Jesup's milk-vetch

(*Astragalus robbinsii* var. *jesupii*)

Draft

REVISED RECOVERY PLAN

Prepared by

New England Field Office
U.S. Fish and Wildlife Service
Concord, New Hampshire

Approved:____
Regional Director, Region 5
U.S. Fish and Wildlife Service

Date: February 28, 2019

DISCLAIMER

The Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.), requires the development of recovery plans for listed species, unless such a plan would not promote the conservation of a particular species. Recovery plans delineate such reasonable actions as may be necessary, based upon the best scientific and commercial data available, for the conservation and survival of listed species. Plans are published by the U.S. Fish and Wildlife Service (Service) and are sometimes prepared with the assistance of recovery teams, contractors, State agencies and others. Recovery plans do not necessarily represent the views, official positions or approval of any individuals or agencies involved in the plan formulation, other than the Service. They represent the official position of the Service only after they have been signed by the Regional Director. Recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new information, changes in species status, and the completion of recovery actions.

ACKNOWLEDGEMENTS

We would like to acknowledge the following people who were instrumental in the development of the recovery plan. Liz Harvey and Elizabeth Farnsworth provided the basis of Part I Background in their 2008 draft of the revised recovery plan. Bob Popp, Bill Brumback, Chris Kane and Sara Cairns provided critical life history and population information and are largely responsible for the gains made in the conservation of the species. We are grateful for their efforts towards the recovery of the Jesup's milk-vetch.

LITERATURE CITATION

Literature citation should read as follows:

U.S. Fish and Wildlife Service. 2019. Jesup's Milk-vetch (*Astragalus robbinsii* var. *jesupii*) Draft Revised Recovery Plan. U.S. Fish and Wildlife Service, Concord, New Hampshire. 75 pages.

EXECUTIVE SUMMARY

CURRENT STATUS: Jesup's milk-vetch (*Astragalus robbinsii* var. *jesupii* Eggleston & Sheldon) is a perennial, herbaceous plant of the Fabaceae family. A narrow endemic, it is known from only three populations along the Connecticut River in New Hampshire and Vermont, comprising 736 natural plants in 2018. Population sizes are highly variable among years; in the years between 1997 and 2018, the global population has ranged from 260 plants to over 2,000 plants. Current estimated population growth rates do not differ significantly from zero for any population. The taxon was federally listed as endangered under the ESA on June 5, 1987 (Federal Register Vol. 52, No. 108, pp. 21481-21484). It is also state-listed as endangered in Vermont and New Hampshire. This draft recovery plan is revising the Jesup's Milk-Vetch (*Astragalus robbinsii* var. *jesupii*) Recovery Plan released on November 21, 1989.

HABITAT REQUIREMENTS AND LIMITING FACTORS: Jesup's milk-vetch inhabits bedrock outcrops of chlorite or phyllite schist that are periodically scoured by flooding and ice-rafting along the Connecticut River. As such, these riparian ledges are sparsely vegetated; however, they support a globally rare natural community type and several rare plant species in addition to Jesup's milk-vetch. Plants at each site occupy a narrow band between a lower bound determined by the most intensive flood scour and an upper bound defined by the deep shade of long-lived woody vegetation. Seed dispersal appears to be very local in general, and gene flow among the populations appears to be minimal.

Immediate threats to the populations include encroachment of competing native and nonnative invasive vegetation, genetic and reproductive problems intrinsic to small populations subject to extreme demographic and environmental stochasticity, hydrological alterations as a result of hydropower management, and the potential effects of climate change on the natural river dynamics and the species' life history. Herbivory and trampling (at one location) by recreational users of the Connecticut River are deemed to be lesser threats to the species.

RECOVERY STRATEGY: The recovery strategy for the endangered Jesup's milk-vetch is to establish and maintain multiple resilient populations within the species' historical range and/or expanded portion of the range in New Hampshire and Vermont. These populations must be protected from threats and require no more than minimal habitat management and population augmentation.

RECLASSIFICATION OBJECTIVE: Secure the species to a point where it is no longer in danger of extinction throughout all or a significant portion of its range. Achieving this objective requires reducing imminent risks by increasing population redundancy through establishment of additional populations, improving the resiliency of populations, and reducing threats.

1. Demographic criteria
    a. A minimum of four persisting populations across the current distribution (the distribution as of 2018, including the expanded portion of the range containing one introduced population).
    b. A persisting population has a site-specific median number of total plants[1] over 5 consecutive years (based on a minimum of one generation) as described below.
        i. Sumner Falls: A median of 113 natural plants (not including augmented plants).
        ii. Hartland Ledges: A median of 132 natural plants (not including augmented plants).
        iii. Jarvis Hill: A median of 477 natural plants (not including augmented plants).
        iv. Introduced sites:
            1. sites similar in area to the Sumner Falls population: a median of 100 plants; and
            2. sites similar in area to the Jarvis Hill population: a median of 400 plants.

2. Threats-abatement criteria
    a. A long-term landowner agreement or other mechanism is in place for each of the persisting historical and introduced populations that provides:
        i. protection against habitat loss. For example, forested buffers are established/maintained between a population and developed land (agricultural land, development, etc.); and
        ii. access for long-term monitoring and management.
    b. A rapid response plan is in place for each of the persisting historical and introduced populations that addresses new threats (e.g., invasive species) and the need for population augmentation (adaptive management).

DELISTING OBJECTIVE: Secure the species to a point where it is not likely to become in danger of extinction throughout all or a significant portion if its range. Achieving this objective requires reducing longer-term risks by further increasing population redundancy through establishment of additional populations, further improving the resiliency of populations, and further reducing threats.

1. Demographic criteria
    a. A minimum of six resilient populations exist across the current distribution (the distribution as of 2018, including the expanded portion of the range containing one introduced population).

[1] Total plant stem counts ensure all age classes are counted.

b. A resilient population has a site-specific median number of plants and a median number of total inflorescences over 8 consecutive years (based on a minimum of three generations) as described below.
    i. Historical populations:
        1. Sumner Falls: A median of 113 natural plants (not including augmented plants) and a median of 193 inflorescences.
        2. Hartland Ledges: A median of 132 natural plants (not including augmented plants) and a median of 507 inflorescences.
        3. Jarvis Hill: A median of 477 natural plants (not including augmented plants) and a median of 4337 inflorescences.
    ii. Introduced populations:
        1. sites similar in area to the Sumner Falls population: A median of 100 plants and a median of 193 inflorescences; and
        2. sites similar in area to the Jarvis Hill population: a median of 400 plants and a median of 4337 inflorescences.

2. Threats-abatement criteria
    a. A long-term landowner agreement or other mechanism is in place for each of the six historical and introduced populations that provides:
        i. protection against habitat loss. For example, forested buffers are established/maintained between a population and developed land (agricultural land, development, etc.); and
        ii. access for long-term monitoring and management.
    b. A rapid response plan is in place for each of the six historical and introduced populations that addresses new threats (e.g., invasive species) and the need for population augmentation (adaptive management).

ACTIONS NEEDED:

1. conserve historical and introduced populations;
2. evaluate status of existing populations;
3. manage habitat;
4. bank seeds and perfect propagation and transplantation techniques; and
5. establish additional populations in the historical and expanded portion of the range.

ESTIMATED COSTS

	Need 1	Need 2	Need 3	Need 4	Need 5	Total
FY1	30,000	130,000	40,000	17,000	15,000	232,000
FY2	30,000	130,000	25,000	9,000	15,000	209,000
FY3	30,000	130,000	25,000	9,000	15,000	209,000
FY4	10,000	75,000	15,000	9,000	7,000	116,000
FY5	10,000	75,000	15,000	9,000	7,000	116,000
Total	110,000	540,000	120,000	53,000	59,000	882,000

DATE OF RECOVERY: Recovery is contingent on the successful introduction of the species to at least two additional locations. The pace of recovery is dependent on securing sufficient funding to implement recovery activities and landowner cooperation to implement monitoring and management actions. Full recovery may be reached within 25 to 30 years with the successful implementation of recovery activities.

TABLE OF CONTENTS

PART I – INTRODUCTION

Recovery is the process by which endangered and threatened species and their ecosystems are restored and their future is safeguarded to the point that protections under the Endangered Species Act (ESA) are no longer needed. Section 4(f)(1) of the ESA requires the U.S. Fish and Wildlife Service to develop and implement recovery plans for endangered and threatened species. Section 4(f)(1)(B) requires that each plan include, to the maximum extent practicable, a description of the site-specific management actions necessary to recover the species; objective, measurable criteria which, when met, would result in a determination that the species be removed from the list of endangered and threatened species; and estimates of the time required and the cost to carry out the measures needed to recover the species and to achieve intermediate steps toward that goal.

This draft recovery plan is revising the November 21, 1989 Jesup's Milk-Vetch (*Astragalus robbinsii* var. *jesupii*) Recovery Plan and satisfies the requirements listed above for the endangered Jesup's milk-vetch.

Astragalus robbinsii (Oakes) Gray var. *jesupii* Eggleston & Sheldon (Jesup's milk-vetch) is a narrow endemic plant. The taxon exists at only three historical sites, two in New Hampshire (NH), Sumner Falls (SF) and Jarvis Hill (JH), and one in Vermont (VT), Hartland Ledges (HL), along a 25-kilometer (km) (16-mile (mi)) stretch of the Connecticut River and one, tentatively successful, introduced site in New Hampshire also on the Connecticut River. Although population sizes vary considerably from year to year, total numbers of plants across all populations have rarely exceeded 1,000. The taxon, *Astragalus robbinsii* var. *jesupii,* was federally listed as endangered under the ESA on June 5, 1987 (Federal Register Vol. 52, No. 108, pp. 21481-21484). It is also state-listed as endangered in Vermont and New Hampshire. Its global rank is G5T1 (reflecting extreme rarity of the infraspecific taxon), and its national rank is N1 (NatureServe 2018a). Demographic and ecological data collected on all three historical populations since 1988 have enhanced the overall understanding of population dynamics, habitat variables, and threats to the taxon.

A. Description and Taxonomy

Jesup's milk-vetch is a short-lived perennial, herbaceous member of the legume family (Fabaceae), 10 to 50 centimeters (cm) (4 to 20 inches (in)) tall with a tap root. Its stems originate from a single root crown and may branch several times. Older plants tend to be more profusely branched than younger plants. Its leaves are pinnately compound, divided into 9 to 15 oblong to elliptical, glabrous leaflets 8 to 20 millimeters (mm) (0.3 to 0.8 in) long. The first true leaves of seedlings are produced in triads and arrayed in a clover-leaf fashion; as plants mature, the number of leaflets per leaf increases. The raceme[2] of 8 to 21 small (9 to 12 mm (0.3 to 0.5 in long)), pale bluish-violet, pea-like

[2] A flower cluster with the separate flowers attached by short equal stalks at equal distances along a central stem.

flowers is borne at the top of the stem (Barneby 1964; USFWS 1989). Flowering plants may have from 1 to 120 racemes. The inflorescence is compact initially, but as flowering proceeds, the stem of the raceme continues to elongate somewhat throughout fruit development, especially in more shaded conditions (Farnsworth and Harvey 2004). The fruit is a legume about 1.5 to 2 cm (0.6 to 0.8 in) long, borne on a short stem, narrowed at both ends and terminated with a distinctive beak 2- to 3-mm (0.8 to 0.1 in) long. The body of the legume has scattered black, appressed hairs. Inflorescences produce, on average, approximately 56 seeds per inflorescence (8 pods per inflorescence, 7 seeds per pod) (Nothnagle 1999), although larger numbers of pods and seeds per pod have been documented (Brumback and Piantedosi 2018a) since larger plants typically produce more pods than smaller plants. Figures 1, 2, and 3 illustrate the characteristic form of Jesup's milk-vetch mature plants, seedlings, and pods with seeds, respectively.

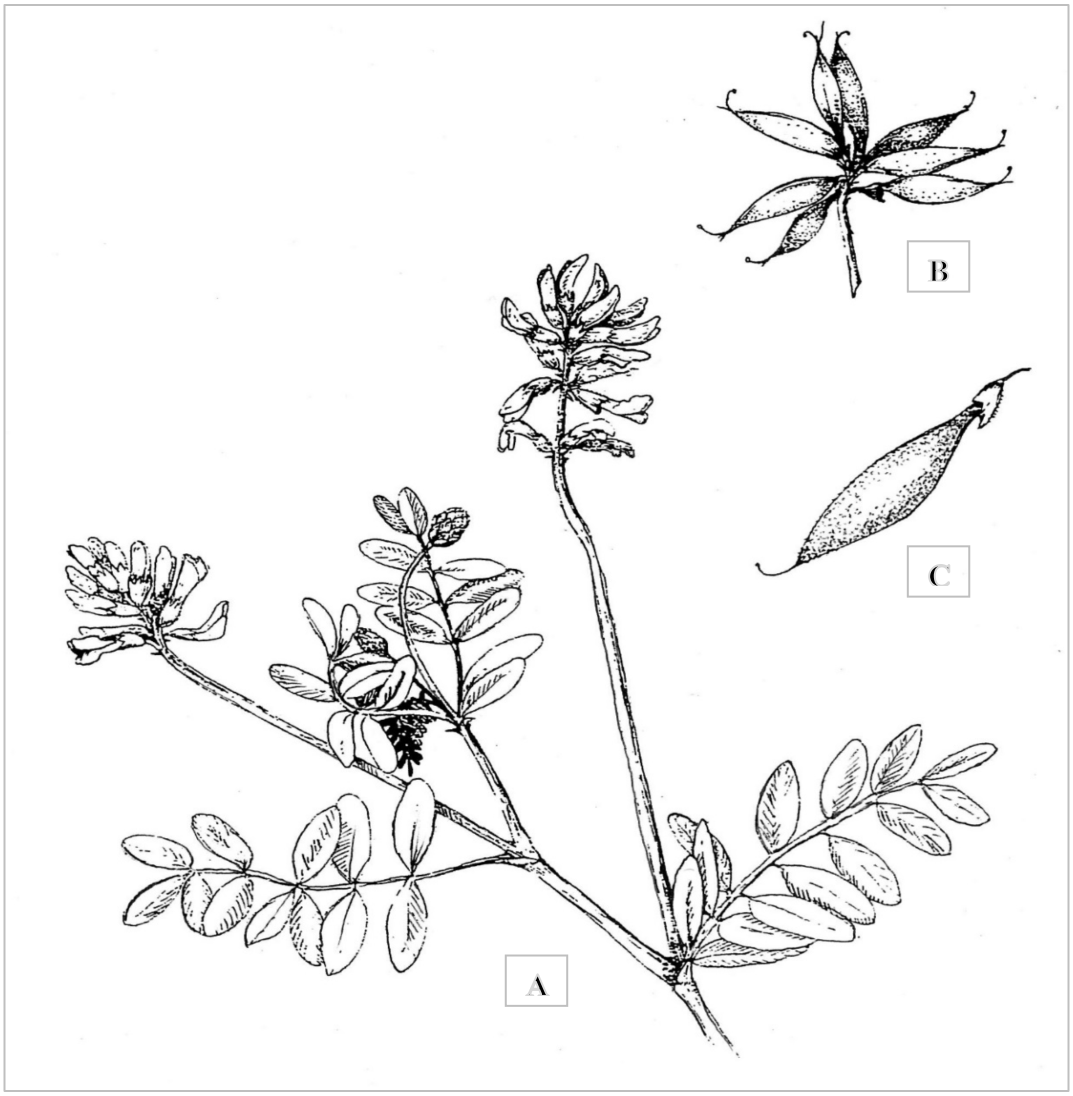

Figure 1. *Astragalus robbinsii* var. *jesupii* (Jesup's milk-vetch). A. Habit. B. Fruit cluster. C. Single legume. Illustration reprinted from Crow (1982).

Figure 2   Jesup's milk-vetch seedling (E. Farnsworth photo).

Figure 3. Jesup's milk-vetch pods and seeds (New England Wild Flower Society [NEWFS] photo).

Jesup's milk-vetch was first collected in 1877 at Sumner Falls in Plainfield, NH by Professor Henry Griswold Jesup of Dartmouth College. The variety (as "jesupi") was subsequently described by Eggleston and Sheldon in 1894 in *Minnesota Botanical Studies* 1: 155, following collection of the specimens (deposited at MINN) by Eggleston on June 7, 1891, on “old ledges above high water of the Connecticut River near Hartland, Vt.... and on ledges near Sumner Falls, near Plainfield, N.H.” (Barneby 1964: 131, w^3Tropicos Database 2004). Recent synonyms for this taxon include *Astragalus jesupii* (Egglest. & Sheldon) Britt. (published in Britton 1901: 1048) and *Atelophragma jesupii* (Egglest. & Sheldon) Rydberg published in *Bulletin of the Torrey Botanical Club* 55: 125 (1928). Although the taxon was federally listed endangered under the synonym *Astragalus robbinsii* var. *jesupi*, and the first recovery plan recognized the taxon as *Astragalus robbinsii* var. *jesupi,* the current nomenclature for the species is *Astragalus robbinsii* var. *jesupii*, following the standards outlined in the International Code of Botanical Nomenclature (https://www.iapt-taxon.org/nomen/pages/main/art_60.html, accessed February 4, 2019).

Astragalus robbinsii (including its varieties) is placed in the *Astragalus* section Oroboidei. It is treated as a collective species (Barneby 1964; Kartesz 1994) with two main areas of distribution: a western Cordilleran section (Colorado to eastern Alaska and western Canada) and a New England/eastern Canada section. In each region, there are three “virtually monomorphic and probably genetically fixed varieties [each] confined to a narrow ecological niche” (Barneby 1964: 123). One additional variety, var. *minor*, is found in both regions. *Astragalus robbinsii* in the eastern region comprises the following varieties:

> 1) var. *robbinsii*: now extinct, was known only from limestone ledges of the Winooski River in Colchester, Vermont prior to 1894, where it was discovered in 1829. This taxon was “obliterated by a dam erected in 1894” (Barneby 1964);
>
> 2) var. *fernaldii*: found in coastal areas of southern Labrador and adjoining Newfoundland and Quebec;
>
> 3) var. *minor*: found, in the eastern part of the species’ range, on mountains and riversides in Vermont, Maine, coastal Nova Scotia, Newfoundland and Labrador; and
>
> 4) var. *jesupii*: endemic on rock outcrops along the Connecticut River in New Hampshire and Vermont and the subject of this recovery plan. In this plan, the infraspecific taxon *Astragalus robbinsii* var. *jesupii* is termed “species” as defined in the Endangered Species Act.

Jesup’s milk-vetch is distinguished from its closest known relative, *Astragalus robbinsii* var. *minor* (the only variety with which it could potentially co-occur, on the basis of range) by its “nearly glabrous foliage and especially by the elongate, erect, or gently declined cusp terminating the distinctly but very gently decurved pod” (Barneby 1964: 131). The varieties of *Astragalus robbinsii* can sometimes be confused with *A. alpinus* var. *brunetianus* (with which it overlaps broadly in New Hampshire and Vermont), but *A.*

alpinus has a prominent floral keel longer than the wings, a higher number of leaflets (15 to 25), and a sharply three-angled, strongly grooved pod (Barneby 1964).

The genus *Astragalus*, encompassing an estimated 2,500 or more taxa, is considered the most speciose in the world (Mabberly 1993; Sanderson and Wojciechowski 1996). Dozens or more of these taxa are narrow endemics of marginal or specialized habitats, and the "Astralagean clade" as a whole appears to be undergoing rapid adaptive radiation (Sanderson and Wojciechowski 1996). Other federally listed *Astragalus* species – e.g., *A. applegatei* and *A. phoenix* – also exhibit extremely restricted ranges (USFWS 1990, 1998).

To date, a genetic analysis has not been undertaken to determine the phylogenetic relationships among *A. robbinsii* varieties or to understand the level of genetic differentiation among Jesup's milk-vetch populations.

B. Distribution and Status

Jesup's milk-vetch has been recorded only from five distinct sites, all clustered within a 25-km (16-mi) sector of the Connecticut River between central New Hampshire and central Vermont. Three sites are extant (and are discussed in detail below): Sumner Falls and Jarvis Hill (NH) and Hartland Ledges (VT). Two additional sites within a few kilometers of the extant sites are known to be extirpated. One, last observed to consist of four plants in 1984, was found on a silty river bank in Hartland, Vermont, directly across the Connecticut River from the Sumner Falls population. This population is believed to have been destroyed by floods between 1984 and 1985. The other extirpated location, last observed in 1881 in Plainfield, New Hampshire, was considered to be a subpopulation of the extant Vermont population. Many specimens were collected from this site, including the type specimen for this species. Thirty-eight herbarium specimens attest to the limited historical distribution of Jesup's milk-vetch (appendix 1).

Concerted searches for additional populations have been undertaken for the species at many sites with potentially suitable habitat along the Connecticut River and its tributaries in central Vermont and New Hampshire. Brackley and Thompson (1985) inspected 21 potential locations from Barnet, Vermont/Monroe, New Hampshire south to the Massachusetts border, a distance of almost 150 river-mi (240 river-km) (Borton *et al*. 1990). Systematic surveys of potential habitat along the Connecticut River from the Waits River in Corinth to Ballock Outcrops in Claremont, New Hampshire were completed in 1992 (Popp 1992). Surveys on the Connecticut River and a number of tributaries were conducted in 2009 (Kane 2009), 2011 (Popp and Kane 2012), and 2012 (Kane 2013), to search for possible new populations and potential locations for establishing new populations. Thirty-two miles (51.5 km) of the upper Connecticut River from Wilder Dam in Lebanon, New Hampshire upriver to Monroe, New Hampshire, and ledges below Bellows Falls in Vermont and New Hampshire were surveyed. Stretches of the White River (VT), the Sugar River (NH), the Ammonoosuc River (NH), the Ashuelot River (NH), the Ompompanoosuc River (VT), and the Waits River (VT) were also searched for additional populations as well as potential introduction sites. No extant Jesup's milk-vetch populations were discovered, although potential suitable habitat was documented.

The extant historical populations of Jesup's milk-vetch occur on ledges of the main stem of the Connecticut River at Sumner Falls, Jarvis Hill, and Hartland Ledges (figure 4). The Sumner Falls and Hartland Ledges populations are about 4 river-mi (6.4 river-km) apart, while the Hartland Ledges and Jarvis Hill populations are about 12 river-mi (19 river-km) apart. A fourth site (Bath-SI), an introduced population in an expanded portion of the range (see F. Conservation Efforts) appears to be persisting after 3 years of transplanting of nursery-grown plants. Currently, it is considered to be a tenuous, self-sustaining population.

The entire occupied habitat of all populations combined is less than 1 acre (ac) (0.4 hectare (ha)) and generally measured in meters (length) because of the patchy nature of suitable habitat (cracks in the ledges or at the top of ledges). For the historical populations, survey protocols established permanent transects to document total plant counts and productivity (appendix 2). Three rows running parallel to the river were established at each site to delineate three elevation bands (see C. Habitat and Ecology) and were further delineated into grids (incorporating the three elevations). The columns of the grids range from 5 to 20 m depending on the site. The rows of the grid (distance above the river) were similar in size within sites but varied between sites. Soil depth, degree of fracturing of the bedrock, and moisture from seepage are believed to play an important role in determining whether within-population locations were favorable to Jesup's milk-vetch seedling establishment and survival of adult plants. These factors were occasionally measured at small plots laid out within the larger area, but it was difficult to consistently measure them throughout each population's rock outcrops. As the introduced population is restricted to a fissure in a rocky outcrop, no transects have been established as of 2018.

Of the historical populations, Sumner Falls has the smallest amount of suitable habitat with a transect length of 30 m. The transect at Hartland Ledges extends 110 m, while Jarvis Hill is divided into two subpopulations (separated by a 40-m stretch of steep, vegetated bank habitat not considered to be suitable habitat), each having 140-m-long transects. Jarvis Hill, with the largest and most expansive population, is about four times the size of the Hartland Ledges population and about 12 times the size of Sumner Falls, which covers only about 250 square meters (m^2). Total population numbers appear to parallel the spatial extent of the population, and possibly reflect overall habitat availability (Farnsworth and Harvey 2004).

Historical populations

Sumner Falls (Sullivan County, New Hampshire): Recorded first in 1876, this small population was probably larger in the past than it is now; Barneby (1964) noted that Jesup's milk-vetch was "still locally plentiful" at this site as of 1950.

Hartland Ledges (Windsor County, Vermont): Jesup's milk-vetch was first described as a taxon from this (type) locality in 1881. This population historically encompassed a subpopulation of plants on a nearby island where specimens were also collected in 1881; this subpopulation is no longer extant.

Jarvis Hill (Sullivan County, New Hampshire): Known since 1956 when plants were first collected and described as "locally common" by A. Hodgdon and F. L. Steele, this population is consistently the largest of the three populations in area and plant numbers.

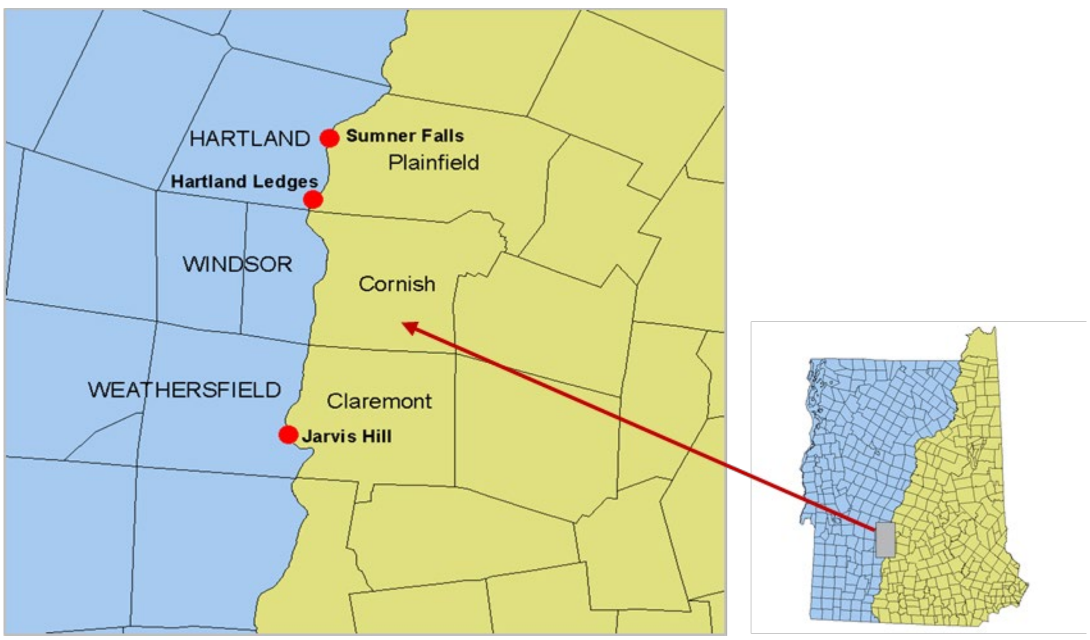

Figure 4. Locations of Jesup's milk-vetch extant populations.

C. Habitat and Ecology

Habitat

Jesup's milk-vetch inhabits the Connecticut River valley in central New Hampshire and Vermont, in the temperate northeast region of the United States on bedrock exposures of the main stem of the Connecticut River. The Hartland Ledges population is located along a constricted section of the River, while the Sumner Falls and Jarvis Hill populations are located on wider stretches, albeit of different river width and configuration. Analyses of the composition of local soils and parent bedrock detected calcium carbonite in the bedrock at Sumner Falls and Hartland Ledges. Sulfides, which contribute to unstable weathering and development of pores and fissures through which water easily percolates, are also plentiful in the bedrock at all tested sites (Bailey 2007). The bedrock on which Jesup's milk-vetch is found does not form regular bedding planes, is subject to relatively even erosion patterns because it easily exfoliates, and is rounded and steeply sloping where it meets the Connecticut River.

Plants are found on the ledges or shelves of the outcrop where a minimal amount of soil has accumulated (figure 5). Both Jarvis Hill and Hartland Ledges have more soil and available habitat than Sumner Falls. Soils at the three sites are generally shallow (only a few centimeters deep), and collect in the interstices between layers and lobes of the bedrock. Some may be weathered in place from the country rock, but much of the soil is probably alluvial sandy loam that is deposited and replenished by periodic river floods. These shallow, well-drained soils are prone to lose water during severe drought periods that may stress or kill some vegetation. Emergent seepage and associated wetland vegetation is usually absent in this type of community, although the community may occur adjacent to the riverside. A gradient from dry soil conditions higher on the bank to moist, fairly enriched conditions lower down may exist at a given site. Plant species within the community, including Jesup's milk-vetch, are distributed patchily, in part due to differences in microsite conditions. A study of soil temperatures relative to elevation documented temperatures at low elevations as high as 22º F above those at the top of the outcrop (NHNHB 2008).

Ecology

Jesup's milk-vetch occurs in the context of a riverbank ecosystem that is periodically subjected to flood- and ice-related scouring and silt deposition. This community type, ranked G2 (Globally imperiled), is classified as a Northern Riverside Rock Outcrop Community (Andropogon gerardii - Campanula rotundifolia - Solidago simplex Sparse Vegetation, CEGL006284) (NatureServe 2018b). The community is restricted to calcareous or basic bedrock outcrops along ice-scoured upper reaches of major rivers such as the Connecticut River in New Hampshire and Vermont and the Kennebec River in Maine; it may also occur in Massachusetts, Connecticut, and New York. Individual occurrences tend to be small; there are probably fewer than 20 known occurrences distributed over 500 ac (202 ha) of this vegetation type rangewide. Currently, five occurrences are documented in New Hampshire, with a total area of less than 20 ac (9 ha) (NatureServe 2018b). The extent of the community reported from Vermont, Maine, and New York remains to be confirmed.

Sites may vary substantially in species composition from site to site and from year to year, although this has not been systematically characterized at the Jesup's milk-vetch localities. Species characteristic of this community type include Andropogon gerardii, Schizachyrium scoparium, Campanula rotundifolia, Solidago simplex, Toxicodendron radicans, Ionactis linariifolius, and Packera paupercula (= Senecio pauperculus). Plant species reported as "most commonly associated with Jesup's milk-vetch" in 1989 included Packera paupercula, Toxicodendron radicans, Poa compressa, Chrysanthemum leucanthemum, Hypericum perforatum, Solidago canadensis, Campanula rotundifolia,

Figure 5. View (north) of Jesup's milk-vetch habitat on sparsely vegetated, steep schist outcrops along the Connecticut River (E. Farnsworth photo).

Erigeron pulchellus, Galium mollugo, Alnus rugosa, Ulmus americana, and *Salix* spp. (USFWS 1989). *Rosa* sp., *Fragaria virginiana,* and *Carex garberi* are now found at all sites as well. A full list of species in the vicinity of Jesup's milk-vetch at the three sites, compiled from annual status reports, is given in appendix 3. Of note is the appearance, especially after 1998, of several nonnative species categorized as invasive, including black swallowwort (*Cynanchum louisiae*), shrubby honeysuckle (*Lonicera morrowii*), cypress spurge (*Euphorbia cyparissias*), and purple loosestrife (*Lythrum salicaria*) (appendix 5).

It is notable that the stretch of river that supports Jesup's milk-vetch also provides habitat for several other state and federally listed species, including the dwarf wedgemussel (*Alasmidonta heterodon*); the cobblestone tiger beetle (*Cicindela marginipennis*), and more than a dozen rare plant species. This sector of the Connecticut River, therefore, contains some of the most ecologically significant natural areas of both Vermont and New Hampshire (USFWS 1989).

Jesup's milk-vetch plants are distributed across different elevations within their rocky outcrop habitat and tracked accordingly. Nothnagle (1998) developed a model that uses gage data to correlate discharge flow rates to river levels relative to Jesup's milk-vetch plant locations on the rocky outcrops. Nothnagle's regression equations were used to derive a river level elevation at each site from the daily mean flow data from the USGS

West Lebanon gage (Nothnagle 1998). The actual elevations of these bolts were subsequently refined by the use of a high-accuracy GPS survey station in 2011 (Normandeau 2013). Permanent bolts were installed for annual censuses to record plant counts relative to the bolts, allowing at least a coarse measure of how elevation affects survival and reproduction. The river levels required to inundate Jesup's milk-vetch plants vary from site to site (table 1). Sumner Falls plants are located at elevations where the lowest plants will be inundated at 43,574 cubic feet per second (cfs), while Hartland Ledges plants would be affected by flows of 23, 906 cfs (Popp 2018). The lowest Jarvis Hill plants are affected by flows reaching 34,454 cfs.

Bolts delineating the different elevation zones at which plants have been observed enable long-term documentation of the effects of high flows on the populations. Since plants are not similarly distributed across the same flood stage elevations (e.g., mild, moderate, or severe), each population may be affected differently at the same flood stage. For example, water reaching the low bolts will have a greater impact at some sites (more plants impacted) than at others (Cairns 2018). Spatial mapping along transects has revealed that within sites, plants are highly clumped in their distribution, and that clusters of plants shift in space from year to year (NHNHB 2003). Plant density is not clearly associated with elevation above the Connecticut River.

Table 1. Flood stages (in cfs) of natural occurrences of Jesup's milk-vetch (Normandeau 2013; Popp 2018).[3]

Site	Mild (L bolt -1 ft)	Moderate (L bolt)	Severe (U bolt)
Sumner Falls	43,574	56,991	89,253
Hartland Ledges	23,906	27,502	39,099
Jarvis Hill	34,454	39,422	60,613

Climate

Current average annual precipitation is approximately 41 in (104 cm), and mean annual temperature is 42.5 °Fahrenheit (F) (5.8 °Celsius (C)). Currently, precipitation is relatively equable throughout the year (figure 6), falling mainly as snow during the winter months. Mean daily temperatures are below freezing during December, January, and February. Winter precipitation and temperatures combine to create conditions for ice formation on the Connecticut River. Winter ice-damming, coupled with high discharges during the spring snowmelt, contributes to scouring of the river shore inhabited by Jesup's milk-vetch populations. During the spring thaw, ice blocks transported by the river raft up onto the ledges where Jesup's milk-vetch occurs and scour the habitat as they are pushed downriver by spring high flows. This periodic disturbance may create open habitat and eliminate potentially competing plant species that are intolerant of such

[3] Data collected at the West Lebanon gage, New Hampshire (https://nwis.waterdata.usgs.gov/nwis/uv?cb_00060=on&cb_00065=on&format=gif_default&site_no=01144500&period=&begin_date=2011-08-26&end_date=2011-09-10).

scour. The majority of Jesup's milk-vetch plants are found below the ice scour line, which constitutes the ecotone between bare rock and the woody vegetated upper areas of the bank. Sumner Falls experiences the most frequent ice scour of the three sites (NHNHB 2003). Soils and litter at this ecotone are very shallow, and are probably regularly transported away during ice-scour events. Conversely, soils may also be deposited during flooding events, burying plants by several inches.

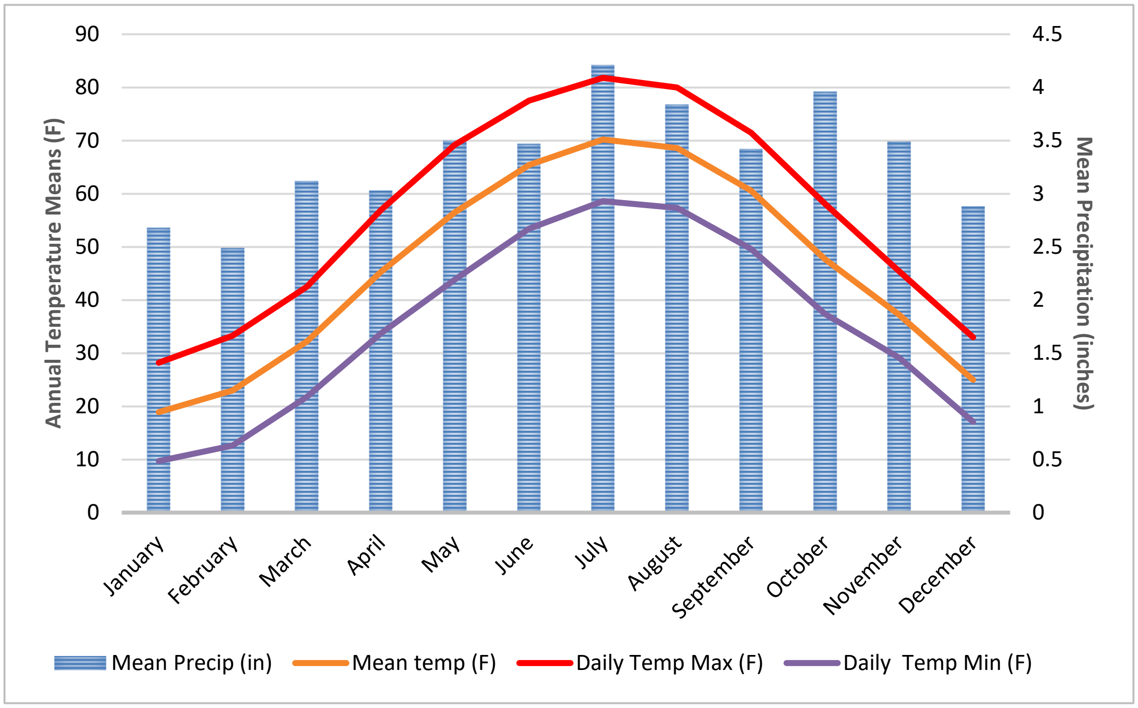

Figure 6. Climate diagram for Hanover, New Hampshire. Data compiled from 1981to 2010. Source: National Climate Data Center (https://www.ncdc.noaa.gov/cdo-web/datatools/normals, accessed October 23, 2018).

Monthly average streamflow on the Connecticut River mainstem reflects spring rains in April, May, and early June, as well as inputs from April snowmelt thaw and flooding. High discharge rates (flows) are typically observed from April to June; they then drop to lower levels during the rest of the summer (figures 7 and 8). Streamflow patterns are heavily influenced by activities of the hydroelectric dam at Wilder Dam (West Lebanon, New Hampshire, above Sumner Falls), which captures 10,000 to 12,000 cfs of discharge during much of the year (Nothnagle 1997).

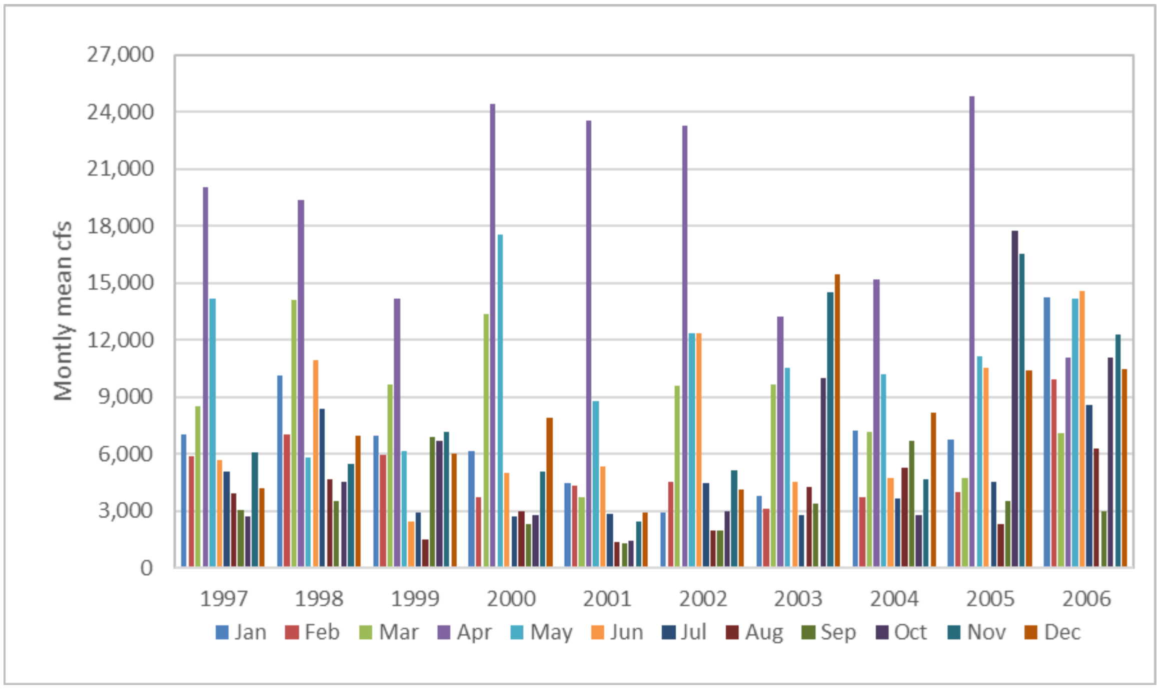

Figure 7. Monthly average streamflow at the West Lebanon, New Hampshire, gauge (1997-2006).

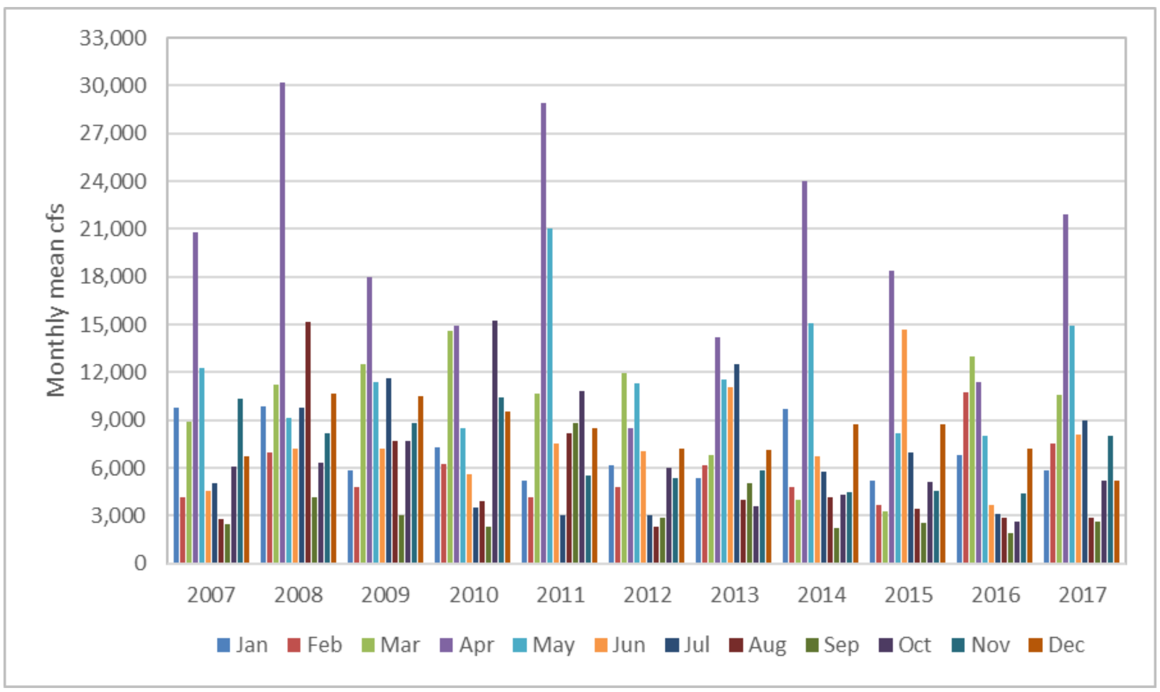

Figure 8. Monthly average streamflow at the West Lebanon, New Hampshire, gauge (2007-2017).

Annual peak flows rarely exceed 60,000 cfs and primarily occur in late winter or early spring (figure 9). However, in August 2011, a peak flow of 105,000 cfs was observed during Tropical Storm Irene with a prolonged discharge well above the August and September median discharges (figures 9 and 10). The entire Jesup's milk-vetch population at Hartland Ledges was inundated for at least 3 days at the end of August.

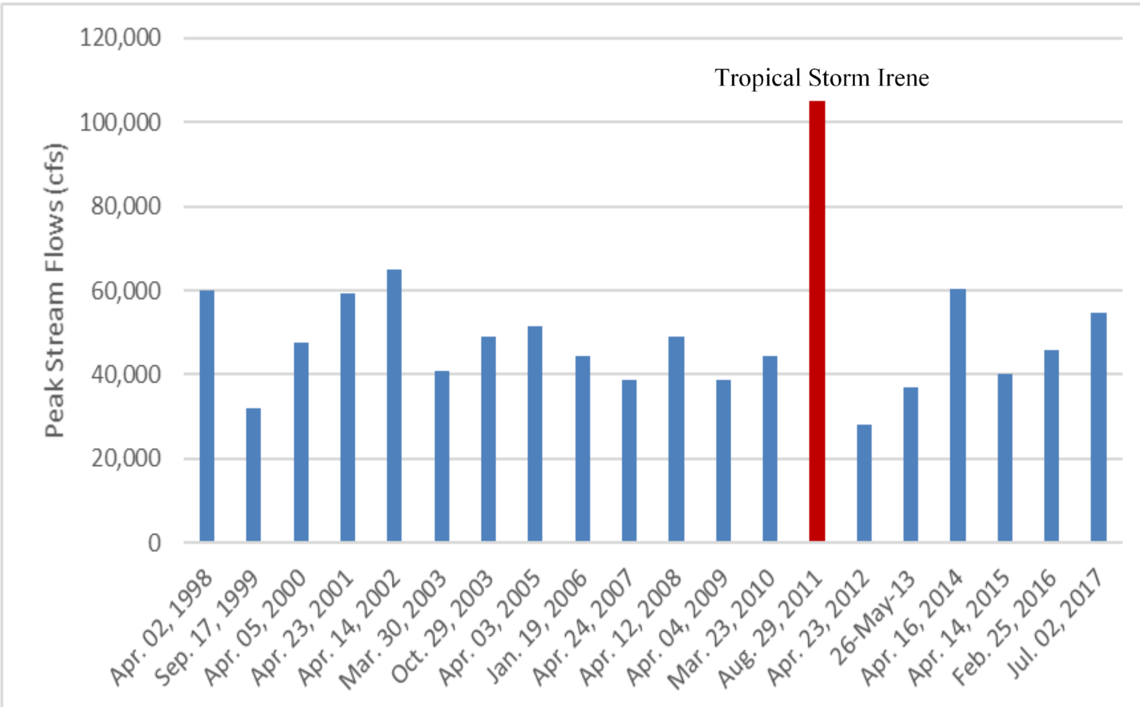

Figure 9. Peak Stream Flows (cfs) from 1998 to 2017.

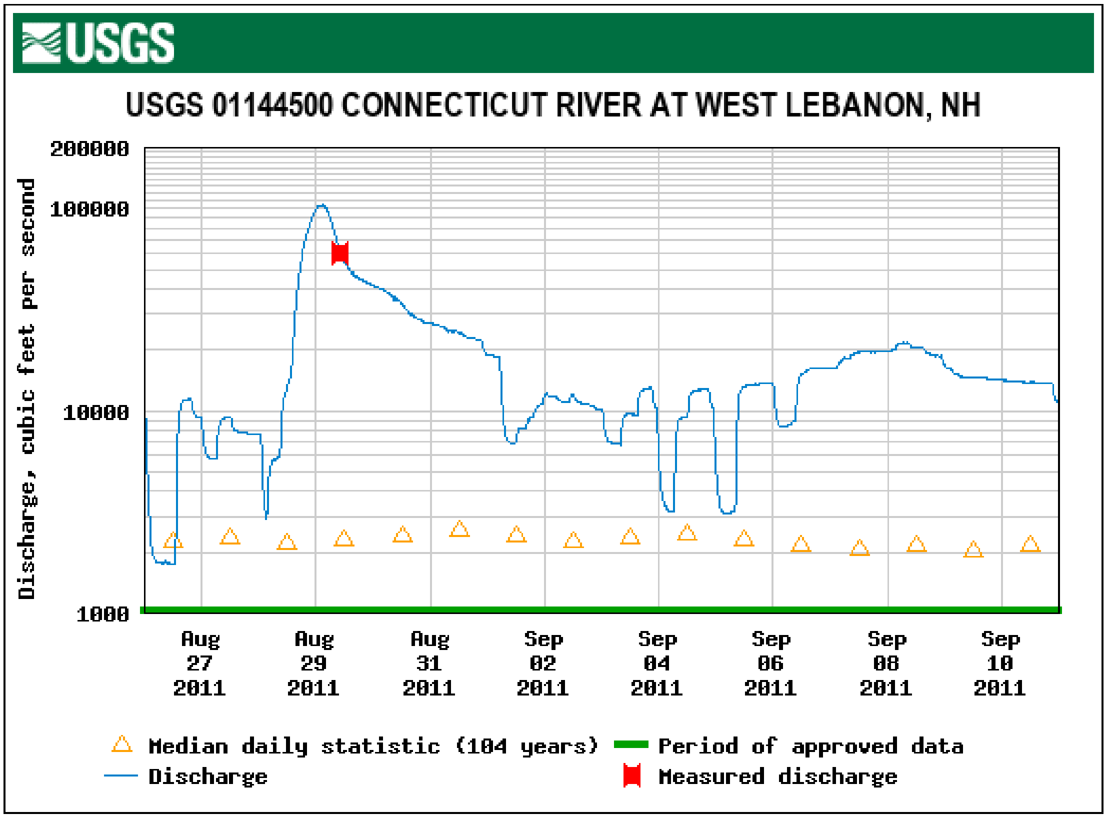

Figure 10. Discharge prior to and after Tropical Storm Irene at the West Lebanon, NH gage. Red lines mark the three flood stages for Hartland Ledges (low, moderate, severe).

D. Life History

Jesup's milk-vetch plants emerge in April (or as soon as ice cover and temperature permits), and bloom in early- to mid-May. Flowering times are variable year to year (Dunlop 1994). Dunlop (1994) observed that the plants closest to the water's edge at all three sites are the last to flower, possibly reflecting longer periods of spring inundation or a cooling effect on the lower slope. Flowering generally lasts to early July, and seed set occurs from late June to mid-July (Brumback 2009). Most fruits have dehisced by early July. Some fruiting stems have typically withered by mid-August, but vegetative stems usually remain green until September or October (Brumback and Piantedosi 2018a). Seed germination is delayed until the following year (or later) (Brumback 2009).

Recent life history investigations tracking individual plants at all three populations documented low numbers of plants surviving up to 3 years, indicating that the typical lifespan of the Jesup's milk-vetch is generally 3 years (Kane 2011a; Kane 2011b). Observations during the growing season documented that there is some die-off of older plants throughout the season while new plants continue to emerge into August (Kane 2011b). The probable life cycle for the species consists of seed germination and growth to seedling in year one; emerging as a small, generally nonflowering plant in year two, flowering in the third year, and dying after flowering. Occasionally some blooming and vegetative plants survive to a fourth year (Brumback and Piantedosi 2018a).

Self-fertilization is commonly documented in the genus *Astragalus*, facilitated by simultaneous maturation of anthers and stigmas (Barneby 1964). Experiments that excluded pollinators from flowers have shown Jesup's milk-vetch to be capable of self-fertilization. In 1990, pollen tested from inflorescences that were bagged to exclude pollinators was found to be 90 to 95 percent viable when tested (Dunlop 1994). Bagged flowers produced seeds, some of which were observed to be germinating while still in the bag; overall seed viability was not tested. However, in 1999 another experiment excluding pollinators found a significant decrease in seed viability in self-fertilized flowers when seeds were collected, stored over winter, and germinated in flats (common gardens) the following spring. The percentage of seeds that germinated from bagged flowers was only 36 percent compared to 57 percent of seeds produced from unbagged flowers (NHNHI 2000). The percent of seeds germinating was significantly lower in the bagged (selfed) population than in the open-pollinated population and the population as a whole (Fisher's exact test, $P<0.01$). This study suggests that outcrossing significantly enhances plant fitness.

Observations made in 1989, 1990, and 1992 indicate that the most common insect visitors of Jesup's milk-vetch flowers are bumblebees identified as *Bombus* subgenus *Pyrobombus vagans vagans* Smith, a widespread and common species. Another rarer visitor was identified as *Andrena* subgenus *Cnemidandrena hirticincta* Provancher, a species that occurs in southern Canada, Michigan, Minnesota, and New England (Farnsworth and Harvey 2004).

Seed dispersal mechanisms are unknown for this species, although there is evidence that long distance dispersal is extremely unusual. Given the proximity of the populations to water, it is reasonable to expect that flooding, especially spring freshets, would play a role in transporting overwintering seeds among sites. However, seed dispersal may be naturally limited since mature seeds readily sink in water (Kane 2011a). Moreover, seedlings are often observed directly down slope of plants known to have flowered the previous season, new plants have not been documented up- or downstream of areas immediately adjacent to known sites, and no additional populations have been discovered despite extensive searches (Kane 2011a). Most seedling establishment appears to be limited to areas close to mature plants or where mature plants were known to occur in the year prior to seedling germination. Kane (2011a) observed seedlings directly below a study plot containing a very large Jesup's milk-vetch plant in the Jarvis Hill population and noted that exceptionally large, fecund plants may distribute seeds directly down slope if suitable habitat is available. Therefore, it is probable that the vast majority of seeds produced by a population likely remain in close proximity to parent plants and that long-distance dispersal is rare.

Most seeds germinate in the spring, but some seeds appear to sprout any time conditions remain suitable for germination. Infrequent precocious germination of seeds still on the maternal plant has been observed in the field (NHNHI 2000). Seeds collected for propagation trials at both NEWFS and New England College were capable of germination upon collection (Dunlop 1994). Seeds that are dried and stored prior to sowing are also capable of germination. Seed germination trials determined that the best germination was achieved by drying and scarifying the seed before sowing in a warm environment, most likely mimicking conditions in the natural environment where the seed coat is broken down through environmental conditions (rain, freezing temperatures, ice or flood scour) (Brumback 2009). Seeds germinated from various years and representing all populations for seedling transplants indicate long-term viability of banked seed. Seed collected in 1989, 1993, 2001, 2004, and 2008 demonstrated generally high rates of germination, ranging from 36 percent (1993) to 84 percent (Brumback and Piantedosi 2018a).

Favorable spring growing conditions (with ample precipitation and moderate temperatures), combined with vigorous reproductive output in the previous year, have been correlated with profuse seedling germination (Dunlop 1994; NHNHI 2001). Overall, observed or estimated seedling survival rates in the field have been low: probably less than 25 percent based on a comparison of total seed produced and numbers of plants observed in subsequent years (NHNHI 2002; Farnsworth 2008). Weather conditions, especially extended dry periods during the growing season, have been shown during augmentation experiments to affect seedling establishment and survival (NHNHB 2005).

Reproductive output per plant varies widely among sites, with Jarvis Hill showing the highest average percent of flowering plants (65 percent) and Hartland Ledges the lowest (44 percent) based on data from 1999 through 2007.[4] On average, over 50 percent of the plants at Sumner Falls and Hartland Ledges are nonflowering, while only 35 percent of the plants at the Jarvis Hill are nonflowering plants (table 2).

Table 2. Median and average percent number of inflorescences per flowering plant (1999-2007) (NHNHB 2008).

	Non-flowering	1 to 2 inflorescences	3 to 10 inflorescences	11 to 20 inflorescences	>20 inflorescences
SF Median	51%	22%	18%	2%	0%
SF Average	51%	23%	18%	5%	4%
HL Median	61%	20%	15%	4%	0%
HL Average	55%	20%	14%	6%	4%
JH Median	39%	24%	28%	8%	2%
JH Average	35%	25%	29%	7%	4%

Since the Jesup's milk-vetch relies on seeding (primarily within the site) to survive, the total number of inflorescences produced each year reflects the amount of seed that may

4 Most recent data readily available at this time.

be released (average of 56 seeds per inflorescence). Inflorescence production (and hence seed production) shows high temporal variability at each site (NHNHB 2017). Combining the total number of plants and inflorescences together should indicate the amount of potential seed produced in a given year at a site. For example, the number of all plants and inflorescences at Sumner Falls in 2016 was 50 plants with 462 inflorescences (approximately 23,100 seed produced); in 2017, there were 32 plants, but only 203 inflorescences (approximately 6,496 seed produced), and in 2018, there were one and one half times as many plants as in 2017 (82), with only 230 inflorescences (approximately 18,860 seed produced). In comparison, Jarvis Hill (the largest population) demonstrated different seed productivity from Sumner Falls; in 2016, 488 plants produced a total of 5,071 inflorescences for approximately 283,976 seed; in 2017, 740 plants with a total of 3,318 inflorescences produced approximately 185,808 seeds, far less than in 2016, yet with almost twice the number of plants. In 2018, 565 plants (more than in 2016) had far fewer inflorescences (1692) producing approximately 94,752 seed. Of the 3 years reviewed for both sites, 2018 was far less productive at Jarvis Hill, while 2017 was a less productive year for Sumner Falls (Brumback and Piantedosi 2018a).

In 1998, permanent bolts were installed at all three sites to establish grids for counting individual plants and inflorescences within each cell of the grid. Since 1998, the number of plants, number of inflorescences per plant, and number of inflorescences per site have been documented. The number of plants and the number of inflorescences vary widely by year (figures 11 and 12), ranging from a minimum of 5 (natural) plants at Hartland Ledges recorded in 2009, to a maximum of 1,798 plants at Jarvis Hill recorded in 2002 (appendix 4). Population size may be related to flowering (inflorescences) and successful fruiting (seed set) that occurred 2 to 3 years previous to the count because of the 3-year life cycle of the species. Seedlings are not counted; only 2-year-old and older plants are documented in population counts; therefore, there is a lag time in population response (increase or decrease) and productivity based on inflorescence counts.

The total global population size of Jesup's milk-vetch as of 2018 is approximately 736 natural[5] plants. As this value is based on full counts of all natural plants observed at each site, it is unlikely to underestimate actual population size by a considerable amount. The Jarvis Hill population has been consistently and significantly larger than the other two populations throughout this time period (figure 11).

Temporal trends in population size indicate that all populations are tenuous, with the populations at Sumner Falls and Hartland Ledges particularly vulnerable to extinction because of the limited available habitat at these two sites (see B. Distribution and Status) and the potential impacts of catastrophic events such as Tropical Storm Irene.

[5] As a rule, the total count does not include augmented plants. However, in a few cases tags marking individual transplants have been lost and augmented plants may have been included in the total count (see G. Conservation Efforts).

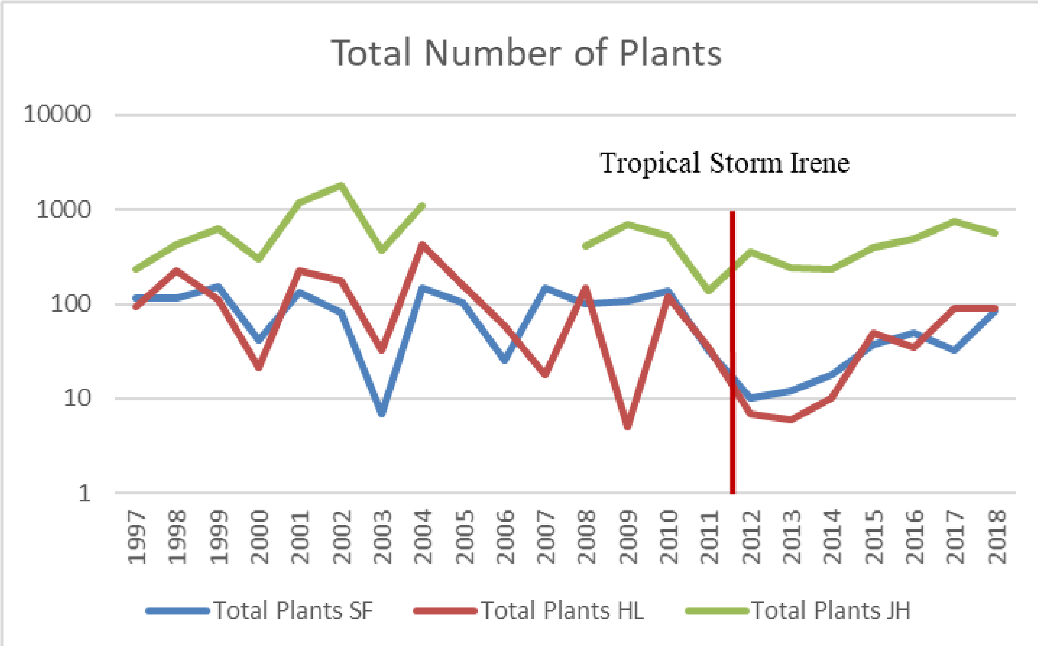

Figure 11. Total numbers of plants by site from 1997 to 2018.

In August of 2011, Tropical Storm Irene resulted in extreme high flows at all three sites, flooding habitat above the highest plant locations causing prolonged inundation and scouring much of the habitat. All three sites experienced dramatic deposition of river sediment extending to elevations above any known elevations of Jesup's milk-vetch plant, in places up to depths of 14 inches (Kane 2011a). The following year, total plant numbers and inflorescences were reduced at Sumner Falls and Hartland Ledges. Jarvis Hill apparently was less affected by the inundation (figures 11 and 12).

Based on analyses of inflorescence counts between 1998 and 2008, a fairly consistent and synchronous pattern of 3-year fluctuations in inflorescence production across all three sites was observed through 2008 (NHNHB 2011; Kane 2011c). A year with low plant numbers would be followed the next year by increasing plant numbers, with the third year surveys generally documenting a higher number of plant and inflorescence counts (Kane 2011c). However, the following year, plant numbers would drop and the cycle would begin again. The cause of the synchrony, the possible effects of weather, including precipitation, and/or spring scouring, is not certain. Kane (2011c) explored a number of hypotheses, but did not reach a solid conclusion as to the cause of the 3-year pattern and synchrony of inflorescence output. The 3-year cycle of synchrony apparently was affected by floods occurring during the growing season with a decrease in the total number of plants and inflorescences in 2009 and loss of synchronous productivity at least through 2018.

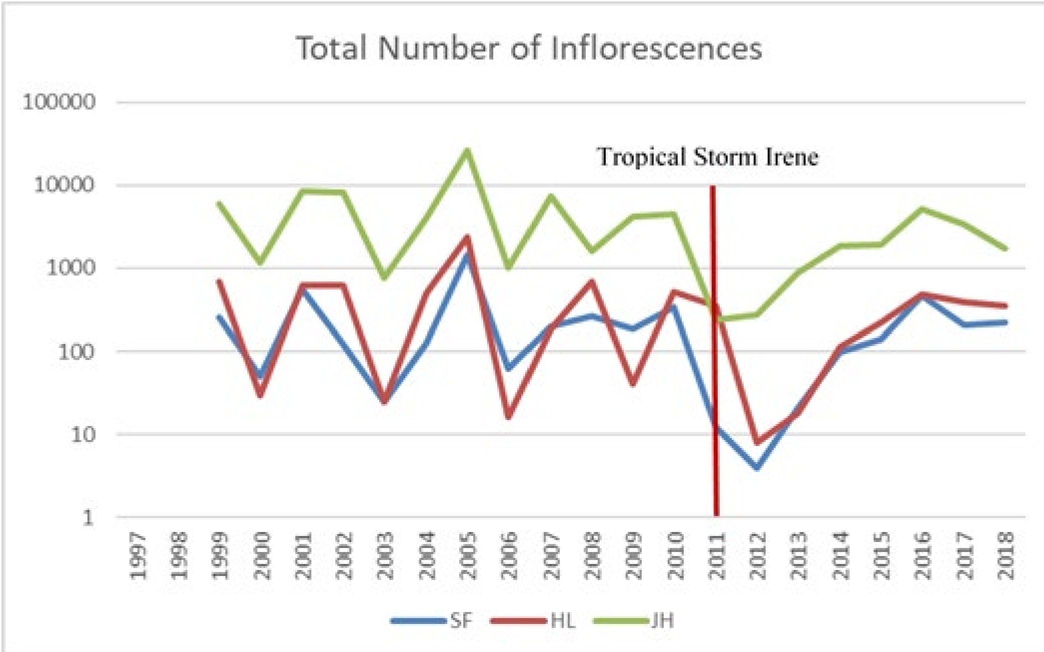

Figure 12. Total number of inflorescences by site from 1997 to 2018.

Determining individual plants versus clustered plants is difficult, and total population numbers may not be accurate from year to year. In 2004, to measure inter-observer variations in plant counts (which stems were considered to be from the same plant), counts were replicated by different observers in one 20-m segment at Jarvis Hill. Total inflorescences differed between observers by only 6 percent, whereas total plants differed by 21 percent (NHNHB 2004, appendix 4). Based on this field research, inflorescence counts are now considered to be a more accurate indicator of reproductive success and would more accurately track population trends (Kane 2011c).

E. Threats

A paucity of long-term data makes it impractical to estimate numerical extinction probabilities for these populations, but the data available clearly indicate that the existing populations of Jesup's milk-vetch are tenuous, with intrinsic rates of increase that are not significantly different from zero (Farnsworth 2008). The populations face many threats, some human-caused and some a consequence of their disturbance-prone habitats. Threats identified in the 1989 Recovery Plan (USFWS 1989) included: (1) habitat alteration, particularly through impoundments that would modify river flow and flooding/ice-scour patterns; (2) over collection of botanical specimens; and (3) trampling by recreational users of the river shore (at one site).

Since the 1989 Recovery Plan was published, research into the life history, habitat and ecology of the species has identified additional factors that may affect the species' viability. Kane (2011c) developed an influence diagram outlining the primary factors that may affect Jesup's milk-vetch positively and negatively (figure 13).

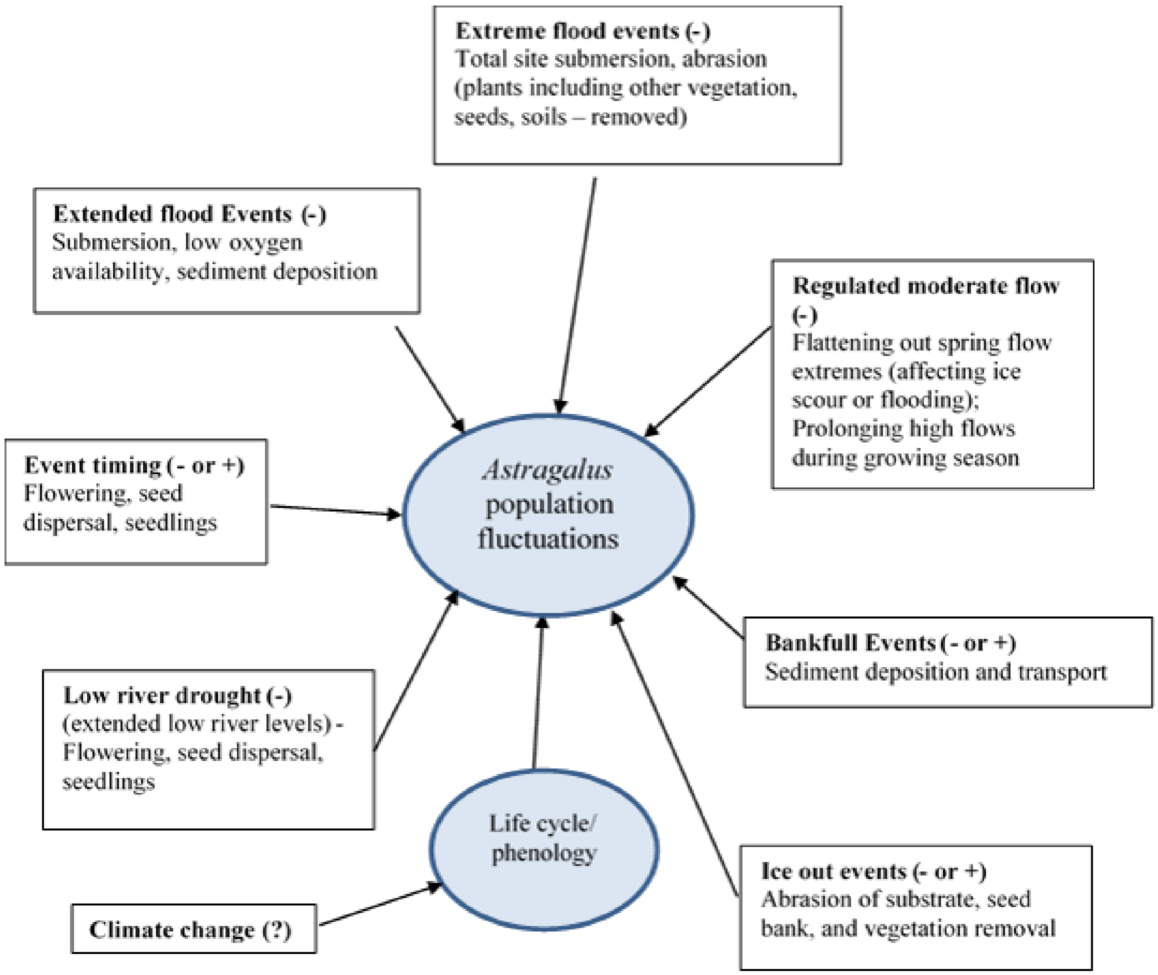

Figure 13. Potential influences on Jesup's milk-vetch population dynamics (Kane 2011c, with modifications).

Currently, construction of new dams on the Connecticut River is not likely, although alteration of the river hydrology as a result of changes in dam management may continue to be a potential threat. Botanical collection, which was very intense in the late 1800s (appendix 1) has largely ceased, in part due to Federal protections on the species. Trampling remains a potential threat to at least one of the populations; the other two are difficult to access, and trampling is less likely to occur. Since the 1989 Recovery Plan, additional threats have been identified including: effects of climate change; inbreeding depression and other risks associated with small population size; encroachment by competing plant species, especially nonnative invasive species; loss of available habitat for colonization; and herbivory.

Climate Change
The impacts of climate change were not considered in the first Jesup's milk-vetch recovery plan. There is little quantitative data for Jesup's milk-vetch population status or trends prior to 1997; therefore, it is difficult to determine the specific effects of climate change over the last century.

Trends for the Northeast in the past 40 years reflect an increase in temperature at a global and fine scale, and an increase in overall precipitation in the form of rain interspersed with periods of summer drought. Climate change analyses for the period 1979 through 2017 for New Hampshire and Vermont (figure 14) demonstrate an increasing trend in average temperature at 2 m above sea level. Over the last 100 years the average annual temperature has increased approximately 3 ºF (-16 ºC) in New Hampshire and 2 ºF (-16.7 ºC) in Vermont (Runkle *et al*. 2017a; Runkle *et al*. 2017b). Winter temperatures are increasing at a greater rate than summer temperatures in these areas (Wake *et al*. 2014).

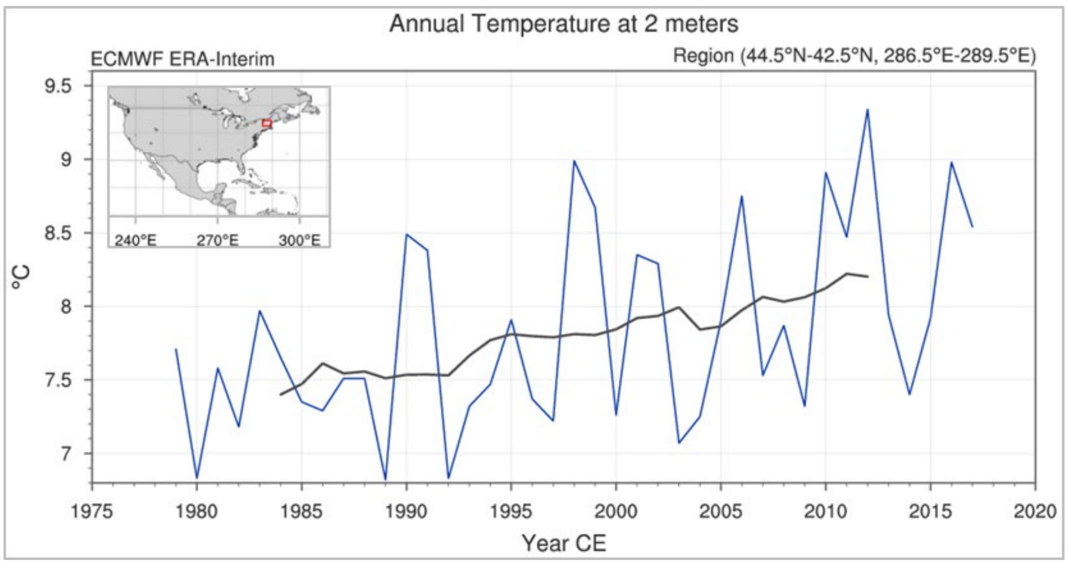

Figure 14. Annual temperature (℃) at 2 m above sea level in Vermont and New Hampshire from 1979 to 2017.

The annual mean precipitation has been above average for the last several decades for both Vermont and New Hampshire (Runkle *et al*. 2017a; Runkle *et al*. 2017b). Specifically, for precipitation during the summer growing season, there have been greater periods of seasonal variability since 2006 (figure 15).

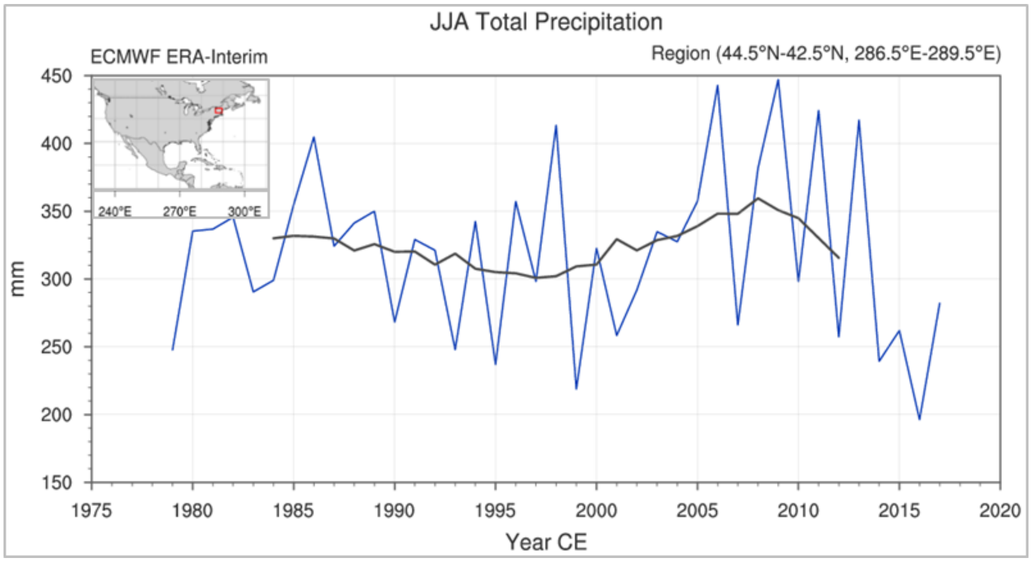

Figure 15. Total precipitation (mm) during June, July, and August in Vermont and New Hampshire from 1979 to 2017[6]

The U.S. Global Change Research Program stated with very high confidence that the observed increase in global carbon emissions over the past 15 to 20 years has been consistent with higher scenarios such as RCP8.5 (Hayhoe *et al*. 2018). It is therefore reasonable to conclude that changes from now through mid-century will also be closer aligned to effects from a RCP8.5 climate change scenario. Under this scenario, models of global climate change, supported by recent recorded trends, predict higher temperatures and more frequent extreme weather events.

Under scenario RCP8.5, the average annual temperatures are predicted to increase by 9.5 °F (-12.5 ºC), with both summer and winter temperatures increasing by 9 to 10 °F (-12.8 to -12.2 ºC) (Hayhoe *et al*. 2018). One effect will be a longer growing season for plants. By the year 2100, the growing season in New England is predicted to increase by 43 days (Rustad *et al*. 2012; NHNHB 2014). Figure 16 shows the comparison of temperatures in January during the 20-year period of 1979 to 2000 (left) to the predicted January temperatures in 2100 (right) of a nearly 10°F (4°C) increase in average monthly temperature. In 2100, winters in Jesup's milk-vetch habitat will more closely resemble current average January temperatures in West Virginia.

6 Each of the spikes represents a year with a summer flooding event, and low marks represent periods of dryness.

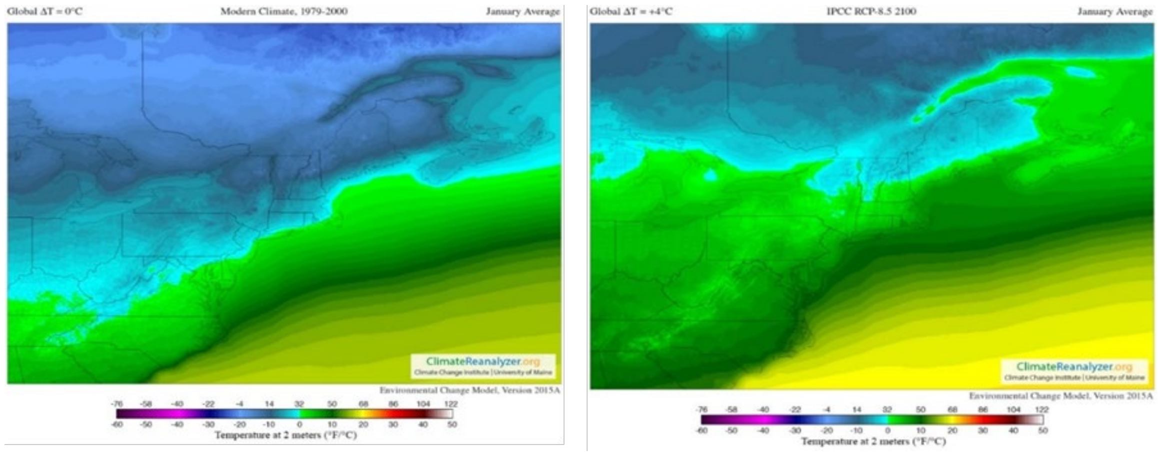

Figure 16. (Left) Average January temperature from 1979 through 2000 compared to (Right) the modeled January temperature at RCP8.5 in the year 2100.

Higher temperatures will likely stress the plants by desiccating whole plants, inflorescences and seeds, especially during droughty periods, and may create an additional competitive advantage for invasive species. Periods of prolonged drought in the summer are expected to increase and intersperse precipitation events, as evidenced by the documentation of more extensive droughts occurring since 2014 (figure 15). Predicted climate changes are also expected to reduce Jesup's milk-vetch habitat both at the high ledge elevations and at the lower elevations. The increased growing season caused by an increase in winter temperature and earlier spring will allow more woody vegetation to establish at the upper elevations of the Jesup's milk-vetch habitat.

Precipitation is predicted to increase by 14 percent with the greatest increase in the fall and winter and in the form of rain rather than snow (Runkle *et al.* 2017a; Runkle *et al*. 2017b). In Jesup's milk-vetch habitat, riverbank ledges are kept clear by ice scour and spring flooding. These disturbances remove other vegetation that might colonize Jesup's milk-vetch habitat and shade out Jesup's milk-vetch seedlings (USFWS 1989), and/or deposit alluvial sediment to renourish Jesup's milk-vetch plants. The most significant annual floods currently occur during spring runoff, with decreasing flows during the summer. With increasing winter temperatures and winter precipitation in the form of rain, the decrease in snowpack may result in reduced spring flooding, a critical component to reduce competition in the rock outcrops.

On average, the total amount of precipitation is not projected to increase in the summer, although intense storms are projected to become more frequent. Recent summer floods (2008, 2011, and 2012) may have affected the reproductive output of Jesup's milk-vetch at some or all sites. In August of 2011, Tropical Storm Irene caused severe flooding at Jesup's milk-vetch locations; late summer, post-storm surveys documented several dead plants at one site and intense scouring of the habitat (Kane 2011b; NHNHB 2014). Following Tropical Storm Irene, total natural plant counts at Hartland Ledges (for example) were exceedingly low in 2012 and 2013, most likely due to lack of recruitment (Popp 2018).

Extreme weather events have increased as well, most notably seen over the last decade. The extreme events affecting Jesup's milk-vetch are summer and fall flooding, resulting in prolonged inundation of the habitat or extreme high flows, may remove seeds and seedlings and destroy individual plants, thereby reducing future populations at the site. Plants occurring at lower elevations will be more prone to frequent summer floods (NHNHB 2014); while seeds and seedlings are most vulnerable, established plants may also be removed depending upon the velocity of the flows.

Jesup's milk-vetch is categorized as "highly vulnerable" to future climate change based on NatureServe's Climate Change Vulnerability Index (CCVI) using a RCP4.5 scenario (NHNHB 2014). The CCVI is based on three categories of variables: (1) indirect exposure to climate change; (2) species-specific traits; and (3) documented responses to climate change that have occurred to date. Two major factors affect a species' vulnerability to climate change: the species rangewide exposure to climate change and how sensitive the species is to the changes it experiences (Young *et al*. 2012). Three potential stressors have been identified arising from climate change that are likely to affect the Jesup's milk-vetch: changes in flooding intensity and seasonality, increased heat and drought; and increased competition from native and nonnative plants (NHNHB 2014). Given that the current climate change scenario is more likely to be RCP8.5, it is possible that the Jesup's milk-vetch's predicted vulnerability to climate change may be higher than was predicted in 2014.

The Intergovernmental Panel on Climate Change (IPCC) Climate Change 2014 Synthesis Report stated that "most plant species cannot naturally shift their geographical ranges sufficiently fast to keep up with current and high projected rates of climate change on most landscapes" (IPCC 2014). Figure 17 represents the biome shift that can be expected by 2050. The current biome that the already sensitive Jesup's milk-vetch requires is expected to continue to shift north. According to RCP8.5 projections, by 2050, the southern range of the Jesup's milk-vetch's appropriate biome will be in the northern half of Vermont and New Hampshire.

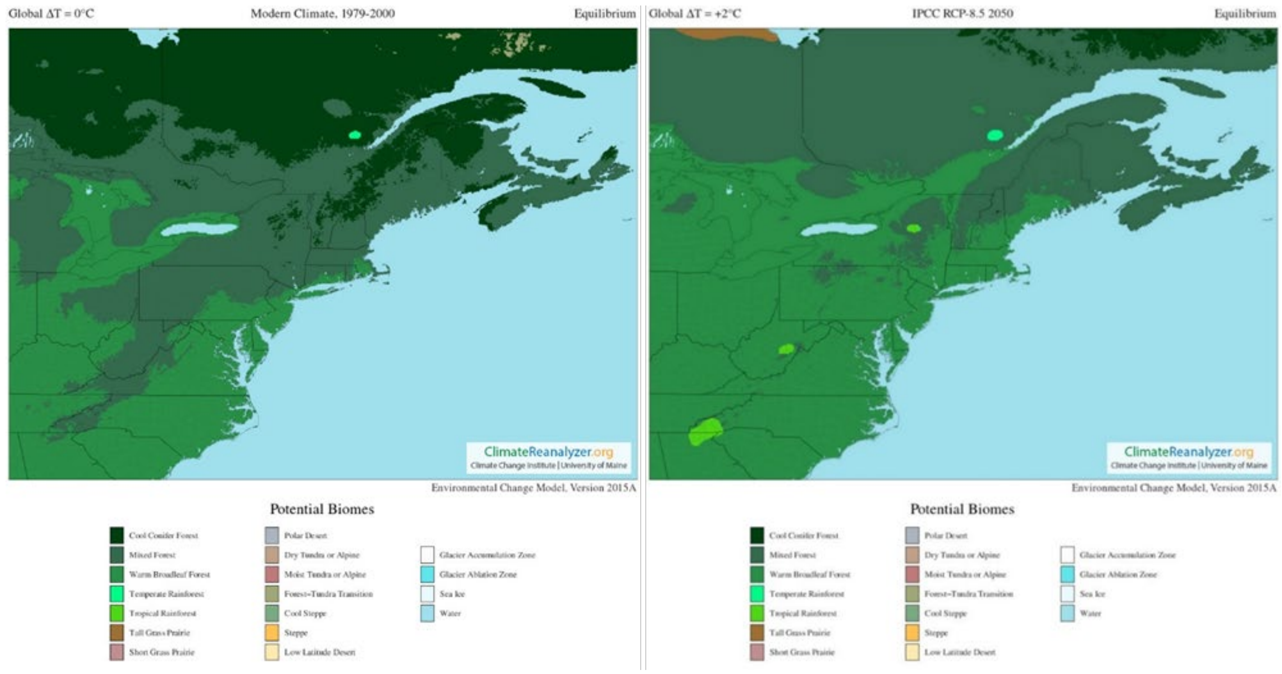

Figure 17. (Left) Biome representation in the modern climate (represented from 1979-2000) compared to (Right) the modeled biome in 2050 using RCP 8.5.

Hydrological alteration

The historical Jesup's milk-vetch populations are located in the 90-mi (145-km)[7] stretch of river with flows directly affected by two hydropower dams, Wilder Dam (Wilder, VT/Hanover, NH) and Bellows Falls Dam (Rockingham, VT/Walpole, NH) (NHNHB 2014). Specifically, the three Jesup's milk-vetch populations occur in the 25 mi (40 km) of free-flowing river between the two dams. The Sumner Falls population is approximately 9.5 river-mi (15 river-km) downriver of Wilder Dam, the Hartland Ledges population is approximately 12.5 river-mi (20 river-km) from the Wilder Dam, while the Jarvis Hills population is above the head of the impoundment for the Bellows Falls Dam. Both dams influence the hydrology of the Connecticut River in the vicinity of the Jesup's milk-vetch populations.

The Wilder and Bellows Falls Dams may not directly affect Jesup's milk-vetch habitat during routine operations. The Sumner Falls, Hartland Ledges, and Jarvis Hill populations would not be affected by flood events until flows exceeded approximately 38,000 cfs, 23,000 cfs, and 29,000 cfs, respectively (Normandeau Associates Inc. 2013). These populations would be periodically inundated by annual peak flows, which average 48,000 cfs (1970 to the present) at the West Lebanon gage (located upriver of all three populations). Based on long-term records, normal operational flows are exceeded less than 10 percent of the time between June and February, 20 percent in March, and 50 percent in April and May (Normandeau Associates Inc. 2013).

7 Measuring from the head of the impoundment at Wilder Dam to the Bellows Falls Dam.

Flood frequency and intensity at historical Jesup's milk-vetch locations are influenced by the Wilder Dam on the mainstem of the Connecticut River and flood control dams on its tributaries. The typical impact of managed dams is to reduce the magnitude of peak flood flow that affects important riverine functions of sediment transport, habitat creation or enhancement, and aquatic connectivity and to disrupt aquatic life cycles. This change in median annual flooding is greatest in large and medium size rivers (Magilligan and Nislow 2005; Fitzhugh and Vogel 2010) such as the Connecticut River. The impacts of managed flows may include major changes in flood frequency, flood duration and total area flooded. If ice scour or spring flooding is reduced, scouring at the critical elevations for Jesup's milk-vetch populations may not occur, enabling an increase in both native and nonnative vegetation. Additional habitat degradation may result if sediment deposition does not occur to replenish depleted soils in the rock outcrops. If managed flows dampen floods during the summer months, scouring of existing Jesup's milk-vetch plants may be prevented if extreme high flows are reduced. However, managed flows may also result in prolonged inundation, especially of plants at the lower elevations, effectively reducing the amount of available habitat on the vulnerable rocky outcrops, in particular, Sumner Falls (see C. Habitat and Ecology).

Nislow *et al*. (2002) modeled the impacts of impoundments on river hydrology in proximity to sites with Jesup's milk-vetch. Riparian communities, which had been flooded on average every 20 to 100 years pre-impoundment, were predicted to flood at more than 100-year intervals, essentially isolating them completely from riverine influence.

The Bath-SI introduced population in the expanded range is also located within the influence of hydropower dams. Dodge Falls Dam in Ryegate, Vermont is located approximately 4 mi (6.4 km) upriver of the Bath-SI population. Wilder Dam is located approximately 44 mi (70.8 km) downriver of the Bath-SI population. The area is regularly subjected to floods because the river is constricted at that location. However, the long-term effect of regulated flows on the introduced population are unknown at this time. The site was selected based on the assumption that the normal flow regime would be protective of the introduced plants.

Problems intrinsic to small populations

Jesup's milk-vetch populations are subject to dramatic "boom and bust" cycles. In 2003, 2009, and 2012 through 2014 all three populations were at some of their lowest numbers since consistent monitoring began in 1997 (appendix 4). While apparent rebounds have occurred after some of the precipitous declines (e.g., 2004 and 2010), monitoring data indicate that these are likely to be followed by future dips under normal conditions. However, extreme storm events in 2008, 2009, and 2011 may have been responsible for the prolonged decline in total plant numbers from 2012 through 2014.

Demographic stochasticity can lead to random extinction, and small populations are particularly vulnerable (Morris and Doak 2002; Farnsworth 2008). These populations are also clearly subject to environmental stochasticity, which further compounds year-to-year variation in population size and is a major driver of extinction probabilities in rare plant populations (Menges 1998). Catastrophic events such as Tropical Storm Irene, or the prolonged inundation of some or all of a population during the growing season, in combination with natural demographic stochasticity, could significantly increase the likelihood of extirpation of one or more of the Jesup's milk-vetch populations.

Small populations may also be prone to inbreeding depression and loss of heterozygosity. Although population genetics for the Jesup's milk-vetch have not been undertaken, several studies have investigated the population genetics of other rare *Astragalus* species. Farnsworth (2008) theorized that given the similarities among the two disparate rare *Astragalus* species in terms of their genetic structure, that the Jesup's milk-vetch populations might show similar minimal divergence. Conversely, seed dispersal may be limited to the immediate vicinity of the individual populations, limiting genetic flow between populations. In this case, genetic drift may be contributing to population divergence (Farnsworth 2008) and it would be critical to conserve genetic representation of all three populations.

Invasive Species

Jesup's milk-vetch relies on the availability of open habitat, which is maintained in an early-successional state by periodic flooding and ice scour. Populations of black swallowwort, shrubby honeysuckle, cypress spurge, and purple loosestrife have been noted by surveyors at one or more sites since 1997. As of 2002, all of these species were present at all three sites (with the exception of purple loosestrife, which occurred only at Hartland Ledges and Jarvis Hill) and (with the exception of cypress spurge) are the focus of intensive removal efforts. Recently, bushy rock-cress (*Caramine impatiens*) is being treated manually at Sumner Falls and Hartland Ledges (Brumback and Piantedosi 2018b).

The Hartland Ledges site has the highest percent cover of invasive species. Black swallowwort appears to be spreading more rapidly than other species, particularly at Hartland Ledges, where a nearby railroad bed is infested in places with up to 100 percent cover and plants are rapidly spreading into the surrounding forest and down onto the riverbank and the rock outcrops where Jesup's milk-vetch grows. Shrubby honeysuckle has been increasing more slowly. Several other native, weedy species are also increasing in cover at the sites, including poison ivy (*Toxicodendron radicans*) and ground-nut (*Apios americana*) at Hartland Ledges.

Land use change

Because Jesup's milk-vetch habitats typically occur far apart from each other, colonization of new habitat and establishment of new populations depends on rare long-distance dispersal events. Land use changes that reduce the availability of appropriate Jesup's milk-vetch habitat can reduce the prospects for successful establishment of new populations. Residential and recreational development is increasing along the Connecticut River. While local regulations may prevent siting of new development in the riparian buffers that provide potential habitat for Jesup's milk-vetch, logging and construction activities in the upland areas can cause erosion of shoreline habitats, lead to dumping of materials (e.g., coarse woody debris) in shoreline habitats, and result in increased human visitation to shoreline habitats. These effects can result in degradation of Jesup's milk-vetch habitat and trampling of Jesup's milk-vetch plants.

Trampling
Trampling of plants has been noted at Sumner Falls on several occasions: 1990, 1992, and 2001. Sumner Falls receives many visits from kayakers who shoot the nearby rapids, fishermen, and other recreational users. Picnicking, landing, and campfire building can threaten plants. Vandalism has been noted in the past; several plants were "pulled up" in 1990. Likewise, activities nearby have inadvertent impacts: a crew erecting signage at Sumner Falls in 2003, for example, dumped brush very near to the plants (but fortunately did not damage any). With so few plants present at the site, the population is vulnerable to even small-scale disturbances. Other sites have not been as attractive for landings, as they are steep to access from the water and overland access points are in private ownership.

Symbolic fencing with signs to keep people from trampling Jesup's milk-vetch plants was erected in 2018 at Sumner Falls. The 1-foot-high fence and sign with the message "Habitat Experiment Area – Please Do Not Disturb" may have reduced the likelihood of trampling, but data on visitor intrusion into the area was not collected to ascertain the efficacy of the symbolic fencing and signage (Brumback and Piantedosi 2018a).

Herbivory
Herbivory has been noted on the stems, leaves, fruits, and seeds of Jesup's milk-vetch since 1990. The major herbivores remain unidentified, but deer and woodchucks were implicated in 1990 and 1992, respectively. The proportion of stems affected is generally small (less than 10 percent). Nothnagle noted the loss of an "estimated 95 percent of flowers to herbivory in 1998" without identifying the herbivore (NHNHI 2002). No similar incidents of large-scale herbivory have been documented in the last decade.

F. Conservation Efforts

Conservation activities have been ongoing since implementation of the 1989 Jesup's milk-vetch recovery plan. Activities include annual monitoring for plants and productivity, seed banking and germination trials, invasive plant species control, land conservation, and augmentation and introduction efforts.

Annual monitoring
Annual censuses of plants at all three sites have been invaluable for determining rates of population increase and for better understanding population dynamics. Transects and permanent plots were the first methods used from 1987 to 1994 to monitor plants using number of inflorescences and percent cover of Jesup's milk-vetch as indices of plant vigor. Because markers are easily dislodged by floods and because plants emerge in variable locations from year-to-year, marked plots did not yield consistent data. In 1998 transect locations were made permanent by reference to bolts drilled into the bedrock at

each site, demarcating linear transects at high (determined by upland vegetation), intermediate, and low elevations with respect to river level. Permanent grids were established in which all plants and inflorescences per plant are counted.

Since 2002, the presence of nonnative invasive plants in proximity to Jesup's milk-vetch plants have also been counted; in 2004, this count included native poison ivy, a recent aggressive invasive species. Full censuses at sites entail tens of person-hours, normally involving three to six surveyors (depending on the site). Censuses take place May to June. Because sampling is complete, the data are comparable from year to year and allow researchers to detect shifts in plant distribution within sites.

Seed banking and germination trials
Seed collection for banking at NEWFS began in 1986 and has continued on an almost annual basis. Seeds from all three populations are represented in the seed bank at NEWFS. Currently, over 4000 seeds each from Sumner Falls and Jarvis Hill and 2500 seeds from Hartland Ledges representing multiple years are held in the NEWFS seed bank. To prevent overharvesting, no more than 10 percent of available seed is collected in a given year. Additional seed has been stored at the National Seed Storage Laboratory (a unit of the National Center for Genetic Resources Preservation) in Fort Collins, Colorado (Brumback 2018b). Germination and propagation trials have established that the seeds of Jesup's milk-vetch show moderate germination rates (up to 60 percent with either pre-drying or direct sowing), seeds can remain viable in the bank for 10 years or more, scarification promotes germination, and irrigation promotes germination (Brumback and Piantedosi 2018a).

Invasive plant species control
Removal of invasive species by hand and the use of herbicides has been undertaken since 1998 at all locations, as invasive species are perceived to be increasing and encroaching on available habitat for Jesup's milk-vetch. Honeysuckle shrubs in Jesup's milk-vetch populations and upland source populations of other invasive plants are removed with brush cutters and other hand tools.

Herbicides are used on species that are virtually impossible to eradicate otherwise, including black swallowwort, shrubby honeysuckle, and poison ivy. Initial herbicide applications were not conducted in the vicinity of Jesup's milk-vetch plants over concerns about potential impacts to the species. A foliar herbicide was first used in 2002 and again in 2003 to control black swallowwort and to spot-treat cut honeysuckle at Hartland Ledges. Jesup's milk-vetch plants were not affected, and it was determined that this method could be safely used in the vicinity of Jesup's milk-vetch plants (NHNHB 2017). Since the initial use of herbicides, the specific treatments have been refined. Currently invasive plant species are tracked annually (by stem counts) to document the effectiveness of invasive plant control treatments and to provide a basis for recommendations for future control efforts (appendix 6). In most cases, herbicides are applied in 3-year intervals, and hand-pulling or other manual removal is implemented as needed (Brumback 2018a).

Land Conservation
The entire range of the species lies within the Silvio O. Conte National Fish and Wildlife Refuge (Conte NFWR) jurisdictional boundaries, albeit not necessarily on lands managed by the Service. The current, potentially successful introduced population in the expanded range is located within the Nulhegan Basin Division of the Conte NFWR and is considered to be permanently protected. One historical population is under a voluntary registry agreement with The Nature Conservancy, although this does not constitute permanent protection. The other two historical populations are not protected. However, access has been obtained to all sites for monitoring and invasive plant management on a year-to-year basis.

Augmentation and Introduction
Augmentation including field irrigation trials to stimulate growth and promote survivorship has been undertaken since 1998 to improve declining populations. Augmentation by transplanting seedlings is primarily focused on the two small populations, Sumner Falls and Harland Ledges. Transplants are grown from seed collected the prior year and from the seed bank.

Sumner Falls was the first population to receive transplanted seedlings grown at NEWFS. Initial trials in 1998 and 1999 were unsuccessful, as all transplants died due to excessively dry soils. An attempt to keep soils hand watered during the growing season of 1998 did not enhance plant survivorship.

In 2000, further work was done to establish Jesup's milk-vetch in the field using a gravity-fed drip irrigation system in situ to irrigate transplanted seedlings. Ultimately, it was determined that irrigation and/or hand watering increased seed germination relative to controls, but did not necessarily increase transplanted seedling survival success (Brumback and Gerke 2013). Nursery-grown seedlings for transplanting to a population are of seed collected from that same location. Seedlings from different populations are not intermingled. Because of the low success rate, after 2009 seedlings were not transplanted to mossy sites, heavily vegetated sites, and sites prone to flooding or erosion (Brumback and Schaeffer 2014).

Nursery-grown seedlings are individually marked and monitored separately from natural plants (all total plant counts are of natural plants only). It is estimated that approximately 25 percent of transplanted seedlings survive depending on favorable climatic conditions.

Flooding has continued to remove flags marking transplanted plants; therefore, determining survivorship from year to year and separating augmented plants from natural plants may be problematic (Brumback and Piantedosi 2018a). In 2018, at Sumner Falls, in areas with more challenging conditions, seedlings and plants were spackled into crevasses in an attempt to increase survivorship. This included 20 percent of seedlings and 40 percent of plants transplanted at Sumner Falls (20 out of 75). There was 15 percent survivorship of spackled seedlings and plants by the end of summer 2018. See appendix 7 for a summary of all augmentation efforts from 1998 through 2018 for natural sites.

Surveys for potential introduction locations identified few suitable sites within the historical range. In 2009, an experimental introduction effort was initiated to evaluate an approach to planting and care of seedlings, with a secondary goal of establishing a new site within the historical range in Cornish, NH (Brumback and Gerke 2013). No transplants from 2009 and 2010 survived at the introduction site. A third transplant effort was attempted in 2013; no transplants survived that summer (Brumback and Schaeffer 2014). No further efforts were undertaken as the Cornish site was deemed unsuitable.

As no other suitable sites were identified within the historical range of the species, introduction efforts were initiated at a number of locations upriver of the historical range (expanded portion of the range) identified during previous surveys (Popp and Kane 2012; Kane 2013). In addition it was considered prudent to establish new populations outside of the influence of the Wilder Dam, so that one catastrophic event would not impact all of the populations.

Popp and Kane (2012) and Kane (2013) conducted surveys of the Connecticut River mainstem north of the historical range and on tributaries within and north of the historical range to identify potential suitable habitat. Potential introduction sites were selected based on specific criteria including:

- similarity in spring flooding events allowing annual scouring of habitat;
- extreme peak flows should be less at upriver locations than within the historical range when occurring at the same point in time (Popp and Kane 2012);
- must present similar geological, soil, and vegetative conditions as existing populations;
- presence of selected indicator species, present at the natural populations;
- must have an absence of invasive species; and
- must have the opportunity for long-term monitoring and management.

Introduction of nursery-grown plants using seeds from the Jarvis Hill population[8] to one location on the Connecticut River in Bath, New Hampshire began in 2014 (Bath-SI). Additional introduction efforts continued at one or both of the locations through 2016. Bath-1 failed and was abandoned after 2016. The transplanted plants at Bath-SI appeared to thrive, and additional transplanting ceased as of 2017. In 2017 and 2018, flowering, vegetative, and seedling Jesup's milk-vetch plants were documented. In 2018, there were 77 plants. Half of these were in flower with a total of 198 inflorescences and an average of 5.2 inflorescences per plant. This population, located essentially in an elongated crack on a rock outcrop, appears to be persisting (Brumback and Piantedosi 2017; Brumback

[8] Seeds for the transplants were taken from the Jarvis Hill population because this is the largest population and most likely to provide a consistent source of seed. This population does not require augmentation;, hence, seed should be available for future population introduction efforts.

and Piantedosi 2018a). It should be noted that the total area encompassing suitable habitat is extremely small and limited to the rock fissure, and, similar to the Sumner Falls population, this population will always have relatively small numbers of plants. Three other locations within the Bath-SI site received transplants in 2014 and 2015 but these efforts were discontinued because there was little to no survival of introduced plants and the sites were deemed to be unsuitable for long-term Jesup's milk-vetch survival (Brumback and Piantedosi 2018a).

In 2016 seedlings were introduced to one additional site in the expanded range, and introductions were continued there in both 2017 and 2018. No plants survived over the 3-year effort, hence the site has been deemed unsuitable and abandoned. Two additional sites in Bath received transplanted seedlings in 2017. As a result of flooding brought on by heavy rains in early July, survival was estimated at 10 percent and 50 percent. Seedling introduction occurred at both sites again in 2018, and at the end of the growing season in early September survival was at 26 percent and 28 percent. Although survival at these sites was well below that at the Hartland natural site (46 percent survival) where augmentation had occurred in 2018, it is comparable to the survival at Sumner's Falls where 32 percent of augmented plants survived in 2018. The intent is to continue the introduction efforts at these two upstream sites for at least one more year. See appendix 8 for a summary of all introduction efforts from 2009 to 2018.

PART II – RECOVERY STRATEGY

There are typically many possible ways (strategies) to recover an endangered or threatened species. A strategy is chosen based on the likelihood of success, which is a function of the scientific uncertainties, cost of implementation, likelihood of necessary partner participation, regulatory considerations, and other factors. The goal of any recovery strategy is to improve the species' viability (reduce its vulnerability to threats) and reduce threats. Viability is generally defined as the ability of the species to sustain populations in natural ecosystems within a biologically meaningful timeframe and can be described in terms of **resiliency**, **redundancy**, and **representation** (together, the 3 Rs) (Smith *et al.* 2018, entire).

The recovery strategy for the endangered Jesup's milk-vetch is to establish and maintain multiple resilient populations within the species' historical range and/or expanded portion of the range in New Hampshire and Vermont. These populations must be protected from threats and must require minimal habitat management and population augmentation.

A. Resiliency

Resiliency is the ability of populations to sustain themselves in the face of environmental variation and stochastic events. Resiliency may be measured by metrics of population health; for example, birth versus death rates and population size, if that information exists. Resilient populations are better able to withstand disturbances such as natural fluctuations in birth rates (demographic stochasticity), variations in rainfall (environmental stochasticity), and the effects of human activities. For the Jesup's milk-vetch, resiliency is measured by the median number of inflorescences produced per plant and a site-specific median number of plants computed over 8 consecutive years. Based on years of field research and testing survey methodology, inflorescence counts are considered to be a more accurate indicator of reproductive success and would more accurately track population trends (Kane 2011c) (see D. Life History). Larger plants (those having three inflorescences or more) have more inflorescences and thus produce more seed for the next generation.

B. Redundancy

Redundancy is the ability of a species to withstand catastrophic events. Redundancy protects species against the unpredictable and highly consequential events for which adaptation is unlikely. Redundancy is about spreading the risk and can be measured through the duplication and distribution of populations across the range of the species. Generally, the greater the number of populations a species has distributed over a larger landscape, the better it can withstand catastrophic events. The Jesup's milk-vetch is a naturally rare species, known to occur at only three historical locations within 16 mi (25 km) of each other on the Connecticut River. The species has never been found outside of the historical range. To date, a single catastrophic event has not equally affected all three populations. For example, Tropical Storm Irene decimated the two smaller populations (Sumner Falls and Hartland Ledges), but had a lesser impact on the larger Jarvis Hill population. However, the species' current redundancy is tenuous at best.

C. Representation

Representation is the ability of a species to adapt to near- and long-term changes in the environment; it is the evolutionary capacity or flexibility of a species. Representation, as measured at the species level, is the range of variation found in a species, and this variation, called adaptive diversity, is the source of species' adaptive capabilities. Representation can be measured through the genetic diversity within and among populations and the ecological diversity of populations across the species' range. Theoretically, the more representation the species has, the higher its potential of adapting to changes (natural- or human-caused) in its environment. In the absence of species-specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of habitat characteristics within the geographical range. The Jesup's milk-vetch has an extremely limited distribution, reducing the likelihood of significant ecological diversity among the three populations and a low probability of consistent genetic exchange between populations since seed are not easily dispersed between the populations. Therefore, the species is considered to have only one representational unit, and the available evidence indicates that the species has a low adaptive capacity.

PART III. RECOVERY GOALS, OBJECTIVES, AND CRITERIA

Recovery criteria serve as objective, measurable guidelines to assist in determining when an endangered species has recovered to the point that it may be downlisted to threatened, or that the protections afforded by the Act are no longer necessary and the species may be delisted. Delisting is the removal of a species from the Federal Lists of Endangered and Threatened Wildlife and Plants. Downlisting is the reclassification of a species from an endangered species to a threatened species. The term “endangered species” means any species (species, subspecies, or DPS) which is in danger of extinction throughout all or a significant portion of its range. The term “threatened species” means any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Revisions to the Lists, including delisting or downlisting a species, must reflect determinations made in accordance with sections 4(a)(1) and 4(b) of the Act. Section 4(a)(1) requires that the Secretary determine whether a species is an endangered species or threatened species (or not) because of threats to the species. Section 4(b) of the Act requires that the determination be made “solely on the basis of the best scientific and commercial data available.” Thus, while recovery plans provide important guidance to the Service, States, and other partners on methods of minimizing threats to listed species and measurable objectives against which to measure progress towards recovery, they are guidance and not regulatory documents.

Recovery criteria should help indicate when we would anticipate that an analysis of the species’ status under section 4(a)(1) would result in a determination that the species is no longer an endangered species or threatened species. A decision to revise the status of or remove a species from the Federal Lists of Endangered and Threatened Wildlife and Plants, however, is ultimately based on an analysis of the best scientific and commercial data then available, regardless of whether that information differs from the recovery plan, which triggers rulemaking. When changing the status of a species, we first propose the action in the *Federal Register* to seek public comment and peer review, followed by a final decision announced in the *Federal Register*.

We provide recovery goals, objectives, and both downlisting and delisting criteria for the Jesup’s milk-vetch, which will supersede those included in the Jesup’s Milk-Vetch (*Astragalus robbinsii* var. *jesupii*) Recovery Plan (USFWS 1989), as follows:

A. Recovery Goal

To ensure the long-term viability of the species, the number of Jesup’s milk-vetch populations must be increased through introductions into the historical[9] and expanded range. These populations should be self-sustaining, secured through the establishment of

---

[9] Almost no suitable habitat for introductions within the historical range has been identified despite years of intensive surveys.

long-term land protection measures, and have long-term monitoring and management plans to address ongoing threats from invasive plant species, natural vegetation succession (in the absence of suitable ice or flood scour), and unanticipated future threats.

The Jesup's milk-vetch occurs at three extant sites within a 16-mi (25-km) stretch of the Connecticut River. Due to the close proximity of populations, the species is considered to be a single representative unit. The three populations occupy generally similar habitat, although microhabitat parameters may vary subtly between the populations. Moreover, the three populations have significantly different amounts of suitable habitat. Sumner Falls has the smallest area of suitable habitat and the smallest number of plants, and Jarvis Hill has the largest area of suitable habitat and the largest number of plants. Genetic analysis of the population structure of the species has not been completed; nevertheless, it may be critical to conserve the genetic variation of individual populations for future introductions to similar habitats within the expanded range (see B. Distribution and Status; D. Habitat and Ecology).

In the near future, self-sustaining introduced populations in the expanded range may not be exposed at the same level as the historical populations to threats from climate change, hydrological alterations, and invasive species given:

- the distance between the populations;
- the different hydrological impacts from upriver and downriver dams; and
- a current lack of invasive plant species for potential introduction locations (criterion for introduction site selection).

In summary, additional populations in the expanded range increase the redundancy in the face of increasing catastrophic events and reduce the threats from invasive plant species and the subsequent need to control their spread. Having resilient populations that are protected and that we expect to persist distributed across the historical and/or expanded range will reduce the risk of extinction from stochastic and/or catastrophic events.

B. Recovery Objectives and Criteria

Reclassification Objective: Secure the species to a point where it is no longer in danger of extinction throughout all or a significant portion of its range. Achieving this objective requires reducing imminent risks by increasing population redundancy through establishment of additional populations, improving the resiliency of populations, and reducing threats.

1. Demographic criteria
    a. A minimum of four persisting populations across the current distribution (the distribution as of 2018, including the expanded portion of the range containing one introduced population).

b. A persisting population has a site-specific median number of total plants[10] over 5 consecutive years (based on a minimum of one generation) as described below.
    i. Sumner Falls: A median of 113 natural plants (not including augmented plants).
    ii. Hartland Ledges: A median of 132 natural plants (not including augmented plants).
    iii. Jarvis Hill: A median of 477 natural plants (not including augmented plants).

    iv. Introduced sites:
        1. sites similar in area to the Sumner Falls population: a median of 100 plants; and
        2. sites similar in area to the Jarvis Hill population: a median of 400 plants.

2. Threats-abatement criteria
    a. A long-term landowner agreement or other mechanism is in place for each of the persisting historical and introduced populations that provides:
        i. protection against habitat loss. For example, forested buffers are established/maintained between a population and developed land (agricultural land, development, etc.); and
        ii. access for long-term monitoring and management.
    b. A rapid response plan is in place for each of the persisting historical and introduced populations that addresses new threats (e.g., invasive species) and the need for population augmentation (adaptive management).

Delisting Objective: Secure the species to a point where it is not likely to become in danger of extinction throughout all or a significant portion if its range. Achieving this objective requires reducing longer-term risks by further increasing population redundancy through establishment of additional populations, further improving the resiliency of populations, and further reducing threats.

1. Demographic criteria
    a. A minimum of six resilient populations exist across the current distribution (the distribution as of 2018, including the expanded portion of the range containing one introduced population).

[10] Total plant stem counts ensure all age classes are counted.

b. A resilient population has a site-specific median number of plants and a median number of total inflorescences over 8 consecutive years (based on a minimum of three generations) as described below[11].
    i. Historical populations:
        1. Sumner Falls: A median of 113 natural plants (not including augmented plants) and a median of 193 inflorescences.
        2. Hartland Ledges: A median of 132 natural plants (not including augmented plants) and a median of 507 inflorescences.
        3. Jarvis Hill: A median of 477 natural plants (not including augmented plants) and a median of 4337 inflorescences.

    ii. Introduced populations:
        1. sites similar in area to the Sumner Falls population: A median of 100 plants and a median of 193 inflorescences; and
        2. sites similar in area to the Jarvis Hill population: a median of 400 plants and a median of 4337 inflorescences.

2. Threats-abatement criteria
    a. A long-term landowner agreement or other mechanism is in place for each of the six historical and introduced populations that provides:
        i. protection against habitat loss. For example, forested buffers are established/maintained between a population and developed land (agricultural land, development, etc.); and
        ii. access for long-term monitoring and management.
    b. A rapid response plan is in place for each of the six historical and introduced populations that addresses new threats (e.g., invasive species) and the need for population augmentation (adaptive management).

Table 3. Medians for Total Plants based on Brumback and Piantedosi (2018a) summary of survey data (corrected).

	Sumner Falls	**Hartland Ledges**	**Jarvis Hill**
Before 2011	113	132	477
2011 - 2018	32	35	358

[11] Median number of plants and median number of inflorescences provided in tables 3 and 4.

Table 4. Medians for Total Inflorescences based on Brumback and Piantedosi (2018a) summary of survey data (corrected).

	Sumner Falls	Hartland Ledges	Jarvis Hill
Before 2011	193	507	4,337
2011 - 2018	119	284	1,780

PART IV. RECOVERY ACTIONS

1. Establish additional populations

Increasing population redundancy requires establishment of additional populations. Introduced populations should represent the range of genetic diversity in the three populations if it is determined that there is significant genetic diversity among the populations (see Task 3.3). Because no suitable introduction sites have been identified within the historical range, populations must be established at suitable introduction sites outside the historical range.

1.1. Identify suitable habitat for introduction of Jesup's milk-vetch plants based on known suitable habitat parameters and site selection criteria (see F. Conservation Efforts)

1.2. Further evaluate previously identified potential introduction sites along the Connecticut River mainstem and tributaries to verify potential introduction sites.

1.3. Determine seed source to be used for introduced populations at locations based on similar habitat characteristics of historical populations, seed availability and/or genetic information (if known).

1.4. Introduce nursery-grown plants to sites in the historical and expanded range.

1.5. Monitor introduced population establishment and demographic trends.
Use established protocols as outlined in Task 2.1 above to monitor survivorship and fecundity of transplants.

1.5.1. Continue annual monitoring using full counts of the population for at least 8 years or until a stable population trajectory is attained (based on demographic modeling).

1.5.2. Evaluate success of the introduction program based on quantitative evidence of sustainable population increase.

2. Protect historical and introduced populations

Securing Jesup's milk-vetch populations requires protecting them from land and water use impacts that cause habitat loss or degradation or result in direct mortality of plants.

2.1. Protect occupied habitat with conservation easements, management agreements, or acquisition.

Although no historical populations are permanently protected, landowners have allowed access to Jesup's milk-vetch populations for monitoring and habitat management purposes. It is essential to perpetuate and strengthen this collaboration to ensure long-term protection of the populations. Since the entire range of the species lies within the Conte NFWR jurisdictional boundaries, the Conte NFWR has the unique opportunity to partner with landowners to secure protection of occupied habitat and/or potential suitable habitat for future introductions through land acquisition, conservation easements, or management agreements.

2.2. Conserve vegetative buffers at Jesup's milk-vetch populations.

Jesup's milk-vetch populations should have natural, forested vegetative buffers uphill of the plants at the uppermost level of the rock outcrops to provide shading and protection from adjacent agricultural, forestry, residential, or commercial land-use impacts and to minimize introduction of invasive plant species.

2.2.1. Determine optimal extent of a vegetative buffer that protects Jesup's milk-vetch populations from land-use impacts.

2.2.2. Protect vegetated buffers with conservation easements, management agreements, or acquisition.

2.3. Develop protective hydrological management regimes for dams potentially impacting historical and expanded range populations.

2.3.1. Examine normal operation flows (daily and monthly) to assess whether there are effects to the historical and expanded range populations.

2.3.2. Coordinate with the Federal Regulatory Energy Commission, stakeholders and hydropower relicensing applicants to develop flow management regimes that reduce the likelihood of prolonged inundation or scour of habitat during the growing season.

3. Evaluate status of existing populations

Annual quantitative monitoring of historical and expanded range populations is necessary to assess population trends and status. Annual monitoring of Jesup's milk-vetch populations will determine whether augmentation is warranted and whether there are a sufficient number of plants to allow for seed collection. Annual monitoring for the presence and density of invasive plant species will determine recovery management actions needed to maintain viable Jesup's milk-vetch populations, or document new threats from future invasive species.

3.1. Annually monitor natural plants and inflorescences using an established monitoring protocol (appendix 2).

3.2. Annually survey for, and monitor invasive plant species using an established monitoring protocol.

3.3. Conduct genetic analyses to determine levels of variation within and among populations**.**

Genetic studies are critical to understanding the level of isolation and differentiation among populations and thus for determining whether material for potential reintroduction can be mixed among populations. It would be valuable to ascertain the degree of genetic isolation between populations and levels of heterozygosity within populations, by conducting genetic analyses of plants from all three sites. Such analyses will clarify whether populations are suffering from inbreeding depression, whether plants appear to be undergoing adaptive radiation, and whether it is advisable to foster panmixis or to preserve reproductive isolation among the populations.

3.4. Continue to study the life history of the plants, including life span, seed production relative to age, and micro-habitat (e.g., soil depth).

Studies done to date have supported increasingly well-supported speculations re: characteristics of the taxon that will play a major role in recovery of declining populations. However, the small population sizes and rocky habitat make it difficult to test theories and measure basic characteristics. Observational data over multiple years with different habitat conditions will have to continue in order to improve predictions relative to changes in population size and application of effective management activities.

4. Manage Habitat

Securing Jesup's milk-vetch populations requires managing their habitats to reduce threats from invasive plant species, recreational activities, and herbivory. Habitat management carries attendant risks of incidental mortality by altering fragile habitats, damaging plants, and attracting people who may intentionally or unintentionally harm the plants or their habitats. All management activities need to be weighed against the risks of non-action, and conducted in a way that will minimize harm to Jesup's milk-vetch and other associated rare elements at the sites. Documentation of protocols must be thorough and data on outcomes must be taken in a statistically meaningful way so that successes can be replicated elsewhere and future failures averted.

4.1. Develop a rapid response augmentation and invasive plant decision matrix.

- 4.1.1. Develop a set of criteria (may be site-specific) to assess when plant augmentation is needed for declining populations that reach critical levels.
- 4.1.2. Develop a set of criteria to determine when and how invasive plant management should be implemented at a population.

4.2. Develop and implement site-specific long-term management plans.

- 4.2.1. Incorporate rapid-response criteria into the plan to abate threats, including small population size and invasive plant species.
- 4.2.2. Incorporate recreational use management strategies to address potential threats from pedestrian trampling or other recreational activities.

4.2.3. Monitor and address threats from herbivory.

4.2.4. Determine threshold populations levels for each site at which point population augmentation would cease. Although augmentation has been a valuable tool in restoring populations at two of the sites, it is not intended to continue indefinitely.

4.3. Annually assess efficacy of management strategies.
Annually assess the positive and negative outcomes of all management actions taken. Revise iterative management plans or rapid response plans according to these outcomes.

5. Bank seeds and perfect propagation and transplantation techniques
Seed banking provides insurance against catastrophic declines in natural populations by enabling the propagation of seedlings for population augmentation or introduction efforts. Genetic representation of all populations is maintained by collecting and preserving seed from all historical populations. Seeds of all historical Jesup's milk-vetch populations are collected and banked at NEWFS.

5.1. Conduct seed collection at regular intervals based on standardized seed collection protocols.

5.1.1. Collect seed collection at 5-year intervals, except in the instance that a population is in imminent danger of extirpation or in the event that additional seed is needed to institute reintroduction or augmentation programs at the sites.

5.1.2. Follow seed collection protocols developed by the Center for Plant Conservation (Guerrant *et al.* 2004).

5.1.3. Seed collection should not exceed 10 percent of the total seed produced by a given population in the collection season.

5.2. Store and test seeds for viability following an established protocol.
Tests conducted to date indicate that Jesup's milk-vetch seed can remain viable for 10 or more years when stored dry at -20ºC. Examine seed samples from existing stocks periodically for viability and germination percentage to develop a predictive curve for seed survivorship in storage.

5.3. Continue to refine propagation and transplantation techniques to minimize mortality.

5.4. Investigate methods to increase transplantation success for introduced populations, i.e., watering transplants as needed based on conditions vs. no watering, anchoring transplants with plant spackle vs inserting them directly into the substrate, and introducing plants to potential habitat immediately upstream of occupied habitat.

PART V. IMPLEMENTATION SCHEDULE

A. Key to Implementation Schedule

The following Implementation Schedule is a guide for meeting the objectives discussed in Part II of this plan. This schedule indicates recovery action priorities, recovery action numbers, brief recovery action descriptions, duration of recovery actions, the responsible agencies, and lastly, estimated costs. These actions, when accomplished, should bring about the recovery of the species and protect its habitat. Priorities in column one of the following Implementation Schedule are assigned as follows:

Priority 1: An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2: An action that must be taken to prevent a significant decline in the species' population/habitat quality or some other significant negative impact short of extinction.

Priority 3: All other actions necessary to meet the recovery objective.

Key to acronyms and other words or phrases used in the Implementation Schedule:

FWS – U.S. Fish and Wildlife Service
NEWFS – New England Wild Flower Society
NHNHB – New Hampshire Natural Heritage Bureau
TNC – The Nature Conservancy
VTNGNHP – Vermont Nongame and Natural Heritage Program

B. Recovery Plan Implementation Schedule for Jesup's milk-vetch

Action #	Action	Listing Factor	Priority	Estimated cost/year	Task Duration (Years)	Partners	Comments
1.1	Identify suitable habitat for introduction of Jesup's milk-vetch plants based on known suitable habitat parameters and site criteria.	A	1	$10,000	3	NHNHB, VTNGNHP, NEWFS, Conte NFWR	
1.2	Further evaluate previously identified potential introduction sites along the Connecticut River mainstem and tributaries to verify potential introduction sites.	A	2	$10,000	3	NHNHB, VTNGNHP, NEWFS, Conte NFWR	
1.3	Determine seed source to be used for introduced populations at locations based on similar habitat characteristics of historical populations, seed availability and/or genetic information.	A	1	N/A	N/A	NHNHB, VTNGNHP, NEWFS	
1.4	Introduce nursery-grown plants to sites in the historical and expanded range.	A	1	$5,000	Ongoing	NHNHB, VTNGNHP, NEWFS	
1.5	Monitor population establishment and demographic trends.	A	1	$5,000	Ongoing	NHNHB, VTNGNHP, NEWFS, Conte NFWR	
2.1	Protect occupied habitat with conservation easements, management agreements or acquisition.	A	1	$75,000	5	NHNHB, VTNGNHP, TNC, NEWFS, Conte NFWR	
2.2.1	Determine extent of a vegetative buffer that protects Jesup's milk-vetch populations from land-use impacts.	A	2	$5,000	3	NHNHB, VTNGNHP, NEWFS	

Action #	Action	Listing Factor	Priority	Estimated cost/year	Task Duration (Years)	Partners	Comments
2.2.2	Protect vegetated buffers with conservation easements, management agreements or acquisition.	A	2	$50,000	3	NHNHB, VTNGNHP, NEWFS, Conte NFWR	
2.3	Develop protective hydrological management regimes for dams potentially impacting historical and expanded range populations.	A, D	1	N/A	N/A	FERC, NHNHB, VTNGNHP, TNC	
3.1	Annually monitor natural plants and inflorescences using an established monitoring protocol.	A	1	$10,000	Annually	NHNHB, VTNGNHP, NEWFS	
3.2	Annually survey for and monitor invasive plant species using an established monitoring protocol.	A	1	$5,000	Annually	NHNHB, VTNGNHP, NEWFS	
3.3	Conduct genetic analyses to determine levels of inbreeding and degree of genetic isolation among populations.	A	3	$15,000	1	NHNHB, VTNGNHP	
3.4	Continue to study the life history of Jesup's milk-vetch, including life span, seed production relative to age, and micro-habitat (e.g. soil depth).	D	3	$10,000	3	NHNHB, VTNGNHP, NEWFS	
4.1	Develop a rapid response augmentation and invasive plant decision matrix.	A	1	$8,000	1	NHNHB, VTNGNHP, NEWFS	
4.2	Develop and implement site-specific long-term management plans.	A	1	$8,000	8	NHNHB, VTNGNHP, NEWFS, Conte NFWR	
4.2.3	Monitor and address threats from herbivory.	E	2	$1,000	Annually	NHNHB, VTNGNHP, NEWFS	

Action #	Action	Listing Factor	Priority	Estimated cost/year	Task Duration (Years)	Partners	Comments
4.3	Annually assess efficacy of management strategies.	A, E	1	N/A	N/A	NHNHB, VTNGNHP, NEWFS, Conte NFWR	
5.1	Conduct seed collection at regular intervals based on standardized seed collection protocols.	A	1	$5,000	Annually	NHNHB, VTNGNHP, NEWFS	
5.2	Store and test seeds for viability.	A	1	$2,000	Annually	NEWFS	
5.3	Continue to refine propagation and transplantation techniques to minimize mortality.	A	2	$5,000	3	NEWFS	
5.4	Investigate methods to increase transplantation success for introduced populations.	A	2	$3,000	3	NEWFS	

LITERATURE CITED

Bailey, S. W. 2007. Preliminary report on a geoecological investigation of Astragalus robbinsii var. jesupii habitat. Northern Research Station, U. S. Forest Service. Campton, New Hampshire, USA.

Barneby, R. C. 1964. *Atlas of North American* Astragalus. Two volumes. New York Botanical Garden, Bronx, New York.

Borton, M. C., B. E. Becker, T. Scannell and G. Mitchell (Editors). 1990. The Complete Boating Guide to the Connecticut River. Embassy Marine Publishing, Connecticut River Watershed Council, Easthampton, Massachusetts.

Brackley, F. and E. Thompson. 1985. Global status report, *Astragalus robbinsii* var. *jesupi*. Unpublished report for U.S. Dept. of the Interior, Office of Endangered Species, Region 5. New Hampshire Natural Heritage Inventory, Concord, New Hampshire.

Brumback W. 2009. Report on transplants, seed collection, and seed germination of *Astragalus robbinsii* var. *jesupii* (Jesup's milk-vetch) during 2008. Report submitted to U.S. Fish and Wildlife Service, Concord, NH. 7 pp.

Brumback, W. 2018a. Electronic transmission to S. von Oettingen dated December 12, 2018. Re: Part 1 Revised JMV plan with attachments.

Brumback, W. 2018b. Electronic transmission to S. von Oettingen dated December 18, 2018.

Brumback W. and J. Gerke. 2013. Establishment of the federally endangered Jesup's milk vetch (*Astragalus robbinsii* var. *jesupii*): 2012 Activities. Report to the Vermont Agency of Natural Resources/Fish and Wildlife Department. 19 pp.

Brumback, W. and M. Piantedosi. 2017. Establishment of the federally endangered Jesup's milk vetch (*Astragalus robbinsii* var. *jesupii*): 2016 Activities. Report to the Vermont Agency of Natural Resources/Fish and Wildlife Department. 19 pp.

Brumback, W. and M. Piantedosi. 2018a. Jesup's milkvetch conservation – Seedling propagation and population augmentation. Report to the U.S. Fish and Wildlife Service, Concord, NH. 17 pp.

Brumback, W. and M. Piantedosi. 2018b. Establishment of the federally endangered Jesup's milk vetch (*Astragalus robbinsii* var. *jesupii*): 2017 Activities. Report to the Vermont Agency of Natural Resources/Fish and Wildlife Department. 22 pp.

Brumback W. and E. Schaeffer. 2014. Establishment of the federally endangered Jesup's milk vetch (*Astragalus robbinsii* var. *jesupii*): 2013 Activities. Report to the Vermont Agency of Natural Resources/Fish and Wildlife Department. 22 pp.

Britton, N. L. 1901. *Manual of the Flora of the Northern States and Canada*. H. Holt and Co., New York.

Cairns, Sara. 2018. Electronic transmission dated December 11, 2018 to S. von Oettingen, USFWS New England Field Office, Concord, NH. Comments regarding Part I of draft revised recovery plan, with attachment.

Crow, G. E. 1982. New England's rare, threatened, and endangered plants. U.S. Department of the Interior, U.S. Fish and Wildlife Service. Washington, D. C.

Dunlop, D. 1994. 1994 Recovery work on *Astragalus robbinsii* var. *jesupii* (Jesup's milk-vetch). Report prepared for the New Hampshire Natural Heritage Inventory and The Nature Conservancy, Concord, New Hampshire.

Farnsworth, E. J. 2004. Patterns of plant invasions at sites with rare plant species throughout New England. *Rhodora* 106: 97-117.

Farnsworth, E. 2008. Jesup's milk-vetch (Astragalus robbinsii var. jesupii) rare plant monitoring and recovery update and reintroduction plan, Draft I, February 2008. Report to the New Hampshire Natural Heritage Bureau, Concord, NH. 48 pp.

Farnsworth, E. and L. Harvey. 2004. Jesup's milk-vetch (*Astragalus robbinsii* var. *jesupii*) recovery plan draft update/revision, 15 September 2004. Report to the U.S. Fish and Wildlife Service, Concord, NH. 51 pp.

Fitzhugh, T.W. and R.M. Vogel. 2010. The impact of dams on flood flows in the United States. River Res. Applications. Published online in Wiley InterScience. 24 pp. http://engineering.tufts.edu/cee/people/vogel/documents/impactsOfDams.pdf.

Guerrant, E. O., P. L. Fiedler, K. Havens and M. Maunder. 2004. Revised genetic sampling guidelines for conservation collections of rare and endangered plants. Pages 419-442 in E. O. Guerrant *et al*. (Editors), *Ex Situ Plant Conservation: Supporting Species Survival in the Wild*. Island Press, Washington, D. C.

Hayhoe, K., D.J. Wuebbles, D.R. Easterling, D.W. Fahey, S. Doherty, J. Kossin, W. Sweet, R. Vose and M. Wehner. 2018: Our Changing Climate. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 72–144. doi: 10.7930/NCA4.2018.CH2

IPCC. 2014. Climate Change 2014: Synthesis Report. Contribution of Work Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pauchari and L.A. Meyer (eds.)] IPCC, Geneva, Switzerland, 151 pp.

Kane, C. 2009. Ast*ragalus robbinsii var. jesupii* (Jesup's milk vetch) rare plant recovery and reintroduction: 2009 life history and habitat characterization study. Report submitted to the New Hampshire Natural Heritage Bureau, Concord, NH. 6 pp.

Kane, C. 2011a. Jesup's milk vetch (*Astragalus robbinsii* var. *jesupii*) Rare plant recovery and reintroduction: 2010 life history and habitat characterization study. Report submitted to the New Hampshire Natural Heritage Bureau, Concord, NH. 7 pp.

Kane, C. 2011b. Jesup's milk vetch (*Astragalus robbinsii* var. *jesupii*) rare plant recovery and reintroduction: 2011 life history and habitat characterization study. Report submitted to the New Hampshire Natural Heritage Bureau, Concord, NH. 11 pp.

Kane, C. 2011c. Investigation of the effects of elevated river levels on (*Astragalus robbinsii* var. *jesupii*) Jesup's milk vetch, a Connecticut River endemic. Report submitted to the New Hampshire Natural Heritage Bureau, Concord, NH. 26 pp.

Kane, C. 2013. Investigation of bedrock ledges along the Connecticut River and tributaries for potential introduction sites for Jesup's milk-vetch. Report submitted to the New Hampshire Natural Heritage Bureau, Concord, NH. 46 pp.

Kartesz, J. T. 1994. *A Synonymized Checklist of the Vascular Flora of the U.S., Canada, and Greenland*. Second Edition. Two volumes. Timber Press, Portland, Oregon.

Mabberly, D. J. 1993. *The Plant-Book: A Portable Dictionary of the Higher Plants*. Cambridge University Press, Cambridge, UK.

Magilligan, F J. and K.H. Nislow. 2005. Changes in hydrologic regime by dams. Geomorphology 71:61–78.

Menges, E. S. 1998. Evaluating extinction risks in plant populations. Pages 49-65 in P. L. Fiedler and P. M. Kareiva (Editors), *Conservation Biology for the Coming Decade.* Second Edition. Chapman and Hall, New York, New York.

Morris, W. F. and D. F. Doak. 2002. *Quantitative Conservation Biology: Theory and Practice of Population Viability Analysis*. Sinauer Associates, Sunderland, Massachusetts.

NatureServe. 2018a. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: December 14, 2018).

NatureServe. 2018b. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: December 14, 2018). https://www1.usgs.gov/csas/nvcs/nvcsGetUnitDetails?elementGlobalId=690014

New Hampshire Natural Heritage Bureau [NHNHB]. 2003. 2002 *Astragalus robbinsii* var. *jesupii* (Jesup's milk-vetch) recovery activities in New Hampshire. Report submitted to the U.S. Fish and Wildlife Service, Hadley, Massachusetts.

New Hampshire Natural Heritage Bureau [NHNHB]. 2004. 2003 and 2004 Monitoring results for *Astragalus robbinsii* var. *Jesupii* (Jesup's Milk-Vetch) at three sites along the Connecticut River. Report to the U.S. Fish and Wildlife Service. Hadley, Massachusetts. 36 pp.

New Hampshire Natural Heritage Bureau [NHNHB]. 2005. 2005 *Astragalus robbinsii* var. *jesupii* (Jesup's milk-vetch) recovery activities in New Hampshire. Report submitted to the U.S. Fish and Wildlife Service. Hadley, Massachusetts. 46 pp.

New Hampshire Natural Heritage Bureau [NHNHB]. 2008. 2007 *Astragalus robbinsii* var. *jesupii* (Jesup's milk-vetch) recovery activities in New Hampshire. Report submitted to the U.S. Fish and Wildlife Service. Hadley, Massachusetts.

New Hampshire Natural Heritage Bureau [NHNHB]. 2011. 2011 Jesup's milk-vetch (*Astragalus robbinsii* var. *jesupii*) recovery activities in New Hampshire. Report submitted to the U.S. Fish and Wildlife Service. Hadley, Massachusetts. 41 pp.

New Hampshire Natural Heritage Bureau [NHNHB]. 2014. Expected effects of climate change on a globally rare plant: Jesup's milk-vetch (*Astragalus robbinsii* var. *jesupii*). Report submitted to the U.S. Fish and Wildlife Service. Hadley, Massachusetts. 33 pp.

New Hampshire Natural Heritage Bureau [NHNHB]. 2017. Final Performance Report of Grant Award No. F16AP00306 Endangered, Threatened, Rare Plant Conservation Program, New Hampshire Natural Heritage Bureau (NHB) Jesup's milk-vetch (*Astragalus robbinsii* var. *jesupii*). Report submitted to the U.S. Fish and Wildlife Service. Hadley, Massachusetts. 11 pp.

New Hampshire Natural Heritage Inventory [NHNHI]. 2000. 1999 *Astragalus robbinsii* var. *jesupii* (Jesup's milk-vetch) recovery activities. Unpublished report, U.S. Fish and Wildlife Service. Hadley, Massachusetts. 31 pp.

New Hampshire Natural Heritage Inventory [NHNHI]. 2001. 2000 *Astragalus robbinsii* var. *jesupii* (Jesup's milk-vetch) recovery activities. Unpublished report submitted to the U.S. Fish and Wildlife Service. Hadley, Massachusetts. 47 pp.

New Hampshire Natural Heritage Inventory [NHNHI]. 2002. 2001 *Astragalus robbinsii* var. *jesupii* (Jesup's milk-vetch) recovery activities. Unpublished report submitted to the U.S. Fish and Wildlife Service. Hadley, Massachusetts. 45 pp.

Nislow K. H., F. J. Magilligan, H. Fassnacht, D. Bechtel and A. Ruesink. 2002. Effects of dam impoundment on the flood regime of natural floodplain communities in the upper Connecticut river. *Journal of the American Water Resources Association* 38: 1533-1548.

Normandeau Associates Inc. 2013. TransCanada Hydro Northeast Inc. Wilder Project Jesup's Milk Vetch Hydrologic Study Final Report. 56 pp.

Nothnagle, P. 1997. Progress report on NHHP Contract # NHH 060997-02 (Investigations of hydrological data with regard to *Astragalus robbinsii* var. *jesupii*). Unpublished report available from New Hampshire Natural Heritage Inventory, Concord, New Hampshire.

Nothnagle, P. 1998. Investigations of hydrological data with regard to *Astragalus robbinsii* var. *jesupii* in New Hampshire. Unpublished report submitted to the New Hampshire Natural Heritage Inventory, Concord, New Hampshire. 26 pp.

Nothnagle, P. 1999. The location and elevation of benchmarks established at Jesup's milk-vetch (*Astragalus robbinsii* var. *jesupii*) sites along the Connecticut River in New Hampshire. Unpublished report submitted to the New Hampshire Natural Heritage Inventory, Concord, New Hampshire. 26 pp.

Popp, R. 1992. Monitoring and searching for populations of Jesup's milk-vetch (*Astragalus robbinsii* var. *jesupii*) in Vermont. 1992 Performance Report for the U.S. Fish and Wildlife Service, Region 5 Office, Newton Corner, Massachusetts.

Popp, R. 2018. Electronic transmission to S. von Oettingen dated August 22, 2018. Re: Updated Recovery Plan for Astragalus.

Popp, R. and C. Kane. 2012. Investigation of bedrock ledges along Connecticut River for potential introduction sites for Jesup's Milk-vetch. Final report of activities and findings of 2011 field surveys. Submitted to the New Hampshire Charitable Foundation. 44 pp.

Runkle, J., K. Kunkel, D. Easterling, R. Frankson and B. Stewart, 2017a. New Hampshire State Climate Summary. NOAA Technical Report NESDIS 149-NH, 4 pp.

Runkle, J., K. Kunkel, S. Champion and L-A. Dupigny-Giroux, 2017b. Vermont State Climate Summary. NOAA Technical Report NESDIS 149-VT, 4 pp.

Rustad, L., J. Campbell, J.S. Dukes. T. Huntington, K.F. Lambert, J. Mohan and N. Rodenhouse. 2012. Changing Climate, Changing Forests: The Impacts of Climate Change on Forests of the Northeastern United States and Eastern Canada. Gen. Tech. Rep. NRS-99. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 48 p.

Sanderson, M. J. and M. E. Wojciechowski. 1996. Diversification rates in a temperate legume clade: Are there "so many species" of *Astragalus* (Fabaceae)? *American Journal of Botany* 83: 1488-1502.

Smith, D.R., N.L. Allan, C.P. McGowan, J.A. Szymanski, S.R. Oetker and H.M. Bell. 2018. Development of a species status assessment process for decisions under the U.S. Endangered Species Act, Journal of Fish and Wildlife Management 9(1):302–320.

U.S. Fish and Wildlife Service [USFWS]. 1989. Jesup's milk-vetch (*Astragalus robbinsii* var. *jesupii*) recovery plan. U.S. Fish and Wildlife Service, Region 5. Concord, New Hampshire. November 21, 1989. http://ecos.fws.gov/recovery_plan/pdf_files/ 1989/891121.pdf (accessed 28 August 2001).

U.S. Fish and Wildlife Service [USFWS]. 1990. Recovery plan for the endangered and threatened species of Ash Meadows, Nevada. U.S. Fish and Wildlife Service, Portland, Oregon.

U.S. Fish and Wildlife Service [USFWS]. 1998. Applegate's milk-vetch (*Astragalus applegatei*) Recovery plan. U.S. Fish and Wildlife Service, Portland, Oregon.

w^{3}Tropicos Database. 2004. *Astragalus robbinsii* var. *jesupii* Eggl. & E. Sheld. Nomenclatural Database, Missouri Botanical Garden. Available at http://mobot.mobot.org/cgi-bin/search_vast (accessed 22 August 2004).

Wake, C. P., C. Keeley, E.A. Burakowski, P. Wilkinson, K. Hayhoe, A. Stoner and J. LaBrance. 2014. Climate change in Northern New Hampshire: past, present and future. The Sustainability Institute. 1. 77 pp.

Young, B., K. R. Hall, E. Byers, K. Gravuer, G. Hammerson, A. Redder, and K. Szabo. 2012. Rapid assessment of plant and animal vulnerability to climate change. In: Wildlife Conservation in a Changing Climate, Chapter: 7, University of Chicago Press, Ed. J. F. Brodie, E. Post, and D. F. Doak, pp.129-152

APPENDICES

Appendix 1. List of *Astragalus robbinsii* var. *jesupii* herbarium specimens[12]

State	Town	Date	Collector	Herbarium and Accession #	Site and Notes
NH	Plainfield	1876, June	H. Jesup	SPR	"In crevices of rocks on banks of Conn't River, with *A. robbinsii*"
NH	Plainfield	1876, June	H. Jesup	SPR	"Plainfield, N.H. – in crevices of rocks"
NH	Plainfield	1877, 2 June	H. Jesup	GH 2	"Sumner Falls in Connecticut River"
NH	Plainfield	1877, 2 July	No data	HNH	"Rocks, Sumner Falls"
NH	Plainfield	1877, 3 June	H Jesup	NY	"Plainfield, Connt. River on rocks at Sumner Falls"
NH	Plainfield	1893, 1 July	W. Eggleston	NEBC	"Dry river ledges above high water, Sumner Falls"
NH	Plainfield	1893, 1 July	E. T. Sheldon and W. W. Eggleston	VT	"Sumner Falls"
NH	Plainfield	1893, 7 June	W. Eggleston	GH	"Dry river ledges above high water, Sumner Falls"
NH	Plainfield	1881, 29 May	G. H. Leland	NEBC	"Hart's Island" Annotated in 1968 by A. R. Hodgdon as "Hart's Island I believe is in NH.
NH	Plainfield	1881, 29 May	G. H. Leland	VT	"Hart's Island; Hartland. Jesup & Leland's station, below Lull Brook" (note, this could be a Vermont population)
NH	Plainfield	1894, 22 May	W. Eggleston	GH	"Sumner Falls"
NH	Plainfield	1898, 26 July	W. Eggleston	HNH	"Sumner Falls"
NH	Plainfield	1896, 30 May	W. Eggleston	HNH	"Sumner Falls"
NH	Plainfield	1926, 13 July	A. Pease	NEBC 19741	"Sandy and gravelly bank of river, Sumner Falls"
NH	Plainfield	1926, 13 July	A. Pease	MASS 48244A	"Plainfield – Sumner Falls"
NH	Plainfield	1955, 13 July	A. Hodgdon, F. L. Steele	NHA	"Rocky shore on Conn R at Sumner Falls with *Alnus crispa, Carpinus, Ulmus*"
NH	Plainfield	1978, 4 June	F. Brackley	NHA	"Rocky bank below Sumner Falls, shore of Conn. R. with *Mimulus moschatus, Senecio pauperculus, Tofieldia glutinosa*"

[12] Data provided by New Hampshire Natural Heritage Bureau. Most specimens have been confirmed through the Herbarium Recovery Project of NEWFS. Herbarium abbreviations follow the Index Herbariorum.

State	Town	Date	Collector	Herbarium and Accession #	Site and Notes
NH	Claremont	1956, 28 June	A. Hodgdon, F. L. Steele	NEBC 9543	"Locally common on ledges of Connecticut River, north of Ashley's Ferry"
NH	Plainfield	1981, 6 July	P. Zika	NEBC 4006	"Thirty branched, sprawling plants on dry ledges, Sumner Falls, Connecticut River"
VT	Hartland	1891, 7 June	W. Eggleston	MIN	Type locality
VT	Hartland	1894, 20 May	W. Eggleston	GH	"Rocky shore, Connecticut River, below Lull Brook"
VT	Hartland	1894, 20 May	W. Eggleston	NEBC	
VT	Hartland	1894, 20 May	W. Eggleston	NEBC	"Hartland, below mouth of Lull Brook"
VT	Hartland	1894, 20 May	W. Eggleston	GH	"Rocky river shores just above high water mark, Connecticut River"
VT	Hartland	1894, 20 May	W. Eggleston	NEBC	"Hartland"
VT	Hartland	1894, 28 June	W. Eggleston	NEBC	
VT	Hartland	1894, 28 June	W. Eggleston	GH	
VT	Hartland	1895, 30 May	W. Eggleston	GH	
VT	Hartland	1896, 11 May	W. Eggleston	NEBC	
VT	Hartland	1896, 20 May	W. Eggleston	NEBC	Fruiting specimen on same sheet collected on 27 June 1898
VT	Hartland	1896, 30 May	W. Eggleston	NEBC	
VT	Hartland	1896, 30 May	W. Eggleston	GH	"Rocky shore, Connecticut River"
VT	Hartland	1897, July	J. A. Bates	SPR	No data
VT	Hartland	1898, 26 June	W. Eggleston	NEBC	
VT	Hartland	1916, 11 June	L. Wheeler	NEBC 156501	"Connecticut River ledges"
VT	Hartland	1918, 7 July	C. Knowlton	NEBC	"Dry ledge by river, Hartland"

Appendix 2**.** Standard Population Survey Protocol. Standard protocol established in 1999 (NHNHB 2009, revised 2018)

The standard JMV census protocol is to:

1) relocate permanent bolts in bedrock outcrops;
2) stretch tapes between bolts to mark off a search grid;
3) search each cell of the grid for JMV, counting total number of plants, number inflorescences per plant and total number of inflorescences (0, 1-2, 3-9, 10 or more, etc.). A plant is defined as all stems emerging within one inch of each other; and
4) make a second search of each cell counting stems of invasive species.

The permanent bolts are arranged at regular intervals in two parallel, horizontal lines. They demarcate low, middle, and upper transects relative to river height (Nothnagle 1999). Transects start (0 m) on the upstream end of each site.

- At Sumner Falls, bolts extend for 30 m along the river bank at 5-m intervals.
- At Hartland Ledges, bolts extend for 110 m at 10-m intervals.
- At Jarvis Hill, two subpopulations are divided by a ca. 40-m stretch of steep, vegetated bank habitat with no JMV plants. Both the upstream (JH-US) and downstream (JH-DS) subpopulations have bolts extending for 140 m at 20-m intervals.

The invasive species typically counted are: cypress spurge (*Euphorbia cyparissias*), black swallowwort (*Cynanchum louiseae*), Morrow's honeysuckle (*Lonicera morrowii*), and purple loosestrife (*Lythrum salicaria*), and poison ivy (*Toxicodendron radicans*).

Drought, flooding, and ice scouring have been identified as important variables likely to affect the three populations of Jesup's milk-vetch. Streamflow measures are based on U.S. Geological Survey data for the West Lebanon, NH gage (Station # 01144500), which is located 11.5 km upstream of Sumner Falls and 15 km upstream of Hartland Ledges (http://waterdata.usgs.gov/nwis/sw). Precipitation data is obtained from the Army Corps of Engineers web site (http://www.reservoircontrol.com) at the nearest available reporting rain gage, located at the North Hartland Dam, which is approximately 5 km upstream from Sumner Falls and 9 km from Hartland Ledges.

Appendix 3**.** Species reported in the vicinity of Jesup's milk-vetch.

Jarvis Hill	
Species	**Year**
Acer negundo	1984
Achillea millefolium	1984, *1994*
Allium schoenoprasum var. *sibiricum*	*1994*
Amelanchier sp.	1984
Amphicarpa bracteata	1984
Anemone canadensis	*1994*
Antennaria pantaginifolia	1984, *1994*
Anthoxylum odoratum	1984
Apios americana	1984, *1994*
Apocynum sp.	*1994*
Aquilegia canadensis	1984, *1994*
Asclepias incarnata	*1994*
Asclepias syriaca	1984
Aster sp.	*1994*
Bidens sp.	*1994*
Campanula rotundifolia	1984, *1994*
Cardamine sp.	*1994*
Carex crinita	*1994*
Carex garberia	*1994*
Cerastium arvense	*1994*
Chrysanthemum leucanthemum	1984, *1994*
Crataegus sp.	*1994*
Cynanchum nigrum	1984
Daucus carota	1984, *1994*
Deschampsia cespitosa	1984
Diervilla lonicera	1984, *1994*
Eleocharis sp.	*1994*
Equisetum arvense	*1994*
Erigeron pulchellus	1984
Erigeron sp.	1984, *1994*
Euphorbia cyparissias	*1994*
Fragaria virginiana	1984. *1994*
Galium sp.	1984, *1994*
Hieracium pratense	1984
Houstonia caerulea	1984, *1994*
Hypericum perforatum	1984, *1994*
Hypericum pyramidatum	*1994*
Impatiens capensis	*1994*
Iris sp.	*1994*
Lespedeza sp.	1984
Lonicera sp.	*1994*
Lychnis flos-cuculi	1984, *1994*
Lysimachia nummularia	1984, *1994*
Lythrum salicaria	1984, *1994*
Medicago sativa	*1994*
Melilotus alba	*1994*
Mimulus sp.	1984

Jarvis Hill	
Species	**Year**
Myosotis sp.	*1994*
Oenothera perennis	1984, *1994*
Onoclea sensibilis	1984
Orobanche uniflora	1984, *1994*
Oxalis sp.	*1994*
Panicum sp.	1984, *1994*
Pantago major	1984
Parthenocissus quinquefolia	*1994*
Pedicularis canadensis	*1994*
Poa sp.	1984
Potentilla anserina	*1994*
Potentilla simplex	1984
Rosa blanda	1984, *1994*
Rubus sp.	*1994*
Rudbeckia sp.	*1994*
Rumex acetosella	1984
Salix sp.	1984, *1994*
Saxifraga virginiensis	*1994*
Senecio pauperculus	1984, *1994*
Sisyrinchium montanum	*1994*
Smilacina stellata	1984
Solanum dulcamara	*1994*
Solidago sp.	1984, *1994*
Spiraea latifolia	1984, *1994*
Spiranthes lucida	1984
Stellaria media	*1994*
Stellaria sp.	1984
Tanacetum vulgare	1984
Taraxacum officinale	*1994*
Thalictrum thalictroides	*1994*
Toxicodendron radicans	1984, *1994*
Trifolium arvense	*1994*
Trifolium aureum	1984
Ulmus americana	1984
Ulmus rubra	*1994*
Vaccinium angustifolium	*1994*
Verbascum thapsus	1984
Veronica officinalis	1984
Vicia craca	1984

Hartland Ledges	
Species	**Year**
Acer saccharinum	1984
Allium schoenoprasium var. sibiricum	1984, *1994*
Alnus rugosa	*1994*
Andropogon gerardii	1984
Anemone canadensis	1984, *1994*
Apocynum cannabinum	1984
Arigeron philadelphicus	1984
Asclepias incarnata	*1994*
Calamagrostis canadensis	1984
Campanula rotundifolia	1984, *1994*
Carex garberi	*1994*
Carex sp.	1984
Cerastium arvense	1984
Chrysanthemum leucanthemum	1984, *1994*
Clematis virginiana	1984
Cornus rugosa	1984
Cynanchum nigrum	1984, *1994*
Daucus carota	1984
Deschampsia cespitosa	1984
Desmodium glutinosum	1984
Eleocharis sp.	1984
Equisetum arvense	1984
Erigeron pulchellus	*1994*
Eupatorium maculatum	1984
Euphorbia cyparissias	*1994*
Fragaria virginiana	1984
Fraxinus americana	1984
Galium mollugo	1984
Galium sp.	*1994*
Galium triflorum	1984
Geranium sp.	*1994*
Hypericum perforatum	1984, *1994*
Hypericum pyramidatum	1984
Juncus dudleyi	1984
Lespedeza sp.	*1994*
Lonicera canadensis	*1994*
Lonicera tartarica	1984
Lychnis flos-cuculi	*1994*
Lysimachia ciliata	1984
Lysimachia nummularia	1984, *1994*
Lysimachia vulgaris	1984
Melilotus alba	1984
Oenothera perennis	*1994*
Onoclea sensibilis	1984
Panicum lanuginosum	1984
Parthenocissus quinquefolius	1984
Poa compressa	1984
Polygala verticillata	1984
Populus balsamifera	1984

Hartland Ledges	
Species	**Year**
Prunus depressa	1984
Rosa blanda	1984
Rubus odoratus	1984, *1994*
Salix sp.	*1994*
Saxifraga virginiensis	*1994*
Sedum sp.	*1994*
Senecio pauperculus	1984, *1994*
Sisyrinchium montanum	*1994*
Solidago nemoralis	1984
Solidago sp.	1984, *1994*
Spiranthes lucida	1984, *1994*
Stellaria media	*1994*
Thelypteris palustris	1984
Tovara virginiana	1984
Toxicodendron radicans	1984, *1994*
Trifolium arvense	*1994*
Verbascum thapsus	*1994*
Veronica serpyllifolia	1984

Sumner Falls	
Species	**Year**
Acer negundo	1984
Achillea millefolium	*1994*
Alnus rugosa	1984
Amelanchier sp.	*1994*
Andropogon gerardii	1984
Anemone virginiana	1984
Antennaria plantaginifolia	1984, *1994*
Apios americana	1984
Apocynum androsaemifolium	1984
Apocynum sibiricum	1984
Aquilegia canadensis	1984
Aster novae-belgii	1984
Carex sp.	1984
Carex pensylvanica	*1994*
Carex sprengellii	1984
Cerastium vulgatum	1984, *1994*
Cornus rugosa	1984
Crataegus sp.	*1994*
Desmodium canadense	1984
Desmodium glutinosum	1984
Diervilla lonicera	1984
Eleocharis sp.	*1994*
Eragrostis cf. *pilosa*	1984
Erigeron anuus	1984
Euphorbia cyparissias	1984
Fragaria virginiana	1984
Fraxinus americana	*1994*
Hemerocallis sp.	1984
Hesperis matronalis	1984
Hieracium sp.	1984
Houstonia caerulea	*1994*
Hypericum perforatum	1984
Hypericum sp.	*1994*
Iris versicolor	1984
Juniperus sp.	*1994*
Linaria vulgaris	1984
Lonicera dioica	1984
Lonicera sp.	1984, *1994*
Lychnis flos-cuculi	1984
Lysimachia quadrifolia	1984
Lythrum salicaria	1984
Matteuccia struthiopteris	1984
Melilotus alba	1984
Onoclea sensibilis	1984
Panicum clandestinum	1984
Panicum lanuginosum	1984
Parthenocissus quinquefolius	1984
Phalaris arundinacea	1984
Physostegia virginiana	1984
Platanus occidentalis	1984

Sumner Falls	
Species	**Year**
Poa compressa	1984
Polygonum sp.	1984
Populus balsamifera	1984
Potentilla anserina	*1994*
Potentilla sp.	*1994*
Prunus virginiana	*1994*
Ranunculus acris	1984
Rubus alleghaniensis	1984
Rubus odoratus	1984
Rubus sp.	*1994*
Saponaria officinalis	1984
Senecio obovatus	1984
Senecio pauperculus	*1994*
Sisyrinchium sp.	1984
Smilacina racemosa	1984
Solanum nigrum	1984
Solidago graminifolia	1984
Solidago sp.	1984
Spiraea latifolia	1984
Stellaria graminea	*1994*
Tanacetum vulgare	1984
Taxus canadensis	*1994*
Thalictrum polygamum	1984
Tilia americana	1984, *1994*
Toxicodendron radicans	1984, *1994*
Tussilago farfara	*1994*
Ulmus americana	1984, *1994*
Verbena hastata	1984
Viola sp.	*1994*
Vitis riparia	1984
Vitis sp.	*1994*
Zizia aurea	*1994*

1984 = community-level floristics surveys by Rawinski *et al*. (unpublished data from New Hampshire Natural Heritage Bureau); *1994* = Floristics data gathered by Debra Dunlop in censuses of permanent plots. Since different methodologies were used, the data should not be used for inferring species gain or loss from sites. Systematic data on species associates have not been gathered since that time. Species in bold occur at all three sites (Farnsworth 2004).

Appendix 4. Total plant and inflorescence counts for all populations, 1997 – 2018.

	Total Plants			Total Inflorescences		
Year	**Sumner Falls**	**Hartland Ledges**	**Jarvis Hill**	**Sumner Falls**	**Hartland Ledges**	**Jarvis Hill**
1997	117	94	234			
1998	116	225	431			
1999	154	111	623	257	697	5,904
2000	42	21	295	51	30	1,175
2001	131	226	1,160	551	615	8,428
2002	81	177	1,798	123	607	8,284
2003	7	33	364	25	25	764
2004	149	426[2]	1,096	124	504	3,997
2005	105	160[2]	--	1,448	2,334	25,884
2006	25	59[2]	430[4]	61	16	1,013
2007	148	185	--	202	188	7,214[5]
2008	99	145[2]	> 406	261	682	1,604[5]
2009	109	5[2]	> 688	184	41	4,218[5]
2010	135	119	> 522	337	510	4,456[5]
2011	33	35[5]	137	12	35[5]	237
2012	10	7	358	4	8	277
2013	12	6	243	21	18	873
2014	18	10[6]	232	98	113	1,868
2015	38	50	401	139	219	1,939
2016	50	35	488	462	480	5,071
2017	32	89	740	203	384	3,318
2018	85	68	565	230	88	1692

Data from Brumback and Pientedosi 2018a.

Appendix 5. Stem counts for invasive species, 2002-2018, at Hartland Ledges (HL) and Sumner Falls (SF).

Site	Year	BS	CS	MH	PI	PL
SF	2002	14	293	4		
SF	2003	9		2		
SF	2004	89	802	12	132	4
SF	2005	112	303	1	68	3
SF	2006	165	205	4	89	
SF	**2007**	235	627	6	138	11
SF	**2008**	69	512	1	113	
SF	2009	30	510		185	1
SF	2010	58	431	1	189	11
SF	2011	53	445	1	120	
SF	**2012**	68	192	8	341	
SF	2013	17	222		148	15
SF	2014	55	345	1	169	
SF	**2015**[1]	109	425		403	18
SF	2016	15	495		79	19
SF	2017	60	278		157	3
SF	2018	100	242	2	111	
HL	**2002**	478	62	32		73
HL	**2003**	362		15		20
HL	**2004**	938	83	26	1446	57
HL	**2005**	1038	237	36	2187	63
HL	**2006**	1559	186	12	1808	203
HL	**2007**	999	339	12	1441	58
HL	**2008**	498	333	6	2327	13
HL	2009	250	149	1	960	34
HL	**2010**	635	226		1537	35
HL	2011*	114	214	3	1076	19
HL	**2012**	344	127	3	1488	88
HL	2013	165	131	21	1109	57
HL	**2015**[1]	520	320	2	1285	212
HL	2016	36	21		67	89
HL	2017	172	560	20	767	2
HL	2018	276	392	33		85

BS = black swallowwort, CS = Cypress spurge, MH = Morrow's honeysuckle, PI = poison ivy, and PL = purple loosestrife. **Year** in bold = herbiciding occurred after the census. Shaded cells: that species not counted (Brumback and Pientedosi 2018a).

Appendix 6. Stem counts for invasive species, 2002-2018, at Jarvis Hill.

Site	Year	BS	CS	MH	PI	PL
JH-US	2002			6		1
JH-US	2003			26		2
JH-US	2004*			28	987	252
JH-US	2005		1	29	1416	10
JH-US	2006	20		25	1737	396
JH-US	2007			20	924	485
JH-US	2008*			48	1905	268
JH-US	2009*					
JH-US	**2010**					
JH-US	2011			18		
JH-US	**2012**			12		
JH-US	2013			8		
JH-US	2014*				Abundant	
JH-US	2015	14		9	2242+	83
JH-US	**2016**[1]			13	4,312	224
JH-US	2017	0		7	2546	30
JH-US	2018	0		6	2380	127
JH-DS	2002	11	1	3		
JH-DS	2003	395	39	5		
JH-DS	2004*	106				
JH-DS	2005	73	80	8	1155	53
JH-DS	2006	166	129	15	3730	335
JH-DS	2007*	600			91	51
JH-DS	2008*	414	116	12	844	89
JH-DS	2009	773	141	29	1761	63
JH-DS	**2010***	415		8		
JH-DS	2011*	541 (231)	145	8 (6)	499 (424)	266 (237)
JH-DS	**2012**	332		12		
JH-DS	2013	225		4		210
JH-DS	2014*	present		some	present	Present
JH-DS	2015	382	1	23	1352	207
JH- DS	2016	540	76	5	1852	162
JH- DS	2017	206	39	10	1646	95
JH-DS	2018	617	34	26	2055	103

JH, US = Upstream, DS = Downstream (Brumback and Pientedosi 2018a). BS = black swallowwort, CS = Cypress spurge, MH = Morrow's honeysuckle, PI = poison ivy, and PL = purple loosestrife. Year in bold = herbiciding occurred after the census. Shaded cells: that species not counted.

Appendix 7. Augmentation efforts at historical population from 1998 to 2018.

	Natural Sites		
	Hartland Ledges	Jarvis Hill	Sumner Falls
1998			Augmentation with seed-fails
1999			Augmentation with seed-watered 2x weekly; fails
2000			19 seedlings planted- gravity fed drip irrigation system *in situ,* 21 percent survivorship
2001			augmentation with seedling-irrigation
2002			
2003			
2004	29 two year old plants transplanted		
2005			
2006	7 one year old plants transplanted		
2007	13 six month old plants transplanted		
2008	30 small vegetative plants transplanted		
2009	14+ small vegetative plants transplanted		
2010			
2011	Transplanted- 10 large vegetative plants, 38 small vegetative plants, 105 irrigated seedlings, 20 non-irrigated seedlings		
2012	102 seedlings planted- 41.7 percent survivorship to Sept		
2013	100 seedlings planted- 35 percent survivorship to Sept; 7.8 percent survivorship from 2012 transplants		
2014	80 seedlings planted- 52.5 percent survivorship to Sept; 1.9 percent survivorship from 2012, 6 percent survivorship from 2013		
2015	67 seedlings planted- 64.2 percent survivorship to Sept; 1.9 percent survivorship from 2012, 2 percent survivorship from 2013, 30 percent survivorship from 2014	30 seedlings planted (20 US, 10 DS)- 30 percent US survivorship to Sept, unknown DS survivorship	
2016	92 seedlings planted- 36 percent survivorship to Sept; 0 percent survivorship from 2012, 0 percent survivorship from 2013, 7.5 percent survivorship from 2014, 28 percent survivorship from 2015		50 seedlings planted- 34 percent survivorship to Sept
2017	29 seedlings planted- 37.9 percent survivorship to Sept; 0 percent survivorship from 2014, 3 percent survivorship from 2015, 9.8 percent survivorship from 2016		28 seedlings planted- 25 percent survivorship to Sept, 10 percent survivorship from 2016
2018	69 seedling planted		50 seedlings planted, 25 plants transplanted (20 total spackled in crevasses)- 15 percent survivorship of spackled and 38 percent survivorship of non-spackled by the end of summer; 0 percent survivorship from 2016

Appendix 8. Introduction efforts from 2009 – 2018.[13]

	Introduced Sites			
Year	Bath (1)	Railroad	Ryegate	Bath (SI)
2014	augmentation –			Site A- 17 seedlings planted, 64.5 percent survivorship to Sept; Site B- 30 seelings planted, 33.3 percent survivorship; Site C- 25 seedlings planted, 24 percent survivorship
2015				Site A- 15 seedlings planted, 53.3 percent survivorship, 41.2 percent survivorship from 2014; Site B- 13.3 percent survivorship from 2014; Site C- 8 percent survivorship from 2014; Site D- 18 seedlings planted, 11.1 percent survivorship to Sept
2016	upstream- 12 seedlings planted, 0 percent survivorship to Sept; midstream- 13 seedlings planted, 0 percent survivorship to Sept			Site A- 15 seedlings planted, 46.7 percent survivorship to Sept, 0 percent survivorship from 2014, 33.3 percent survivorship from 2015; Site B- 10 percent survivorship from 2014; Site C- 4 percent survivorship from 2014; Site D- 5.6 percent survivorship from 2015
2017	upstream- 12 seedlings planted, 0 percent survivorship to Sept; midstream- 0 planted; downstream- 21 seedlings planted, 0 percent survivorship to Sept	west end- 30 seedlings planted, 3.3 percent survivorship to Sept; east end- 20 seedlings planted, 0 percent survivorship to Sept	upstream end- 41 seedlings planted, 12.2 percent survivorship to Sept; downstream end- 21 seedlings planted, 0 percent survivorship to Sept	
2018	25 seedlings transplanted (seed from JH), 0 percent survivorship to Sept– abandoning future augmentation efforts	50 seedling transplanted (seed from JH), 28 percent survivorship to Sept	50 seedling transplanted (seed from JH), 28 percent survivorship to Sept	

13 Summarized from information provided in Brumback and Piantedosi (2018b) and NHNHB (2015).