Furbish's Lousewort

(*Pedicularis furbishiae*)

Ex Situ Conservation Planning Workshop Final Report

Fredericton, NB

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New Nouveau Brunswick CANADA

IUCN SSC Species Survival Commission

CONSERVATION PLANNING SPECIALIST GROUP

Changing the Future for Wildlife

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A full list of participants for the Furbish's Lousewort *Ex Situ* Conservation Planning Workshop is provided in Appendix C of this document and all are thanked for their time and contributions. Special thanks to Mariah Perley and Gretta Goodine.

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Acronyms

ACCDC	Atlantic Canada Conservation Data Centre
CFS	Canadian Forest Service
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
COSSAR	Committee on the Status of Species at Risk
CPSG	Conservation Planning Specialist Group
ECCC	Environment and Climate Change Canada
IUCN	International Union for Conservation of Nature
NB	New Brunswick
NB DNRED	New Brunswick Department of Natural Resources and Energy Development
SSC	Species Survival Commission
UNB	University of New Brunswick

Executive Summary

Furbish's Lousewort (*Pedicularis furbishiae*) is a unique and globally rare herbaceous perennial, found only along the Wolastoq/Saint John River in New Brunswick and Maine. It was the first plant to be designated as Endangered nationally by the Committee on the Status of Endangered Wildlife in Canada (1980) and to be listed provincially under the New Brunswick Endangered Species Act (1982). The plant's status was recently reassessed and confirmed as Endangered by the Committee on the Status of Species at Risk in New Brunswick (NB COSSAR 2023). It was determined that the provincial population has declined by 73% since 2002 and three of the four remaining subpopulations are nearing extirpation (NB DNRED 2023). The main cause of the decline is increased frequency and severity of flooding and ice scouring due to climate change (NB DNRED 2023).

The New Brunswick Department of Natural Resources and Energy Development (NB DNRED) is in the process of updating the Recovery Strategy and developing an Action Plan for Furbish's Lousewort. Recent *in situ* and *ex situ* conservation efforts and research on threats, habitat requirements, seed storage, germination, and genomics have been undertaken to support the recovery of the plant. The Canadian Forest Service is contributing to recovery efforts through *in situ* surveys and extant habitat monitoring *ex situ* cryopreservation, genomics and field bank establishment to provide a basis for *ex situ* conservation and future translocation efforts. These advancements provide an opportunity to apply IUCN guidelines to conservation planning for this species and consider the full spectrum of *ex situ* roles and conservation translocation options which may contribute to its recovery to inform the revision of the provincial Recovery Strategy.

The Canada Regional Resource Centre of the IUCN SSC Conservation Planning Specialist Group (CPSG Canada) was invited to design and facilitate a workshop process intended to evaluate *ex situ*/conservation translocation roles that could be integrated into the existing recovery program. Specifically, the purpose of the workshop was to evaluate the potential conservation value and feasibility of conservation translocation/reintroduction methodologies for Furbish's Lousewort using the established *ex situ* population, identify and recommend strategies with the most conservation benefit, and provide recommendations for initial action planning, including timelines, monitoring requirements, and exit strategies. The workshop was held at the Hugh John Flemming Forestry Centre in Fredericton, NB from July 30-August 1, 2024 with financial support from the Wolastoq / Saint John River Priority Place Fund. Seventeen attendees participated in the workshop including *in situ* and *ex situ* species experts and research scientists, and representatives from provincial and federal governments, local First Nations communities, land conservancies, and landholders.

In a structured and transparent process based on the IUCN *Guidelines for Reintroductions and Other Conservation Translocations* and other internationally-accepted guidelines and best practices, workshop participants identified fundamental objectives for engaging in conservation interventions for Furbish's Lousewort, evaluated and agreed on the best alternative conservation approach to meet the objectives, and discussed potential risks to the ecosystem, focal species, and the *ex situ* source population if the alternative were to be implemented as well as mitigation and contingency measures for higher priority risks. To facilitate implementation of the recommended alternative, participants developed goals and objectives, outlined high-level actions required over the next ten years, and provided recommendations for the planning and design of the translocation program.

The recommended alternative conservation approach for Furbish's Lousewort in New Brunswick is to restore existing sites if they are still viable and establish new sites on the Wolastoq as well as establish new sites outside of the Wolastoq, subject to implementation planning and dependent on specific decision triggers or conditions being met. The alternative combines *in situ* and *ex situ* conservation methods, including:

- standardized population, habitat, and threat monitoring of existing sites as well as newly transplanted sites and potential areas of colonization downstream from restored or introduced sites,
- vegetation management and bank stabilization of existing sites as needed to maintain population viability and at sites with restoration potential to improve habitat suitability,
- propagation of plants and production of seed for transplantation efforts in established field banks under an adaptive management approach to maximize genetic diversity and increase efficiency,
- genetic augmentation of highly inbred extant sites to increase genetic diversity and resilience and/or reinforcement of declining sites where suitable habitat remains, based on results of site assessment, using the *ex situ* population as source of seeds and/or adult plants, and
- establishment of new sites along the Wolastoq and along other rivers (e.g., Tobique) with suitable habitat, based on results of ground truthing, using *ex situ* seeds and/or plants.

The overarching recovery goal is to reinforce existing sites and establish new sites on the Wolastoq and outside of the current range in order to maximize population viability of Furbish's Lousewort in New Brunswick. Short- and long-term objectives, that can be incorporated into the provincial Recovery Strategy, were developed based on current COSEWIC criteria to downlist the species and ensure resiliency.

Implementation of the recommended alternative will require actions focused on both existing sites and new sites and will include two phases over the next ten years. Phase 1 includes management of existing sites, experimental planting trials on existing sites, and identification of potential recipient sites. If the planting trials are successful and recipient sites are identified and support secured then Phase 2, which includes planting trials on new sites on the Wolastoq followed by sites on other tributaries, can be implemented.

Recommendations are provided and knowledge gaps are highlighted for pre, during, and post translocation actions including source material and recipient site selection, planning for population growth, experimental design, monitoring, exit strategy, and community/collaborator engagement.

This report summarizes the results of the workshop process and is intended as a resource for the New Brunswick Department of Natural Resources and Energy Development to evaluate potential *ex situ* and *in situ* strategies for the recovery of Furbish's Lousewort and provide guidance for the development of the Provincial Recovery Strategy and Action Plan.

A. Chabot

Conservation Situation

Species Status

Since 1980, Furbish's Lousewort has been designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The species is a hemiparasitic plant that relies on the attachment to a host plant for nutrients (e.g., alder, licorice, trefoil). Furbish's Lousewort is only found along the banks of the Wolastoq/Saint John River in New Brunswick (NB) and Maine, and relies on periodic flooding and ice scouring to maintain or create early-successional stage habitat. While needed, these disturbances can also eliminate populations, resulting in a dynamic system of colonization and extirpation. However, an increase in the severity of ice scour and flood erosion due to climate change has caused declines in the meta-population and prevented populations from re-establishing after disturbance events. Currently there are only four populations of Furbish's Lousewort in New Brunswick with 96% of individuals occurring at a single site and modelling indicates increasing volatility of the Wolastoq/Saint John River will likely extirpate more populations. The remaining NB populations are further threatened by alder encroachment and debris accumulation and may also face warmer conditions, competition from invasive species, and loss of pollinators in the future. Most of the Furbish's Lousewort population in Maine is located upriver in managed forested habitat that is less fragmented than downriver habitat including New Brunswick. However, declines have also been observed in the Maine population, especially in the smaller, fragmented downriver populations, following severe ice scour events and the population has not rebounded from the most recent ice scour events in 2012.

Meagan Racey/USFWS

In addition to *in situ* conservation efforts such as surveys for new sites, slope reinforcement, fence repairs, and alder removal to protect the existing sites in New Brunswick, *ex situ* strategies are being used to safeguard the species and provide a basis for *ex situ* conservation roles and future translocation efforts. Since 2018, the Canadian Forest Service has been contributing to recovery efforts through collecting seeds, establishing a seed bank, developing propagation methods, and establishing two field banks (Williams 2021). The seed bank cryogenically preserves the genetic diversity from the three main populations in New Brunswick (Grand Falls, Medford, and Big Flat) as well as seed lots from various subpopulations in Maine. The plant has been successfully propagated in a nursery and outplanted to two secure field banks. The field banks contain individuals from all three New Brunswick and two Maine subpopulations and are producing viable seed. Plants from unsuitable locations were also translocated to these existing *ex situ* populations. Additionally, new research on threats and habitat requirements, seed storage and germination, and genomics has been undertaken to support the recovery of Furbish's Lousewort.

In 2023, the Committee on the Status of Species at Risk in New Brunswick (NB COSSAR) reassessed and confirmed the status of Furbish's Lousewort as Endangered. NB DNRED determined that the recovery of the species in New Brunswick is feasible if management actions are implemented (NB DNRED 2024a).

Detailed background information on the species, conservation efforts, and recent research can be found in Appendix A. Backgrounder and in the following summaries of background presentations given at the 2024 *Ex Situ* Conservation Planning workshop.


Meagan Racey/USFWS

Background Presentations

Can We De-List Furbish's Lousewort? Review of COSEWIC Criteria
Graham Forbes, University of New Brunswick (UNB)

COSEWIC listing status is based on adapted IUCN Red List criteria with quantitative and objective thresholds of significance for each status. Furbish's Lousewort meets the thresholds for four of the five criteria and is listed as Endangered in Canada. Under the IUCN criteria, Furbish's Lousewort in Canada is Critically Endangered; however, COSEWIC procedures do not allow for a possible status of Critically Endangered.

Criteria	Definitions	Thresholds for Endangered applicable to Furbish's Lousewort in New Brunswick (COSSAR)
A	Decline in total number of adults	A2a = decline >50% in last 30 years
B	Small area **and** decline of sites	B1 = < 5000km^2 'general range' B2 = < 500km^2 'site range' and a) = < 5 locations b) ii, iii, iv, v = declining in area, # sites, quality, population
C	Small **and** declining number of adults	C1a = < 2500 adults, with ongoing decline of 20% over next 20 yrs
D	Really low population	D1 = < 250 adult plants

Generation time and location are key factors in determining species' status. Generation time is the number of years required to reach maturity or the average age of the breeding population (e.g., Furbish's Lousewort = 8-10 years). Location is defined by a specific threat to a population within a generation/short period. Furbish's Lousewort may have only one or multiple locations depending on the severity of the main threats (i.e., hydrology/climate change may have the same effect on all populations or vary in some areas along the river).

There are two primary goals for listing a species: 1. to prevent further decline and 2. to eventually remove it from the list. In order to down-list (and potentially delist, as the best-case scenario) Furbish's Lousewort, the following measures could result in the population eventually exceeding the listing thresholds for each of the four criteria:

- **Criterion A** could be addressed if successful planting efforts stop the decline, which can take over 20 years.
- **Criterion B** could be addressed through successful planting on new rivers and at additional, less threatened sites.
- **Criterion C** could be addressed if successful planting results in a viable, self-sustaining population, with an increase in the number of adults or this criterion could be addressed with a small number of plants as long as the population is not declining.
- **Criterion D** could be addressed if planting is successful at increasing the number of adult plants.

Although unknown, it is possible that this plant does not flower every year, and therefore, more adults may be present in the population. Consultation of experts in Maine and gathering data on adult plants could help refine the evaluation of these criteria.

Down-listing Furbish's Lousewort from Endangered to Threatened is feasible, if new populations can be established (i.e., sites do not erode). Given the historic decline, the A2 Criterion (decline over last 3 generations) would require 20 years before it could be removed as a criterion. The down-listing effort will require extensive collaboration, time, and resources. Identifying safe sites along the Wolastoq River and exploring new rivers and locations are crucial steps. While delisting would be the ideal outcome in the future, achieving down-listing would be a significant conservation victory for this species.

Furbish’s Lousewort Status and Recovery Efforts Update in NB

Martin Williams, Canadian Forest Service

Furbish’s Lousewort exists as a metapopulation across the Wolastoq. In a balanced system with high levels of connectivity some patches would go extinct while other areas would be colonized. However, currently the metapopulation is in a state of non-equilibrium as patches go extinct without new ones being colonized. The populations face significant challenges due to the limited availability of suitable patches, inadequate connectivity and dispersal between patches and ongoing threats.

Currently there are only four remaining sites in NB:

1. **Grand Falls** (Figure 1) - appears to be the most dependable site, holding 96% of the population in NB and divided in 2 main patches about 50m apart, with few individuals found upstream and downstream. However, competing vegetation and erosion influences the viability of individuals downstream and upstream patches are potentially susceptible to drought.
2. **Medford** - approximately 97% of the Medford population compared to its max of 294 in 2008 has been lost mainly due to alder growth and the remaining individuals were vegetative (not flowering) in 2024.
3. **Stirrett** - approximately 99% of the Stirrett population has been lost due to ice scour, competing vegetation, and alders. Habitat viability for reinforcement is unknown with limited soil available.
4. **Big Flat** - only one individual, which was non-flowering in 2024, remains at Big Flat. Individuals were previously rescued in 2020 and translocated to the Cavendish field bank. Soil has been lost due to ice scouring, leaving rocks from the river to the treeline, while the hill above is eroding. This patch. where most of the previous individuals were found, is non-viable.

The population at Aroostook, which was of unknown origin and not a good site for rescue, has been extirpated since 2019 mostly likely due to a high density of leaf litter (Red Oak, *Quercus rubra*) following cessation of vegetation management as well as disturbance from recreation and roads.

Ex situ conservation efforts including seed banking and field banks have been used to preserve and increase the genetic diversity of Furbish's Lousewort (i.e., 57 seed lots from NB and 70 from Maine; genetic mixing in field banks) and to support future reintroduction efforts (i.e., field banks produced over 30,000 seeds).

Figure 1. Furbish's Lousewort habitat at the Grand Falls site along the Wolastoq/Saint John River in New Brunswick.

The Evolutionary History of Furbish's Lousewort
Richard Ree, Chicago Field Museum

Pedicularis is a large genus of hemiparasitic plants with around 600 species worldwide, over half of which occur in China. Some species are widespread, but many are rare and endemic to single areas. The genus is noted for its floral diversity, consisting of three main flower types: beakless, beaked, and long-tubed. All species are exclusively pollinated by bumblebees. However, only beakless flowers produce nectar. In beaked species, bumblebees forage for pollen and the flower morphology determines where pollen is deposited on the bee facilitating prezygotic isolation among species. Beaked and long-tubed flowers have evolved many times across the genus and nectar production has been gained and lost.

North American species are a result of wide global dispersals from East Asia via Beringia in the last 5-10 million years. Data indicate that Furbish's Lousewort (*P. furbishiae*), a microendemic species, is part of one of two Pacific clades which includes species such as P. rainierensis, P. bracteosa, and P. capitata. Although, the chloroplast data indicates potential hybridization or a chloroplast capture event and further genomic research is needed to confirm the history. Other North American species likely descended from a widespread Arctic ancestor.

Conservation Genetics of Pedicularis furbishiae
Dawson White, Harvard University Herbaria

Population declines and isolation due to habitat loss can lead to increased inbreeding and thereby reduce fitness of individuals resulting in reduced adaptive potential and elevated risk of extinction. In order to determine the extent of inbreeding and genetic structure of populations across the range of Furbish's Lousewort and understand the potential need for genetic rescue, 104 individuals throughout the range in NB and Maine were sampled using genotyping by sequencing (GBS).

Preliminary findings from this research were presented at the workshop that highlighted the importance of maintaining unique genetic diversity through preserving seed stocks from all populations and the value in allowing novel mixes between the populations while also noting that further demographic research is needed to understand the impact of inbreeding on fitness. Analysis of the genomic dataset continued after the workshop and the most recent results are presented in Appendix H. Furbish's Lousewort Population Structure and Genetic Diversity.

***Lessons Learned from Gulf of St. Lawrence Aster Recovery Efforts in Kouchibouguac National Park* – David Mazerolle, Parks Canada**

The Gulf of St. Lawrence Aster is an endangered rare plant species experiencing continual declines that has been extirpated from Kouchibouguac National Park. While the life history and ecology of the Gulf of St. Lawrence Aster is very different from Furbish's Lousewort (e.g., annual species), the aster also requires specific habitat conditions in a disturbance zone (along the shore of coastal ponds) which is rapidly changing and is threatened by severe storms that are becoming more frequent resulting in erosion, debris/sand deposition, and flooding.

The recovery project involved producing seeds and plants *ex situ*, surveying potential habitat sites, conducting experimental seeding and transplanting trials over two years and then monitoring plot conditions, germination success, and plant survival for four years following the trials to determine if sites were self-sustaining before recommencing seeding. Project constraints prevented complex habitat modelling, but simple modelling and ground surveys were used to identify potential sites and seeding trials were used to assess habitat suitability. Successful sites showed significant recruitment numbers over several years beyond what was initially seeded (i.e., seedlings producing their own seeds) and underscored the importance of a large seed bank for the survival of this species.

Results of the project showed that transplant survival is not a good indicator of site suitability as germination and early growth are the main bottlenecks to establishment (i.e., less tolerant of extreme site conditions). Better understanding of important habitat requirements was gained (e.g., substrate salinity, moisture, algal growth, indicator plants, etc.), most of which cannot be determined from remote sensing, limiting the use of habitat modelling for this species. Lessons learned from the recovery of the Gulf of St. Lawrence Aster can be used as guidance for the development of recovery strategies for Furbish's Lousewort.

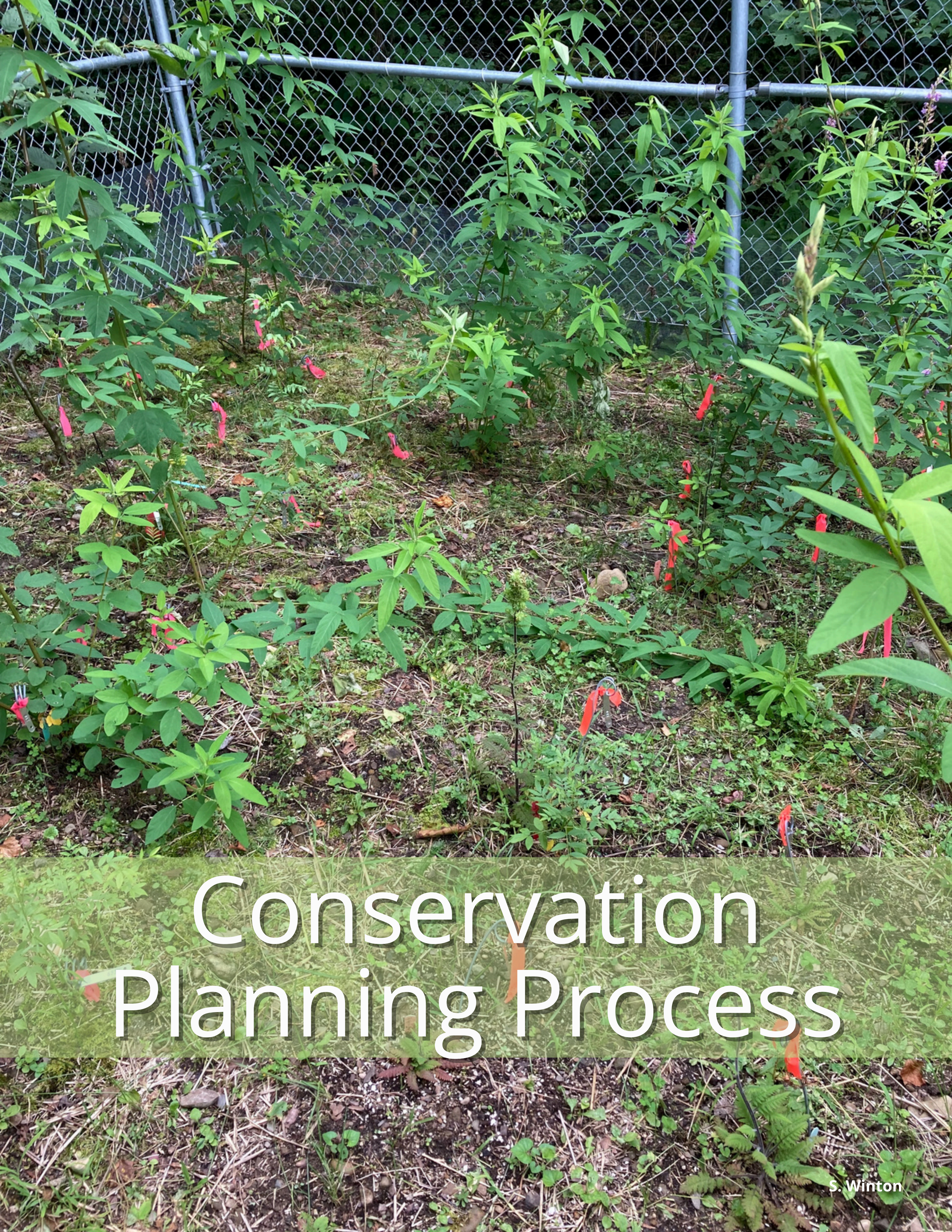
Habitat Suitability Model (including GIS, River Hydrology, and Ground Truthing Results) **– Graham Forbes, UNB; Wendy Monk, Environment and Climate Change Canada/UNB; Parise Ouelette, NB DNRED**

The Wolastoq is a large river system and Furbish's Lousewort grows in certain conditions (see Figure 1 for example of suitable habitat), so it's possible there may be other places on the Wolastoq with suitable conditions or even other rivers where impacts from threats may be less.

A GIS model was created using LiDAR mapping (resolution: 1m unit pixels) and included indicators of drip line/moisture, slope, slumpage, and scouring. Additional hydrological data was included to capture areas with enough erosion to control competition but not enough to destroy soil. Ecologically relevant indicators based on Furbish's Lousewort requirements included in the model were trends in river flow (including winter flows), flow duration, and ice. Availability of data over the years from stations along the river is irregular and there are gaps in confidence (e.g., measuring moisture on slopes).

Local temporal trends on the Wolastoq indicated an increase in shock events. There have also been increases in winter flows on the Wolastoq and midwinter rainfall events resulting in big chunks of ice taking more soil. Banks can be undercut from the power of the river and certain sites are washing away. It is possible that parts of the region are more suitable than others; however, there is limited hydrological information available for other rivers (e.g., Restigouche, Tobique) so it is hard to compare between river systems. Runoff is a potential indicator that could be used for this purpose but does not account for many finer scale variables within river systems.

Ground truthing surveys evaluated vegetation (including indicator species and competitors), water seepage, moisture, level of disturbance, slope angle and stability, erosion, and soil availability for 108 sites (101 on Wolastoq and 7 on Tobique). Results indicated that only a small amount of area is potentially suitable for Furbish's Lousewort; however, several potentially good sites were identified on the Wolastoq. Further ground truthing is needed for these sites as well as other potential areas identified from previous surveys (i.e., AC CDC) and the habitat model. The evaluation of identified potential sites would further benefit from an assessment of their hydrology and consideration of the downstream colonization potential (i.e., seed sources migrating downriver) given the need for early successional habitat.



Conservation Planning Process

S. Winton

Past Planning Work

There is an urgent need to develop a revised conservation plan for Furbish's Lousewort as previous efforts have been insufficient to recover the population in the province and the species continues to decline. Fortunately, collaborative efforts to safeguard the species and enable future conservation interventions, such as translocations, have been undertaken in recent years. The 2024 *Ex Situ* Conservation Planning Workshop builds upon previous planning work and considers existing strategies and recommendations from recent work, including:

✦ Furbish's Lousewort Workshop (Fredericton, NB, 2018):

In situ and *ex situ* alternatives, including translocation, were presented and discussed by experts, managers, and stakeholders to identify priorities and options for the conservation of Furbish's Lousewort in Canada.

Key outcomes of the workshop included:

- The priority recommendation was to maintain/improve conditions at extant sites on the Wolastoq/Saint John River through *in situ* conservation activities.
- Should extant sites continue to decline, primary and secondary alternatives discussed were to establish sites first within the natural range along the main branch of Wolastoq/Saint John River and then outside the natural range.
- Given the likely continued decline of extant sites, the need to work towards conservation translocations (introductions or assisted colonization) using *ex situ* methods (seeds or plants grown in source gardens) to restore a sustainable population of Furbish's Lousewort was identified.

✦ Report on *Ex Situ* Conservation of Furbish's Lousewort in New Brunswick: Potential for aligning future work with IUCN guidelines (Gyllström 2021):

Compilation of work conducted following the 2018 workshop through 2020 and assessment of this work and next steps within the IUCN conservation planning framework.

Work conducted from 2018-2020 to enable future translocations included:

- Increasing knowledge base for threat and feasibility assessments:
  - Habitat suitability model (including hydrology)
  - Population surveys, demographic studies
  - Range-wide genomic studies and comparison of genetic diversity

- Translocations:
  - Translocation of plants from vulnerable site to extirpated site (reintroduction)
  - Rescue of remaining plants at vulnerable site to establish source garden
- *Ex situ* conservation and research:
  - Wild seeds collected, research on seed storage and germination techniques
  - *Ex situ* source garden established
- *In situ* actions:
  - Slope reinforcement, site protection
  - Agreement with landowner of source garden site

Key recommendations from the 2018 report included:

- evaluate the best alternatives (including suitable locations for translocations) and assess feasibility and risks of proposed actions, and
- develop detailed plans and priorities for *ex situ* and translocation methods, including clearly outlined goals, estimates of resources and time, monitoring and exit strategies, and a framework for practical documentation.

Current Planning Purpose and Process

The 2024 *Ex Situ* Conservation Planning Workshop focused on the evaluation of *ex situ* and conservation translocation approaches for Furbish's Lousewort and the ability of such activities to contribute effectively to its recovery in the wild, corresponding with several of the planning stages of the IUCN SSC Species Conservation Planning Cycle, from building a vision and setting goals to planning actions (IUCN/SSC Species Conservation Planning Sub-Committee 2017). The results of this workshop lay the groundwork for the implementation phase.

The workshop was based around the structured decision making approach of the IUCN SSC *Guidelines for Reintroductions and Other Conservation Translocations* which provide guidance on the justification, design, and implementation of any conservation translocation (IUCN/SSC, 2013). Conservation translocations are the intentional movement and release of a living organism where the primary objective is a conservation benefit. These movements can include individuals from wild and/or *ex situ* origins; however, given the precarious situation of the wild population of Furbish's Lousewort and the established *ex situ* population, only conservation translocation options using *ex situ* plants and seeds were considered in this process.

Additional guidance from the *Centre for Plant Conservation Best Plant Conservation Practices to Support Species Survival in the Wild* (CPC 2019), specifically Part 4 on Rare Plant Reintroductions and Other Conservation Translocations, and the *Guidelines for the Translocation of Threatened Plants in Australia* (Commander et al. 2018) were incorporated into the planning process, primarily for designing and planning details of proposed translocation actions. These guidelines provide comprehensive information specifically for plant translocations and were used to support the more general IUCN reintroduction guidelines.

This structured and transparent process based on accepted IUCN guidelines supports a One Plan Approach to conservation of Furbish's Lousewort (Traylor-Holzer et al., 2019), and involves both *in situ* and *ex situ* species experts at the planning stage to fully evaluate conservation needs and opportunities.

2024 Ex Situ Conservation Planning Workshop Proceedings

The Regional Resource Center in Canada for the IUCN SSC Conservation Planning Specialist Group (CPSG Canada) was invited to design and facilitate a workshop process to evaluate and recommend the best approach forward for recovery of Furbish's Lousewort in New Brunswick, including identifying and recommending strategies with the most conservation benefit and detailing initial action planning. CPSG supports governments, zoos, NGOs, and other conservation organizations to develop inclusive species conservation plans using scientifically sound, collaborative processes. CPSG's approach to planning is deeply rooted in a set of principles for good planning, that emphasize sound science, neutral facilitation and the meaningful participation of all interested and impacted parties that has proven effective at helping to reverse the decline of threatened species (CPSG 2020, Lees et al. 2021).

The purpose of the Furbish's Lousewort *ex situ* conservation planning workshop was to evaluate the potential conservation value and feasibility of translocations to contribute to the recovery of Furbish's Lousewort in the wild and how the *ex situ* population could support that effort, based on the available information. To accomplish this, facilitators led the participants through the application of the IUCN's *Guidelines for Reintroductions and Other Conservation Translocations* to the specific conservation issues facing this species. This report presents the outcomes of the workshop and is intended as a guidance document with recommendations and advice including suggested purpose and structure of the recommended alternatives and next steps for planning and implementation (e.g., timelines, monitoring requirements, exit strategy).

The workshop was held in-person over three days (July 30 - August 1, 2024) at the Hugh John Flemming Forestry Centre in Fredericton, New Brunswick (NB), with an online option available for several key participants and presenters who were unable to attend in-person (Appendix B. Workshop Agenda). Seventeen attendees participated in the process including representatives from provincial and federal governments and local First Nations communities, species experts and research scientists, land conservancies, and landholders (Appendix C. Participant List).

Prior to the workshop, background information on Furbish's Lousewort biology, ecology, distribution, current and future threats to recovery, past and current conservation efforts and outcomes/lessons learned, and recent research findings was compiled and shared with participants (Appendix A. Backgrounder) along with the report on Ex Situ *Conservation of Furbish's Lousewort in New Brunswick* (Gyllström 2021) and the *Furbish's Lousewort* Pedicularis furbishiae *in New Brunswick: Status Report* (NB DNRED 2023). Participants were also provided with resources for *ex situ* management and conservation translocations for plants (see Next Steps section for a selection of these resources).

To start the workshop in a good way, Indigenous Knowledge Keeper Mariah Perley performed an opening ceremony and offering. This was followed by a tour of the Atlantic Forestry Centre greenhouse and nursery led by Gretta Goodine (Field Nursery Technician, CFS), and Martin Williams (Forest Genomics Research Scientist, CFS). Further welcoming remarks were provided by Chris Norfolk (Director Forest Planning and Stewardship, NB DNRED) emphasizing the urgency and importance of the workshop and the provincial government's commitment to recovering the species and incorporating the outcomes of the workshop into the Recovery Strategy.

Shaylyn Wallace (Biologist Species at Risk, NB DNRED) gave an overview presentation on the biology of Furbish's Lousewort, the current status, threats, and history of recovery planning and conservation efforts in New Brunswick and Maine, and the purpose of the workshop. This was followed by a presentation on the CPSG approach to planning and the proposed workshop process and ground rules from workshop facilitator, Stephanie Winton (CPSG Canada).

Following the opening activities and presentations, participants were asked to identify their main concerns and what they hoped to achieve regarding the recovery of the species. A concise set of four distinct fundamental objectives that addressed all concerns and aspirations were developed to guide the rest of the process and performance indicators for measuring the fundamental objectives were identified. This included an initial discussion on the definitions of spatial units for Furbish's Lousewort over various scales to ensure clear understanding of what would be measured.

Additional background presentations were given from members of the organizing team to provide all workshop participants with a more detailed understanding of the current status, distribution, threats, recovery actions and recent research updates for Furbish's Lousewort. Other species experts provided additional context on the evolutionary history and conservation genetics of Furbish's Lousewort as well as lessons learned from recovery efforts for the Gulf of St. Lawrence Aster, another at-risk plant species in New Brunswick. See summaries of background presentations in the previous section.

The second day of the workshop started with a summary of the GIS and river hydrology components included in the habitat suitability model and a presentation of the results of the 2024 ground truthing surveys of suitable habitat areas identified by the model. This was followed by an open discussion of potential model improvements and expanded applications. Several sites from the 2024 surveys were noted for further evaluation.

Bringing together the information shared in presentations and the foundational discussions held on Day 1, participants discussed and refined a final set of alternative conservation approaches to address the fundamental objectives. The facilitators then guided participants through evaluating the alternatives using a consequence table, a decision-making tool that highlights trade-offs and uncertainties to ensure the most optimal alternative approach is selected, and identifying the best performing alternative. The recommended alternative combined restoring and/or

reinforcing existing sites on the Wolastoq where necessary and feasible, establishing new sites both on the Wolastoq and outside of the Wolastoq using *ex situ* conservation translocation methods.

After this activity, a semi-quantitative risk assessment was conducted where participants evaluated the risks associated with implementing the recommended alternative. Risk categories included risks to the ecosystem at the recipient site as well as the focal species and *ex situ* source population. The group discussed risk definitions, spatial scope for each risk, likelihood and severity of each risk, and potential mitigation and contingency measures as needed for high priority risks.

The day ended with a field trip to the Acadia Research Forest to view the Furbish's Lousewort *ex situ* field bank.

The final day of the workshop was devoted to the initial design of the recommended alternative conservation approach. Participants developed a goal statement for the recommended alternative as well as short (10 year) and long-term (30 year) population objectives. Guided by these objectives, participants then mapped key steps and actions that would need to be taken in the next ten years onto a timeline.

In a World Café-style activity, participants develop recommendations for strategies and high-level actions for implementing the recommended alternative based on their species and context-specific knowledge. Discussions were guided by prompt questions from international guidelines and best practices focused on the topics of source material, recipient site, planning for population growth, monitoring, exit strategy, experimental design, and community/collaborator engagement. Knowledge gaps were identified to inform conservation research priorities.

Next steps in the provincial recovery planning process were presented and Knowledge Keeper Mariah Perley closed the workshop with a song for the Wolastoq.

Evaluation of Alternatives

G. Forbes

Fundamental Objectives

As a first step in the decision process, workshop participants established what they hoped to achieve by engaging in conservation interventions for Furbish’s Lousewort and what was most important to consider for evaluating alternative approaches.

Fundamental objectives are concise statements of what matters or what is important when making a decision (Hemming et al. 2022). Fundamental objectives are driven by values that matter to individuals and communities so they can include socio-political as well as biological considerations. It is important to identify fundamental objectives at the outset to guide decision making and to inform criteria against which success should be judged. Effective monitoring requires clear objectives and adequate indicators to measure them.

To clearly articulate the fundamental objectives, participants were asked to consider the concerns they were trying to address and the outcomes they hoped the recovery process would achieve regarding those concerns. In four successive rounds, participants brainstormed concerns and aspirations following the guiding questions listed below, then shared their ideas, identified where overlap occurred, and grouped concerns and aspirations by common themes, and finally turned the common themes into objectives (e.g., concise statements of ‘what matters’ and the desired direction of change).

Guiding questions for identifying concerns and aspirations:

- What concerns are you trying to address?
- What is the worst thing that could happen?
- What do you hope to achieve?
- What would be the best outcome?

The list of objectives developed by participants was evaluated to distinguish fundamental objectives (end trying to achieve) from means objectives (way of achieving an end), to ensure the list of objectives was complete and addressed all concerns while still being concise and only including the minimum number of objectives required for quality analysis, and finally to ensure the objectives were distinct or independent from one another (Table 1).

Table 1. Fundamental objectives for Furbish's Lousewort conservation in New Brunswick based on concerns and aspirations.

Concerns	Aspirations	Fundamental Objectives
Extirpation of Furbish's Lousewort in NB/Canada or total extinction; Unlikely persistence of species (and processes) with underlying climate change impact challenges; Loss of local populations / Population viability / Lack of extant sites; The species is extirpated without trying/while planning **Loss/fragmentation of suitable habitat** for Furbish's Lousewort under current and future conditions (e.g., dams, climate change); Threat of the Wolastoq on current sites and potentially new sites (i.e., intensity of the Wolastoq; unpredictability/lack of ice scouring); The ecosystem appears to be changing; projected increased habitat-related challenges; Our ability to mitigate hydrology/climate change related threats **Lack of resilience**; A catastrophic event knocks out the single Canadian healthy site **Declining populations**; Only 1 area with a population over 7 individuals (concentrated in 1 area) **Lack of genetic diversity**; Inbreeding depression over time; Lack of connectivity impacting genetic diversity and adaptive potential to future threats	**Species secure/species extirpation prevented** (e.g., stable population in 50 years; downlisted from endangered to threatened); Long-term species stability and increase in number (under a changing climate); Increase Furbish's Lousewort population (i.e., see meaningful increases in the population indicating recovery is happening) **Self-sustaining Furbish's Lousewort population** in NB/globally; Recreate a stable metapopulation on Wolastoq or tributary / Self-sustaining ecological corridor throughout the Wolastoq **Ecosystem recovery**; Achieve a more secure species condition through improved ecosystem function supporting biodiversity in general; Saving species means saving ecosystems **Resilient**; Expanded geography of Furbish's Lousewort in Canada (i.e. more dots on the map) **Diverse genetics**	**Maximize population viability** • Increase number of sites • Increase number of individuals • Increase genetic diversity
Long-term management/constant management of the species; Feasibility of reintroduction efforts; If ex-situ, who is going to do the work?; Something catastrophic happens to the CFS nursery that impacts growing more plants	Self-sustaining Furbish's Lousewort population in NB that <u>does not require intervention</u>; A strong plan for Furbish's Lousewort for 2025 and <u>beyond</u>	**Minimize the need for human intervention** (including *in situ* management and reliance on *ex situ* source population)

Concerns	Aspirations	Fundamental Objectives
Cost of ex situ; Heavy cost for maintaining species on the landscape	Balancing decision with economic and social needs; Resources are being allocated efficiently to conserve ecological processes; Cost minimization	**Minimize cost**
Who cares if Furbish's Lousewort survives? Good advice is produced but the government has other **priorities** **Lack of knowledge** for species needs across all stages (e.g., disturbance recovery, reproduction and succession, long-term stability) / Lack of knowledge of barriers on populations impacts our efforts to assess (e.g., mixing genetics, number of individuals needed to recover from stochastic events, breaking dormancy in the field) / Lack of knowledge of historical population distribution or conditions (potential Indigenous knowledge)	Balancing decision with economic and social needs (e.g., minimal impact to NB Power operations) More opportunity for **Indigenous collaboration**, incorporation, and perspective; Good purpose **More public awareness/appreciation** of the plant and a sense of stewardship; The public understands that scientists and land managers are working together to achieve the common good/that we save species because biological diversity improves human health **Address key knowledge gaps**; learn from recovery of other species	**Maximize collaboration in Furbish's Lousewort conservation** • Indigenous community involvement • Supportive stakeholders • Collaborations / partnerships

Performance Indicators

Performance indicators are specific metrics that can be used to consistently estimate and report the anticipated consequences of a management alternative with respect to a fundamental objective. Performance indicators or measures help further describe the objectives, and by doing so, help to evaluate alternatives. Together fundamental objectives and their performance indicators help to project the consequences of each alternative by estimating how well each alternative will perform in meeting the objectives. The IUCN Conservation Translocation Specialist Group guidance suggests that performance indicators should be complete, concise, unambiguous, understandable, direct and operational.

In preparation for evaluating and choosing an alternative for detailed action planning, participants were asked to identify what would best represent a metric by which each fundamental objective could be measured (Table 2). They were asked to ensure the indicator was measurable (i.e. could be recorded and analyzed in quantitative or qualitative terms), time-bound and understandable (i.e. defined the same way by everyone). Participants were allowed to consider indicators ranging from quantitative measures by which they could directly report on achievement (e.g. number of populations at carrying capacity), proxy or indirect quantitative measures (e.g. measure of a key resource for a species such as food source), or constructed (e.g. a relative or sliding scale). Participants were encouraged as a group to consider a scenario in which they were looking back in time to determine if the decision made today derived good outcomes and then ask themselves 'what attribute(s) would you measure to determine this?'. They were then asked to provide a directionality to the measure – either an increase or decrease as the desired direction of change.

Table 2. Performance indicators to measure the fundamental objectives for Furbish's Lousewort conservation in New Brunswick and the desired direction of change.

Fundamental Objective	Performance Indicator	Direction
Maximize population viability • Increase number of sites • Increase number of individuals • Increase genetic diversity	• Number of subpopulations/groupings • Number of plants (all individuals, as per 2024 protocols) • Genetic diversity (e.g., allelic diversity)*	Increase / Increase or maintain (genetic diversity)**
Minimize the need for human intervention (including in situ management and reliance on ex situ source population)	Number of person days per year after 10 years	Decrease
Minimize cost	Cost over 10 years ($)	Decrease
Maximize collaboration in Furbish's Lousewort conservation • Indigenous community involvement • Supportive stakeholders • Collaborations / partnerships	• Opportunity for Indigenous involvement • Number of supportive stakeholders • Number of Furbish's Lousewort projects	Increase

* Further discussion needed to determine the best measure of genetic diversity.
** Maintaining genetic diversity (i.e., no decrease) is a standard measure as it can be difficult to increase genetic diversity and there are potential issues including outbreeding depression or loss of local adaptation that need to be considered before new genetics can be added to a population.

Definitions

During the workshop, participants were asked to define some key terms. Draft definitions were developed as noted below, but ultimately it was decided that further work, outside of the workshop, would be needed to agree upon definitions for ‘site’ and ‘patch’. These definitions could be guided by efforts in Maine and should take into consideration COSEWIC and COSSAR guidelines.

Patches: within a site; area of occupancy 10m2

Site: subpopulation, groupings within <1km and separated by >1km (COSSAR)

[**Subpopulation (COSEWIC definition)**: as used in Criteria B and C, subpopulations are defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less). The size of a subpopulation is measured as numbers of mature individuals only.]

Alternative Conservation Approaches

Bringing together the fundamental objectives and associated performance indicators with the best available information on Furbish's Lousewort and plant conservation actions, workshop participants evaluated the performance of potential management alternatives to reach consensus on the best approach (or combination of approaches) for recovery of Furbish's Lousewort in New Brunswick.

Prior to the workshop, the organizing team developed six alternatives (status quo + alternatives 1-5) and detailed descriptions of the actions comprising each alternative, including monitoring, *in situ* site management, *ex situ* population management, and conservation translocation measures were provided to participants for review on Day 1 of the workshop (Appendix D. Alternative Conservation Approaches).

Through a plenary discussion of the alternatives on Day 2, the following changes were made, resulting in a final list of seven alternatives for consideration (Table 3):

- Actions towards reintroductions of extirpated populations were removed given the lack of suitable habitat remaining at historical sites along the Wolastoq.
- Another alternative was added that includes restoring existing sites on the Wolastoq, establishing new sites on the Wolastoq, and establishing new sites outside of the Wolastoq (Alternative 6).


S. Winton

Table 3. Summary of the high level actions for alternative conservation approaches considered for Furbish's Lousewort in New Brunswick. Xs indicate relative level of effort for each action.

	Actions								
	Monitoring			*In situ* site management		*Ex situ* population management		Conservation translocation	
Alternative	Existing sites (4)	Potential sites	New sites	Vegetation management	Bank stabilization	Seedbank	Field banks / nursery	Restore existing sites (reinforcement)	Establish new sites
Status Quo (maintaining extant sites + *ex situ* insurance population)	X	X		X	X	X	X		
1. Population Restoration (Increasing extant sites and restoring extirpated sites on the Wolastoq)	XX	XX		XX	XX	X	XX	X	
2. Assisted Colonization A (Establishing new sites on the Wolastoq)	XX	XX	XX	X	X	X	XX		X
3. Assisted Colonization B (Establishing new sites outside the Wolastoq)	X	XX	XX	X	X	X	XX		XX
4. Population Restoration + Assisted Colonization A (Restoring existing sites and establishing new sites on the Wolastoq)	XX	XX	XX	XX	XX	X	XX	X	X
5. Population Restoration + Assisted Colonization B (Restoring existing sites on the Wolastoq and establishing new sites outside of the Wolastoq)	XX	XX	XX	XX	XX	X	XX	X	XX
6. Population Restoration + Assisted Colonization A & B (Restoring existing sites on the Wolastoq and establishing new sites on and outside of the Wolastoq)	XX	XX	XX	XX	XX	X	XX	X	XXX

A consequence table was used to summarize how each alternative is predicted to perform relative to the others with respect to each fundamental objective and its indicator(s). Consequence tables are decision support tools that help organize the evidence, enable comparison of alternatives, and highlight expected trade-offs (Hemming et al. 2022). While some supporting evidence and data were available to predict the consequences of the management alternatives for Furbish's Lousewort, confident estimates for most of the objectives were not available at the time of the workshop (e.g., lack of population viability assessment). To make optimal recommendations in light of these unknowns, expert judgement and evaluation of the available empirical evidence was used to rate the performance of each alternative against the others while explicitly identifying uncertainties and encouraging discussion.

Before completing the consequence table, it was decided that Alternative 2 (Assisted Colonization A) and Alternative 3 (Assisted Colonization B) should be removed from further consideration as neither alternative included actions to reinforce existing sites. As so few sites remain in the province and to ensure no further sites are lost in the near future, restoration and/or reinforcement of existing sites was agreed to be a priority action for the conservation of Furbish's Lousewort. It was also specified that Stirrett and Medford are the only potentially viable sites for population reinforcement at this time. While the habitat has deteriorated there is enough soil remaining at both sites to justify management and/or planting efforts; however, the appropriate site-specific actions need to be determined (e.g., alder management without reinforcement planting could be sufficient to restore the population at Medford). Grand Falls is currently stable and does not require reinforcement efforts at this time while Aroostook and Big Flat are considered functionally extirpated and the success of reinforcement/reintroduction efforts is anticipated to be extremely low given the lack of suitable habitat; however, all existing sites should be monitored for potential changes in condition (i.e., deterioration or improvement) that may warrant a re-assessment of the need for potential restoration measures (e.g., improvement in soil conditions at Big Flat due to slumping from above).

During the discussion, several uncertainties were noted and research or logistical needs were identified. There was uncertainty around the success of establishing a population as well as how much management will be needed over time for new site establishment based on habitat quality, particularly when comparing whether introduction efforts on the Wolastoq or other rivers will have a greater chance of success. These uncertainties stem from a lack of knowledge about the future

conditions and habitat on the Wolastoq given the current state of decline and what threats or other risks may impact populations on outside rivers where the history is less well known. Therefore, it was agreed that there is a need to conduct pilot research/trials to establish protocols and determine success *in situ*.

Alternative 6 was the best performing alternative for three of the four fundamental objectives. The exception was in minimizing cost; however, it was agreed that maximizing population viability (e.g., through establishing new populations) outweighed minimizing the cost and that there was minimal difference between the magnitude of cost for all the proposed alternatives. Major costs include the *ex situ* program (e.g., set up, growing plants), *in situ* translocations (e.g., travel to sites, support staff), and long-term monitoring, but it was further noted that there are ways to vary the effort (i.e., scale, locations, number of plants, etc.) that could be explored to reduce costs while still ensuring the best approach to establishing a viable population. As such, Alternative 6 ("all of the above") was determined to be the preferred strategy. Results of the consequence table are presented in Table 4.

The recommended alternative conservation approach for Furbish's Lousewort in New Brunswick is to restore existing sites and establish new sites on the Wolastoq as well as establish new sites outside of the Wolastoq. The alternative comprises the following activities:

Monitoring

- **Existing and new sites:** Conduct annual standardized population, habitat and threat surveys of existing and new sites with additional monitoring efforts in the first 5 years post-planting to assess transplantation success. Continue ongoing monitoring for 10 years, then re-evaluate frequency for established or non-established sites based on COSSAR criteria.
- **Potential sites:** Conduct surveys for unknown/new sites prior to translocation activities and then every 10 years targeting potential areas of colonization downstream from the restored or introduced sites based on ground truthing of habitat model.

In Situ *Site Management*

- **Vegetation management and bank stabilization:** Trim and remove alders to create openness and remove debris such as grass and leaf litter, as needed. Monitor erosion levels and stability of sites as part of annual survey to determine need for emergency protection measures (i.e., when loss of a site is imminent), such as water diversion or log dams. Includes efforts to improve habitat suitability at sites with restoration potential.

Ex Situ *Population Management*

- **Seedbank:** No ongoing collection from the *in situ* population as the seedbank contains seeds collected from all main sites in NB and various sites in Maine. Re-evaluate the need for *in situ* seed collection following establishment of sites.
- **Field banks:** Propagate plants and produce seed for transplantation efforts in established field banks under adaptive management approach. Manage to maximize genetic diversity through natural cross- pollination of known sources. Collect seeds from novel crosses for the seedbank. Conduct experiments to increase efficiency of propagation.

Conservation Translocation

- **Reinforce existing sites:** Increase genetic diversity and resilience of highly inbred extant sites through genetic augmentation and/or reinforce declining sites where suitable habitat remains, based on results of site assessment, using the *ex situ* population as source of seeds and/or adult plants.
- **Establish new sites:** Introduce *ex situ* seeds and/or plants at new sites along the Wolastoq, and/or other rivers (e.g., Tobique) with suitable habitat based on results of habitat assessment and ground truthing. Priority for sites managed by province or conservation partners.

Table 4. Relative performance rating of alternative conservation approaches against fundamental objectives for Furbish's Lousewort conservation in New Brunswick. * = worst performing alternative, ***** = best performing alternative. Uncertainty indicated by '?'. Preferred alternative indicated in light green.

	Alternative Conservation Approaches				
	Status Quo	Alternative 1	Alternative 4	Alternative 5	Alternative 6
	Status Quo (maintaining extant sites + *ex situ* insurance population)	**Population Restoration** (Increasing extant sites on the Wolastoq) **Medford, Stirrett**	**Population Restoration + Assisted Colonization A** (Restoring existing sites and establishing new sites on the Wolastoq)	**Population Restoration + Assisted Colonization B** (Restoring existing sites on the Wolastoq and establishing new sites outside of the Wolastoq)	**All of the above** (Restoring existing sites and establishing new sites on the Wolastoq and establishing new sites outside of the Wolastoq)
Fundamental Objectives					
Maximize population viability - Increase number of sites - Increase number of individuals - Increase genetic diversity	*	**	*** / **** ?	*** / **** ?	*****
Minimize the need for human intervention (including in situ management and reliance on ex situ source population)	*	*	*** / **** ?	*** / **** ?	*****
Minimize cost	***	**	*	*	*
Maximize collaboration in Furbish's Lousewort conservation - Indigenous community involvement - Supportive stakeholders - Collaborations / partnerships	*	**	****	****	*****

Risk Assessment

Risk is the possibility of something negative occurring as a result of the conservation intervention. The IUCN Conservation Translocation Specialist Group guidelines are explicit that planners need to identify priority risks and plan for reducing negative impacts of the risk to the environment and on project success as part of the evaluation of translocation options as well as the action planning process. Before moving into action planning, participants were asked to consider priority risks, both to the *in situ* and the *ex situ* population, as these could potentially impact the success of the project.

Participants were provided with background information on likely risks (Appendix E. Risk Categories), and then identified additional risks and considerations regarding the recipient site, focal species and the *ex situ* population (see below). Participants were then asked to address both the likelihood of the event happening and the impact where the event to occur using a constructed scale for risks to the recipient site and focal species (Table 5). Mitigation measures (actions to reduce likelihood of the risk occurring) and contingency plans (actions to minimise consequences of the reality of the risk) were developed. Risk assessment was completed for both the host (trefoil) and focal species (see Appendix A for additional information on the species' life cycle and reproduction). It was noted that it is possible that the risks could be larger for the host species simply due to its larger size.

Additional Considerations for Risks with Impact to Recipient Site:

- **Disease/invasion:** Risk of introducing pathogens or pests is most likely to come from the soil mix used for the translocated plants (e.g., cactus mix in particular). However, the greenhouse uses similar methods for many other species with no history of negative consequences to date. It is also likely that any introduced pest would be native to the area.
- **Gene escape:** Discussions are needed to determine if and what mitigation strategy may be required to address inbreeding depression, including consultation with Maine. However, to date, results from the *ex situ* population management, which crosses lineages, does not indicate outbreeding depression is a concern.
- **Hybridization:** The risk for hybridization is very low for the focal and host species given they are both native to the area. Thus, even with knowledge gaps around trefoil pollination, congeners, etc., the likelihood was believed to be "highly unlikely" and the severity would be "no impact."
- **Socio-economic:** Additional work is required to assess potential socio-economic risks as part of site selection and develop appropriate mitigation strategies, considering in particular existing infrastructure and all parties that may be impacted if new populations are identified as a result of restoration activities (e.g., presence of protected species in new areas resulting in protections or restrictions to development or operations impacting NB Power, First Nations communities, etc.).

Additional Considerations for Risks with Impact to Focal Species:

- **Disease:** Translocation could increase the spread of disease without due consideration of biosecurity protocols: however, to date, there is no evidence that there is high impact.
- **Financial:** The degree of funding will vary based on the mitigation strategy being implemented. Funding is needed to ensure the mitigation can be adequately implemented.

Risks to *Ex Situ* Population:

- **Financial:** Funding is needed to continue to maintain the *ex situ* population (grow, plant, manage, test and store seed source), to ensure a viable source for conservation interventions. Linked to political risk.
- **Political:** Changes in administration at facilities such as the Canadian Forest Service, where the *ex situ* population is being maintained may lead to changing priorities that impact the capacity of current program leads to maintain the *ex situ* population.
- **Disease/Pathogen/Pests:** The *ex situ* population may face novel diseases/pathogens/pests both in the field bank and the greenhouse (e.g., mixed with other species in greenhouse).
- **Seed source viability:** A key knowledge gap remains regarding long-term viability of cryopreserved seed. The field bank is a mitigation strategy for the seed bank but also faces risks.
- **Catastrophe to infrastructure (e.g., fire):** Some redundancy exists through the two field banks, but there is no backup for seed stock or nursery. Redundancy could be implemented but is not currently part of the *ex situ* population management plan.
- **Loss of expertise and capacity:** The knowledge required to maintain the *ex situ* population was historically limited to very few individuals. Management of the *ex situ* population now includes a broadening group of knowledgeable staff and plans for a publication for knowledge transfer are underway to mitigate this risk.
- **Long-term plan:** Currently, there is no long-term agreement for the living *ex situ* collection. The living seed bank will continue to grow as seed sources continue to be collected but there has been no long-term management plan identified.

Table 5. Semi-quantitative assessment of risks to recipient site and focal species from implementing conservation intervention measures for Furbish's Lousewort in New Brunswick.

Likelihood: 1=highly unlikely, 2=unlikely, 3=moderately likely, 4=highly likely, unknown; Severity: 1=no impact, 2=low impact/severity, 3=moderate impact, 4=very severe, unknown; Mitigation measures: actions to reduce likelihood of risk occurring; Contingency measures: actions to minimize consequences when risk becomes reality.

Risk	Definition	Likelihood	Severity	Mitigation Measures	Contingency Measures
Impact to Recipient Site					
Ecological Risk	Impacts at translocation site to ecosystem structure and functions	Trefoil =2 Furbish =1	Trefoil =2 Furbish =1	Monitoring for potential risks (tbd) as well as success. Develop survey protocol for as many risk factors as possible.	
Disease Risk	Introducing new diseases/pathogens into site	Unknown	2	Monitoring of *ex situ* population, develop protocols for new problems. Develop a monitoring process for soil. Keep on top of relevant literature and knowledge.	n/d Get permit to destroy plants as needed. Find new stock of soil or other source of pest/pathogen/disease
Invasion Risk	Focal species become invasive	1	1	No mitigation required	
Invasion Risk	Accidentally releasing new species (pests)	Unknown	2	Monitoring of *ex situ* population, develop protocols for new problems. Develop a monitoring process for soil. Keep on top of relevant literature and knowledge.	n/d Get permit to destroy plants as needed. Find new stock of soil or other source of pest/pathogen/disease
Gene Escape	Genetic swamping of populations being reinforced	1	1	Reassess across the range on a periodic basis. If loss of fitness noted, then develop monitoring strategy	
Hybridization	Hybridization with other species	Trefoil = unknown by us but likely can get information Furbish = 1	Trefoil = unknown until we have more information Furbish =1		

Risk	Definition	Likelihood	Severity	Mitigation Measures	Contingency Measures
Socio-economic Risk	Direct and indirect negative impacts on human livelihood, new restrictions posed, leisure activities, future flora/fauna management at the site	2	3-4	Step 1 is consultation for existing and potentially suitable habitat prior to activity as part of potential site selection and understanding the consequences. Step 2= ID and avoid zones of conflict for future activities. *Note, consultation is part of the Recovery Strategy development process and includes both 'survival habitat' (existing sites) and 'recovery habitat' (suitable sites).	Move the plants - if the managed populations produce new populations downstream that become a problem (e.g., impacting a dam site), then the plants would be moved.
Financial Risk	Need for funding to remediate unexpected consequences	1	Unknown (too many factors to assess)		
Transboundary Risk	Causing environmental harm to neighbouring states/provinces/nations (e.g., genetic impacts to populations in other regions)	Unknown	Unknown	Do consultation on potentially suitable habitat prior to activity i.e. during site selection process. Step 2= ID and avoid zones of conflict for future activities.	
			Impact to Focal Species		
Disease Risk	Exposing focal species to new diseases/pathogens	Unknown	2	Monitoring of *ex situ* population, develop protocols for new problems. Develop a monitoring process for soil. Keep on top of relevant literature and knowledge	n/d Get permit to destroy plants as needed. Find new stock of soil or other source of pest/ pathogen/disease
Financial Risk	Management of the site will be too costly to be feasible	2	Unknown/ Variable		

Planning and Design

S. Winton

Goal Statement and Population Objectives

Clearly defined goals and objectives that express the intended result of the conservation intervention and include measures of success, such as size and number of populations within a specified timeframe, facilitate estimates of resources and time needed, the design of monitoring to evaluate success, and development of exit strategies if the goals cannot be met (IUCN/SSC 2013). Further, the Department of Natural Resources and Energy Development is required to include in the recovery strategy a statement of the population and distribution objectives that will assist in [the species] survival and recovery, to the extent possible at the time (NB DNRED 2024b).

Participants were asked to articulate the desired change and intended benefit of the preferred alternative and to revise draft population objectives developed by NB DNRED in order to measure success in the short and long term (Box 1). Participants considered what could be achieved within the timeframes and estimates of the required number of populations and population sizes for persistence in the province.

Box 1. Recovery goal and short and long term population objectives for Furbish's Lousewort in New Brunswick.

Recovery Goal
Reinforce existing sites and establish new sites on the Wolastoq and outside of the current range in order to maximize population viability of Furbish's Lousewort in New Brunswick.
Population Objectives
<u>Short-term population objective (10 years):</u> By 2033, the population objective is to increase the total population to greater than 1000 mature individuals with at least six self-sustaining subpopulations, one of which is greater than 250 mature individuals. <u>Long-term population objective (30 years):</u> By 2053, achieve and maintain a minimum of 11 self-sustaining Furbish's Lousewort subpopulations.

While knowledge gaps such as the number of individuals needed for a self-sustaining population, the availability, location, and carrying capacity of suitable habitat, and the natural metapopulation dynamics of a balanced ecosystem were acknowledged, the general consensus was that the objectives should be to work towards downlisting the species based on the current COSEWIC criteria and ensuring resiliency within the New Brunswick population. It was recognized that as the criteria are general and may change within the next 10 years, if the downlisting requirements are not met, it does not mean the program has failed. It was also noted that clarification of whether Furbish's Lousewort would be designated as critically endangered by COSEWIC (i.e., under criterion C2) and whether subpopulations established outside of the current range would be considered a separate DU is needed.

Action Implementation Timeline

To visualize and align timing of concurrent projects and key actions over the next 10 years, participants developed a preliminary timeline of high level actions required to implement the recommended alternative (Appendix F. Ten-year Timeline). This timeline outlines the suggested, relative order and estimated timeframes for recovery activities. It should be reviewed and refined or revised as needed when detailed planning is undertaken (e.g., when decision points are reached) and as further understanding is gained as the recovery program progresses. Actual timelines will depend on various factors such as site availability (e.g., approvals, permits, etc.) as well as funding availability.

The discussion focused on two main topics: existing sites and new sites. Two phases of recovery were identified in this process: Phase 1 starting in fall 2024 until spring 2027, including the completion of the New Brunswick recovery planning process, *in situ* management of existing sites (e.g., cutting back alders, removing debris, etc.), experimental planting trials on new sites (Table 7).

Immediate assessment of the habitat conditions of the existing population and implementation of vegetation management measures at Medford and potentially Stirrett were identified as initial steps for Fall 2024 while the Recovery Strategy and Action Plan are being finalized and funding is secured but prior to conducting transplanting trials. Following these assessments, consultation with landholders, and preparation of the existing sites as well as the development of growing, planting, and monitoring strategies, experimental planting trials will be conducted at the existing sites over a suggested two year period starting in Spring 2025 and will include monitoring for success (i.e., plants surviving and flowering).

Identification, mapping, and assessment of baseline conditions of potentially suitable habitat (including potential island habitat), based on ground truthing of habitat suitability model results and AC CDC data, will be undertaken concurrently to the assessment of habitat at existing sites in Fall 2024. The selection process will include consideration of socio-political aspects and early and ongoing consultation with potential landholders to ensure the most appropriate locations are identified and supported (e.g., prioritize provincial crown or protected areas, First Nations partners, or larger landholders like NB Power and Irving). Further, recovery planning and identification/selection of transplantation sites will be conducted in collaboration with Maine as much as possible.

While a decision point for where and how to proceed with planting on new sites is anticipated to be reached in 2027 after two years of planting trials, the duration of Phase 1 and the start of Phase 2, may vary depending on the timing and outcomes of the initial planting trials and site identification efforts. If sufficient knowledge of how to successfully outplant at existing sites is gained in the planting trials and candidate introduction sites are identified and support secured then a second set of planting trials can be conducted starting with sites on the Wolastoq (range: 2-4 sites), followed by sites on other tributaries. The second set of planting trials will be informed by the knowledge learned from reinforcement of the existing sites (planting trials #1), including planting methods and habitat requirements. As with the initial planting trials, success of the planting trials at new sites should be evaluated and the habitat model updated based on new information. If planting is not successful within the Wolastoq watershed, planting trials on other watershed(s) may be considered at that time.

Throughout the 10-year timeframe, ongoing monitoring of existing, new, and potential habitat will be conducted annually, including measures of ice scour, vegetation conditions, and associated watershed monitoring.

Table 6. Project timeline for Phase 1, fall 2024 - spring 2027, of Furbish's Lousewort recovery actions in New Brunswick. (Q1 = Winter: January-March, Q2 = Spring: April-June, Q3 = Summer: July-September, Q4 = Fall: October-December)

	Year 1	Year 2				Year 3				Year 4
	2024	2025				2026				2027
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
NB Recovery Planning										
Status Report (complete)										
Feasibility of Recovery (complete)										
IUCN Conservation Planning Workshop Process (complete)										
Recovery Strategy (draft - fall 2024)										
Funding										
Protection Assessment (goal 2025)										
Consultation (including collaboration with Maine)										
Recovery Strategy and Action Plan (final)										
Existing Sites: Habitat Management and Planting Trials #1										
Establish baseline site conditions										
Medford - site management (fall 2024)										
Vegetation management trials (i.e., Stirrett - determine management needs & site expansion options)										
Develop growing, planting, and monitoring strategies										
AC CDC Survey (5 year basis)										
Planting trials (experimental approach e.g., numbers of plants)										
Post-planting monitoring (e.g., survival and flowering)										
New Sites: Habitat Identification										
Identification/ground truthing new sites on Wolastoq (fall 2024)										
Identification/ground truthing new sites on a new tributary (fall 2024)										
Socio-political conflict screening										
Consultation with landholders										
AC CDC Survey (5 year basis)										
Pre-site monitoring										

Table 7. Project timeline for Phase 2, 2027 - 2033, of Furbish's Lousewort recovery actions in New Brunswick. (Q1 = January-March, Q2 = April-June, Q3 = July-September, Q4 = October-December)

	Year 4			Year 5				Year 6				Year 7				Year 8				Year 9				Year 10			
	2027			2028				2029				2030				2031				2032				2033			
	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
Existing Sites: Habitat Management and Planting Trials #1																											
Alder management (5 year basis)																											
Evaluate in situ seed collection needs																											
Planting Trials #2 (establish new sites)																											
Planting trials on Wolastoq																											
Planting trials on other tributaries																											
AC CDC Survey (5 year basis) - evaluate dispersal																											
Assess success (i.e., long term viability)																											
Evaluate habitat management needs																											
Habitat model update																											
Planting trials on other watershed(s), if deemed necessary																											
NB Recovery Planning																											
Status assessment																											
Recovery Strategy review																											

Action Planning Recommendations

The purpose of the workshop was to explore two main questions regarding how to keep Furbish's Lousewort within the province: 1) what is the best approach (i.e. process and exit strategy), and 2) what is the action plan that will be required for on-the-ground management activities, including priorities and timelines.

During discussion and work leading up to the workshop, the organizing team identified specific questions that needed to be addressed, including:

Site Selection

- What information do we use to choose sites for restoration or introduction?
- What is the geographic scope under consideration for planning?
    - ***Existing Sites***
        - What is the viability of existing site (i.e. should we even plant on the Wolastoq/Saint John River)
        - How do we manage existing populations, critical habitat, and required features of a site (i.e. how much management is needed and for how long)?
    - ***New sites (on Wolastoq/Saint John River or outside)***
        - Are there sites with suitable habitat?
        - How many new sites should be established? How much redundancy do we need and how should we increase redundancy (on Wolastoq/Saint John River or other river systems)? What are appropriate criteria for a suitable site?
        - How far from the original range should new sites be and how far apart between sites?
        - Do sites along other river systems have the same dynamics as the Wolastoq/Saint John River?

Number of Plants

- How many individuals are needed for a viable/stable population? How many plants to introduce into sites (e.g. 20/site, or 50/site)?
- Is more seed needed at a site to ensure viability?
- What criteria used to determine numbers? Should we increase or decrease number of individuals based on specific plant?
- How many seedlings do we have? resources for planting?

Source

- What source stock should be used for transplanting?
- How many *ex situ* plants are needed for transplantation? What is the feasibility of achieving 250 plants at one site?
- Can you mix seed sources from within New Brunswick or between Maine and New Brunswick without outbreeding depression or is there local adaptation?
- How long can the seed be stored?
- Is it preferable to plant 'adult' plants or seedlings?
- Is a host plant required?

Knowledge gaps/ research questions to address

- Why is the species currently limited (e.g. climate, hydrology, temperature, etc.)?
- What thresholds must be achieved to recover the species?
- Knowledge gaps regarding the plant's ecology (e.g. what is the amount of seed production required at a site to ensure viability?)
- What is the 'balance' within a system (i.e. redundancy in populations, rate of loss of plants and populations)?
- What other sites along other river systems have the same dynamics as the Wolastoq/Saint John River?
- How much habitat was available historically i.e. how much redundancy was on the river before?
- How many individuals do you need for a stable population?
- Will there be impacts from the 'rescue effect'?

Risks

- Will there be negative impacts from introducing a species into a new watershed
- What is the impact of invasive plants at new sites on the focal species?

Recommendations for actions were developed by having participants break into smaller working groups to discuss 'what is known', 'what is not known', and 'what needs to be known' (or 'what would be nice to know') when considering key questions under a series of thematic topics. In addition to the discussion topics identified by the organizing team, other considerations for action planning were identified based on recommendations in the IUCN SSC Conservation Translocation Specialist Group's *Guidelines for Reintroductions and Other Conservation Translocations* (IUCN/SSC 2013), the Australian Network for Plant Conservation's *Guidelines for the Translocation of Threatened Plants in Australia* (Commander et al. 2018), and the Center for Plant Conservation's *Best Plant Conservation Practices to Support Species Survival in the Wild* (CPC 2019). Specifically, the CPC's Best Plant Conservation Practices include a comprehensive list of questions and considerations to be addressed at all stages of a translocation that were used in the workshop and could help guide future action planning (Appendix G: CPC Guiding Questions).

The following is a list of thematic discussion topics and guiding questions for each, with a summary of recommendations and knowledge gaps identified during the working group sessions. In keeping with the group's agreement to take a precautionary approach, it was noted that knowledge gaps may exist, but that they may not necessarily be impediments to action and, in some cases, could be addressed as part of action plan implementation. The action planning session was not comprehensive and further discussion and and detailed planning is needed for these, as well as other, topics.

Recipient Sites

How will you choose/rank suitable sites for assisted colonization?

Recommendations:

- Revise, as needed, the habitat assessment datasheet used when ground truthing the existing habitat model. Revisions could include: hydrology, land ownership (e.g. public, private, conserved) and refinement of definition for 'mature plant.'
- Develop a ranking system based on the habitat assessment characterization.

Knowledge gaps:

- How to define 'mature plant.'

How close/far apart should patches/sites be?

Recommendations:

- Distance criteria is likely not a suitable approach. Rather, sites for translocation should be interspersed among existing *in situ* populations.
- A working definition of 'site' was developed during the workshop as 'areas separated by at least 1 km' but this needs to be revisited and refined. Efforts to do so should consider information from Maine, where populations are 'healthy.' The definition may vary in tributaries outside of the Wolastoq/Saint John River.
- Ideally, there would be 4 to 5 patches in every site (i.e. 1 km stretch of river). However, as with the definition of 'site', a suitable definition for 'patch' needs to be revisited and refined. Information on patch dynamics in Maine could be used to determine metrics such as average or maximum distance between patches and generally provide guidance on what characterizes a healthy distribution.

Knowledge gaps:

- Dispersal dynamics and distance are unknown, which impacts the ability to refine a metapopulation definition for the species i.e. sites can not be defined without further information on dispersal distance. Genomics research has provided some clarification of population structure but appears to have limited utility at this time to address this question.

How can we improve the existing habitat model?

Recommendations:

- No model revisions are needed, or likely to be of value at this time. However, as transplants are monitored, a better understanding of site characteristics will likely emerge. The model should be revisited using new information resulting from the monitoring and revised as possible.
- Rather than a focus solely on identifying habitat from the model output, consider the dynamics of the river system as it relates to dispersal. While dispersal dynamics are not fully known, it is likely that areas downstream are being established from populations upstream.

What should our planting strategy be?

Recommendations:

- Use mature plants (~2 year) per patch (i.e. distinct area within a site) as well as GA treated seed. Ideally, use a minimum of 20 mature plants per patch, but actual number should be determined based on the size of the patch.
- Develop/refine planting distance based on data from Maine from healthy populations and, as suitable, sites on the W or from historic data.

Knowledge gaps:

- Suitable/optimal spacing between patches.
- Suitable/optimal distance between plants.
- Planting scheme for patches – should translocations occur in all suitable patches or should some be left to colonize naturally?

What site preparation is required before the plants can be installed? Will there be any site management after plants are installed?

Recommendations:

- Little site preparation should be required beyond that required to establish the transplant.
- Management needs should be minimal for suitable sites. However, alder management may be needed to address shade.
- Management needs may change over time e.g. new sites may require management at a later date due to e.g. alder encroachment.
- Experience from past and on-going management activities can be used to help gauge the need for and guide future management action.

What after care is needed for transplants?

Recommendations:

- After care would ideally be limited to monitoring.
- After care needs are not currently fully understood and should be addressed over the course of management action implementation.

Source Material

How will you choose suitable stock for sites where you are reinforcing the species and/or for assisted colonization?

Recommendations:

- Seeds have been collected from multiple sites throughout the species range in New Brunswick, and it is likely that the existing seed stock harbours adequate variability.
- Currently, the propagation is mixing lineages to maximize genetic diversity. The goal is not to develop specific genotypes (i.e. line-breeding) but rather to create plants with high variability as this is believed to be the most effective mechanism to support population health.

How will you ensure a continued supply of suitable stock?

Recommendations:

- Field banks have been established to ensure an on-going supply of seeds. The nursery is being used to ensure an on-going supply of seedlings for the seed banks.
- Potentially, the field banks may need to be supplemented from *in situ* seed or plants. i.e. to replace plants that do not survive.
- Field bank and nursery propagation should strive to ensure fully genetically representative stocks.
- Secure funding, institutional support, and knowledge transfer is required to ensure a continued supply of suitable stock.

What genetic management is needed?

Recommendations:

- Genetic management is likely not needed. Although genetic diversity may be low, no known concerns or issues about viability have been noted in the crossed seed lots.
- Recommendations in lay-person terms should be developed from the results of the on-going/recently completed genomic research regarding the need to mix stock.

Knowledge gaps:

- Viability of seed stock in comparison to source populations is unknown.
- The degree of local adaptation to specific sites is unknown. However, the proximity of the sites along the river system would suggest that the environment is homogenous and thus local adaptation would be limited. Further, the river system likely facilitates gene flow/dispersal from headwaters to downriver.

What further genetic information would be useful to guide choosing source material?

Recommendations:

- Development of markers to track adaptive versus neutral genetic diversity would help to address if local adaptation is occurring.
- We don't have time to address the question of local adaptation as site recovery is needed immediately. Further, the best available information suggests that while there is some intraspecific genetic differentiation, outbreeding depression is not occurring when lineages are mixed.

Knowledge gaps:

- Little is known of local adaptation, which would help to guide propagation. i.e. do we outcross or is there a benefit in keeping lineages separate.

What would be the pros/cons of using seeds as a source?

Recommendations:

- Pros include ease of use, lower cost and diminished risk in comparison to transplanting a plant and host.
- Cons include likely lower overall success due to lack of dormancy (noting that dormancy is a knowledge gap), and later production of adults from seed (i.e. 3 to 5 years to flowering).
- Further consideration is needed regarding the pros and cons of treated versus untreated seed.

Knowledge gaps:

- Dormancy under field conditions.

What would be the pros/cons of using plants as a source?

Recommendations:

- Pros including likelihood of same year seed production.
- Cons include time required to grow plants to suitable stage/size, increased cost, lower numbers available, the need for a host, the increased labour required for transplanting and the need for infrastructure to produce the plants.

If you are using plants, what age/stage would be preferable?

Recommendations:

- The flowering stage would be best as it would ensure seeds are produced on the site.
- It would be possible to use 'potentially mature' plants that might flower (i.e. a 2nd year plant), but there are knowledge gaps regarding how to ensure the flowering process will occur. Some knowledge exists from the field bank, but conditions may not be the same as that *in situ*.

Knowledge gaps:

- Flower rate *in situ* of 2-year-old plants grown from seed in the nursery, in particular in comparison to rates exhibited in the field bank.

Planning for Population Growth

What founder population size will be used? What size and stage structure of plants will be used? How will the founding population be spatially configured to favour demographic persistence? Are there conditions to improve germination/survival *in situ*?

Recommendations:

- Transplantation should be done as a 'transplant unit.' Three seeds are planted per cell with one host plant. Not all seeds will survive. Regardless, the seeds are not separate from the host, thus each 'transplant unit' includes a host plant and one to three lousewort.

- Transplantation should mimic species ecology *in situ*, using the best available knowledge, but be undertaken using an adaptive management approach in which the lessons learned will be built upon over time to improve the likelihood of success.
- Transplantation should consider and, to the degree possible, make use of known dispersal mechanisms i.e. when selecting new sites, considerations will include seed dispersal by gravity and down-stream transport.
- A two-phase approach was recommended:
  - Phase 1:
    - Stabilize existing sites/populations using plants sourced from the *ex situ* population, specifically planting mature seed bearing plants with hosts produced by mixing genetic lineages.
    - Plant multiple sites (i.e. areas of suitable habitat located 1+ km apart). New sites would include at least 3 to 4 unique patches within them to allow dispersal among patches, but differing to the degree that scouring would operate differently among them.
    - Within each patch, cluster 3 transplant units per square meter, with 5 to 10 clusters per patch. Each cluster would be placed in the most favourable area (e.g. outside scouring and shade) and would mimic natural 'grandmother plants' i.e. those located higher on the slope so seeds disperse down, given that gravity is likely a dispersal vector.
  - Phase 2:
    - Detailed planning will be required, building on the lessons learned in Phase 1. Specific notation of a two-phase approach underlines the importance of taking an adaptive management approach i.e. learn, re-group and operationalize the next phase.

Knowledge gaps:

- Some outstanding questions about specific site characteristics that would be useful for future seeds to grow in and host – learn as the translocation occurs.

<u>How will population growth, recruitment and survivorship be monitored? And by whom?</u>

Recommendations:

- Need to work toward immediately developing a protocol to monitor plant growth, recruitment and survivorship that includes all necessary collaborators.

- Once a protocol is in place, additional collaborations and partnerships to facilitate monitoring should be identified and pursued after initial securing of sites.

Experimental Design

<u>What research needs/knowledge gaps exist and how could these be addressed in an experimental fashion when reinforcing extant sites / implementing assisted colonization?</u>

Recommendations:

- When implementing experiments as part of the management actions, consideration should be made as to what we need to know i.e. is necessary to be successful for recovery, versus would be nice to know.
- Research could be undertaken as part of the transplanting efforts to address the following areas of species ecology that remain poorly known/ unknown:
    - dormancy/germination in the wild and how to improve germination / break dormancy for *ex situ* propagation other than through the use of treated seed e.g. using moist stratification, etc.
    - dispersal and distribution methods (which could also potentially be addressed through use of historic air photos, data from Maine, and genomics)
    - min/max distance between flowering plants / density of plants within a patch and patches within a site
    - threshold numbers (plants, patches and site) to achieve a self-sustaining population
    - proportion of existing plants *in situ* that are mature
- Research could be undertaken to develop an 'erosion risk map' which would help to better understand the erosion and deposition process happening within the river to understand where, when and if the species will survive. River power affects rates of erosion and creation of suitable habitat, but these dynamics are not fully understood in the Wolastoq/Saint John River i.e., the blink in and blink out effect. The overall suitability of the river to support a metapopulation is currently unknown. Work to date has focused on hydrological characterization of the river, but other approaches are likely needed to better understand the river dynamics on a finer scale. This information will be critical to identifying future site suitability and the processes creating habitat in the future – while we can quantify currently suitable habitat, we do not know how long it will remain so, or where new suitable habitat will occur, either spatially or temporally.

- A population viability analysis might be useful for guiding management decisions. Efforts are underway to gather existing data, however, a partner who can conduct the modelling has not been identified.
- Little is known of pollinators *in situ*.

Knowledge gaps:

- Population Viability Analysis consultant with skills to develop a suitable model
- Little is known about the characteristics of the up-river sites. Biophysical modelling has been done in Maine with some ground-truthing. This information and research of water characteristics is needed to identify potentially suitable other tributaries.
- Adaptive genetic markers need to be identified, if possible

Monitoring

What are the most important aspects of the program to document? What baseline data will you collect?

Recommendations:

- The type of monitoring program implemented must consider the time required to complete monitoring i.e. intensive monitoring will be time intensive.
- If a detailed system of individual plant categorization is desired, it would be useful to review the system used in Maine.
- Monitoring survival and change in numbers is likely adequate for monitoring.
- Monitoring seed production and viability could be a metric to address likelihood of population persistence, which is more important than plant growth.
- Monitoring could be tiered, for example, shorter term and more intensive monitoring could be undertaken to address knowledge gaps/ research questions but over the longer term, simple counts of plants could be used to judge overall program success, or periodic monitoring over a shorter term could be implemented that is focused on translocated plants, with new wild plants not being monitored to same degree of intensity.
    - Specific recommendations for monitoring at different phases of translocation are as follows. *Note these were not considered to be an exhaustive list and discussion included some debate on the value of certain metrics such as monitoring environmental variables.*

- A) Pre-translocation,
    - Aspect, vegetation (e.g. alders), seepage, tree line to water distance, stability, slope, erosion, presence of flowering plants, and moss.
- B) During translocation
    - GPS coordinates of plants, # plants/square meter, # plants per transplant unit (i.e. three seeds are planted with each host, but not all may successfully germinate, therefore, transplant units will include one host and up to three focal species plants), metadata regarding seed-stock, etc.
- C) Post-translocation
    - Plant survival, flowering status, overall plant numbers (i.e. previous wild and/or transplanted plants as well as new seedlings), growth/plant stage (e.g. seedlings maturing over time) seed production, bud set, bud flush, environmental conditions (e.g. temperature, relative humidity), viability of seed, seed survival, physical change to the site and disturbance (e.g. vegetation, ice-scour, erosion, pest-pathogens, etc.).

Knowledge gaps:

- How to measure success at the habitat patch scale for an individual translocation?

Will baseline data collection differ for sites being reinforced versus those selected for assisted colonization?

Recommendations:

- Data collection should be the same regardless of the type of management activity.

Will you monitor individual plants? What data will be collected? E.g. fates (survival, growth, fecundity, seed production, etc.)

Recommendations:

- Monitoring needs will vary over time. For example, monitoring in the first year should focus on the 'transplant unit' (i.e. host and focal species). However, in the second growing season, monitoring could extend to the population within the site and by the 5th season following translocation, surveys should be implemented to identify newly established sites/populations.

- Ideally a system to enable monitoring individual plants over time would be implemented. For example, a land survey pin might be stable despite annual river dynamics and would provide a fixed point from which to map out a grid for use in monitoring.
- A monitoring schedule should be developed e.g. from spring through fall, within which monitoring methods could vary. For example, spring to fall monitoring could focus on transplant units but from year to year, monitoring may only be possible at a coarser scale of overall population count.
- Drone ortho-imagery photography with geo-reference pictures would assist at site and patch level as a monitoring method.
- Data loggers could assist in monitoring environment variables such as temperature, relative humidity, etc.
- Photographs taken on-site, similar to those obtained during ground truthing activities in 2024, could be useful in monitoring.

Knowledge gaps:

- How to implement a monitoring system that facilitates standardized monitoring over time i.e. is resilient to the impact of annual river dynamics.

<u>How will you incorporate results of monitoring into adaptive management?</u>

Recommendations:

- Lessons learned from site establishment should be reviewed and incorporated into on-going activities.

<u>What is your plan for reporting results?</u>

Recommendations:

- Reporting should follow federal and provincial requirements, but also include publication of work in peer-reviewed journals.

What additional knowledge is needed about the species biology or other factors?

Recommendations/knowledge gaps:

- Information regarding dormancy in the wild is lacking, including consideration of stratification, and scarification requirements as related to dormancy.
- Information on dispersal vectors and how best to mimic dispersal in the wild to assist with establishment of new sites. Translocation activities could provide a means to better understand dispersal, depending on how the actions are implemented and monitored.

How long will monitoring be conducted?

Recommendations:

- Monitoring should be conducted annually for the first five years following management action, and then re-evaluated.

How will the plants be mapped and marked/numbered?

Recommendations:

- As noted earlier, a system should be developed that would enable individual plants to be monitored over time, which could include tools such as georeferencing, land survey pins, use of a grid system, and/or ortho-imagery.

Knowledge gaps:

- As noted earlier, a system to facilitate monitoring needs to be developed that will withstand the annual river dynamics.

Exit Strategy

Considering both program failure and success, at what point does investing further resources become unjustified? What would be the undesired and unacceptable consequences that need to occur to trigger an exit strategy?

Recommendations:

- An exit strategy needs to consider two spatial scales:
    - Larger scale includes the entirety of the Wolastoq/Saint John River or another tributary.
    - Smaller scale focuses on sites within the Wolastoq/Saint John River or another tributary.
        - The exit strategy for a site will depend on factors such as over-winter survival, river dynamics, etc.
- Time scale for assessing if the exit strategy should be engaged may vary between spatial scales.
    - A larger time scale is more suitable for the larger spatial scale. A recommendation was made for the review to occur after 10 years, given that it will likely take several years to optimize transplantation methods. At the 10 year mark following the development of a recovery strategy, and on the ground activities, if none of the sites have reproducing plants, the exit strategy should assess why (e.g. poor translocation success, river dynamics, lack of suitable habitat). If no viable solution can be found, then other tributaries should be assessed as potential areas for translocation.
    - An exit strategy should also be developed under a shorter time scale for smaller spatial scales i.e. site-specific exit strategies. For example, if a site was not producing seeds within 3 years, then a site-specific exit strategy could be triggered.
- An exit strategy should also be prepared in the case of project success i.e. plants are reproducing, and sites are viable/ self-sustaining. In this case, the exit strategy may entail cessation of action and move to monitoring alone.

Knowledge gaps:

- Are there safeguards that can be implemented to sustain the project?
- What are the roles and responsibilities of each stakeholder/rights-holder during project termination?

Community and Collaborator Engagement

<u>Who are key community partners and collaborators? What engagement strategies will be employed and who will lead the invitations to partners to participate in conservation actions? How should land and rights holders and the public be engaged?</u>

Recommendations:

- Three levels of engagement were identified: collaborators, community partners and the public.
  - Collaborators are those responsible for drafting the recovery strategy, decision makers, field partners, etc.
  - Community partners are those that are the focus of and may be included in the consultation process – this group does not dictate the direction of the conservation program but are those who would be involved in implementation or affected by actions e.g. species experts, non-government organizations, First Nations Chiefs, land holders, etc.
  - Public includes individuals who have a perception about Species at Risk and with whom decision makers need to be transparent with.
- A flow of information is needed between the groups.
- Targeted meetings between collaborators and community partners may help to engage the community partners, who may then move into a collaborator role.
- The consultation process may want to include a marketing plan to ensure that the public understands the value of the species and, as possible, identify actions that the public can take to support the government-led activities.
- Mechanisms to engage the public do not necessarily need to have a goal of hands-on engagement but rather could focus on communication to improve interest and awareness, e.g. public registry, social media, etc. Engaged public could move to community partner roles, e.g. through participation in a Citizen Science monitoring program.

Knowledge gaps:

- Actions that the public can take to support government plans and activities.

Next Steps

This report presents the outcomes of the workshop investigating possible *ex situ* and *in situ* strategies to support Furbish's Lousewort recovery in New Brunswick using the best available knowledge, including a suggested course of action and exit point considerations. It is intended as a resource to guide the development of the Furbish's Lousewort Provincial Recovery Strategy and Action Plan. The action planning recommendations and suggested timing of activities over the next ten years as well as highlighted knowledge gaps are intended to assist implementation of the recommended management alternative with actions starting as early as fall 2024 including initial steps towards recipient site selection and consultation.

A list of resources for *ex situ* management and conservation translocations specific to plants to assist with further design and implementation is provided below.

Additional analysis of the genomics dataset was undertaken following the workshop to address knowledge gaps about the structure and genetic diversity of Furbish's Lousewort populations and inform decisions around *ex situ* outcrossing and population reinforcement (including genetic augmentation) to maintain genetic diversity. Results and recommendations are presented in Appendix H. Furbish Lousewort Population Structure and Genetic Diversity.

Resources for* Ex Situ *Management and Translocation of Plants

Guidelines and Best Practices

Centre for Plant Conservation (www.saveplants.org)

- CPC Best Plant Conservation Practices to Support Species Survival in the Wild (CPC 2019)
    - Figure 4.1. Recipient site assessment based upon ranking criteria related to logistics and habitat quality (pages 4-18 and 4-19)
    - Table 4.1. Advantages and Disadvantages of Using Seeds or Whole Plants for a Reintroduction (page 4-28)
    - Table 4.2. List of actions essential to monitoring plans for reintroduced plant populations (page 4-40)

- CPC online resources:
    - CPC Best Plant Conservation Practices to Support Species Survival in the Wild
        - Rare Plant Reintroduction and Other Conservation Translocations
    - CPC Rare Plant Academy
        - Applied Plant Conservation Course

Australian Network for Plant Conservation (www.anpc.asn.au)

- Guidelines for the Translocation of Threatened Plants in Australia, Third Edition (Commander 2018)
    - Factsheet: New guidelines for the translocation of threatened plants in Australia

British Columbia Ministry of Environment

- Guidelines for Translocation of Plant Species at Risk in British Columbia (Maslovat 2009), available from: Natural resource best management practices

Research Articles

- Identifying predictors of translocation success in rare plant species (Bellis et al. 2024)
- The role of aftercare in plant translocation (Corli et al. 2023)
- Species distribution and habitat attributes guide translocation planning of a threatened short-range endemic plant (Elliott et al. 2024)
- Comparison of reintroduction and enhancement effects on metapopulation viability (Halsey et al. 2015)
- Model-based scenario planning to develop climate change adaptation strategies for rare plant populations in grassland reserves (Phillips-Mao et al. 2016)

Status Assessment and Recovery Planning

- COSEWIC Guidelines on Manipulated Wildlife Species

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Appendices

Appendix A. Backgrounder

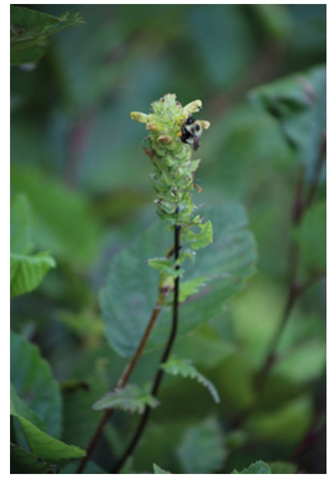

Photo by: Meagan Racey/USFWS

Furbish's Lousewort (Pedicularis furbishiae)

Species Status

New Brunswick: Endangered (2023, COSSAR)
Canada: Endangered (re-assessed in 2011, COSEWIC)
IUCN Red List: Endangered (2018)

Legal Listings

New Brunswick Species at Risk Act: Endangered (2013)
Canada's Species at Risk Act, Schedule 1: Endangered (2003)
US Endangered Species Act: Reclassified from Endangered to Threatened (2021)

Furbish's Lousewort was the first plant to be designated as endangered in Canada at the provincial and federal level. This designation was determined based on three identified populations; two along the Wolastoq/Saint John River and one along a railroad embankment (COSEWIC, 2000). There are a total of 20 populations of Furbish's Lousewort: 15 in Maine and five (4 extant; 1 extirpated) in New Brunswick (5-15% of the global population, Environment Canada 2010). Three of the four remaining populations in New Brunswick are at risk of extinction with 7, 2 and 1 individual plants remaining (Williams, 2024), leaving one population (Grand Falls) harboring 96% of NB plants. As a species with a specialized habitat, population fluctuations are common and impacts from stochastic events can result in the extirpation of a vulnerable population (Rochester, 2018).

Biology

Furbish's Lousewort is a herbaceous plant consisting of a basal rosette of leaves and one or more upright flowering stems on mature plants. Since the first and second years' growth after germination consists of only the basal rosette, they are particularly susceptible to overtopping by other herbs and woody plants (Gawler et al. 1987). It is reported to be an obligate outcrosser, requiring bumblebees to carry pollen from one plant to another (Menges 1988). It has also been observed that plants can self-pollinate and produce viable seed (Williams 2022). Seeds lack sophisticated mechanisms for wind or animal dispersal. However, their small size and loose reticulate outer seed coat enable them to float in water for several days (Menges 1988). River dispersal from whole scapes, which contain hundreds of seeds, is probably more likely than single seed for new site colonisation. The scapes are brittle, especially in the fall when seeds are ready, are occasionally browsed by small mammals such as voles and can also float. Seedlings can benefit from a nearby host in order to develop (Macior 1980), however greenhouse experiments have shown that plants can survive with no host. It is currently unknown whether plants with no hosts will mature as fast as plants with hosts over time (Williams 2024). [Source: COSEWIC 2011]

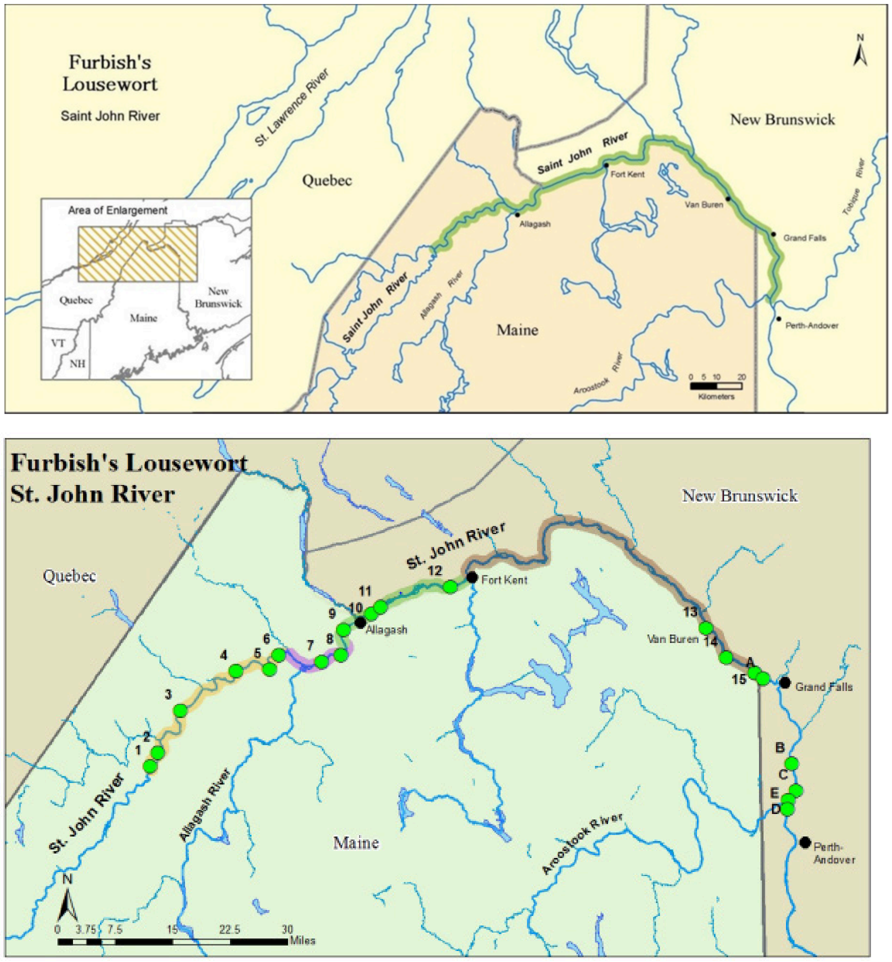

Figure 1. A. Furbish's Lousewort range, Environment Canada, 2010, B. Locations of the 15 subpopulations in Main (1-6 upriver, 7-15 downriver) and 5 in New Brunswick (A-E), USFWS, 2018.

Reproduction

Furbish's Lousewort is a hemi-parasitic perennial that reproduces sexually and produces seeds with limited dispersal ability, resulting in seed colonization around mature plants. Mature plants drop their seeds in late-September to germinate in cool, moist soils (seed capsules ~1mm in length). As a hemiparasitic species, Furbish's Lousewort seeds connect to a host plant using a haustorium - a root-like structure that supports plant attachment to a host to obtain nutrients and mature. Seedlings emerge from June through August as a basal rosette with fern-like leaves. These seedlings are the result from the previous year's reproduction, as the seeds lack dormancy (USFWS, 2023). When an individual reaches approximately three years of age or leaves reach a certain size, one or more stems (usually one) emerge in late May-June and even sooner if produced in the greenhouse. Each stem produces at least one inflorescence, which can support up to 25 flowers. Flowering occurs from mid-July to the end of August, and flowers are pollinated by the Half-black Bumble Bee *(Bombus vagans)*, the only known pollinator of Furbish's Lousewort. Following pollination, the cycle begins again as mature plants drop their seeds (USFWS, 2023).

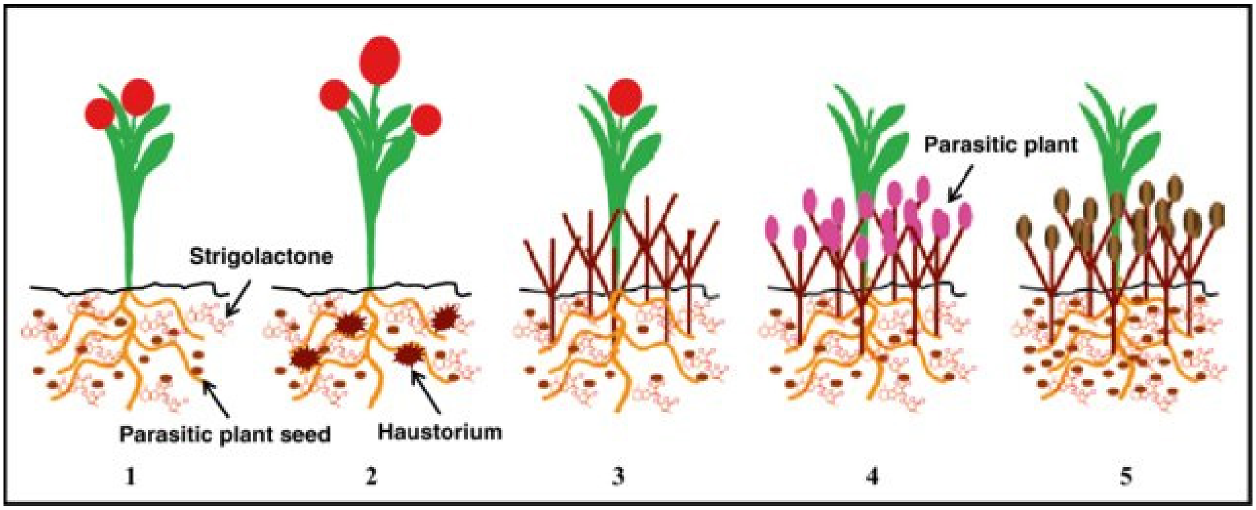

Figure 2. Life cycle of root parasitic plants. (a) Seeds are buried in the soil and perceive the germination stimulants exuded by the roots of the host plant, strigolactones, and germinate. (b) The germinated seeds form a haustorium by which they attach to the host root, establishing a xylem-xylem connection. (c) The parasitic plant develops, and the shoots emerge from the soil. There is areduction of host growth. (d) Parasitic plant flowering and crop yield reduction. (e) Production of mature seeds that end up in a new generation of seeds in the soil (figure from [López-Ráez, Bouwmeester & Pozo, 2011])

Figure 3. Visualization of Furbish's Lousewort life cycle. 1) Seeds and capsules, 2) Emergence of seedlings, representing a basal rosette with fern-like leaves, 3) Development of stems and flowers and, 4) Half-black Bumble Bee *(Bombus vagans)* pollinating flowers. (Photos: Williams, 2021)

Ecology

Native to the banks of the Wolastoq/Saint John River, Furbish's Lousewort is a hemiparasitic plant that relies on the attachment to a host plant for nutrients (i.e. alder, licorice and trefoil). Furbish's Lousewort thrives along sloped riverbanks within a dynamic, open ecosystem, with moist, well-drained soils and mixed shrubs (Maine Gov, 2021). Periodic flooding is a natural and expected occurrence on the Wolastoq/Saint John River and is critical for maintaining habitat in an early-intermediate stage of succession ideal for Furbish's Lousewort. The nature of its habitat is shaped by natural disturbances such as ice scouring, flooding, undercutting and slumping (USFWS, 2005). Furbish's Lousewort's reliance on a specific and vulnerable habitat, combined with limited geographic distribution, increases its susceptibility to environmental changes. However, Furbish's

Lousewort relies on these disturbances to create new habitat, while populations are simultaneously destroyed. As a "fugitive" species, Furbish's Lousewort may disappear from one area as a result of disturbance, but reappear in another.

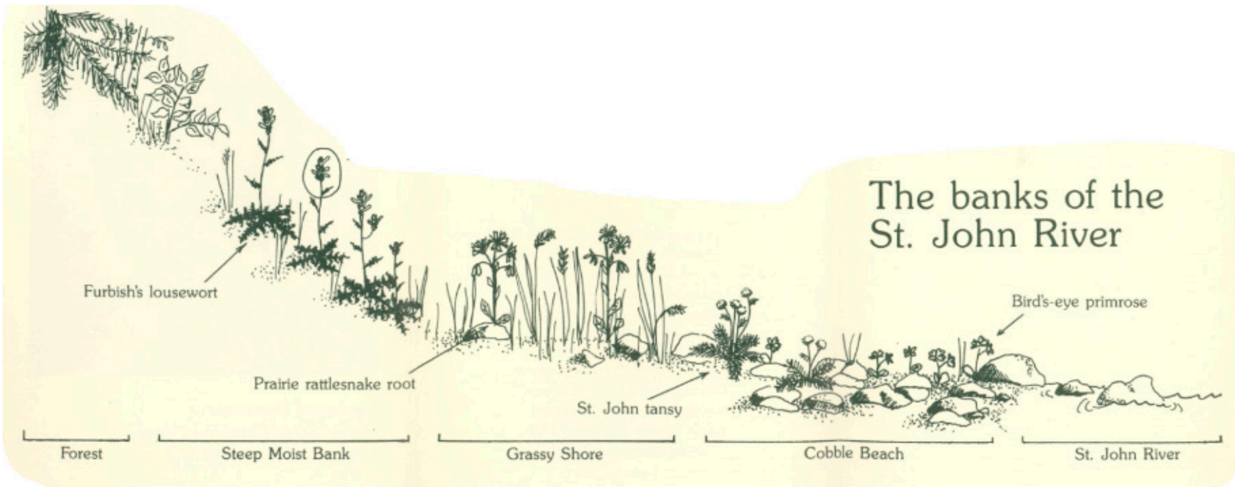

Figure 4. Dynamic ecosystem of Furbish's Lousewort (diagram from Droege, 1993).

Distribution in Canada

Furbish's Lousewort is known from five (4 extant; 1 extirpated) subpopulations (collections of occurrences within 1 km of one another and separated from other such collections of occurrences by at least 1 km) along a 35 km stretch of the Wolastoq/Saint John River from Grand Falls to just north of the mouth of the Aroostook River (Figure 1). All occurrences are in the Centreville-Grand Falls Ecodistrict of the Saint John Valley Ecoregion. An 1882 specimen collected by G.U. Hay from "Andover" at the Fowler Herbarium, Queen's University, suggests Furbish's Lousewort once extended at least another 5 km to 7 km further downstream prior to loss of shoreline habitat to the Beechwood Dam headpond (NB DNRED, 2023).

Figure 5. Aerial view of Furbish's Lousewort sites in New Brunswick. Yellow: extant sites; Red: extirpated site.

Current and Future Threats

1.0 Climate change

1.1 Ice scour and flood erosion

While periodic flooding is critical for maintaining habitat, the numbers of plants lost to flood-related erosion and bank slumping in the last 20 years has far exceeded the numbers of new plants recruited into the population. Major ice jams also impact Furbish's Lousewort habitat, increasing the potential of greater changes made to shoreline habitats (NB DNRED, 2023). This has the potential to increase site availability due to increased disturbance. However, it is unknown if the site turnover will be too quick for populations to be able to survive, even with increased site redundancy.

1.2 Temperature extremes

Ideal and maximum summer temperatures for the species are not well understood, but it is likely that Furbish's Lousewort may be negatively affected by predicted increased summer temperatures i.e., 1-3.5°C warmer by 2050 and 3-6°C warmer by 2080 (NB DNRED, 2023).

2.0 Competition

2.1 Invasive and problematic native species

A diverse community of exotic plant species co-occur with Furbish's Lousewort on the shores of the Wolastoq/Saint John River. The presence of invasive species results in overcrowding and competition for resources such as sunlight, nutrients and water. Common exotic species known to propagate along this shoreline include: Colt's-foot *(Tussilago farfara)*, Reed Canary Grass *(Phalaris arundinacea)*, White Sweet Clover *(Melilotus albus)*, Common St. John's-wort *(Hypericum perforatum)* and Purple Loosestrife *(Lythrum salicaria)* (NB DNRED, 2023).

As a result of natural succession, native species such as Red Oak *(Quercus rubra)* have influenced the decline of Furbish's Lousewort habitat within Aroostook. Within the Medford and Stirrett sites, alder creates excessive levels of shade, impacting the development and sustainability of the subpopulations (Environment Canada, 2010).

2.2 Herbivory and seed predation

Herbivory (by rabbits, rodents and deer) and seed predation are thought to occur independently of one another, preventing seeds from reaching maturation and contributing to a decline in Furbish's Lousewort seed set. Impacts on populations have not been quantified, and no clear mitigation measures exist (Menges, Waller and Gawler, 1986).

3.0 Habitat loss and degradation

3.1 Deforestation & Vegetation Destruction

Removal of forest canopy eliminates partial shade protection for Furbish's Lousewort and destruction of surrounding vegetation results in the inability of seedlings to connect to neighbouring plants for nutrients.

3.2 Development

Hydroelectric dam construction, gravel pits, and garbage dumping can alter hydrological features and river dynamics (Environment Canada, 2010). Road construction adjacent to riverbanks occupied by Furbish's Lousewort can cause erosion and slumping which appears to prevent upward migration on suitable shaded bank habitat (NB DNRED, 2023). It is unclear if these anthropological activities have had any impacts on NB sub populations in the past. With only one main population left upstream of the Grand Falls dam, it is worth keeping in mind that this might impact downstream dispersal of seed from this site to other potential available habitat downstream.

3.3 Recreational activities

Recreational trails with access to docks, marinas and picnic areas have been developed using pre-existing roads and railways. This increased access to Furbish's Lousewort and its habitat has led to site conversion (i.e. NB trail) and damages of the Aroostook subpopulation due to all-terrain vehicles (NB DNRED, 2023).

4.0 Lack of genetic diversity

Genetic analysis shows that there are high levels of inbreeding at sites with very small subpopulation sizes, which may impact fitness.

5.0 Loss of pollinators

5.1 Half-black Bumble Bee *(Bombus vagans)*

The Half-black Bumble Bee *(Bombus vagans)* is the only effective pollinator of Furbish's Lousewort, and is currently ranked S5 (Demonstrably Secure) in New Brunswick. The extent to which pollination limitation affects Furbish's Lousewort is thus unclear (NB DNRED, 2023).

Population Trend

Recent population data for New Brunswick's Furbish's Lousewort subpopulations, enables a strong understanding of population trends. In 2024, the total number of individuals in the New Brunswick subpopulation was 260 (Table 1). The total number has declined dramatically since the early 2000s, with most of that decline occurring after 2008. A maximum of 915 plants was recorded in 2002. Comprehensive population counts since that time showed a decline of 29% by 2008 and an even steeper decline of 83% from 2002-2014, followed by a fairly stable population of ~200 individuals between 2018 and 2024. Every subpopulation, except Grand Falls, has declined substantially. Relative to the highest totals recorded at each site, Big Flat, Aroostook, Medford and Stirrett have lost 98-100% of their plants, while Grand Falls has lost 16% of its plants according to the most recent survey (2024). (NB DNRED 2024 and Williams 2024)

Table 1. Counts of total number of individuals (flowering and non-flowering) at all New Brunswick subpopulations of Furbish's Lousewort since 2000 (after which data collection became more consistent and all recent subpopulations had been discovered). Data from NB DNRED (Sabine pers. comm. 2021, 2022), Canadian Forest Service (Williams pers. comm. 2021, 2024) and AC CDC (2021). Yellow shaded cells for the Big Flat and Aroostook subpopulations include information related to transplantation as explained in the footnotes. For counts from years before 2000, refer to NB Recovery Strategy (Appendix B, Table A).

YEAR	Grand Falls	Medford	Stirrett & vicinity	Big Flat[1]	Aroostook[2]	NB TOTAL
Site max (yr)	298 (2001)	294 (2008)	225 (1984)	131 (2004)	388 (2006)	
2000		no count	62	no count	84	**unknown**
2001	298	no count	147	no count	314	**unknown**
2002	243	187	137	124	224	**915**
2003	264	171	104	no count	204	**unknown**
2004	no count	no count	no count	131	no count	**unknown**
2006	no count	no count	46	no count	388	**unknown**
2007	no count	no count	43	no count	241	**unknown**
2008	68	294	41	48	198	**649**
2014	62	36	4	35	20	**157**
2018	71	64	5	64	2	**206**
2019	116	43	2	24 [-5]	0 [+5]	**190**
2020	no count	78	2	14 [-7]	0 [+2]	**unknown**
2021	152	61	2	3	0 [+1]	**219**
2022	183	59	no count	2	0	**244 - 246**
2023	225	37	1	1	0	**264**
2024	250	7	2	1	0	**260**

[1]The counts at Big Flat for 2019 and 2020 include the initial totals (24, 14) and indicate that five and seven plants were removed for transplantation because of concern about loss to erosion. The five plants removed in 2019 were translocated to Aroostook. The seven plants removed in 2020 were translocated to the Grand Falls garden site. [2]Counts at Aroostook for 2019 to 2021 include totals for naturally established plants (0) plus remaining transplanted individuals originating from Big Flat, all of which were lost as of 2022. (Gyllström, 2021)

Conservation planning and efforts to date

Rationale for current planning process

The New Brunswick Department of Natural Resources and Energy Development is in the process of updating the Recovery Strategy for Furbish's Lousewort. Currently there are only 4 populations of Furbish's Lousewort within New Brunswick and action is needed as soon as possible to prevent the species from being extirpated in the province. Modelling indicates increasing volatility of the Wolastoq/Saint John River will likely extirpate populations in NB. We have successfully been able to collect seed and cryogenically preserve remaining genetic diversity from the 3 main populations in NB (e.g., Grand Falls, Medford, Big Flat) as well as preserve seed lots from various Maine sub populations. We have also been successful in propagating plants in the greenhouse and outplant these in 2 secure field banks across the province. Both field banks presently contain individuals from all 3 NB sites and from 2 Maine subpopulations. Field bank plants have already produced viable seed and we're currently in a position to consider future options. Possible in situ & ex situ strategies need to be investigated to decide the next steps for the species and new funding has become available to work through the possible strategies.

Previous Plans and Workshops

☐ Recovery Strategy

Recovery strategy for Furbish's lousewort (Pedicularis furbishiae) in New Brunswick. 2006. Furbish's Lousewort Recovery Team. New Brunswick Department of Natural Resources. Fredericton, New Brunswick.

- Adopted by the federal government under SARA. Recovery Strategy for the Furbish's Lousewort (Pedicularis furbishiae) in Canada. 2010. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. vi pp. + appendices.
- The goals adopted in both the provincial and national strategies are: to monitor the existing sites, to increase the population size and the number of occurrences of Furbish's Lousewort, and to maintain quality habitat within its range in New Brunswick over the long term.
- Includes broad ex situ approach: Establishment of new sites (Action Plan Required)

☐ Furbish's Lousewort Workshop 2018

Goal: Identify priorities and options for the conservation of Furbish's Lousewort in Canada by gathering experts, managers, and stakeholders together to discuss research, threats, and opportunities.

- There was consensus that the focus, at least initially, would be on maintaining extant sites on the Wolastoq/Saint John River.
- However, given the decline of extant sites and the threat analysis indicating that the causes of the decline are not likely to diminish, ex situ conservation and translocation were also discussed as alternatives.
    - To decrease the risk of extant sites continued to deteriorate, the prioritized translocation option was to establish sites within the natural range.

- The discussions introduced the possibility that establishing sites outside the natural range, along the main branch of the SJR, could become a necessary alternative.
- Translocation (seeding) program and research program suggested as next steps among other activities

☐ ***Ex Situ* Conservation of Furbish's Lousewort: Report on potential for aligning future work with IUCN guidelines** (Gyllström, 2021)

- The report documents the foundational work during the period from 2018 through 2020. It also attempts to place it, as well as the proposed next steps within the lessons learned across the considerable international array of ex situ conservation projects and plant translocations, as reflected in IUCN guidelines.

Previous Conservation Efforts

In Situ

Monitoring

- Regular surveys of populations are undertaken and data is collected and shared amongst the team. Monitoring of translocated sites has yet to be formally initiated. Currently, no available criteria or protocol has been developed to determine frequency and evaluate additional variables pertaining to both the population and threats it faces. However, conversations have been initiated to involve Indigenous communities in monitoring the progress of seeding programs.

Bank Stabilization

- The slopes at the Big Flat site were reinforced in 2018 as a measure to decrease the progression of habitat erosion as result of bank cuts and slides.

Fencing

- Fencing was repaired to the side of the road where the Aroostook subpopulation was found.

Vegetation control at Medford & Aroostook

- Tree canopy, shrubs and leaf litter were removed to prevent complete shade coverage and overcrowding of Furbish's Lousewort.

Reintroduction (Aroostook)

- A wild-to-wild translocation occurred, reintroducing five plants from Big Flat to Aroostook in 2019, where the remaining two individuals observed in 2018 at Aroostook were no longer present.

(Gyllström, 2021)

Ex Situ

***Ex situ* cryostorage program (seed bank)**

- Ensuring long-term seed viability, Furbish's Lousewort has an established seed bank at the NRCan's National Tree Seed Centre. An inexpensive genetic storage method where seeds are stored in liquid nitrogen at -196℃. Seed representing all 3

Ex situ cryostorage program

main subpopulations in NB (57 seed lots) Maine (70 seed lots) are stored for future conservation efforts (Williams, 2024).

Field bank establishment

- A field bank was first established in Grand Falls, NB in 2020, followed by a second field bank in 2021 at the Acadia Research Forest in Noonan, NB. The field banks provide secure sites away from river based threats such as ice scouring/bank erosion for the outplanting and preservation of plants with multiple purposes such as: 1) produce seed, 2) combining individuals from various subpopulations for increasing genetic diversity of the seed sources through cross-pollination, 3) evaluate the life cycle of the species which is for the most part unknown. Seeds collected from the field bank further contribute to existing sites through supplementation or will support colonization of new sites (Williams, 2021). Since establishment, field bank plants have produced 29 seed lots for a total of over 31,000 seeds.

Field bank establishment

Population Rescue

- In 2019, five plants at the lower Big Flat site were translocated to Aroostook, and in 2020, seven plants were moved to the Grand Falls field bank site. This action was taken due to concerns that erosion could impact the status of these populations. However, by 2022, the translocated individuals from Aroostook had disappeared (NB DNRED, 2023). The plants translocated to Grand Falls survived the transfer to the Cavendish field bank and have been producing seed since the rescue.

Recent research findings

Genomics

Genomic research has been undertaken over the past few years. First, the genome of a Grand Falls individual was sequenced using both long read (Oxford nanopore) and short read (Illumina) sequencing through the extraction of DNA from Furbish's Lousewort leaf tissue. Secondly, leaf tissue from 131 individual plants from 9 different subpopulations from Maine and NB were collected, the DNA extracted and sequenced using a Genotyping by sequencing (GBS) approach. Using both the genome reference and the GBS dataset, DNA markers were identified and used to evaluate genetic diversity, population structure and inbreeding. The best current dataset will be presented at the workshop. This work was undertaken by CFS in collaboration with the Field Museum (Chicago, Illinois), U. Laval (IBIS) and Canada 150 Sequencing Initiative from Canada's Genomic Enterprise (Williams, 2021).

Habitat suitability model

Parameters:

- Between 2 and 10m above the LiDAR-defined water level
- Slope greater than 2m vertical change to 1m of horizontal change
- Aspects of NW, W, or SW
- Includes hydrology for Wolastoq and Tobique rivers

Areas were stratified by probability of ice scouring and canopy height information.

Based on the model, the amount of suitable habitat determined along the shore of the Wolastoq/Saint John River, on other tributaries and crown land include:

- **Shore of the Wolastoq/Saint John River**: 3200m^2 | **Crown land:** 320m^2
- **Other tributaries (primarily the Tobique):** 3400m^2 | **Crown land:** 57m^2

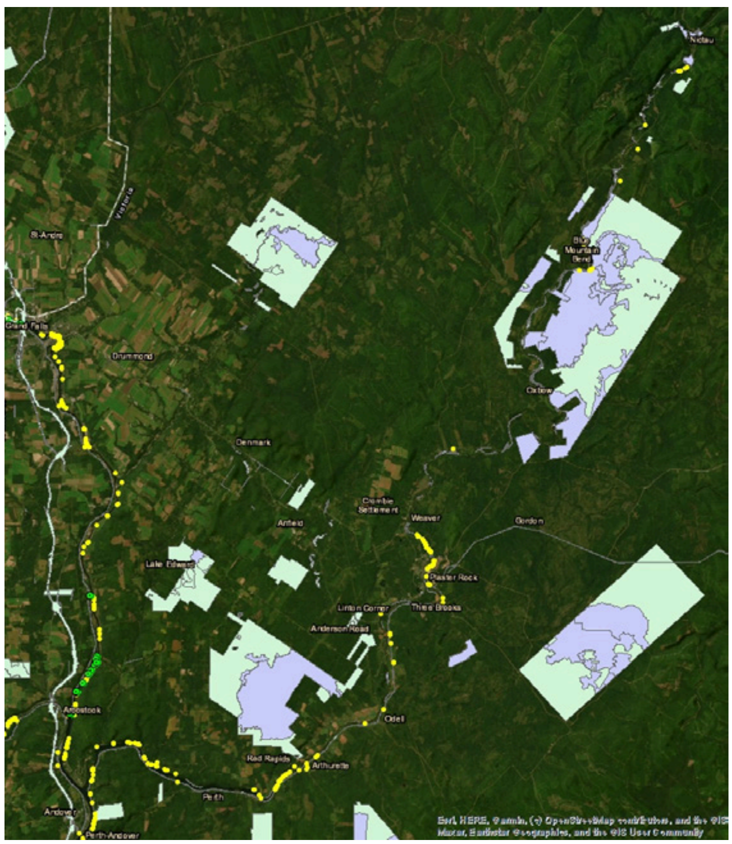

Figure 6. Outputs of habitat suitability model along the occupied segment of the Wolastoq/Saint John River and along the Tobique. Yellow dots indicate areas of potentially suitable habitat, green dots indicate Furbish's Lousewort locations. Green polygons are crown land and purple polygons are protected areas.

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Photo by Meagan Racy/USFWS:

https://commons.wikimedia.org/wiki/File:Furbish_lousewort_(37055900462).jpg

Appendix B. Workshop Agenda

Furbish's Lousewort (*Pedicularis furbishiae*)
***Ex Situ* Conservation Planning Workshop**

July 30 - August 1, 2024
Hugh John Flemming Forestry Centre, 1350 Regent St, Fredericton, NB

DRAFT Workshop Agenda

*Please note, the following agenda provides general guidance on the activities for each day. Timing may change based on the outcomes of interactive sessions.

Workshop Objectives (DAY 1-3): Evaluate and recommend any appropriate role(s) of the *ex situ* population to contribute to the conservation of *Pedicularis furbishiae* in the wild including suggested purpose, structure, and next steps for planning and implementation.

Facilitators: Stephanie Winton and Amy Chabot assisted by Katie Zajac (online), Conservation Planning Specialist Group (CPSG) Canada

DAY ONE: Tuesday, July 30
Establish conservation situation and set objectives

8:00 *****Meet at front entrance of the Forestry Centre*****
Opening ceremony - Mariah Perley, Knowledge Keeper
Tour of Atlantic Forestry Centre greenhouse and nursery - Gretta Goodine and Martin Williams (Canadian Forest Service)

9:30 **Coffee / tea break (provided)**

10:00 *****Reconvene in Board Room 222*****
Participant introductions
Welcoming remarks - Chris Norfolk (NB DNRED)

Setting the Stage: Introductory Presentations

10:30 Workshop context: overview of species (including status, threats, and recovery efforts in Maine and New Brunswick); rationale and scope of workshop within species recovery planning process - Shaylyn Wallace (NB DNRED)

10:50 Workshop process: Introduction to the CPSG species conservation planning process and the *IUCN SSC Guidelines for Reintroductions and Other Conservation Translocations*, required outputs, and workshop ground rules - Stephanie Winton (CPSG Canada)

Identification of fundamental objectives

11:00 Plenary activity
- Brief presentation introducing fundamental objectives vs means objectives
- Develop fundamental objectives

12:30 **Lunch (provided)**

Background Presentations (~20 minutes each, w/ 10 min for questions)

1:00 Can We De-List Furbish's Lousewort? Review of COSEWIC Criteria - Graham Forbes (UNB)
1:30 Furbish's Lousewort Status and Recovery Efforts Update in NB - Martin Williams (CFS)
2:00 The Evolutionary History of Furbish's Lousewort - Richard Ree (Chicago Field Museum)
2:30 Conservation Genetics of *Pedicularis furbishiae* - Dawson White (Harvard University Herbaria)
3:00 Lessons learned from Gulf of St. Lawrence Aster Recovery Efforts in Kouchibouguac National Park - David Mazerolle (Parks Canada)

3:30 Coffee / tea break (provided)

Identification of criteria for measuring objectives

3:40 <u>Plenary activity</u>

- Plenary discussion: reflect on fundamental objectives
- Brief presentation explaining process for developing criteria
- Determine how fundamental objectives will be measured

4:50 Day 1 closing remarks
5:00 End of Day 1

Evening: Dinner together (optional)

<u>DAY TWO: Wednesday, July 31</u>
Evaluation of alternatives and risk assessment

8:00 Recap of Day 1 and set up focus for Day 2
Present final fundamental objectives; discuss/refine as necessary

Background Presentation

8:30 Presentation and discussion of habitat suitability model including GIS and river hydrology components and ground truthing results - Graham Forbes, Wendy Monk (ECCC/UNB), Parise Ouelette (NB DNRED)

Evaluation of alternatives against fundamental objectives

8:50 <u>Plenary activity</u>

- Brief presentation explaining process to evaluate alternatives against fundamental objectives
- Present alternatives; discuss/refine as necessary
- Consequence table: assess performance of alternatives
- Review and discuss how alternatives compare

Coffee / tea available (break as needed)

Risk assessment

11:00 <u>Plenary activity</u>

- Brief presentation explaining process
- Identify high level risks from implementing recommended alternative, evaluate likelihood and severity, and discuss mitigation and contingency measures

12:00 Lunch (provided)

1:00 Risk assessment continued

3:00 Day 2 closing remarks

3:10 Field trip to Acadia Research Forest (field bank)

~5:00 Return to Forestry Centre - End of Day 2

Evening: Dinner together (optional)

DAY THREE: Thursday, August 1
Planning and Design

8:00 Recap of Day 2 and set up focus for Day 3

Specify what is to be done

8:30 Plenary activity: Develop goal statement(s) for alternative and review draft population objectives

9:00 Plenary activity: Detail out major steps to turn alternative into reality on timeline

10:00 Coffee / tea break (provided)

10:20 Working Group activity: Provide species/context specific recommendations for action planning

- Brief presentation explaining activity (World cafe-style discussion groups)

Session 1: Pre-translocation

- Topic 1: Recipient site
- Topic 2: Source material
- Topic 3: Planning for population growth
- Report back to main group on working group outputs

12:00 Lunch (provided)

1:00 Session 2: During translocation

- Topic 4: Experimental design/research needs
- Topic 5: Monitoring
- Report back to main group on working group outputs

3:00 Coffee / tea break (provided)

3:10 Session 3: Post-translocation

- Topic 6: Engagement
- Topic 7: Exit strategy
- Report back to main group on working group outputs

3:50 Revisit timeline, identify priorities

4:20 Discuss next steps, closing remarks

4:30 Closing ceremony (Mariah Perley, Knowledge Keeper)

Appendix C. Participant List

Participant	Organization	July 30, 2024	July 31, 2024	August 1, 2024
Martin Williams	Canadian Forest Service	✓	✓	✓
Peter Fullarton		AM		
Richard Ree*	Chicago Field Museum	PM (presentation only)		
Kathy St.Laurent*	Environment and Climate Change Canada	✓	✓	✓
Wendy Monk	Environment and Climate Change Canada & University of New Brunswick	✓	✓	
Dawson White*	Harvard University Herbaria	✓		
Carli le Roux	Nature Trust of New Brunswick	✓		AM
Brittany Dixon	New Brunswick Department of Natural Resources and Energy Development	✓	✓	✓
Chris Norfolk		AM		AM
Heather Loomer		✓	✓	✓
Mary Sabine		PM		AM
Parise Ouelette		✓	✓	✓
Shaylyn Wallace		✓	✓	✓
Jeff Babcott	New Brunswick Power	✓	✓	
Katie Arsenault		✓	✓	✓
David Mazerolle	Parks Canada	✓		
Graham Forbes	University of New Brunswick	✓	✓	✓
Kianna Bear-Hetherington	Wolastoqey Nation in New Brunswick	✓	✓	

* online participant

Appendix D. Alternative Conservation Approaches

Table D1. Detailed descriptions of the required actions for each alternative conservation approach for Furbish's Lousewort in New Brunswick.

Status Quo (maintaining extant sites + ex situ insurance population)	
Monitoring	**Existing sites:** Standardized Visual Surveys of adult plants, Critical Habitat attributes (biotic and abiotic), erosion levels, potentially problematic invasive species establishment, and other threats (e.g., excessive herbivory, evidence of pollinators, human disturbance). Surveys conducted annually at 5 existing sites by boat, drone, or on foot. **Potential sites:** Surveys for unknown/new sites, ~5-10 year frequency (conducted by AC CDC). Ground truthing of habitat model to identify potentially suitable sites to survey for new subpopulations and for release sites following Standardized Visual Survey methods (2024). **New sites:** n/a
In Situ Site Management	**Vegetation management:** Trimming and removal of alders to create openness and removal of debris such as grass and leaf litter, as needed (e.g., last 5 years at Medford). **Bank stabilization:** Monitoring of erosion levels and stability of sites as part of annual survey to determine need (i.e., when loss of a site is imminent) for emergency protection measures (e.g., water diversion, log dams).
Ex Situ Population Management	**Seedbank:** No ongoing collection from the *in situ* population. Seedbank contains seeds collected from all 3 main sites in NB and various sites in Maine. Viability assessments/germination trials conducted with 15 seeds for every seedlot over 100 seeds. **Field banks:** Propagation of plants and production of seed in 2 established field banks under adaptive management approach. Managed to maximize genetic diversity through natural cross- pollination of known sources. Seeds from novel crosses collected for the seedbank. Individuals from Big Flat, Grand Falls, Medford, St-Paul and long rapids are present in the field banks. Conducting experiments with 3 seedlots to increase efficiency of propagation.
Conservation Translocation	**Restore existing sites (reinforcement and/or reintroduction):** n/a **Establish new sites:** n/a

Population Restoration (Increasing extant sites and restoring extirpated sites on the Wolastoq)	
Monitoring	**Existing sites:** Same as status quo with additional monitoring efforts in the first 5 years post-planting (e.g., maturation rate, seeding, fitness, expansion to adjacent areas). Continue ongoing monitoring for 10 years, then re-evaluate frequency based on COSSAR criteria.

	Potential sites: Conduct surveys for unknown/ new sites prior to translocation activities and then every 10 years targeting potential areas of colonization downstream from the restored sites, based on ground truthing of habitat model. **New sites:** n/a
In Situ Site Management	**Vegetation management:** Same as status quo with additional efforts to improve habitat suitability at sites with restoration potential. **Bank stabilization:** Same as status quo with additional efforts to improve habitat suitability at sites with restoration potential.
Ex Situ Population Management	**Seedbank:** Same as status quo **Field banks:** Seed sources utilized will be the same as the ones generated within both currently operational field banks
Conservation Translocation	**Restore existing sites (reinforcement and/or reintroduction):** Potential genetic augmentation of highly inbred extant sites to increase genetic diversity and resilience. Reintroduce extirpated sites where suitable habitat remains, based on results of site assessment, using the *ex situ* population as source of seeds and/or adult plants. **Establish new sites:** n/a

Assisted Colonization A (Establishing new sites on the Wolastoq)	
Monitoring	**Existing sites:** Same as status quo. **Potential sites:** Same as Population Restoration targeting potential areas of colonization downstream from the introduced sites. **New sites:** Standardized Visual Surveys (Status Quo) with additional monitoring efforts in the first 5 years post-planting (e.g., maturation rate, seeding, fitness, expansion to adjacent areas). Continue ongoing monitoring for 10 years, then re-evaluate frequency for established or non- established sites based on COSSAR criteria.
In Situ Site Management	**Vegetation management:** Same as status quo. **Bank stabilization:** Same as status quo.
Ex Situ Population Management	**Seedbank:** Same as status quo **Field banks:** Same as Population Restoration
Conservation Translocation	**Restore existing sites (reinforcement and/or reintroduction):** n/a **Establish new sites:** Introduce *ex situ* seeds and/or plants at new sites along the Wolastoq with suitable habitat based on results of ground truthing. Priority for sites managed by province or conservation partners.

Assisted Colonization B (Establishing new sites outside the Wolastoq)	
Monitoring	**Existing sites:** Same as status quo. **Potential sites:** Same as Assisted Colonization A. **New sites:** Same as Assisted Colonization A.
In Situ Site Management	**Vegetation management:** Same as status quo. **Bank stabilization:** Same as status quo.
Ex Situ Population Management	**Seedbank:** Same as Assisted Colonization A. **Field banks:** Seed sources utilized will be the same as the ones generated within both currently operational field banks.
Conservation Translocation	**Restore existing sites (reinforcement and/or reintroduction):** n/a **Establish new sites:** Introduce *ex situ* seeds and/or plants at new sites along other rivers (e.g., Tobique, Restigouche, Meduxnekeag) with suitable habitat based on results of ground truthing. Priority for sites managed by province or conservation partners.

Population Restoration + Assisted Colonization A (Restoring existing sites and establishing new sites on the Wolastoq)	
Monitoring	**Existing sites:** Same as Population Restoration. **Potential sites:** Same as Population Restoration and Assisted Colonization A. **New sites:** Same as Assisted Colonization A.
In Situ Site Management	**Vegetation management:** Same as Population Restoration. **Bank stabilization:** Same as Population Restoration.
Ex Situ Population Management	**Seedbank:** Same as Assisted Colonization A. **Field banks:** Same as Assisted Colonization A.
Conservation Translocation	**Restore existing sites (reinforcement and/or reintroduction):** Same as Population Restoration. **Establish new sites:** Same as Assisted Colonization A.

Population Restoration + Assisted Colonization B (Restoring existing sites on the Wolastoq and establishing new sites outside of the Wolastoq)	
Monitoring	**Existing sites:** Same as Population Restoration.

	Potential sites: Same as Population Restoration and Assisted Colonization A. **New sites:** Same as Assisted Colonization A.
In Situ Site Management	**Vegetation management:** Same as Population Restoration. **Bank stabilization:** Same as Population Restoration.
Ex Situ Population Management	**Seedbank:** Same as Assisted Colonization A. **Field banks:** Same as Assisted Colonization B.
Conservation Translocation	**Restore existing sites (reinforcement and/or reintroduction):** Same as Population Restoration. **Establish new sites:** Same as Assisted Colonization B.

Population Restoration + Assisted Colonization A + B (Restoring existing sites and establishing new sites on the Wolastoq and establishing new sites outside of the Wolastoq)*	
Monitoring	**Existing sites:** Same as Population Restoration. **Potential sites:** Same as Population Restoration and Assisted Colonization A. **New sites:** Same as Assisted Colonization A.
In Situ Site Management	**Vegetation management:** Same as Population Restoration. **Bank stabilization:** Same as Population Restoration.
Ex Situ Population Management	**Seedbank:** Same as Assisted Colonization A. **Field banks:** Same as Assisted Colonization A + B.
Conservation Translocation	**Restore existing sites (reinforcement and/or reintroduction):** Same as Population Restoration. **Establish new sites:** Same as Assisted Colonization A + B.

*Alternative developed by participants during the workshop.

Appendix E. Risk Categories

Table E1. Categories of Risk (from the IUCN Guidelines for Reintroductions and Other Conservation Translocations)

Biological Risks
Ecological Risk ● Major impacts at transplantation site on other species, and/or on ecosystem structure and functions i.e., the introduction of a species into a habitat where it has not occurred previously, or where it has not occurred for a long time, may in some cases lead to the displacement of non-target species or may influence the structure and composition of the vegetation community. ● Activities associated with translocation (such as planting, soil preparation, fencing, watering, increased pedestrian activity) may impact detrimentally on other species either directly through destruction and trampling, or indirectly by altering ecological processes. ● Could the species be invasive outside of its natural range? **Disease Risk** ● Risk of introducing new diseases or pathogens to natural populations or habitat if appropriate phytosanitary techniques are not applied at the ex situ location(s) and in any subsequent population restoration or conservation introduction (i.e., transfer of known disease/pathogen from translocation material that are likely to have a negative impact on other organisms at the recipient site, including the wild population of Furbish's Lousewort) **Associated Invasion Risk** ● Risk of potentially invasive species/pests being accidentally released with individuals of the focal species **Gene Escape** ● Risk of intraspecific hybridisation: Where translocations involve reinforcement, or reintroductions close to existing populations, there is a risk of genetic swamping of the resident population(s) by the translocated individuals. This can potentially cause a reduction in vigour or reproductive success in a small, stable, resident population if a large proportion of the subsequent reproductive output is derived from the less well-adapted translocated stock.
Risks around human concerns
Socio-economic Risks ● Potential direct and indirect negative impacts on human interests, health and safety - dangers to people, indirect effects impacting food supplies, clean water, pollination; public against removing individuals in source area; adverse public relations **Financial Risks** ● If the translocated species causes significant unacceptable consequences would there be a need for funding to discontinue the translocation or

to apply remedial funding to any damage caused by the translocated species?

Transboundary Risk

- Common duty and international law aim to prevent, reduce and control environmental harm to neighbouring countries, and to promote cooperation to manage transboundary environmental risks. States should carefully consider risks to neighbouring territories. Can include First Nations and sub-national boundaries (provinces, territories, states).

Appendix F. Ten-year Timeline

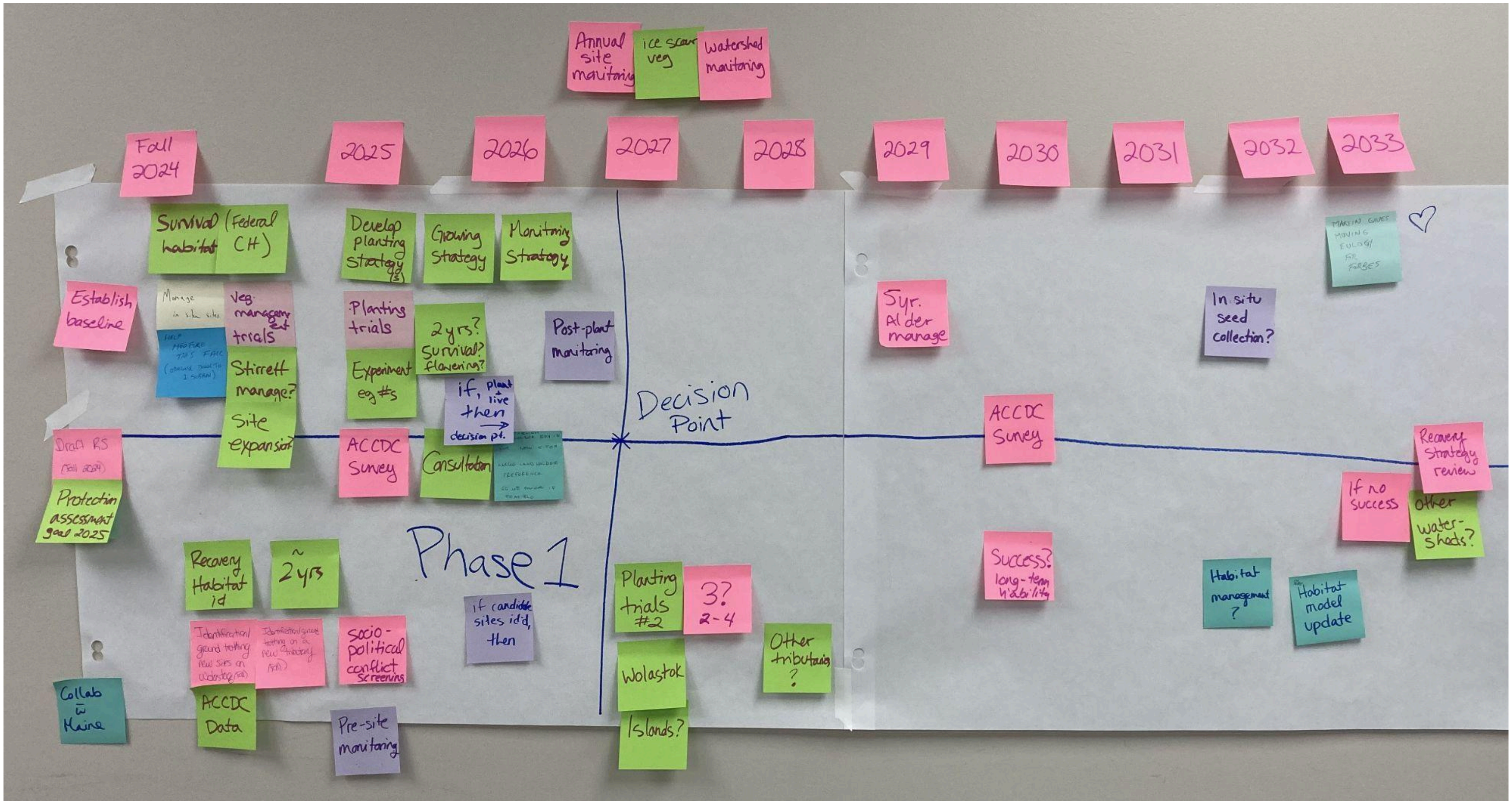

Figure F1. Suggested ten-year timeline for implementation of high level recovery actions for Furbish's Lousewort in New Brunswick. (Note: colours are not significant).

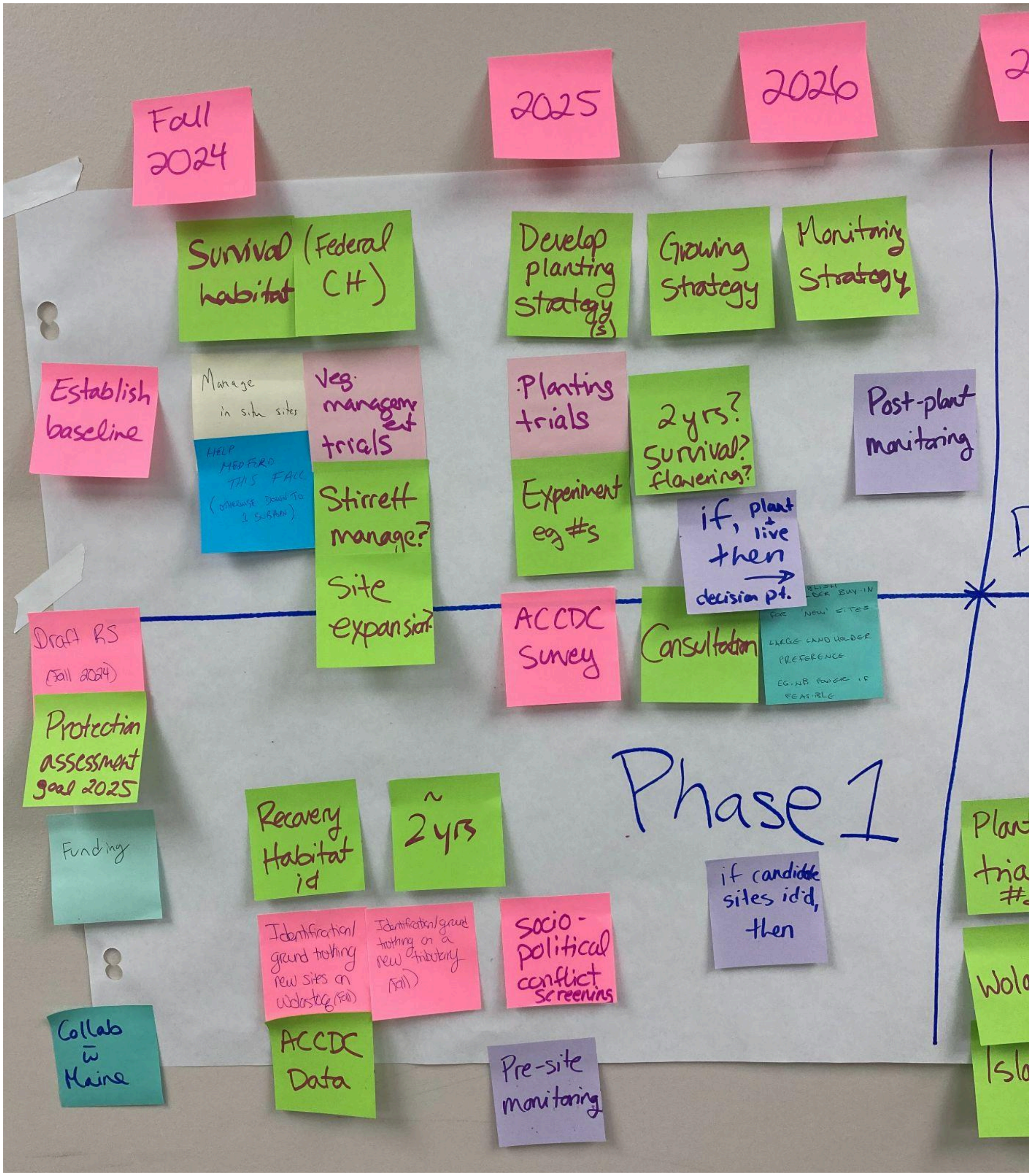

Figure F2. Phase 1 of the suggested implementation timeline (approx. 2024 - 2027).

Appendix G. CPC Guiding Questions

Guiding questions for rare plant reintroduction and other conservation translocations compiled from sections 4C, 4D and 4E of the Center for Plant Conservation Best Practices (CPC 2019).

Pre-translocation

Planning a reintroduction:

- ☐ Is the taxon already living at the recipient site, was it historically present there, or is this a completely new location?
- ☐ Have you considered legal issues, logistics, and land management?
- ☐ Is the biology and ecology of the species understood?
- ☐ Are genetic studies needed?
- ☐ Have germination protocol and propagation methods been determined?
- ☐ Has a suitable recipient site been identified and are land managers supportive?
- ☐ Are pollinators known and present?
- ☐ Are plants susceptible to herbivory? Will they be protected?
- ☐ Have threats been reduced or eliminated?
- ☐ How many plants or seeds are available and how many are needed?
- ☐ What is the experimental design?
- ☐ How will success be measured?
- ☐ What kind of aftercare for plant and site management will be needed and how frequently should it be performed?
- ☐ What is the involvement of the land manager/owner?
- ☐ What is the monitoring design and plan for reporting results?
- ☐ In what ways will you involve the public in your project?
- ☐ Suitable habitat is not available, nor understood.

Designing reintroduction experiments:

- ☐ What additional knowledge is needed about the species biology or other factors? How can the reintroductions be planned as experiments to address these unknowns?
- ☐ What is the experimental design? How much replication is needed for adequate statistical power? How will the study be analyzed?
- ☐ Have you considered testing aspects of ecological theory, such as founder events, small population dynamics, establishment phase competition, dispersal and disturbance ecology, succession, metapopulation dynamics, patch dynamics on population persistence, resilience and stability over time?

- ☐ Using the reintroduced population as a cohort, will you examine natural variation in survival, mortality, and recruitment and tie these to environmental factors?
- ☐ Will the reintroduction test key habitat gradients of light, moisture, elevation, or temperature?
- ☐ Will the underlying environmental drivers of population growth be measured?
- ☐ Will genetic factors be part of the experimental design?
- ☐ What traits will be monitored and how will they be analyzed?
- ☐ Will the reintroduction further our knowledge of key principles related to rare species' ability to cope with climate change?
- ☐ Are you testing factors within a single site or across multiple sites?
- ☐ Has a monitoring plan been developed? How long will monitoring be conducted? Have you considered an adaptive monitoring plan? What will the duration of the experiment be?
- ☐ Have you developed a clear unambiguous datasheet to track reintroduced plant growth, reproduction and survival? If the monitoring persists for decades, will your successors be able to interpret the data you have collected?
- ☐ Will the data be housed within your institution or elsewhere so that your successors will able to use it?
- ☐ How will the plants be mapped and marked/numbered?
- ☐ If plants are susceptible to herbivory, will their response be included in the design or should the plants be protected?

Selecting recipient sites:

- ☐ Have you researched the history of the recipient site?
- ☐ Have you incorporated species-specific factors related to optimal population growth to assess suitable recipient sites for your taxon?
- ☐ Have you identified species-specific environmental and community factors in occupied versus unoccupied patches?
- ☐ Have you ranked several potential suitable recipient sites to determine the best place for the reintroduction to occur?
- ☐ Is there still suitable habitat left within the species' range?
- ☐ Are recipient sites of sufficient quality and with sufficient long-term protection to ensure the long-term security of the reintroduced population?
- ☐ Are threats absent or adequately managed at the site?
- ☐ What were the previous threats that may have caused the species to become extirpated from site?
- ☐ What is the potential for future threats?
- ☐ Is current and future land use of the recipient site and surrounding sites compatible with sustainability of the reintroduced population?
- ☐ Are potentially hybridizing congeners present at recipient site? Which ones? Are they present at nearby sites? Are they present within the target species' range?

- ☐ Is the recipient site within the species' climate envelope now? Are there models suggesting the location will be safely within the climate envelope in the future?
- ☐ What site preparation is required before the plants can be installed (for example, canopy thinning, invasive removal, etc.)? Will habitat manipulation continue after plants are installed?
- ☐ Does the species require habitat conditions that no longer exist on site (for example, fire, periodic inundation, etc.)? Can those conditions be mimicked?

Habitat and landscape considerations:

- ☐ Does the recipient site contribute to natural patterns of heterogeneity in the species' distribution?
- ☐ Have you considered habitat connectivity? Is healthy suitable habitat nearby that will allow for the restored population to expand in area and number of individuals? Is adjacent property suitable habitat? Is adjacent property protected?
- ☐ Are there metapopulation possibilities? Have you accounted for between site factors as well as within site factors? Is the site located in close proximity to extant populations or other reintroduced populations?
- ☐ What are the distances between the proposed reintroduction and nearby wild populations?
- ☐ What benefits or detriments do the nearby sites give the restored population?

Genetic studies required:

Within-population issues:

- ☐ Population has fewer than 50 individuals flowering and setting fruit.
- ☐ The species is clonal.
- ☐ Little or no viable seed is being set.
- ☐ There are potential taxonomic concerns (taxonomic ambiguity, potential hybrids, or variation in ploidy).

Issues across the species' range:

- ☐ The species is declining and little is known about the biology or life history of the species.
- ☐ The species has highly fragmented and isolated populations.
- ☐ The species looks different in different locations.
- ☐ One or more populations of the species has distinct ecology from the majority of populations.

Wild population considerations:

- ☐ What is the genetic structure of the wild populations?
- ☐ What is the dispersal capability of the species?
- ☐ If hybridization is a concern, what are the ploidy levels of the wild populations?

- [ ] Does the species suffer symptoms of inbreeding depression?
- [ ] Is there evidence of outbreeding depression?
- [ ] Based upon special ecology, unique morphology (that is, ecotypes) or spatial disconnection from other populations, do you suspect that a population has local adaptation?
- [ ] Based upon the presence of a congener in the wild population and/or variable morphology, do you suspect that the species is hybridizing with a congener?

Genetics of source material:

- [ ] From which wild population(s) should the material be collected for use in the reintroduction?
- [ ] What is the basis for collecting source material from a particular location?
- [ ] How will the source material be sampled?
- [ ] What is the genetic composition of the material reintroduced?
- [ ] Should material come from an ex situ source, only one wild source population, or mixed population sources?

Planning for population growth:

- [ ] What founder population size will be used?
- [ ] What size and stage structure of plants will be used?
- [ ] How will the founding population be spatially configured to favor demographic persistence and stability?
- [ ] What is known about population growth, recruitment, and survivorship in wild habitats and what environmental or community factors are correlated with population growth rates?
- [ ] How will population growth, recruitment, and survivorship be monitored in the reintroduced population? And by whom?

During Translocation

Logistics for implementation:

- [ ] What is the best season to transplant or sow seeds? Keep in mind that best season for rainfall may also be the hottest time of the year and plants may require more attention.
- [ ] Have you invited participation from enough staff, volunteers, community members, agency and landowners, or land managers to execute the reintroduction?
- [ ] Have permits been acquired and are they up-to-date?
- [ ] How will you ensure that plants will be able to be tracked for many years in the future? Are plants tagged and positions recorded with GPS?

- ☐ How will you transport plants to the recipient site? Do you have necessary off-road equipment for transport away from roadways?
- ☐ What is the planting layout design?
- ☐ How are you going to water plants?
- ☐ Have you notified the press or have you arranged for photos to be taken of the event? (Note that there may be circumstances when the exact location of the conservation translocation must not be publicized to prevent unauthorized collection of the taxon; however, good conservation news with general descriptions of the reintroduction can be used to engender public enthusiasm for plant conservation. If you are uncertain, talk to your regulatory agency prior to notifying the press.)

Post-translocation

Post-planting/monitoring:

- ☐ What aftercare will be needed and how frequently will this require attention?
- ☐ What habitat management and threat abatement is needed? How frequently?
- ☐ Has a monitoring plan been prepared and reviewed?
- ☐ How often/how long will the reintroduction be monitored?
- ☐ How will success be measured?
- ☐ Are sufficient funds available for aftercare?
- ☐ Do permits cover aftercare activities?

Appendix H. Furbish's Lousewort Population Structure and Genetic Diversity

Manuel Lamothe[1], Dawson White[2], Richard Ree[3], Eric Normandeau[4], and Martin Williams[1]

[1]Canadian Forest Service, [2]Harvard University Herbaria, [3]Chicago Field Museum, [4]Université Laval

Background

Genetic diversity is critical to the resilience of species to various environmental and biotic threats and their ability to adapt to future environmental scenarios. Due to its specific habitat requirements on disturbed riverbanks and its limited long distance dispersal potential, it seems likely that the existing stands of Furbish's Lousewort along the St. John/Wolastoq river might be isolated from one another and thus very susceptible to loss of genetic diversity through inbreeding and genetic drift. Strategies to evaluate and augment genetic diversity have been discussed extensively in rare species conservation to limit the impacts of inbreeding depression. As such, it is crucial to gain knowledge about the structure and genetic diversity of populations and be able to use that knowledge to guide ex-situ outcrossing and population enrichment programs to maintain standing genetic diversity within the species. A first study using 18 isozymes found no profile differences across 28 individuals, providing no basis for understanding population structure and indicating low genetic diversity overall (Waller et al., 1987).

Approach

To build on this research, we increased the sensitivity and breadth of the analysis with a Next-Generation DNA Sequencing approach that sampled many individuals from every major stand in the watershed. Our study had three main objectives: (1) to assess the extent of population structure within and between the remaining stands of Furbish's Lousewort, (2) to evaluate genetic diversity and inbreeding levels within each subpopulation, and (3) to determine whether crossbreeding individuals from different populations within the species' endemic range could produce more genetically diverse seed sources for population enrichment planting.

We sequenced and assembled the first genome for *Pedicularis furbishiae*, then used the Genotyping-By-Sequencing (GBS) protocol of Elshire et al. (*PLoS One*, 2011) to sequence thousands of loci across the genome in a total of 132 individuals from 9 stands (4 from Maine, 5 from New-Brunswick). Using standard population genetic analyses, variable markers were used to determine population structure among stands and calculate the level of genetic diversity and inbreeding within these populations.

Results

Our population structure analysis revealed strong support for the existence of four genetic populations: one in Maine and three in New Brunswick (Grand Falls, Medford, and Big Flat). The three identified New Brunswick populations correspond exactly to the sampling sites and there is no gene flow between them via either seeds going downstream or pollen going up or downstream. Genetic diversity within these sites is estimated to be low in all subpopulations assessed but similar across the different sites in Maine and New Brunswick revealing that these populations could have been large enough in the past to maintain some genetic diversity and outcrossing within sites. Inbreeding is estimated to be high in Grand Falls and Medford (FIS>0.3), but lower in Big Flat (FIS=0.13). In Maine, the four stands (Big Black, Castonia, Dickie Bridge, and Pelletier Brook) form one population. Sampling within these sites was lower but we do find evidence of isolation-by-distance, indicating the existence of subpopulations within Maine and some gene flow between them. The Maine population also has low to moderate inbreeding (FIS=0.19). However, inbreeding is driven by an excess of homozygotes in the Dickie Bridge and Pelletier Brook stands (FIS=0.22), compared to little or no inbreeding in the Big Black (FIS=0.02) and Castonia (FIS=0.12) stands. These results taken together show that the three New Brunswick populations are effectively isolated from each other and that there was significant genetic diversity, as well as variable levels of inbreeding, within them at the time of sampling.

In a healthy, non-fragmented metapopulation formed by stands located in close proximity, the dispersal of migrants or gene flow from pollinators can maintain and even increase genetic diversity. In Maine, the shorter distances between stands and the number of individuals within them, together with the genetic evidence, suggest ecological processes could still be maintaining the habitat and connectivity of Furbish’s Lousewort stands. However, more research is needed to support the existence of such a functional ‘meta-population’ in Maine that could be buffering stands against extirpation.

Conversely, the New Brunswick populations are small, isolated, and both site numbers and plant numbers per site are declining. The recent population declines at Medford and Big Flat have resulted in the near total extirpation of Furbish’s lousewort from these sites and as a result Grand Falls is the final viable natural population in New Brunswick. The isolation and vulnerability of these populations to drastic demographic size changes emphasizes their vulnerability and the importance of the ex-situ breeding and population enrichment programs.

The data supporting these results do come with a caveat. Namely, the number of variable SNPs used to draw these conclusions is very low (137 SNPs) compared to what similar studies report, thus representing a small portion of the whole genome. However, the low number of markers found is probably indicative of low genetic diversity among the sequenced samples. Since non-variable markers are not kept in these analyses, this can lead to overestimates in the assessed levels of genetic diversity and inbreeding, meaning that the real populations could be at an even greater risk of extirpation than suggested here.

Recommendations

Since this species is facing an extreme risk of extirpation in New Brunswick and is globally endangered with extinction, our results, together with the startling population declines observed in New Brunswick, support the objective to **transplant as many Furbish's lousewort individuals from combined Maine and NB seed sources to enhance at existing and colonize new sites showing suitable conditions.**

We make these specific recommendations to support this aim:

1. Seed Banking: Cooperate with Maine authorities to continue seed collection from throughout the range of Furbish's Lousewort for cryogenic preservation and to provide germplasm representing the entire endemic species range.
2. Ex-situ propagation: propagate plants from all subpopulations and plant them in common gardens to allow for cross pollination and maximize genetic diversity within the seed sources.
3. Enrichment planting at existing stands: if decisions are made that the habitat is still viable for Furbish's lousewort, plants that are transferred on site should be sourced from all available seed sources including those generated from outcrossing plants of different origin from the field banks.
4. Enrichment planting at new sites: plants that are transferred on site should be sourced from all available seed sources including those generated from outcrossing plants of different origin from the field banks.

References:

Elshire RJ, Glaubitz JC, Sun Q, Poland JA, Kawamoto K, Buckler ES, et al. (2011) A Robust, Simple Genotyping-by-Sequencing (GBS) Approach for High Diversity Species. PLoS ONE 6(5): e19379. https://doi.org/10.1371/journal.pone.0019379

Gawler SC, Waller DM, Menges ES. (1987) Environmental Factors Affecting Establishment and Growth of Pedicularis furbishiae, a Rare Endemic of the St. John River Valley, Maine. *Bulletin of the Torrey Botanical Club*, *114*(3), 280–292. https://doi.org/10.2307/2996466