed in order of prevalence at actual sites.

Invasive and Non-Native Species

Because senescence of *Floerkea* is hastened by a closing canopy, an invasion of woody plants that leaf out earlier than existing woody species at a *Floerkea* site would pose a threat. Demonstrably invasive shrubs and vines occurring in *Floerkea* habitat include *Berberis thunbergii*, *Rosa multiflora*, and *Celastrus orbiculatus*. Also of concern are certain exotic trees, such as *Catalpa* cf. *speciosa* and *Acer platanoides*. *Catalpa* cf. *speciosa* is a dominant canopy tree over a suboccurrence of CT .004 (North Haven/Wallingford).

Invasive herbaceous species are present at all extant sites but the magnitude of their threats to *Floerkea* is difficult to assess, given *Floerkea*'s early phenology. Dense concentrations of taller herbaceous species over which *Floerkea* plants probably cannot climb to reach light are the most likely threats. Such invasive species include *Alliaria petiolata*, *Aegopodium podagraria*, *Fallopia japonica*, and *Hesperis matronalis* (all of which are present at one or more extant *Floerkea* occurrence). However, Moorhead has observed a patch of *Floerkea* growing with and climbing over lush *Aegopodium* 2-3 dm high at one site. Likewise, the low-growing invasive buttercup *Ranunculus ficaria* virtually covers the ground over tens of hectares in the same location as the largest extant concentration of *Floerkea* plants known in New England (CT .004 [North Haven/Wallingford]). This species shares a similar phenology with *Floerkea* and other co-occurring spring ephemerals. *Ranunculus ficaria* could compete with *Floerkea* for moisture and nutrients, but not for light, since *Floerkea* can climb over the prostrate *Ranunculus* plants. Garlic mustard (*Alliaria petiolata*) presents a major threat to *Floerkea* in Wisconsin (Smith, unpublished data); it is currently noted at all present occurrences in New England, but its actual threats to *Floerkea* are unknown. Garlic mustard could competitively exclude the species were it to infest these sites heavily.

More research is needed to determine the precise effects of herbaceous invasives on *Floerkea.*

Habitat Conversion or Destruction

Habitat destruction by way of development, filling of low lying riparian habitat, road construction, channelization and impoundment of streams has almost certainly destroyed or reduced *Floerkea* habitat and population size in New England in the past. However, with the passage and subsequent enforcement of state, federal, and local wetlands and watercourse protection laws, the threat from these kinds of activities has been much reduced. Habitat conversion of riparian forest for agriculture, timber harvest, and development of riverside recreational facilities are also activities that in the past likely had significant impacts on actual and potential *Floerkea* sites. These activities are either less strictly regulated or exempted from regulation altogether under wetlands and watercourse protection laws, in all three states from which *Floerkea* is known, and hence they represent a continuing potential threat. The threat from these activities is probably not significant for the existing known populations of *Floerkea* in Connecticut, where the species has State-Endangered status. However, these activities may pose a serious potential threat to undiscovered *Floerkea* populations in Connecticut, Massachusetts, and Vermont (*Floerkea* has no legal status in the two latter states). The population at CT .004 (North Haven/Wallingford) is perhaps most directly threatened by upland development for industrial and residential interests. Non-point pollution sources (from parking lots and roads) are numerous along this stretch of river, most perched on well-drained sandplain soils. Road salt, volatile organic compounds from vehicles, and herbicides/nutrients from suburban yards can find their way into the floodplain and river, potentially altering soil chemistry.

All-terrain Vehicles and Trail Bikes

Heavy ATV and/or trail bike use may be an actual and potential threat at CT .004 (North Haven); tracks traverse much of the *Floerkea* habitat. Crushing of plants, particularly early in the growing season before they have reproduced, could be very harmful to populations. While some disturbance of leaf litter cover may actually enhance the habitat by creating bare microsites favorable to *Floerkea* establishment, soil compaction is likely to be detrimental. Future visits should document whether such vehicles are directly trampling plants.

Changes in Disturbance Regimes

While occasional moderate flooding events may remove leaf litter, eliminate some potential competitors, and open up new colonization sites, *Floerkea* is not likely to tolerate a significant increase in flooding frequency or intensity in the floodplain sites it inhabits. Likewise, catastrophic flooding from large storms or abnormal spring freshets

could eliminate whole populations and alter available habitat by eroding banks, depositing debris, and contributing to nitrogen-loading that may favor competitors. Above-average spring streamflow rates accompanying warm, rain-biased winters are forecast for Vermont, New Hampshire, and Connecticut under global warming scenarios (New England Regional Assessment Group 2001). Changing disturbance regimes cannot be definitively identified as actual threats to *Floerkea* at existing sites, but may have eliminated populations at historic stations. Hydrological changes, vulnerability to flooding, and fragmentation of available colonization sites should be taken into account in conservation planning.

Deer

Herbivory by deer must be considered as at least a hypothetical threat, especially at two of the Connecticut occurrences that are on private non-profit nature preserves where there are obvious impacts from over-browse on nearby plant communities. However, visitors to sites have reported no direct unambiguous evidence that deer or other mammals eat *Floerkea*, save for a few apparently bitten plants amidst a mat of intact stems. Given that *Floerkea* is an annual with a shallow root system, it is possible that a browsing deer would pull up the entire plant, leaving little trace. Still, one would expect to see some evidence of trampling and pawing, and scarified areas where plants had been pulled, which has not been reported. It is possible that *Floerkea* is unpalatable or toxic, due to its flavonol glycoside content (Wagner 1979).

The Fungus Peronospora floerkeae

This host-specific fungal parasite occasionally infects *Floerkea* and reduces plant fecundity (Smith 1983a). Smith (1983a) did not view it as having a significant impact on the demographics of *Floerkea* populations in southern Wisconsin. It is not known whether the fungus exists in New England, but it has been documented in New York State (Donald Pfister, Harvard University, personal communication). Moorhead found no specimens identified as *Peronospora floerkeae* in the fungus collection at the G. S. Torrey Herbarium (CONN) at the University of Connecticut. Some leaf damage by an unidentified fungus has been noted on a very small portion of the plants at CT. 003 (Southbury), but the extent of the threat appears minor at this time.

DISTRIBUTION AND STATUS

General Status

Floerkea proserpinacoides is ranked G5 (Globally Secure), and is accorded National Ranks of N? in both Canada and the United States, indicating some uncertainty as to its true status (NatureServe 2003). It is regarded as "Not at Risk" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This widespread species

occurs in 30 U. S. states and four Canadian provinces. It is listed as rare (S1 or S2) in four states and two provinces constituting 20% of its range. Two additional states, Massachusetts and Vermont, list the species as historic (SX and SH, respectively). Table 2 and Figure 1 summarize the distribution of *Floerkea* throughout North America.

At the Great Plains, there is likely a large discontinuity in the transcontinental range of *Floerkea* that is not evident on the current *Floerkea* range map maintained by NatureServe (NatureServe 2002). This map represents the western and eastern parts of the range of *Floerkea* bridged by North Dakota, where the species has a state rank of "SU." However, there is reason to doubt that it has ever been confirmed in North Dakota. Rydberg (1932: 507) attributed *Floerkea proserpinacoides* to "Meadows and wet places" and gave North Dakota as part of its range. Stevens (1963) included the species as part of the North Dakota flora, and gave as its habitat "wet grassland," but made it clear that it was included solely on the basis of Rydberg's attribution, and that he, Stevens, had never seen the species in North Dakota. The Great Plains Flora Association did not include *Floerkea* in either the *Atlas of the Flora of the Great Plains* (1977) or the later *Flora of the Great Plains* (1986). It reasonable to conclude that no voucher specimens of *Floerkea* from North Dakota were known to the Association. Also, Rydberg is believed to have published range attributions for a number of species without having seen voucher specimens (Caleb Morse, University of Kansas, personal communication). The Rydberg (1932) attribution, by way of Stevens (1963), is the basis for the North Dakota Natural Heritage Inventory's tracking of the species in their state as a "SU" species (Rachel Seifert-Spilde, North Dakota Natural Heritage Inventory, personal communication).

Assuming that *Floerkea* was attributed to North Dakota in error, the westernmost known stations of the eastern segregate and the easternmost known stations of the western segregate of *Floerkea* are separated by a gap of about 700 miles (1100 km). The eastern limit of *Floerkea*'s western range closely follows the eastern slope of the Rocky Mountains, while the western range limit of the eastern *Floerkea* range closely follows the western limits of the eastern forest vegetation.

Closer to New England, *Floerkea* is reported from 26 counties in New York, including six that border Connecticut, Massachusetts, and Vermont (New York Flora Atlas 2003).

Table 2. Occurrence and status of *Floerkea proserpinacoides* 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 REPORTED OR UNVERIFIED	HISTORIC (LIKELY EXTIRPATED)
Connecticut (S1, E): 4 current and 3 historic occurrences	Illinois (S?): 24 counties (USDA, NRCS 2003)	California (SR): 11 counties (USDA, NRCS 2003)	Massachusetts (SX): 1 historic occurrence
District of Columbia (S1)	Kentucky (S3?): 2 counties (USDA, NRCS 2003)	Colorado (SR): documented part of both East and West Slope floras.	Vermont (SH): 3 historic towns each with 1 or more, occurrence
Iowa (S1, E): 2 current occurrences and other no historic occurrences	Louisiana (S?): 1 or 2 historic occurrences	Delaware (SR)	
Minnesota (S2, T): 10-12 current occurrences	Michigan (S?): 22 counties (USDA, NRCS 2003)	Idaho (SR)	
Quebec (S2): 18 occurrences, all extant	Missouri (SU): current site in 5 counties, historic in 2 counties	Indiana (SR)	
	Montana (SU)	Maryland (SR)	
	New Jersey (S4)	New York (SR): 3 counties with 1990+ observations/collections, and 24-25 counties with pre-1990 observations and collections (New York Flora Atlas 2003)	
	Nova Scotia (S2S3): 1 current and 20 historic (pre-1968) occurrences, but Heritage botanist feels this reflects low inventory effort since mid-20th century	Nevada (SR)	
	Ontario (S4)	North Dakota (SU): reported presence in state based on citation in literature appears to be in error	
	Pennsylvania (S?)	Ohio (SR)	
	Virginia (S3): current in 5 northern and 1 western county - very abundant along the Potomac River	Oregon (SR)	

Table 2. Occurrence and status of *Floerkea proserpinacoides* 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 REPORTED OR UNVERIFIED**	**HISTORIC (LIKELY EXTIRPATED)**
	Wyoming (S2S3): 51 specimen-documented locations in 5 western and 2 central counties; not tracked by state Heritage Program (USDA, NRCS 2003)	Tennessee (SR): attributed to state by NatureServe and USDA PLANTS, but excluded from state checklist maintained by TENN (2003), due to lack of specimen (Chris Fleming, University of Tennessee, personal communication)	
	British Columbia (S2S3): 13 current occurrences (Douglas et al. 2002)	Utah (SR): 13 specimen-documented sites in mountains in northern half of state	
		Washington (SR)	
		West Virginia (S?): 15 counties (USDA, NRCS 2003)	
		Wisconsin (SR): Along south and western borders of state (USDA, NRCS 2003)	

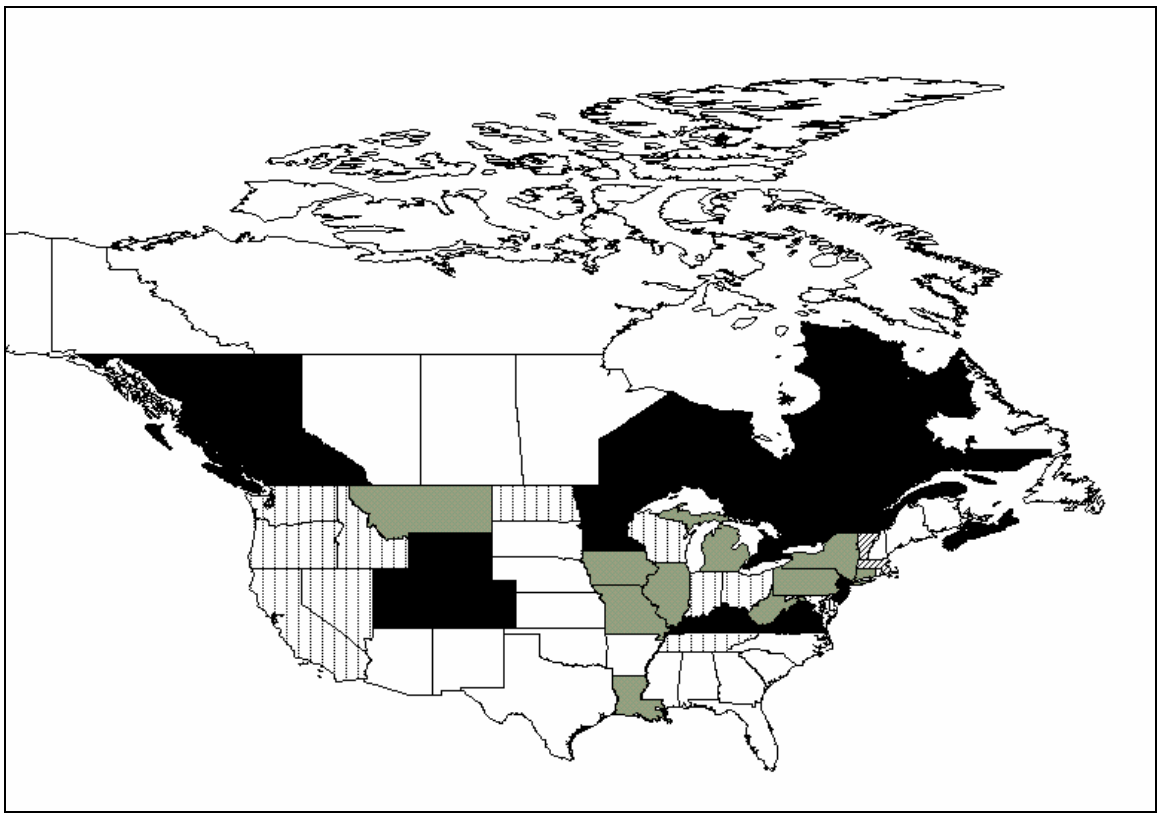

Figure 1. Occurrences of *Floerkea proserpinacoides* in North America. States shaded in gray have one to five (or an unspecified number of) current occurrences of the taxon. States and provinces shaded in black have more than five confirmed occurrences. The states with diagonal hatching are designated "historic," where the taxon no longer occurs. States with stippling are ranked "SR" (status "reported" but not necessarily verified). Note: *Floerkea* may be reported erroneously from North Dakota (see text). See Appendix for explanation of state ranks.

Status of All New England Occurrences — Current and Historical

Floerkea proserpinacoides is known from 11 occurrences total in New England: three historic sites in Vermont, one in Massachusetts, and four extant and three historic occurrences in Connecticut. It is ranked a Division 2 taxon (Regionally Rare) by the *Flora Conservanda:* New England (Brumback and Mehrhoff et al. 1996).

The status of all New England occurrences of *Floerkea proserpinacoides* is summarized below in Table 3, and Figures 2 and 3 show the distribution of extant and historic occurrences, respectively.

Table 3. New England Occurrence Records for *Floerkea proserpinacoides.* Shaded occurrences are considered extant.

State	EO #	County	Town
VT	.001	Chittenden	Shelburne
VT	.002	Rutland	Castleton
VT	.003	Rutland	Fair Haven
MA	.001	Franklin	Greenfield
CT	**.001**	**Fairfield**	**Greenwich**
CT	.002	New Haven	Oxford
CT	**.003**	**New Haven**	**Southbury**
CT	**.004**	**New Haven**	**North Haven/Wallingford**
CT	**.005**	**New Haven**	**Meriden**
CT	.006	New Haven	Orange
CT	.007	New Haven	North Haven

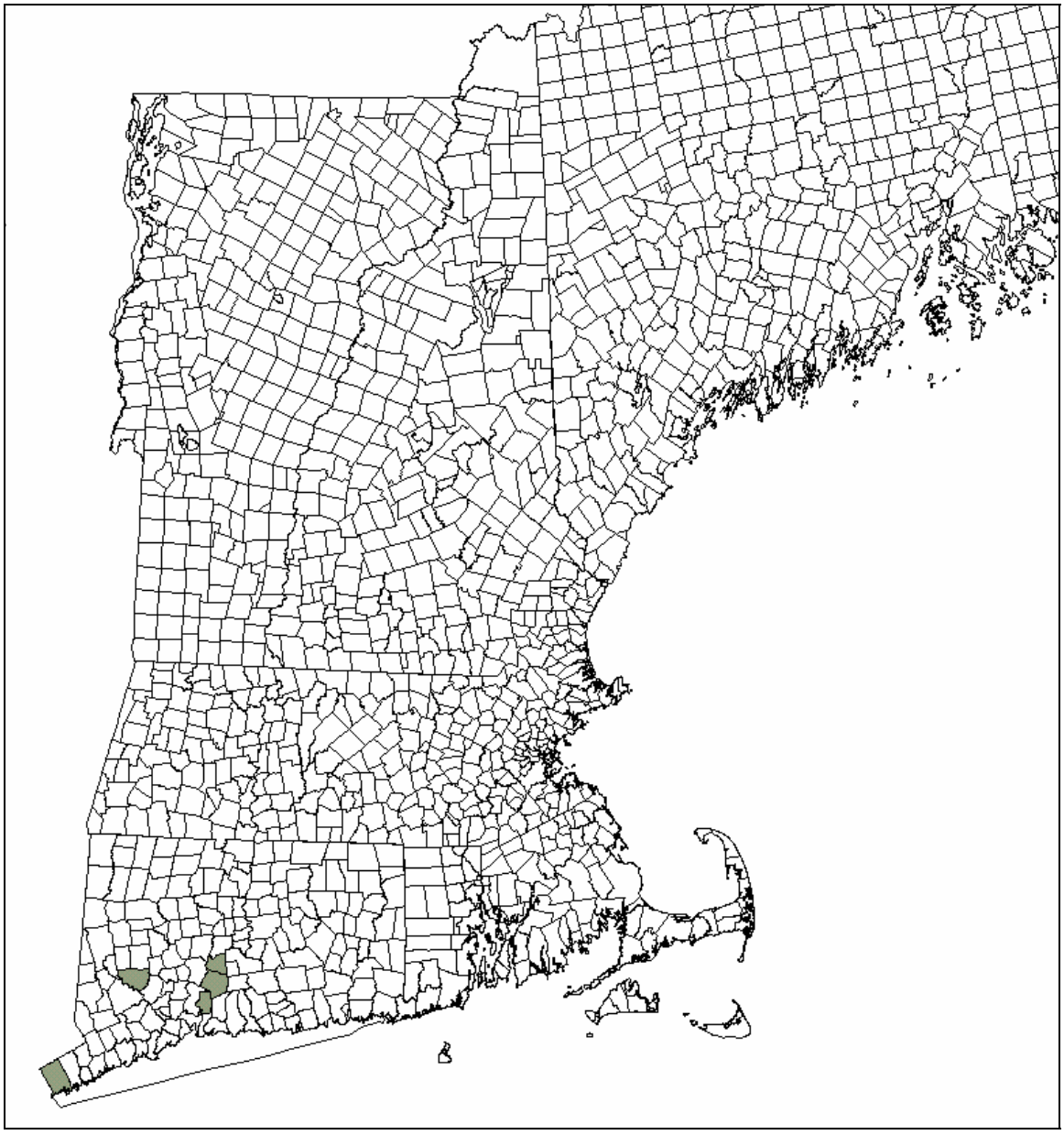

Figure 2. Extant occurrences of *Floerkea proserpinacoides* in New England. Town boundaries for New England states are shown. Towns shaded in gray have one to five extant occurrences of the taxon.

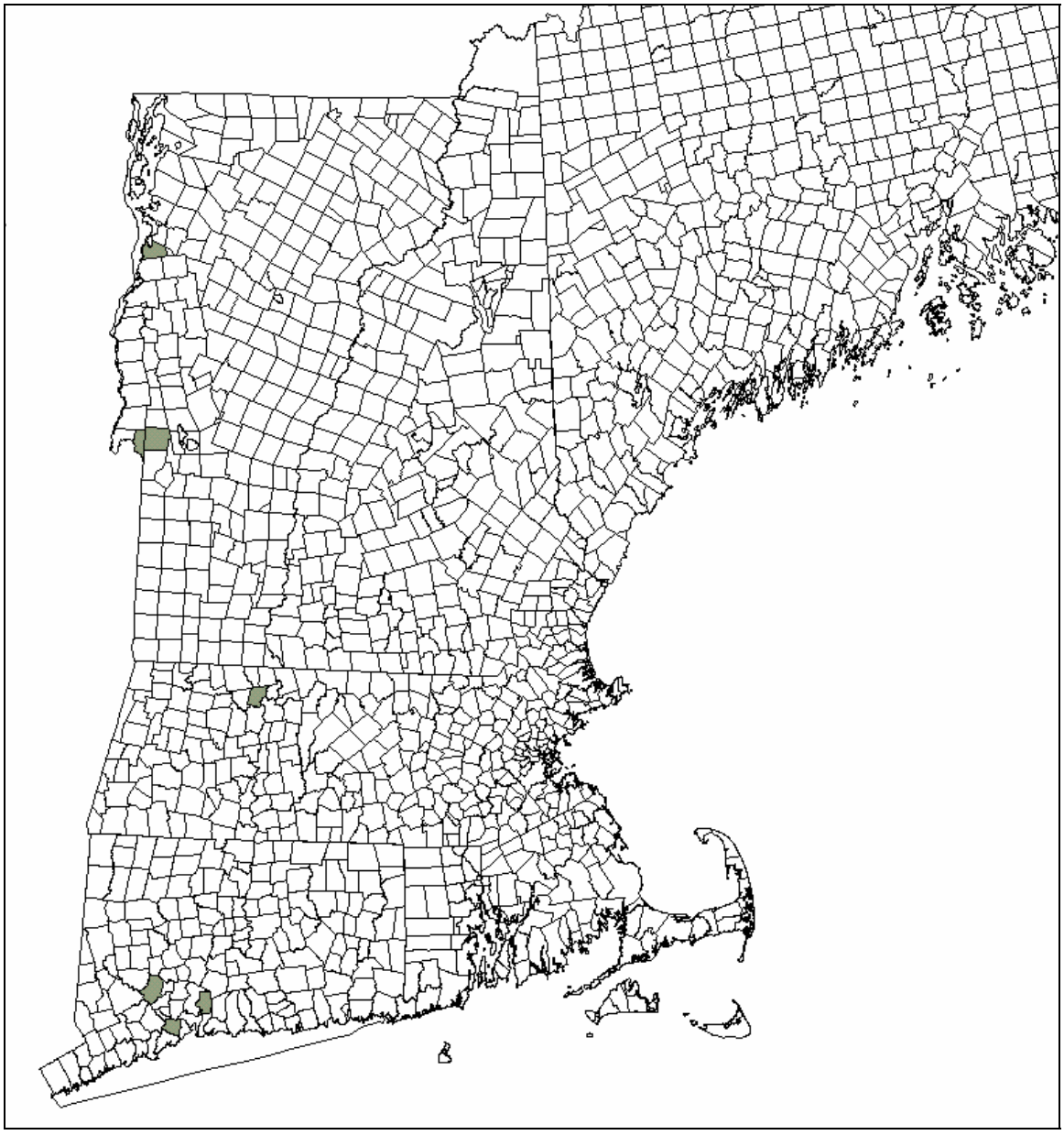

Figure 3. Historical occurrences of *Floerkea proserpinacoides* in New England. Towns shaded in gray have one to five historic records of the taxon.

II. CONSERVATION

CONSERVATION OBJECTIVES FOR THE TAXON IN NEW ENGLAND

The primary conservation objective for *Floerkea proserpinacoides* in New England is to protect and maintain the four extant Connecticut populations with a mean annual size of 1,000 to 100,000 stems (with local densities approaching or exceeding 100-1,000 stems/m^2, occupying at least several 100 m^2 each). To minimize population losses due to both environmental and demographic stochasticity, these populations should ideally consist of several subpopulations. This objective will entail taking a watershed-based approach to ensure the availability of mesic and riparian forest habitat in and around the major river systems where the species currently occurs.

A secondary goal will be to discover or rediscover *Floerkea* populations in Connecticut, Vermont and Massachusetts, where it is only known historically, and to secure protection and management, if necessary, for these sites. With abundant available habitat still present in these states (Leif Richardson, Vermont Nongame and Natural Heritage Program, personal communication; Moorhead and Farnsworth, personal observation), the probability of discovering new or historic populations is good. Thus, we set a provisional, iterative long-term goal of achieving protection of eight or more viable populations of at least 1,000 stems each in at least three separate watersheds in New England. Because reintroduction is not necessarily a viable option at the disturbance prone sites where the species is currently found in the region, this provisional goal is contingent on locating new populations through additional surveys.

However, with only 11 occurrences ever documented in New England, *Floerkea proserpinacoides* appears to have always been rare in the region. Though it is a small plant that is only detectable 2-3 months out of the year, it is not cryptic. It tends to form conspicuous patches, and it occurs in places that attract the attention of botanists. Thus, its apparent historic and current rarity is probably real. Considering the abundance of unoccupied potential habitat in the region and results of recent experiments with introduction (Houle 2002), its historic and current rarity in New England appears most likely to be a function of low fecundity and restricted ability to disperse over long distances (McKenna and Houle 2000a). Therefore, the overall objective of maintaining the four extant occurrences is conservative in approach, and should be revised up or down as a better picture of the species' distribution and possibly unusual ecology in New England is obtained.

The minimum viable population size for *Floerkea proserpinacoides* in not known. In the biodiversity conservation literature addressing minimum viable population (MVP) for plants, the difficulty of developing realistic estimates of MVP is generally acknowledged and emphasized; estimates on the order of 1,000 to 1,000,000 individuals have been proposed as sufficient to buffer a plant population against environmental stochasticity (Lande 1995, Allendorf and Ryman 2002). Using these population size

criteria alone, it would appear that all four known extant occurrences of *Floerkea* in New England are currently large enough to be buffered against these potential natural threats. However, *Floerkea* should probably be treated conservatively (requiring higher effective population sizes) because of the very high densities at which it may occur. Also, it is very challenging to determine population trends in *Floerkea* populations without much more comprehensive, quantitative data on each New England occurrence. Tens or hundreds of thousands of plants may occupy small areas, and it logically follows that an occurrence that is restricted to a small area is more vulnerable to natural and anthropogenic disturbances. Therefore, minimum area of occupation is probably at least as important as static population size to consider when developing conservation objectives for *Floerkea*. It is also probably important to protect both floodplain and the terrace-slope complexes along the riparian systems where *Floerkea* is found; other studies have shown that broader riparian management zones tend to capture higher species richness and unique plant assemblages (Goebel et al. 2003). Given that flooding may periodically cause local population declines (at least at two of the Connecticut occurrences), multiple subpopulations are probably necessary to buffer the impacts of environmental stochasticity.

An additional index of plant health is the capacity to produce mature seed. Seed production declines when resources such as water and light are limiting (McKenna and Houle 2000b), and when intraspecific densities reach highly competitive levels (Smith 1983b). Mean seed yield ranges from 4-12 seeds per plant in vigorous populations (Struik and Curtis 1962, Smith 1983b, Houle et al. 2001). We recommend that populations be monitored for fecundity as well as overall numbers, and that appropriate conservation actions to boost reproduction should be taken when seed output drops below four seeds per plant.

Two of the existing occurrences are in part protected by nature preserves, but the true extent of their protection can only be assessed through more extensive surveys. The remaining two occupy areas within the Quinnipiac River watershed, while other historic occurrences are in the Green River watershed in Massachusetts and the La Platte and Castleton Rivers in Vermont. Populations are apparently long-lived. Thus, *Floerkea* may benefit to a certain extent from localized efforts to protect and manage specific occurrences and from wetlands laws that curtail development on floodplains. In the long run, a watershed-level approach to conservation (protecting water quality, sustaining hydrological dynamics that favor plant persistence, and reducing the impact of vehicles, dumping, and pollutants) will provide the ultimate means for protecting both current and future habitat for the species (as well as other rare floodplain plants).

Although floodplains are important habitats for *Floerkea* in the northeastern states and provinces, a review of the plant's typical domain elsewhere in its range indicates a more generalized preference for rich, moist woods, wet meadows, or seepy areas. In fact, *Floerkea* probably should not be thought of as the type of "disturbance specialist" one would expect to find in areas subjected to frequent floods, and the current areas to which it is apparently restricted in this region may not be conducive for the species in the long term. Although the logical first sites to search for *Floerkea* should be on or near

floodplains, the species should be watched for in areas that more broadly reflect its range-wide affinities. Likewise, ecologically-based conservation strategies should reflect new information if it is found in different types of localities in New England. Research is needed to characterize the hydrology, disturbance regime, and other environmental features of all of the habitats where the species is found in the northeast.

III. LITERATURE CITED

Allendorf, F. W. and N. Ryman. 2002. The role of genetics in population viability analysis. Pages 50-85 in S. R. Beissinger and D. R. McCullough (Editors), *Population Viability Analysis.* University of Chicago Press, Chicago, Illinois, USA.

Atlantic Canada Conservation Data Centre. 2002. List of vascular plants in Nova Scotia: March 2002 update. Available at http://www.accded.com/data/general/nsvasc.dbf (accessed 1 February 2003).

Baskin, J. M., C. C. Baskin, and M. T. McCann. 1988. A contribution to the germination ecology of *Floerkia proserpinacoides* (Limnanthaceae). *Botanical Gazette* 149: 427-431.

Britton, N. L., and A. Brown. 1913. *An Illustrated Flora of the Northern United States and Canada*. Volume II. Dover Publications, Inc., New York, NY, USA.

Bradley, L. J. 1955. *The Ferns and Flowering Plants of the Audubon Center, Greenwich, Connecticut.* National Audubon Society of Greenwich, Inc., Greenwich, Connecticut, USA.

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: 233-361.

Burtelow A. E., P. J. Bohlen, and P. M Groffman. 1998. Influence of exotic earthworm invasion on soil organic matter, microbial biomass and denitrification potential in forest soils of the northeastern United States. *Applied Soil Ecology* 9: 197-202.

Cooperrider, T. S. 1995. *The Dicotyledonae of Ohio. Part 2. Linaceae through Campanulaceae.* Ohio State University Press, Columbus, Ohio, USA.

Dale, M. R. T. 1999. *Spatial Pattern Analysis in Plant Ecology.* Cambridge University Press, Cambridge, UK.

Deam, C. C. 1984. *Flora of Indiana*. J Cramer, Vaduz, Liechtenstein.

Douglas, G. W., D. V. Meidinger, and J. L. Penny. 2002. Rare native vascular plants of British Columbia. Second Edition. British Columbia Ministries of Sustainable Resource Management and Forestry, Victoria, British Columbia, Canada.

Dowhan, J. J., and R. J. Craig. 1976. Rare and endangered species of Connecticut and their habitats. State Geological and Natural History Survey of Connecticut Report of Investigations No. 6, Hartford, Connecticut, USA.

Eilers, L. J. and D. M. Roosa. 1994. *The Vascular Plants of Iowa: An Annotated Checklist and Natural History.* University of Iowa Press, Iowa City, Iowa, USA.

Fahey, J. W., A. T. Zalcmann, and P. Talalay. 2001. The chemical diversity and distribution of glucosinolates and isothiocyanates among plants. *Phytochemistry* 56: 5-51.

Fernald, M. L. 1950. *Gray's Manual of Botany: A Handbook of the Flowering Plants and Ferns of the Central and Northeastern United States and Adjacent Canada*. American Book Company, New York, New York, USA

Gauthier, B., and C. Rousseau. 1973. L'ècologie du *Floerkea proserpinacoides* Willd. à l'Île aux Grues, Montmagny, (Quebec). *Naturaliste Canadien* 100: 371-383.

Gleason, H. A. and . Cronquist. 1991. *Manual of Vascular Plants of the Northeastern United States and Adjacent Canada*. New York Botanical Garden, Bronx, New York, USA.

Goebel, P. C., B. J. Palik, and K. S. Pregitzer. 2003. Plant diversity contributions of riparian areas in watersheds of the northern lake states, USA. *Ecological Applications* 13: 1595-1609.

Great Plains Flora Association. 1977. *Atlas of the Flora of the Great Plains.* Iowa State University Press, Ames, Iowa, USA.

Great Plains Flora Association. 1986. *Flora of the Great Plains.* University Press of Kansas, Lawrence, Kansas, USA.

Greig-Smith, P. 1983. *Quantitative Plant Ecology.* Third Edition. University of California Press, Berkeley, California, USA.

Gundale, M. J. 2002. Influence of exotic earthworms on the soil organic horizon and the rare fern *Botrychium mormo. Conservation Biology* 16: 1555-1561.

Hendricks, E. G., and K. Matz. 1999. Compilation of phenology of wildflowers, 1988 – 1999. Web page. The Dawes Arboretum. Available at http://www.dawesarb.org/Reports/wildflower_phenology.htm (accessed 2 February 2003).

Houle, G. 2002. The advantage of early flowering in the spring ephemeral annual plant *Floerkea proserpinacoides. New Phytologist* 154: 689-694.

Houle, G., M. F. McKenna, and L. Lapointe. 2001. Spatiotemporal dynamics of *Floerkea proserpinacoides* (Limnanthaceae), an annual plant of the deciduous forest of eastern North America. *American Journal of Botany* 88: 594-607.

Johnston, H. F. 1942. May 24[, 1941] field trip to Orange. Pages 6-8 in Turner, M. I. (recording secretary). *Connecticut Botanical Society, Incorporated – 1942 Yearbook*. New Haven, Connecticut, USA.

Jones, G. N. 1945. *Flora of Illinois, Containing Keys for the Identification of the Flowering Plants and Ferns*. The University Press, Notre Dame, Illinois, USA.

Kartesz, J. T. 1999. A Synonymized Checklist and Atlas with Biological Attributes for the Vascular Flora of the United States, Canada, and Greenland. First Edition. In: Kartesz, J. T., and C A. Meacham. *Synthesis of the North American Flora, Version 1.0*. North Carolina Botanical Garden, Chapel Hill, North Carolina, USA.

Lachschewitz, F. 1991. Vascular Plans of West-Central Montana: Identification Guidebook. U. S. Department of Agriculture, Forest Service General Technical Report INT-277. Washington, D. C., USA.

Lande, R. 1995. Mutation and conservation. *Conservation Biology* 9: 782-791.

Library of the Gray Herbarium. N. D. William Oakes (1799-1848) papers. Short biography and description of Oakes papers held by library. Available at http://www.huh.harvard.edu/libraries/archives/OAKES.html (accessed 30 March 2003).

Link, D. A. 1992. The floral nectaries in the Limnanthaceae. *Plant Systematics and Evolution* 179: 235-243.

Martin, A. C. 1946. The comparative internal morphology of seeds. *American Midland Naturalist* 36: 513-660.

Mason, C. T. 1952. A systematic study of the genus *Limnanthes* R. Br. *University of California Publications in Botany* 25: 455-512.

McKenna, M. F., and G. Houle. 2000a. Under-saturated distribution of *Floerkea proserpinacoides* Willd. (Limnanthaceae) at the northern limit of its distribution. *Ecoscience* 7: 466-473.

McKenna, M. F. and G. Houle. 2000b. Why are annual plants rarely spring ephemerals? *New Phytologist* 148: 295-302.

Mehrhoff, L. J. 1996. *A Phytogeographical Analysis of the Vascular flora of Connecticut with Special Emphasis on those Taxa Exhibiting Restricted Ranges within the Region*. Ph.D. Dissertation, University of Connecticut, Storrs, Connecticut, USA.

Minnesota Natural Heritage and Natural Resources Program. 2003. Vascular plants - Threatened. Available at http://www.dnr.state.mn.us/ets/vascular_threatened.html (accessed 1 February 2003).

NatureServe: An online encyclopedia of life [web application]. 2002. Version 1.4 . Arlington, Virginia, USA: Association for Biodiversity Information. Available at http://www.natureserve.org/ (accessed July 2003).

Neale, J. J. 1945. Items of botanical interest. Page 18 in Neale, J. J. (Editor). *Connecticut Botanical Society, Incorporated -1945 Yearbook.* New Haven, Connecticut, USA.

New England Regional Assessment Group. 2001. *Preparing for a Changing Climate: The Pontential Consequences of Climate Variability and Change. New England Regional Overview.* U. S. Global Change Research Program, University of New Hampshire, Durham, New Hampshire, USA.

New England Wild Flower Society. 1992. New England Plant Conservation Program. *Wild Flower Notes* 7: 1-79.

New York Flora Atlas. 2003. Limnanthaceae: *Floerkea proserpinacoides.* County-level voucher map available from http://www.nyflora.org/html/atlas/maps/_Rosidae/Limnanthaceae/Floerkea_proserpinacoides.html (accessed November 2003).

Oakes, W. 1841. Notice of some rare plants of New England, with descriptions of some new species. *Hovey's Magazine of Horticulture* 7: 178-186.

Oakes, W. 1842. Botany of Vermont. Section 1: Catalogue of Vermont Plants. Pages 173-221 in Z. Thompson (Editor), *History of Vermont, Natural, Civil, and Statistical, Part 1: Natural History*. C. Goodrich, Burlington, Vermont, USA.

Ornduff, R. and T. J. Crovello. 1968. Numerical taxonomy of Limnanthaceae. *American Journal of Botany* 55: 173-182.

Parker, W. H. and B. A. Bohm. 1979. Flavonoids and the taxonomy of the Limnanthaceae. *American Journal of Botany* 66: 191-197.

Peck, M. E. 1961. *Manual of the Higher Plants of Oregon*. Second Edition. Binfords and Mort, Portland, Oregon, USA

Reeder, J. R. 1960. May 9 (Saturday) Sands[sic] Plains and Quinnipiac River Floodplain. Report of [1959] field trips. Pages 1-30 in Neale, J. J. (Editor). *Connecticut Botanical Society, Incorporated – 1960 Yearbook*. Connecticut Botanical Society. New Haven, Connecticut, USA.

Reveal, J. L. 1999. PBIO 450 Lecture Notes. Selected Families of Angiosperms: Rosidae. Available at: http://www.inform.umd.edu/EdRes/Colleges/LFSC/life_sciences/ .plant_biology/ pb450/rosi26.html (accessed 2 February 2003).

Rhoads , A. F. and T. A. Block. 2000. *The Plants of Pennsylvania: An Illustrated Manual.* University of Pennsylvania Press, Philadelphia, Pennsylvania, USA.

Roland, A. E., and E. C. Smith. 1969. *The Flora of Nova Scotia*. Nova Scotia Museum, Halifax, Nova Scotia, Canada.

Russell, A. M. 1919. A comparative study of *Floerkea proserpinacoides* and allies. *Contributions of the Botanical Laboratory of the University of Pennsylvania* 4:401-418.

Rydberg, P. A. 1910. Limnanthaceae. *North American Flora* 25: 97-100.

Rydberg, P. A. (completed by M. A. Howe). 1932. *Flora of Prairies and Plains of Central North America.* New York Botanical Garden. The Scientific Press Printing Company, Lancaster, Pennsylvania, USA.

Sharp, A. J., R. E. Shank, J. K. Underwood, and E. McGilliard. 1960. *A Preliminary Checklist of the Monocots and Dicots of Tennessee*. *Parts A and B.* Privately published by authors, University of Tennessee, Knoxville, Tennessee, USA.

Smith, B. H. 1981. *The Population Biology of* Floerkea proserpinacoides*, a Forest Understory Annual.* Ph.D. Dissertation, University of Wisconsin, Madison, Wisconsin, USA.

Smith, B. H. 1983a. Demography of *Floerkea proserpinacoides*, a forest-floor annual. I. Density-dependent growth and mortality. *Journal of Ecology* 71: 391-404.

Smith, B. H. 1983b. Demography of *Floerkea proserpinacoides*, a forest-floor annual. II. Density-dependent reproduction. *Journal of Ecology* 71: 405-412.

Smith, B. H. 1983c. Demography of *Floerkea proserpinacoides*, a forest-floor annual. III. Dynamics of seed and seedling populations. *Journal of Ecology* 71: 413-425.

Smith, B. H. 1984. Optimal design of a herbaceous body. *American Naturalist* 123: 197-211.

Spichiger, R. and V. Savolainen. 1997. Present state of Angiospermae phylogeny. *Candollea* 52: 435-455. http://wwwcjb.unige.ch/recherche/angiophy/angiophy.html. Accessed 2 Feb 2003.

St. John, H. 1963. *Flora of Southeastern Washington and Adjacent Idaho*. Third Edition. Outdoor Pictures, Escondido, California, USA.

Stevens, O. A. 1950. *Handbook of North Dakota Plants*. North Dakota Institute for Regional Studies, Fargo, North Dakota, USA.

Stevens, P. F. 2001. Angiosperm phylogeny website, version 4. Available at http://www.mobot.org/MOBOT/Research/APWeb/orders/brassicalesweb.htm (accessed November 2003).

Steyermark, J. A. 1940. *Spring Flora of Missouri*. Missouri Botanical Garden, St. Louis, Missouri, USA.

Strasbaugh, P. D., and E. L. Core. 1978. *Flora of West Virginia.* Second Edition. Seneca Books, Morgantown, West Virginia, USA.

Struik, G. J. and J. T. Curtis. 1962. Herb distribution in an *Acer saccharum* forest. *American Midland Naturalist* 68: 285-296.

Sutherland, W. J. 1996. *Ecological Census Techniques: A Handbook.* Cambridge University Press, Cambridge, UK.

Tatnall, R. R. 1946. *Flora of Delaware and the Eastern Shore: An Annotated List of the Ferns and Flowering Plants of the Peninsula of Delaware, Maryland, and Virginia.* The Society of Natural History of Delaware. Intelligencer Printing Company, Lancaster, Pennsylvania, USA.

TENN - University of Tennessee Herbarium. 2003. Checklist of vascular plants of Tennessee. Available at http://tenn.bio.utk.edu/vascular/checklist/dicotsa.html (accessed 12 June 2003).

Theiret, J. 1989. A mermaid by mistake. *Flora of North America Newsletter* 3: 37-38.

Torrey, J. 1843. *A Flora of the State of New York, Volume I*. Carroll and Cook, Printers to the Assembly, Albany, New York, USA.

USDA, NRCS - United States Department of Agriculture, Natural Resources Conservation Service. 2002. The PLANTS Database, Version 3.5. Baton Rouge, Louisiana 70874-4490 USA. Available at http://plants.usda.gov (accessed 12 June 2003).

Vermont Department of Environmental Conservation. 1999. Wetlands fact sheet: Vermont wetland rules summary. Waterbury, Vermont, USA. Available at http://www.vtwaterquality.org/wetfactsheets.htm (accessed 25 August 2003).

Wagner, H. 1979. Phenolic compounds in plants of pharmaceutical interest. *Recent Advances in Phytochemistry* 12: 589-616.

Weber, W. A. 1987. *Colorado Flora: Western Slope*. Colorado University Press, Boulder, Colorado, USA.

Weber, W. A. 1990. *Colorado Flora: Eastern Slope*. Colorado University Press, Boulder, Colorado, USA.

IV. APPENDICES

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1. Habitats of *Floerkea proserpinacoides* Throughout Its Range

2. Associated Species of *Floerkea proserpinacoides* at Extant New England Occurrences

3. An Explanation of Conservation Ranks Used by The Nature Conservancy and Natureserve

1. Habitats of *Floerkea proserpinacoides* Outside New England

State/ Province	Habitat	Citation
British Columbia	Seepage slopes in the montane zone, often (or perhaps always) in rocky places that are open or in openings in forest, and often in seeps that dry out later in growing season. Recorded elevations: 820 -1460 m	Douglas et al. 2002
Colorado	"Of wet montane meadows" on eastern and western slopes of the Rockies	Weber 1987, 1990
Delaware	"Common in moist alluvial soil, northern Newcastle and Cecil Counties "	Tatnall 1946
Idaho	"Meadows and moist woods, common in ...Craig Mountains"	St. John 1963
Illinois	"Wet ground, local"	Jones 1945
Indiana	"Locally abundant in thick woodland in rich, moist soil, usually associated with sugar maple, beech, white oak, and white elm."	Deam 1940
Indiana	"Mesic, old-growth stands dominated by sugar maple, and often well away from water"	Brent Smith, personal communication
Iowa	"Shaded seepage areas" in extreme eastern part of state	Pearson, Iowa Natural Areas Inventory, reading from Eilers and Roosa 1994
Iowa	Deciduous forested area in extreme eastern part of state	Iowa Natural Areas Inventory 2003
Kentucky	"Mixed mesic forests, often along streams, under sugar maple, beech, white ash, white oak, and American elm... populations tend to be few and far between. ...known to me only from the extreme northern counties"	Theiret 1989
Louisiana	Western Louisiana: no habitat data	Two specimens from late 1800s at Tulane Univ. herbarium (S. Darwin, Tulane University, personal communication)
Massachusetts	"Forming dense carpet in springy woods by the Green River"	Fernald 1915 specimen label, as reported by MANHESP, Haines, unpublished data
Missouri	"In low alluvial woodland in valleys of streams near the Missouri River or tributary streams of that river"	Steyermark 1963
Minnesota	Deciduous sugar maple-oak-basswood forest, localized on hillsides at more or less perennial seepage; southeast part of state	Minnesota Natural Heritage and Natural Resource Program 2003
Montana	"Rare in wet to moist, often shaded habitats in the valleys and foothills. Collected along Deer Creek, northeast of Missoula and the northwest part of the Bitterroot Valley"	Lackschewitz 1991
New York	"Marshes and shady banks of rivers"	Torrey 1843:126

1. Habitats of *Floerkea proserpinacoides* Outside New England

State/ Province	Habitat	Citation
New York	Duchess Co.: narrow (25 m) forested floodplain of 3-m-wide low-gradient stream, with red maple, silver maple, and *Fraxinus pennsylvanica*. Adjacent slopes with an alkaline component.	Troy Weldy, New York Natural Heritage Program, personal communication
New York	Duchess County: "Low woods and adjacent slopes along stream"; "Moist woodland along Sleepy Hollow Creek." Bronx County: "dry soil along path in Van Cortland Park"	Specimens at New York Botanical Garden
North Dakota (?)	"Wet grassland." Stevens (1950) cites Rydberg (1910), as source of *Floerkea*'s attribution to North Dakota, but species not included in more recent florae covering the state (Great Plains Flora Association 1977, 1986). Kartesz (1999) cites no voucher and Stevens (1950) as basis of attribution to state.	Stevens 1950
Nova Scotia	Mostly, but not exclusively, riparian, in both forested and open habitats: "brook bank;" "wet meadow edges and brookside;" "wet brook edges;" "muddy soil near river;" "damp meadow at margin of river;" "swale on edge of river;" "wet river meadow[s on Cornwallis River];" "meadow;" "meadow swale;" "shaded brook edge;" "moist stream bank in ravine;" "washed banks of the river under cherry, apple and hawthorn;" "shaded mountain stream sides;" "damp places in rich hardwood forest"	Atlantic Canada Conservation Data Centre 2002
Nova Scotia	"In slow-moving water;" "forming carpets in ravine hardwoods;" "locally abundant in mats in a meadow;" "mat in low muddy depression [along a river]"	Roland and Smith 1969
Nova Scotia	"Deciduous ravine slopes, river margins, and intervale forests"	Roland and Zink 1998
Ohio	"Rich moist woodlands;" "Throughout most of Ohio, but absent from south-central and some western counties"	Cooperrider 1995
Ohio	Blanketing floodplains in the Columbus area "like a weed"	Donald Les, University of Connecticut, personal communication
Ontario	"Mainly occurs in the 'Carolinian Zone' (or Eastern Deciduous Forest Region) of southwestern Ontario, where it is locally abundant in moist woods, often on clay soil, and often in floodplains. It does occur sporadically further north [as far north as] Sault Ste. Marie"	M. Oldham, Ontario Natural Heritage Information Centre, personal communication
Ontario	Wet depressions in undulating clay forest very close to the shore of Lake Erie	Sean Blaney, personal communication
Oregon	"Moist ground at moderate altitudes in the mountains"	Peck 1961
Pennsylvania	"Locally abundant in moist woods and floodplains"	Rhoads and Block 2000: 491
Quebec	"Mostly restricted to rich, low woods on islands of the St. Lawrence River;" two occurrences associated with Chateauguay River; one not associated with a river.	McKenna and Houle 2000a

1. Habitats of *Floerkea proserpinacoides* Outside New England

State/ Province	Habitat	Citation
Quebec	On two islands in St. Lawrence River: "with *Tovara virginiana*, *Hydrophyllum virginianum*, *Impatiens pallida*, *Tilia glabra*, and *Acer rubrum*, wet woods;" "wet mesic hardwoods: *Ulmus americana, Fraxinus americana, Acer saccharinum, Carya ovata;*" "bois humide"	Specimen label data reported in Gauthier and Rousseau 1973
Tennessee(?)	Probably reported from the state in error. Attributed to state by NatureServe (2002) based on Kartesz (1999), who cites no voucher and a 1960 report (Sharp et al. 1960). But species is excluded from the state checklist maintained by TENN (2003), due to lack of any known specimen documentation	Fleming, personal communication
Utah	"Mountain brush, sagebrush, aspen, and spruce-fir communities, often in spring, pond, and stream margins and other moist situations, at 1890 to 2700 m"	Welsh et al. 1993
Virginia	In five northern counties, in rich floodplain forests along the Potomac River, Bull Run and a few tributaries, and a 3rd-order tributary to Rappahannock River; in one w. VA county, in rich forests on floodplain and adjacent limestone-influenced valley slopes along the Jackson River	G. Fleming, Virginia Department of Conservation and Recreation, personal communication
West Virginia	"Moist woods"	Strasbaugh and Core 1978
Washington	"Meadows and moist woods, common in Blue Mountains"	St. John 1963
Wisconsin	"Upland, mesic, [sugar maple dominated] old-growth sites," one "on top of a hill, the nearest stream was at least a mile away "	Smith 1983a and personal communication

2. Associated Species of *Floerkea proserpinacoides* at Extant New England Occurrences

Associate plants[1]	**CT .003 (Southbury)** Northern-most SubEO	**CT .003 (Southbury)**Southern-most SubEO	**CT .004 (North Haven)**	**CT .004 (Walling-ford) Northern-most subEO**	**CT .001 (Greenwich)**	**CT .005 (Meriden)**
Acer negundo			T			
*Acer platanoides**						T
Acer rubrum			T	T		
Acer saccharinum			T	T		
Acer saccharum	T, S, H	T	T	T, H	T, H	T, H
*Aegopodium podagraria**	H					
Agrostis sp.			H			
Ailanthus altissima						T
Ajuga sp.					H	
*Alliaria petiolata**	H	H	H	H	H	H
Allium sp.			H	H		
Allium tricoccum		H	H	H		
Ambrosia trifida			H			
Artemisia sp.*			H			
Aster cf. *schreberi*	H					
Aster cordifolius				H		
Aster divaricatus				H		
Athyrium filix-femina						H
*Berberis thunbergii**	H				S	
Betula lenta			(T)			
Brachyelytrum erectum					H	
Cardamine diphylla					H	
*Cardamine impatiens**	H		H			
Carex amphibola	H		H			
Carex bromoides			H			
Carex debilis					H	
Carex sp.				H		
Carex sprengelii	H					
Carpinus caroliana	S			S		
Carya cordiformis				H	H	
Carya ovata						T
*Catalpa speciosa**			T			
Celastrus orbiculatus					(H)	
*Chelidonium majus**				H		
Cinna arundinacea			H			
Circaea lutetiana			H	H		H
Claytonia virginica	H	H	H			
Cornus amomum				S		
Cornus florida						S
Cryptotaenia canadensis					H	
Dicentra cucullaria	H	H				
Elymus hystrix			H			
Erythronium americanum			H	H		

2. Associated Species of *Floerkea proserpinacoides* at Extant New England Occurrences

Associate plants[1]	**CT .003 (Southbury)** Northern-most SubEO	**CT .003 (Southbury)**Southern-most SubEO	**CT .004 (North Haven)**	**CT .004 (Walling-ford) Northern-most subEO**	**CT .001 (Greenwich)**	**CT .005 (Meriden)**
*Fallopia japonica**	H			H – linear park subEO		
Festuca subverticillata			H			
Fraxinus americana					T	T
Fraxinus pennsylvanica			T	T		
Galium asprellum					H	
Geranium maculatum						H
Geum canadense			H	H		
Glechoma hederacea				H		
Glyceria striata			H		H	
Helianthus cf. *decapetalus*				H		
*Hemerocallis** sp.	H					
Heracleum lanatum	H					
Hesperis matronlis	H			H		
Impatiens capensis					H	
Impatiens sp.			H	H		
Laportea canadensis			H			
Leersia virginica			H	H	H	H
Lindera benzoin			S	S, H	S	S, H
Liriodendron tulipifera					T	T
*Microstegium vimineum**			H			
Onoclea sensibilis				H		
Oxalis cf. *stricta*				H		
Parthenocissus quinquefolia				T	H	H
*Phalaris arundinacea**			H			
Platanus occidentalis	T	T	T	T		
Poa cf. *pratensis*	H					
*Poa nemoralis**	H					
Poa sp.			H	H	H	
Polygonatum biflorum var. *commutatum*	H					
Polygonatum pubescens				H		H
Polygonum virginicum					H	
Populus deltoides	T	T		T		
Polystichum acrostichoides						H
Prunus serotina			(T)			
Prunus virginiana	H					
Quercus rubra			(T)	T		
*Ranunculus ficaria**			H			
Ranunculus recurvatus					H	

2. Associated Species of *Floerkea proserpinacoides* at Extant New England Occurrences

Associate plants[1]	**CT .003 (Southbury)** Northern-most SubEO	**CT .003 (Southbury)**Southern-most SubEO	**CT .004 (North Haven)**	**CT .004 (Walling-ford) Northern-most subEO**	**CT .001 (Greenwich)**	**CT .005 (Meriden)**
*Rosa multiflora**	H			S	S	S
Sassafras albidum						T
Smilacina racemosa	H			H		
Solidago caesia						H
Solidago flexicaulis	H					
Solidago gigantea			H	H		
Solidago rugosa			H			
Symplocarpos foetidus					H	
Thelypteris noveboracensis					(H)	
Tilia americana	T					
Toxicodendron radicans			H	T		
Trillium erectum			H		H	
Tsuga canadensis						T
Ulmus americana	T, S		S	T		
Urtica cf. *dioica*			H			
Veratrum viride			H			
Verbena urticifolia			H			
Viola cf. *sororia*	H					
Viola pubescens var. *leiocarpon*			H			
Viola sp.	H		H			
Vitis sp.				T		

T = occurring in the tree stratum, i.e., > 5 m high (this includes tree-height lianas)
S = occurring in the shrub stratum, i.e. 1-5 m high
H = occurring in the herb stratum, i.e., either herbaceous or ≤ 1 m high
X = occurring in unspecified stratum
Symbols in parentheses indicate that taxon occurs nearby but in different habitat from *Floerkea*
[1]Except for those followed by superscript [2] (see next table footnote), all taxa were observed and recorded as associates of *Floerkea* by Moorhead on visits to extant Connecticut occurrences
[2]Taxa reported by other visitors to *Floerkea* occurrences, but not observed/recorded by the authors
*non-native (Dowhan 1979) and/or invasive species (Mehrhoff et al. 2003) in Connecticut

3. An Explanation of Conservation Ranks Used by The Nature Conservancy and NatureServe

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 are known to be extirpated. Not all EOs have received such ranks in all states, and ranks are not necessarily consistent among states as yet.