Technologies for conserving climate-sensitive species at risk: Rare plants

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Executive Summary

Climate change together with landscape fragmentation has the potential to threaten species that are climate sensitive and dispersal limited. One adaptation strategy to dealing with this threat is to proactively translocate individuals to higher latitudes or altitudes outside of their current range (distribution). This management strategy has commonly been referred to as assisted migration and is hotly debated in conservation due past challenges associated with translocations of other species and the appearance that losses of extant populations can be mitigated by human-assisted establishment of new 'artificial' populations. Here we examine the efficacy of using this anticipatory conservation tool in Alberta by examining its use for two range restricted and uncommon plants that occur at the ecotone between the boreal forest and the grasslands in east-central Alberta. The two species included are northern blazing star (*Liatris ligulistylis*) and long-leaved bluets (*Houstonia longifolia*). In 2012, 60 mature plants and 600 seeds of northern blazing star were translocated to 3 sites in Alberta (20 plants and 200 seeds per site). The three sites represent contrasting environmental conditions of the species including a control site where climate is similar to source (extant) populations, a northern site representing what would be targeted for this species under assisted migration, and a southern site representing warmer and drier conditions than the species currently occurs in yet is projected for current populations thus testing climate change vulnerabilities. In 2013, seeds and seed delivery systems, such as seed balls, will be introduced to the 3 experimental sites for both species, the performance of 2012 and 2013 translocations assessed (e.g. germination, survival, phenology, growth, and fecundity [seed production]), as well as a more in-depth assessment of the autoecology of the two focal species in its current range in order to better understand what limits current populations.

1. *Introduction:*

Climate change in the last 100 years has been implicated in observed shifts in the geographic ranges and local species distribution for plants and animals around the world (IPCC 2007, Parmesan 2006, Crimmins et al. 2011). These shifts in distribution are projected to be even more profound over the next few decades to century given the current climate change scenarios (Thomas et al. 2004, Hamann and Wang 2006). Despite efforts to maintain and restore landscape connectivity to facilitate migration of species, many species will struggle to respond to shifts in their climate niches because of dispersal limitation, biotic interactions between species, genetic adaptation, natural or anthropogenic migration barriers, or the potentially irregular pace of climate change (Early and Sax 2011, Loss et al. 2011, Gillson et al. 2013). For species of conservation concern, assisted migration, also referred to as assisted colonization, assisted translocation, or managed relocation, has been proposed as a tool for averting extinctions of species and populations and for maintaining biodiversity in the face of climate change and habitat fragmentation (McLauchlin et al. 2007, Schwartz et al. 2012). Assisted migration involves the intentional and planned translocation of a species beyond its current distribution to areas where climate is predicted to be more favourable for that species in the future (McLauchlin et al. 2007, Schwartz et al. 2012).

The potential use of assisted migration as a conservation strategy is hotly debated, and involves scientific, regulatory, and societal challenges (Schwartz et al. 2012). A central concern among opponents is the high uncertainty surrounding the potential for a translocated species to have unintended, and potentially severe consequences on the recipient ecosystem (Ricciardi and Simberloff 2009). Supporters argue that costs of inaction (i.e., species extinctions) will be too high for some species, and that in some cases sufficient information exists to evaluate the potential impacts of a candidate species on the recipient ecosystem (e.g., Sax et al. 2009). There is a need for the development of decision-making frameworks that clearly outline the suite of potential actions for preventing species extinctions in the face of climate change, around which the costs and benefits of a proposed assisted migration effort can be weighed (Hoegh-Guldberg et al. 2008, Richardson et al. 2009, McDonald-Madden et al. 2011, Schwartz et al. 2012). However, for these frameworks to be useful, they must rely on ecological data to identify and prioritize candidate species for assisted migration and to support the evaluation of costs and benefits for the species of concern and the donor and recipient communities (McLauchlin et al. 2007, Hewitt et al. 2011).

Experimental assisted migration trials can be used to assess both the potential for successful establishment of the new population that has been translocated, and the potential realized climate-related extinction risk to the source population. Such trials can be used to assess the relative importance of biophysical and climatic factors in determining individual fitness and population persistence. Furthermore, they can be used to evaluate methods of undertaking the translocation itself. To date there have been few experimental tests of assisted migration as a potential conservation tool (Hewitt et al. 2011, but see McLane and Aitken 2012), despite the clear information needs they address.

Many plant species will be highly vulnerable to climate change because of their limited dispersal capabilities. Assisted migration may therefore be particularly useful for this group. Plants are also among the lowest risk for assisted migration experiments because the species selected for conservation reasons (common garden experiments have a long history of research for common plants, including trees) are rare and unlikely to become invasive, provided translocations occur within a single continent (Mueller and Hellman, 2008). Translocations are not without concern due past failures of establishment, lack of understanding of environmental limits and biotic interactions, challenge of matching current and future climates, and effects of translocations on source populations (depletion). From an experimental perspective, plants are also an appealing taxon with which to test assisted migration because they are typically easy to translocate and monitor. Here we begin experiments to evaluate the efficacy of using assisted migration as a conservation tool to mitigate the effects of climate change for two species of plants that are range restricted to central Alberta and regionally rare.

2. *Focal Species:*

Two focal species with contrasting life history traits but similar range restrictions in Alberta (northern and southern range limits both occur in Alberta), as well as habitat requirements (stabilized sandy aeolian dunes), were selected for experimental assisted migration. The species are northern blazing star (*Liatris ligulistylis*) and long-leaved bluets (*Houstonia longifolia*). Both species are regionally rare and occur at their northwestern limits in North America. Neither species is federally or provincially 'at risk', but provide a reasonable surrogate for at risk species for assisted migration trials by virtue of their regional rarity. Populations of both species occur as small, isolated populations in east-central Alberta's aspen parkland natural subregion with presumably narrow climate niches since populations are not known further south (grassland natural subregions) or north (dry sandy habitats in the boreal forest). Given the current narrow climate niche, climate change projections for the area would presumably pose significant long-term risks for the species, particularly since the landscapes they currently reside in are characterized by having some of the highest levels of habitat loss and fragmentation in Alberta.

2.1 Northern blazing star (Liatris ligulistylis)

The first species is northern (meadow) blazing star (*Liatris ligulistylis*). This species is a perennial forb and member of the Asteraceae family found in south-central Canada (Alberta, Saskatchewan & Manitoba) and the Midwestern USA including small, isolated threatened populations along the US Rocky Mountains. Overall, North America contains 27 species of *Liatris*. Although some of the 27 species of Liatris are common (e.g. *Liatris punctata* and *L. spicata*), quite a few species are threatened despite having similar growth forms/traits and broadly similar habitats. In Alberta, the conservation status of northern blazing star is vulnerable (S3), while the status in Saskatchewan is considered 'secure' (S5) and for its eastern Canadian distribution in Manitoba as 'apparently secure' (S4) (NatureServe 2013). The distribution of northern blazing star within Alberta is limited to the aspen parkland region east of Edmonton (Figure 1) from the southern boundary of the boreal forest to the approximate northern range limit of the grassland natural region containing its common sister species the dotted or narrow leaf blazing star (*Liatris punctata*). Although the species elsewhere is known to grow in mesic to even hydric soils, extant populations in Alberta are largely limited to patchy aeolian deposits of loamy sand occurring regionally as small isolated populations often only within forest openings or along the edges of disturbed soils such as verge habitat along roadsides. It is not known whether mesic prairies in the aspen parkland region historically supported northern blazing star. It is quite possible given that most remaining prairie habitat in the aspen parkland of Alberta occurs on drier sites where agricultural land use conversion did not occur. Regardless of their presence in other historic prairie habitats of the aspen parkland, the historic distribution within Alberta appears to have been limited by drier conditions south of the parkland region and colder conditions to the north since similar stabilized aeolian prairie habitats or forest openings are available in both the grassland and boreal regions. Dispersal limitations, as well as competition with conspecifics (e.g. dotted blazing star) or other grassland species, cannot be ruled out as a factor limiting its distribution.

Locally, northern blazing star blooms in late July to mid-August (Figure 2a) attracting numerous pollinators with its showy flowers. It therefore does not appear to be limited by pollinators, although seed predators may affect local populations (Glasier and Nielsen, personal observation). Seeds mature in late August through September (Figure 2b) and are dispersed by wind in late September to November (Nielsen, personal observation) with the help of its achenes common to other Asteraceae species. One characteristic of the species that facilitates translocation of mature plants is the presence of a corm (Figure 2c) which can be excavated after senescence in the fall. In fact, other species of *Liatris* are commonly available for purchase at garden centres as dormant corms and named either blazing star or gayfeathers.

2.2 Long-leaved bluets (Houstonia longifolia)

The second species chosen for assisted migration trials is long-leaved bluets (*Houstonia longifolia;* synonyms *Hedyotis longifolia*). This species is a member of the Madder (Rubiaceae) family and is a short-statured perennial forb characterized by semi-disturbed sandy grassland habitats or elsewhere in its range on rocky soils. In Alberta, its conservation status is imperiled (S2), with conservation status in other parts of its range in Canada varying from ‘not ranked’ (Saskatchewan), to ‘apparently secure’ (S4) in Manitoba and Ontario, and ‘critically imperiled’ (S1) in Quebec (NatureServe 2013). Excluding the NE USA where its status is imperiled or critically imperiled, long-leaved bluets throughout the Midwest and southeastern USA is considered secure (S5) or unranked with its range occurring from Florida and Texas in the south to Maine in the northeast and North Dakota in the Midwest. Alberta therefore represents the far northwestern limit of the species. Within Alberta the distribution of long-leaved bluets is similar to northern blazing star with its range limited to the aspen parkland region east of Edmonton (Figure 3) from the southern boundary of the boreal forest to the approximate northern range limit of the grassland natural region. Like northern blazing star, populations can be found in roadside verge habitat (Figure 4b) where soil conditions are suitable and competition is limited (Nielsen, personal observation).

Long-leaved bluets flower earlier than northern blazing star in approximately late June to mid-July (Figure 4a) with seeds maturing by September (Nielsen, personal observation). Little is known about its pollinators, but flowers of long-leaved bluets are known to be distylous (heterostylous) having two distinctive floral forms and general incompatibility (self-incompatible) within forms leading to fruit-set failure (Beliveau & Wyatt 1999). Although small in number and only at one location, personal observations of flowers in July and seed capsules in September at Smoky Lake suggest that seed set is not limiting. Dispersal distance of bluets is unlikely to be far given the small size of its seed (300,000 seeds per ounce; Prairie Moon Nursery) and lack of dispersal associations with other species or wind. Further research is needed to confirm the reproductive ecology of bluets and to better understand its dispersal ability. This would allow for any identification of potential limitations in populations beyond habitat associations and climatic niches.

3. Habitat modelling:

Given the limited number of known locations of the two focal species and the presence-only nature of the data, Maximum Entropy models of potential habitat were developed using the software Maxent (Phillips et al. 2004; 2006). Habitat models were developed to help identify the environmental niche of the two species, the current range limits, and potential habitat for future surveys. Environmental predictors used to estimate the distribution of the two species across Alberta included 11 climate variables using climate normals for the period 1960-1990 (Climate WNA software; Wang et al. 2012) and edaphic conditions that identified the location of sand dunes and aggregates (sand and gravel) in Alberta (Edwards and Budney 2004). Models were predicted at a 250 metre resolution and classified into four different habitat categories: (1) non-habitat; (2) low suitability; (3) moderate suitability; and (4) high suitability. In both cases, habitat models predicted strong associations with areas of sand and gravel (primarily stabilized aeolian dunes) within east-central Alberta where temperature and precipitation were moderate relative to other parts of Alberta (Figure 5).

4. Experimental translocations:

No translocations of long-leaved bluets were completed in 2012, while three contrasting translocations were established in 2012 for northern blazing star. These include: (1) a northern translocation to a 'cooler' environment to test the feasibility of establishment and growth of plants north of its range; (2) a control translocation within the same climate niche as source populations; and (3) a southern translocation to a 'warm and dry' environment to evaluate the sensitivity of the species to future climate warming. Given the strong association of each species with sandy habitats, selection of recipient sites were based on the location of mapped sand deposits within, north and south of its current range based on habitat models from the above section (1.3). Given mapped ranges of the species, the northern recipient site was targeted to be within the central mixedwood boreal forest natural subregion that begins in the area north of Lac La Biche, Alberta. The southern recipient site, on the other hand, was targeted to be within the dry mixedgrass grassland natural subregion that begins in the area south of Hanna, Alberta. Finally, the control translocation was selected to occur within its range in the Edmonton region. Only private lands were considered as recipient sites with the three final locations selected as: (1) Dunroven private property north of Lac La Biche (rental agreement with landowner); (2) Woodbend Forest near Devon, Alberta which is owned and managed by the Department of Renewable Resources, University of Alberta; and (3) Duchess (Mattheis) Ranch owned and managed by the Faculty of Agriculture, Life and Environmental Sciences, University of Alberta near Duchess, Alberta (Figure 6). All three sites occur on stabilized dunes, but differ in current climate.

Source plants for northern blazing star translocations included two sites: (1) Bruderheim, Alberta in verge habitat along roads (road right of way) associated with industrial developments; and (2) Ukalta, Alberta again in verge habitat along road right of ways northeast of Bruderheim (Figure 6). In total, 30 mature plants were collected evenly from the two different sources (i.e. 15 each) in September of 2012. Both sites contained what was considered to be secure populations (>500) with plants only removed from disturbed roadside ditches that were likely to be graded in the future. Size of each plant and seed production was measured and the corm separated from the above ground stem that was stored individually in labeled plastic bags. Each corm were stored in #2 plastic nursery pots of the source sites soil (sand) and kept moist and cool until translocation.

Translocations occurred in mid to late October at the Woodbend Forest, Dunroven and Duchess Ranch properties. The experimental design for each recipient site included translocation of 10 mature corms and 200 seeds (collected from the same 15 plants at each site) each split in half between the two source populations (Bruderheim and Ukalta). Half of the corms and half of the seed where planted in the source soils, while the other half were planted in the recipient soil, but all within buried #2 plastic nursery pots for corms or plastic trays for seed (Figure 7). Wire exclosures were placed over the seed trays and wire exclosures (cages) prepped for installation over plants (corms) during the next growing season when new growth begins. All seed and plant trials were mapped and marked with reference to pin stakes.

Although no translocations occurred in 2012 for long-leaved bluets, seed was collected from one roadside ditch site near Bellis, Alberta (depicted in Figure 4b) during early September. These seeds will be used for translocation experiments to Woodbend Forest, Dunroven, and Duchess Ranch in 2013 (see section 1.5 below).

5. Upcoming (2013-2014) work:

5.1 General translocation experiments

Translocation experiments will be added for long-leaved bluets using seed collected from 2012. No seedling or mature plants were considered for translocation for this species given the small nature of the plant, general short longevity, and small, fine root system. We may consider, however, translocation of mature plants through removal of the plant with associated soil. At each translocation (recipient) site, establishment rates of seed (long-leaved bluets and northern blazing star), survival of adult plants (northern blazing star), and the phenology (flowering and senescence), growth, and fecundity (seed production) assessed. This will be part of an MSc thesis of Jennine Petersen who will start in May of 2013.

5.2 Seed delivery systems and microsite enhancements to increase establishment success

Given that species selected for assisted migration are rare and in many cases the seed limited, methods that enhance germination and establishment success would be desirable. As part of the 2013 translocation work, seed delivery systems will be assessed, including the use of clay 'seed balls' (or discs) with soil amendments (charcoal, water retention gels, and micronutrients) and a rodent repellant that uses Capsaicin. Seed enhancements will also be examined relative to applications of coarse woody debris (CWD) in order to modify microsite conditions, which is known to greatly enhance germination of seeds for some species (Harper 1977). The four experimental treatments for 2013 translocation of seeds (2x2 factorial design of microsite and seed enhancements) will include: (1) a seed-only, open microsite control (no treatment of seed beyond stratification and no application of CWD); (2) seed-only, microsite manipulation (no treatment of seed beyond stratification and an application of CWD); (3) seed ball (disc), open microsite (seed enhancement, but no microsite manipulation); and (4) seed ball (disc), microsite manipulation (seed enhancement and microsite manipulation). Three replicates of >100 seeds each will be used in the experiment at a minimum of one site. Seed delivery and enhancement experiments are being done in collaboration with Tim Vinge who has previously examined the use of seed pucks for tree and shrub seeds.

Seed source for long-leaved bluets will be from Alberta, while experiments for northern blazing star will include not only the Alberta source, but also seed originating from Saskatchewan (Blazing Star Nursery) and Minnesota (Prairie Moon Nursery) in order to increase seed availability for the experiment and to further test climate limitations within a common garden environment.

5.3 Population ecology of extant populations

As well as examining translocation success, studies of the population ecology of northern blazing star and long-leaved bluets will be examined east and northeast of Edmonton. This will include general surveys of population size, pollination efficiency, and seed production within extant populations during July (long-leaved bluets) and August (northern blazing star).

5.4 Prioritizing additional species for assisted migration experiments

In addition to the existing two focal species being evaluated, additional plant species will be prioritized for assisted migration (translocation) experiments based on their ranges in Alberta, population sizes, habitat fragmentation, and dispersal ecology.

5.5 Relevance to policy and regulations

Translocations of plants that are not protected by the Species At Risk act or Alberta's Wildlife Act are not regulated with respect to translocations and no current policies exist with respect to use of translocations for conservation reasons including climate change.

6. References

Beliveau, B.D. & R. Wyatt. 1999. Compatibility relationships in distylous bluets: *Houstonia serpyllifolia* and *H. longifolia* (Rubiaceae). The American Midland Naturalist, 141(2).

Crimmins, S.M., S.Z. Dobrowski, J.A. Greenberg, J. Abatzoglou, and A.R. Mynsberge. 2011. Changes in climatic water balance drive downhill shifts in plant species' optimum elevations. Science 331: 324-327.

Early, R. and D.F. Sax. 2011. Analysis of climate paths reveals potential limitations on species range shifts. Ecology Letters 14:1125-1133.

Edwards, W.A.D. and H.D. Budney. 2004. Alberta Sand and Gravel Deposits with Aggregate Potential. Digital Data 2004-0034.

Gillson, L., T.P. Dawson, S. Jack, and M.A. McGeoch. 2013. Accommodating climate change contingencies in conservation strategy. Trends in Ecology & Evolution 28:135-142.

Hamann, A. and T. Wang. 2006. Potential effects of climate change on ecosystem and tree species distribution in British Columbia. Ecology, 87(11):2773–2786.

Harper, J.L. 1977. Population biology of plants. Academic Press, London, 892 pages.

Hewitt, N., N. Klenk, A.L. Smith, D.R. Bazely, N. Yan, S. Wood, J.I. MacLellan, C. Lipsig-Mumme,and I. Henriques. 2011. Taking stock of the assisted migration debate. Biological Conservation 144:2560-2572.

Hoegh-Guldberg, O., L. Hughes, S. McIntyre, D.B. Lindenmayer, C. Parmesan, H.P. Possingham, and C.D. Thomas. 2008. Assisted colonization and rapid climate change. Science 321:345-346.

Loss, S.R., L.A. Terwilliger, and A.C. Peterson. 2011. Assisted colonization: integrating conservation strategies in the face of climate change. Biological Conservation 144:92-100.

McDonald-Madden, E., M.C. Runge, H.P. Possingham, and T.G. Martin. 2011. Optimal timing for managed relocation of species faced with climate change. Nature Climate Change 1:261-265.

McLachlan, J.S., J.J. Hellmann, and M.W. Schwartz. 2007. A framework for debate of assisted migration in an era of climate change. Conservation Biology 21:297-302.

McLane, S.C. and S.N. Aitken. 2012. Whitebark pine (*Pinus albicaulis*) assisted migration potential: testing establishment north of the species range. Ecological Applications 22:142-153.

Mueller, J.M. and J.J. Hellmann. 2008. An assessment of invasion risk from assisted migration. Conservation Biology 22:562-567.

NatureServe. 2013. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: March 5, 2013).

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution and Systematics 37:637-69.

Phillips, S.J., Dudík, M., and Schapire, R.E. 2004. A maximum entropy approach to species distribution modeling. In Proceedings of the Twenty-First International Conference on Machine Learning, pages 655-662.

Phillips, S.J., Anderson, R.P., and Schapire, R.E. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling, 190:231-259.

Ricciardi, A. and D. Simberloff. 2009. Assisted colonization is not a viable conservation strategy. Trends in Ecology & Evolution 24:248-253.

Richardson, D.M. et al. 2009. Multidimensional evaluation of managed relocation. Proceedings of the National Academy of Sciences 106:9721-9724.

Rosenzweig, C. et al. 2007. Assessment of observed changes and responses in natural and managed systems. Climate Change 2007: Impacts, Adaptation and Vulnerability.Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry,O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 79-131.

Schwartz, M.W. et al. 2012. Managed relocation: integrating the scientific, regulatory, and ethical challenges. BioScience 62:732-743.

Thomas, C.D. et al. 2004. Extinction risk from climate change. Nature 427(8):145-148.

Wang, T., A. Hamann, D.L. Spittlehouse, and T.Q. Murdock. 2012. ClimateWNA - High-resolution spatial climate data for western North America. Journal of Applied Meteorology and Climatology 51: 16-29.

Table 1. Climatic normals (1971-2000) for source and recipient sites. Climate models from Climate WNA (Wang et al. 2012).

Location or records	MAT	MAP
L. ligulistylus (AB herbarium locations)	2.0 (SE=0.3)	435 (SE = 19)
min-max range	1.4 to 2.6	416 to 473
Source sites		
Ukalta	1.8	434
Bruderheim	1.8	446
Translocation sites		
Dunroven (north site)	0.9	450
Woodbend (central site)	2.3	522
Duchess (south site)	3.6	328

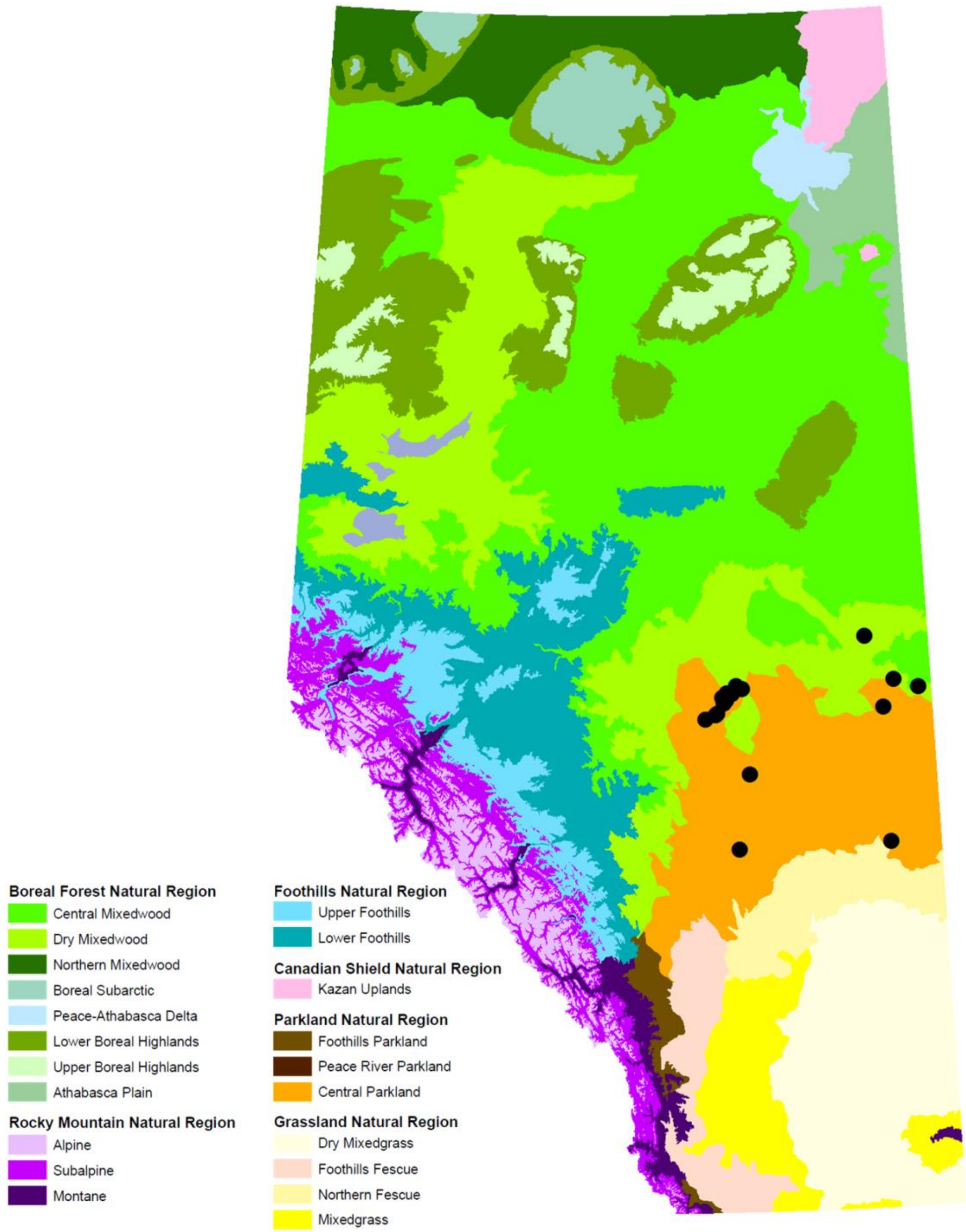

Figure 1. Known locations (black circles) of northern blazing star (*Liatris ligulistylis*) in east-central Alberta, Canada.

a. b. c.

Figure 2. Northern blazing star (*Liatris ligulistylis*) inflorescence (a.), mature seed heads (b.), and corm (c.) from central Alberta (Photographs by S. Nielsen).

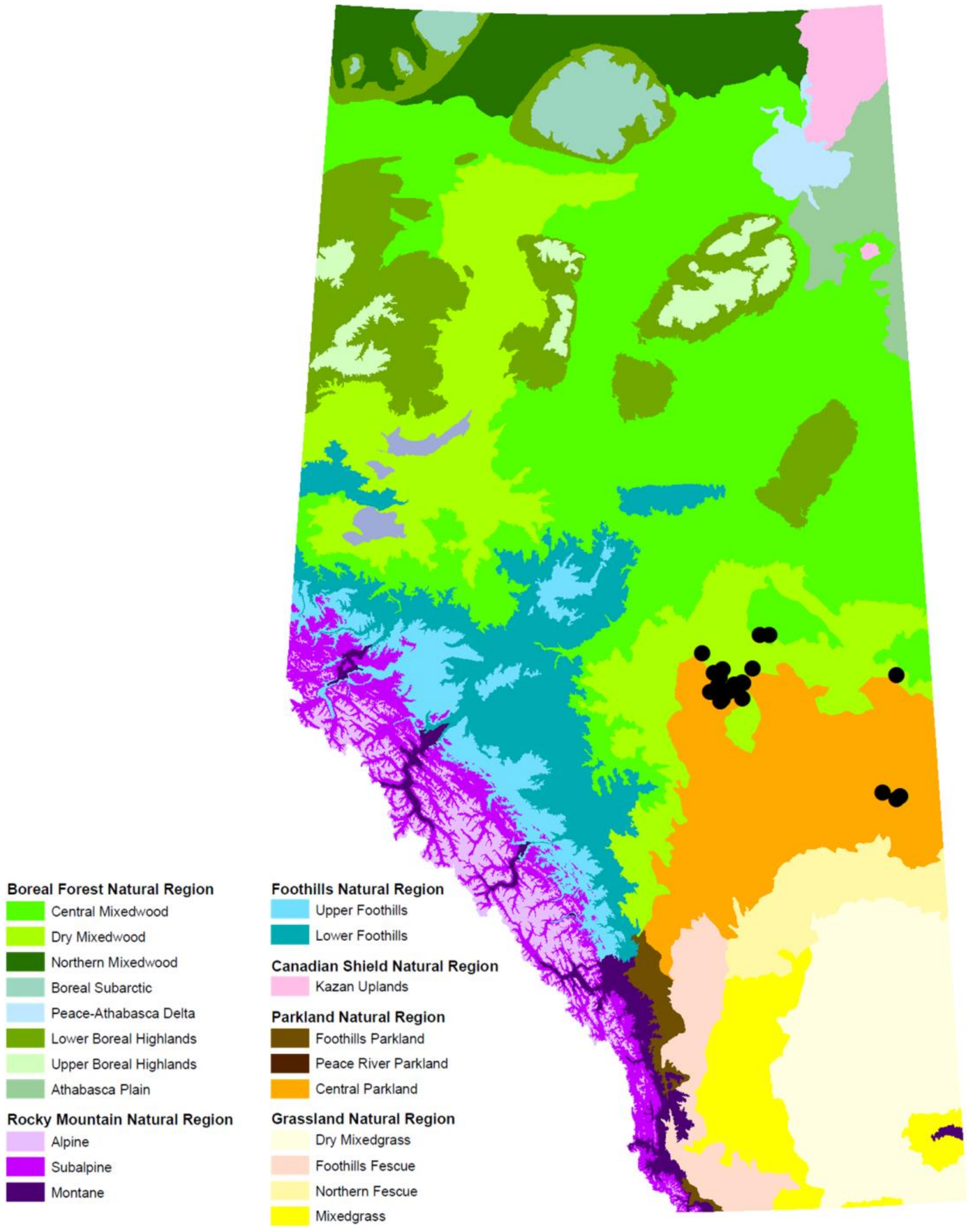

Figure 3. Known locations (black circles) of long-leaved bluets (*Houstonia longifolia*) in east-central Alberta, Canada.

a. b.

Figure 4. Long-leaved bluets (*Houstonia longifolia*) inflorescence (a.) and typical habitat in east-central Alberta (b.) (Photographs by S. Nielsen).

a. b.

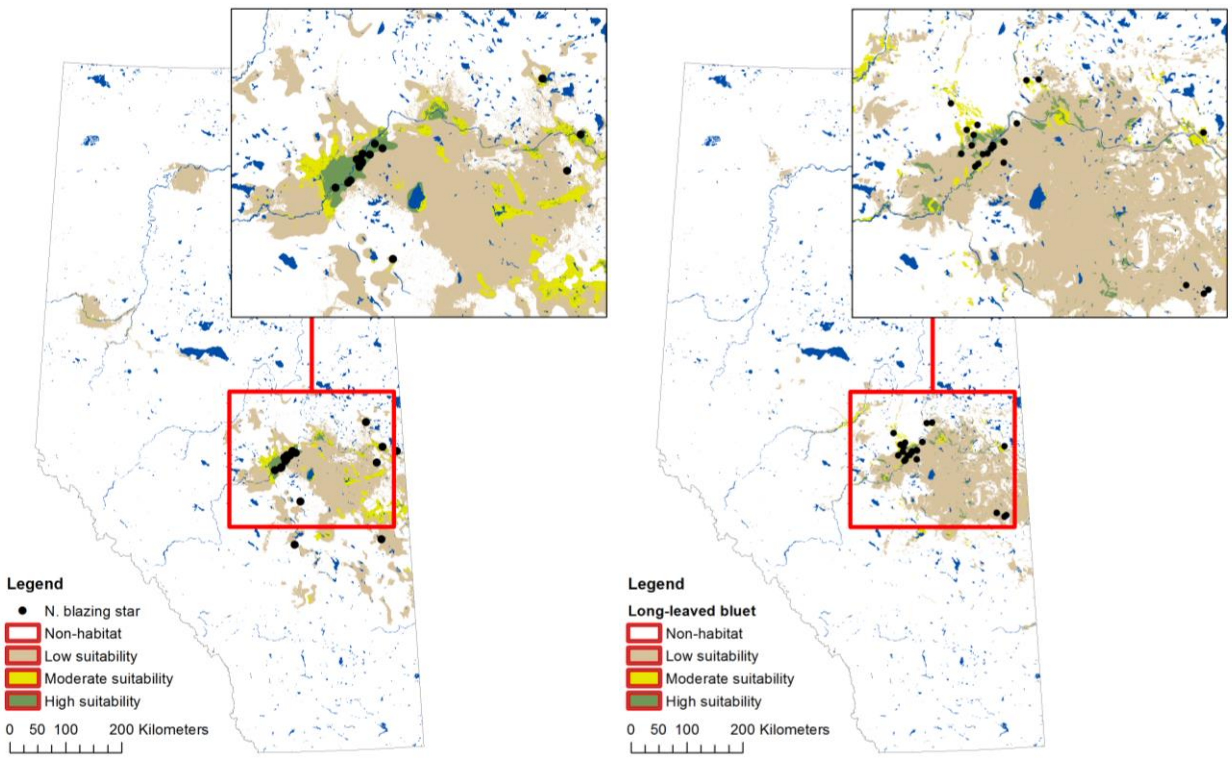

Figure 5. Species distribution (habitat) models predicting current potential habitat suitability for northern blazing star (a.) or long-leaved bluets (b.) in east-central Alberta.

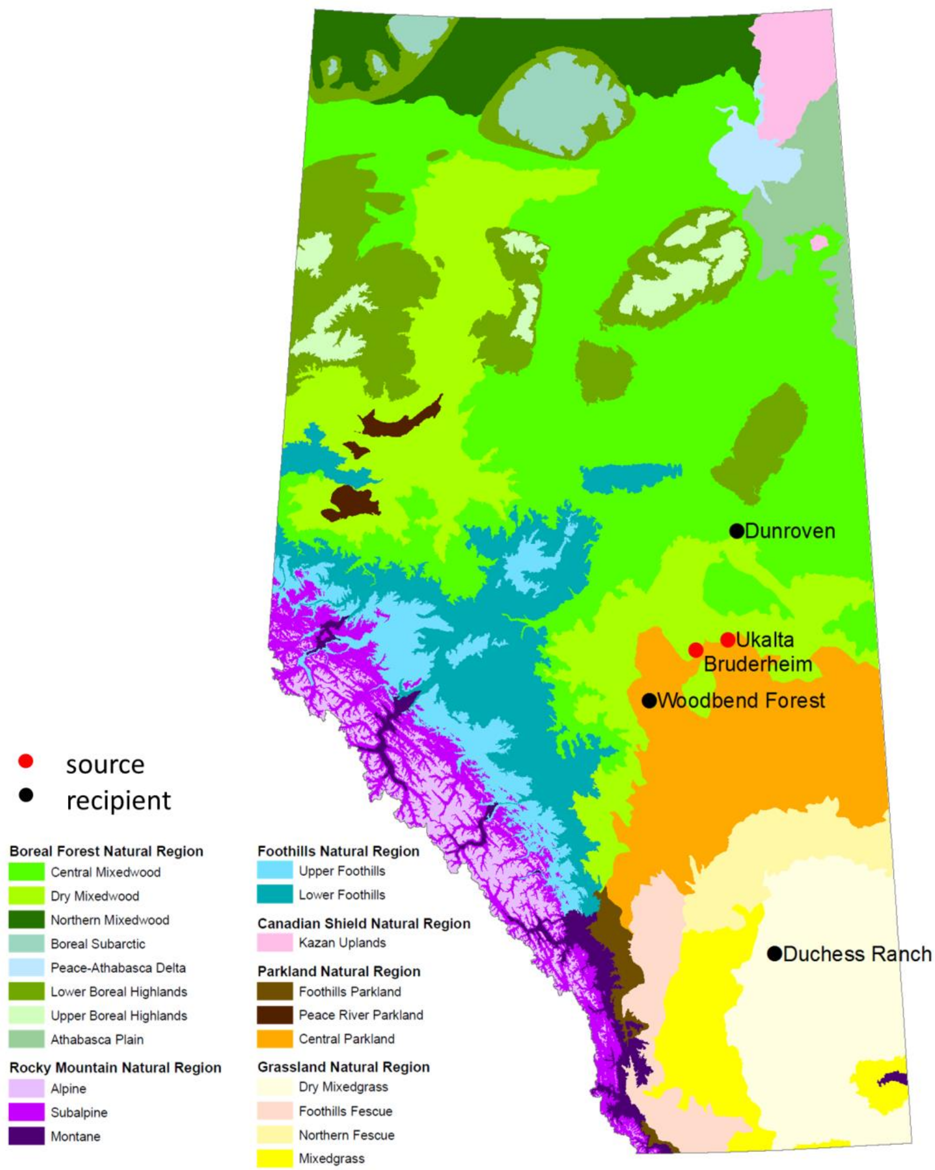

Figure 6. Locations of source (red circles) and recipient (black circles) sites for 2012 blazing star translocation experiments.

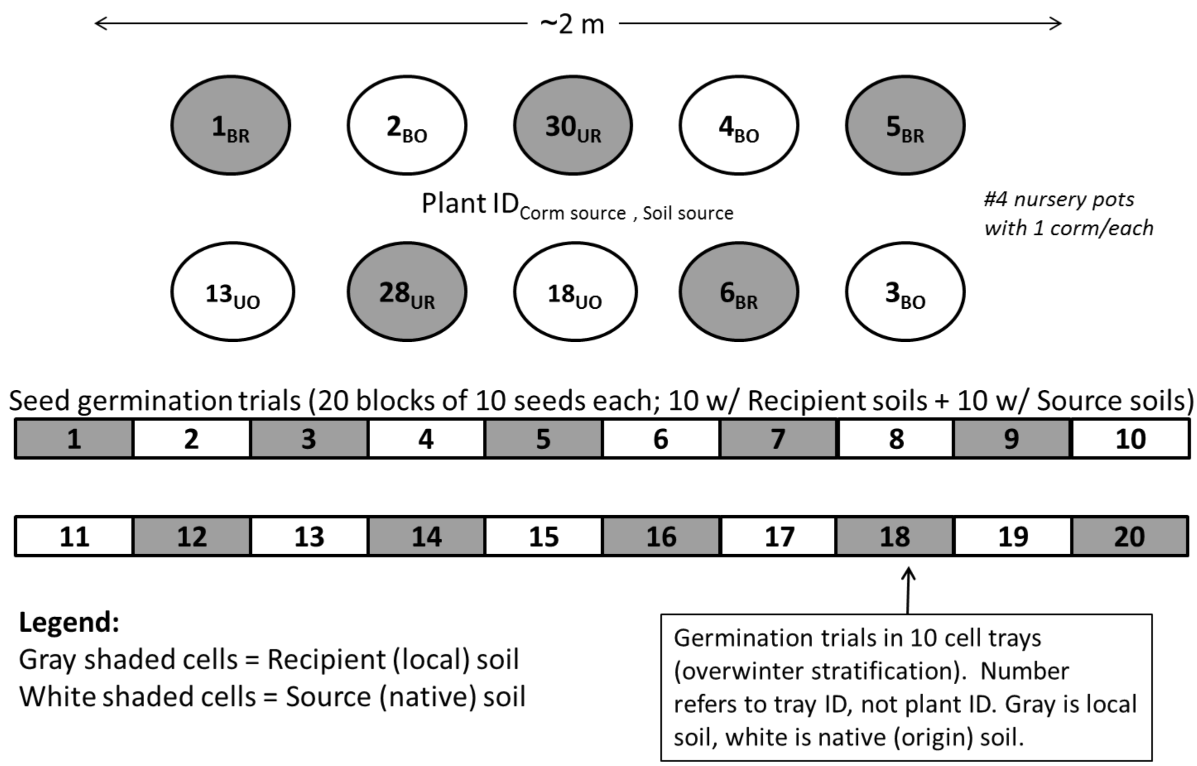

Figure 7. Site-level design of translocation experiments for northern blazing star (*Liatris ligulistylis*).