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1. Introduction/Background

As climate change continues, climatically suitable geographic ranges of species will shift (1). Species with limited dispersal abilities may not migrate rapidly enough to respond to warming and thus may face increased risk of extinction or extirpation (1, 11). This will be particularly true for species with both narrow climatic niches and high habitat-specificity. In order to prevent such extinctions or extirpations, and the associated loss of biodiversity, assisted migration (assisted colonization) has been suggested as a proactive conservation tool (9). This process involves moving organisms to areas outside their current range, to ranges that are predicted to be more suitable under future climatic scenarios (3, 4). There have been fears that moving species out of their range may result in the species being too successful (invasive), and thus may cause negative impacts on native species and ecosystem processes (10). However, plants are demonstrably unlikely to become invasive, especially when they are translocated within the same continent (5).This proactive tool is especially important in preventing the declines of species unable to shift their geographic distributions (8). However, assisted migration for the purpose of conservation has had few experimental trials (2).

As a case study in assisted migration, we are translocating within Alberta two rare and range-restricted plant species, the Northern Blazing Star (*Liatris ligulistylis*) and Long-Leaved Bluets (*Houstonia longifolia*) (7). According to the online database Naturserve Explorer, the Northern Blazing Star has a conservation status in Alberta of vulnerable (S3) (7), and is found within the aspen parkland natural subregion (6). The Long-Leaved Bluets has a conservation status in Alberta of imperiled (S2) (8), and is found in the same region as the Northern Blazing Star.

Two specific research objectives are being tested in this study. First, a test of whether these species are vulnerable to projected climate change (i.e., future warming). This is being tested through translocations of the species to more southern locations in which the current climate resembles what the climate in their current geographic range is predicted to be like by ~2050. Secondly, we are testing whether assisted migration could be used as a conservation tool for preventing extinction and extirpation as climate change progresses. This is being tested through assessing survival, growth and fecundity (seed production) of both species when translocated to a region north of their current ranges. At the same time, we are undertaking studies of the autoecology of these species in existing populations in order to gain more insight into their vulnerabilities and to determine which factors most affect their survival.

2. Methods

2.1 Populations Ecology

In 2013 surveys were conducted to locate populations of the Long-Leaved Bluets. Initial surveys began as plant flowering was finishing resulting in a limited number of effective surveys, due to low detectability of this cryptic species. More emphasis was placed on the Northern Blazing Star. Surveys will be undertaken in the summer of 2014 to locate and estimate population size of the Long-Leaved Bluets for selected sites in Alberta. This will also provide a source of local seed for translocation experiments if populations are large enough.

Line transects (500 meters) were used to locate Northern Blazing Star populations and estimate population size for six different areas in central Alberta: Northwest of Bruderheim Natural Area, North Bruderheim Provincial Recreation Area, Bellis Lake Natural Area, Halfmoon Lake Natural Area, Redwater River Natural Area, and Opal Natural Area (Table 1, Figure 1). These 500 meter line transects involved having two pre-determined GPS points 500 m away from each other and walking a straight line from the starting waypoint to the end waypoint. While walking these transect, the number of individual plants was measured and recorded based on visual observation.

Due to the large numbers of Northern Blazing Star individuals found from 500 m line transects in the North Bruderheim Provincial Recreation Area, additional quadrat surveys were conducted in this area to estimate population size. Line transects consisted of 100 metre lines (tapes) run on an east to west orientation with 1-m^2 circular quadrats systematically spaced every five meters. In each quadrat species composition (% cover) was recorded along with: canopy cover (%), bare ground (%), slope and aspect. When Northern Blazing Stars were present in the quadrat, additional measurements were taken for this species including the number of plants that were currently flowering, number of plants that were basal (juvenile stage), number of plants with evidence of flowering in the prior year, number of plants browsed, and the number of florets on each individual plant. In total, 61 transects (100 m) and 1215 quadrats were surveyed in the North Bruderheim Provincial Recreation Area (Table 2).

Although Northern Blazing Stars were not detected with the 500 m line transects in the Northwest of Bruderheim Natural Area, a previously located large patch of Northern Blazing Stars along a cleared pipeline area was surveyed to estimate its population size with a similar quadrat method as outlined above. Line transects in this patch consisted of 30 meter lines with 1-m^2 quadrat placed systematically every five meters. In total, 5 transects (30 m) and 26 quadrats were surveyed in this small, but dense patch (Table 2).

A small population of Northern Blazing Stars were found in Bellis Lake Natural area along the 500 m line transects. To increase detections, additional meander searches were carried out within open habitat to increase detection rates. Meander searches occurred in open habitat in this natural area and involved a random zig-zag walking surveying approach with visual detections recorded.

2.1.1 2012-13 translocations

Three experimental sites were established in the fall of 2012. At each site 10 Northern Blazing Star corms were translocated (planted) and 200 seeds sown. Corms and seeds were taken from populations along roadside ditches in both the Ukalta and Bruderheim areas (Figure 2). When these Northern Blazing Stars were collected in the early fall of 2012 seed production and height of each plant was measured by Scott Nielsen and James Glasier. Corms of these plants were then separated from the above ground stem and stored in nursery pots containing source soil, and kept cool and moist until translocation later in the fall.

Using the average density of 0.22 plants/ m^2 (SE=0.05) in 1215 quadrats and multiplying this by the amount of estimated open habitat in the North Bruderheim Provincial Recreation Area of 40 ha, a population estimate was calculated. This estimate was used to gain permission to remove

150 Northern Blazing Stars from the area, according to the Alberta Native Plant Council guidelines. During removal of these Northern Blazing Stars, the GPS location, height and number of florets were recorded. For each Northern Blazing Star the floral stem was removed from the corm and placed in a paper bag and marked with a GPS location. The corm was placed in a plastic bag labeled with a matching GPS location to the paper bag containing the floral stem. Plastic bags contained soil from where each plant was removed (within the source patch). In the lab, paper bags containing the floral stems were placed in a window to allow the seeds to dry. Plastic bags containing corms were placed in a growth chamber set to 10 degrees Celsius until they were ready to be translocated. Of the 150 corms removed, 146 were used along with their seed for transplantation to nine additional sites in the fall of 2013. The remaining 4 corms were grown in a greenhouse and in the lab.

At each of the nine new translocation sites, 16 adult corms were planted and 1000 seeds were sown. A thousand seeds were also sown in the fall of 2013 at each of the three existing 2012 translocation sites. The 16 adult corms placed at each new translocation sites were chosen by organizing those Northern Blazing Stars collected in the North Bruderheim Provincial Recreation Area into 14 patches, then randomly selecting a corm from each of these patches to be placed in one of the 16 pots at each translocation site. This ensured good geographic representation of source populations at each experimental transplantation site. We also tested the influence of edaphic conditions by planting/sowing the species into either local (recipient) or native (source) soil. At each site, soil type was randomly assigned to plants/sown pots. This allows for separating of the effect of climatic as opposed to edaphic factors, although sites for translocation were targeted to be similar (sandy soils). Tomato cages were used as fencing around each pot to prevent herbivory of adult plants since we have observed deer do graze on blazing star.

Seed plots, which were placed near planted corms, were delineated using pigtails. At each plot 10 quadrants (~30 cm x 30 cm) were delineated and separated by a 20 cm buffer. A hundred seeds were placed in the center of each of these 10 quadrants. Seeds were randomly selected from 10 patches out of the 14 defined patches in this area. Seeds were first counted in the lab and the achene heads removed by hand to separate them from the seeds. Only viable seeds were used in these plots. Viability was determined by rolling the seeds gently between ones figures and determining if the seed was full (i.e. viable) or empty.

In total 12 translocation sites, consisting of both adult corms and seed, have been established. Three experimental sites were established in southern Alberta near Duchess, about 450 km south of the species' current range to determine if this species will be vulnerable to future climate change. Six experimental sites were established in northern Alberta, north of the species' current range, with three sites in the Lac La Biche area, and three sites just north of McCelland Lake, north of Fort McMurray (about 500 km north of this species’ current range). Finally, three sites were established within this species' current range; two in the North Bruderheim Provincial Recreation area and one in the Woodbend Forest. These three sites act as controls (within the current range and current climate).

2.1.1.1 Response Measures

In the summer 2013, plant growth was measured, along with germination rates of seeds at each of the three 2012 translocation sites. For the adult corms, measurements were taken on mean height, maximum height, survival, and number of buds. Maximum height for my study refers to the tallest shoot within an individual plant.

The Northern Blazing Star typically has multiple flowering shoots, and therefore the height of the tallest shoot (maximum height) was used as a measure of growth performance for preliminary analyses. Using the software package R, a Permutational ANOVA was run due to the lack of normality in the data. This ANOVA was run to determine the effect of site (current range, northern and southern), source population (Ukalta and Bruderheim) and soil type (local and Native) on maximum height of translocated Northern Blazing Stars.

2.1.1.1.1 Seed Puck Translocations and Seed Viability

Experimental seed pucks were created in May 2013 to test their viability as a potential way to promote successful translocation of seeds to translocation sites. Seed puck recipe tested incorporated clay (2.5 kg), sand (8 cups), peat (8 cups), charcoal (1 cup), seaweed (3/4 cup) and water (6 cups). This recipe was mixed with an electric drill and the seed pucks formed by hand. A loonie was used for sizing.

Northern Blazing Stars from a Minnesota nursery and wild local Alberta sources (Ukalta and Bruderheim) were incorporated into these seed pucks. A small indent was made for the seed and covered with the seed puck mixture. Long-Leaved Bluets seeds from a local Alberta source (Bellis) were also incorporated into the seed pucks. These seeds need sunlight to germinate, and therefore could not be fully covered when incorporated into the seed pucks. Therefore, a small indent was made in the top of the seed puck and the seed was placed in this indent. An Elmer's Glue solution (1 part glue: 10 parts water) was pipetted into each indent in order to keep the seeds from blowing away in the wind. This Elmer's glue solution is non-toxic and dried clear to allow light penetration.

In June 2013 these seed pucks and bare seed were placed at each of the three translocation sites established in 2012. A four by four grid of cardboard rings was set up. These cardboard rings were four inches deep and ~22 cm wide. The four inch rings were pressed down into the soil so that only a 1 inch border remained, and were placed 1 ring length apart (~22 cm). In each ring either 20 seed pucks or 20 seeds were placed. Two sites were set up in the current range recipient site, with one being in an open sunny area and the other in a forested shady area. The northern recipient site and southern recipient site had only one grid site set up at each of them.

After seed pucks were transferred to the three translocation sites, an additional 12 Northern Blazing Star seed puck recipes were tested in the lab, using different combinations of clay, wet peat, dry peat, sand, charcoal and seaweed. Jiffy pucks were also tested as a potential seed puck option (Table 7). Due to a lack of local seeds, the 12 new seed puck recipes only incorporated Northern Blazing Star seeds from a Minnesota nursery source.

In the lab seed viability was tested for the Northern Blazing Stars. Six petri dishes were washed with a 50% water 50% bleach solution. Filter paper was moistened with distilled water and

placed in the petri –dishes. Local Northern Blazing Star seeds were placed in three of these petri dishes (30 in each). Northern Blazing Star seeds from Minnesota were placed in the other three petri dishes (30 in each)

Seed viability was also tested for the Long-Leaved Bluets. Two petri dishes were washed with a 50% water 50% bleach solution. Filter paper was moistened with distilled water and placed in the petri dishes. Two petri dishes were also filled with agar and placed in the greenhouse. In each of these four petri dishes 30 Long-Leaved Bluet seeds were placed.

3. Results

3.1 Population Density of Northern Blazing Star

No Northern Blazing Star plants were detected in line transects (500 m) in Redwater, Halfmoon Lake, Opal or Northwest of Bruderheim Natural Areas (Table 1), while Northern Blazing Star were detected in Bellis Lake Natural Area and North Bruderheim Provincial Recreation Area.

Due to detection of Northern Blazing Stars in Bellis Lake Natural Area, further meander searches were carried out resulting in the detection of 116 Northern Blazing Stars found in four patches. The largest patch was found in a cleared area under power lines.

A large number of Blazing Star plants were found within 500 m line transects in the North Bruderheim Provincial Recreation Area (NBPRA). Additional surveys were done to estimate population size. Average density of Northern Blazing Stars at in this area was estimated at 0.22 plants/m^2 (SE = 0.05). By estimating the amount of available open habitat in the area by using aerial imagery to be 400,000 m^2, we estimated population size to be ~88,000 Northern Blazing Stars (Table 2).

Using quadrat observations for Northern Blazing Star in this recreation area we found that 28.1% were flowering, 53.2% were basal (juvenile) plants, 16.5% showed evidence of flowering the prior year, and 2.1% were considered to have been browsed. Average number of florets was 10.9, average flowering plant height was 47.1 cm, and average maximum height (tallest shoot) was found to be 42.1 cm. (Table 2)

Generally in the NBPRA, species grew in patches on mid to upper slopes, often with westward aspects. Most of the juvenile plants (basal form) were observed near mature flowering plants, suggesting low dispersal abilities, but also successful recruitment following the 2009 Bruderheim fires. It was also observed that plants were associated with sandy habitats with a ground cover consisting mostly of grasses/sedges and sub-shrubs/forbs thriving in areas of low competition with bare ground present in most of the plots where the species occurred.

As stated in the methods section, a previously located large patch of Northern Blazing Stars along a cleared pipeline area in Northerwest of Bruderheim Natural Area was surveyed to estimate population size. The average density of Northern Blazing Star patch was estimated at 2.42 plants/m^2 (SE=0.62). Using data from the quadrats in this patch it was found that for the Northern Blazing Star, 34.3% were reproductive (flowering or had flowered that year), 59.7% were found to be basal (juvenile) plants, 6.0% showed evidence of flowering the prior year, and

0% of plants were browsed. Average number of florets was 9.6, average flowering plant height was 58.9 cm, and the average maximum height (tallest shoot) was found to be 47.7 cm. (Table 2)

3.1.1 Translocations

For the Northern Blazing Stars corms transplanted in fall 2012, all 10 grew at the current range site and southern site. Eight of 10 corms grew at the northern site (Table 3).

For all sites, bud emergence occurred from June 24 to June 27. A lower proportion of plants translocated to the northern and southern locations produced blooms, as compared to those transplanted to the current range site. At the central site, 6 out of 10 plants reached full maturity and produced blooms. In the north site, 8 plants grew and 3 produced blooms. At the south site, 4 out of 10 plants produced blooms. Those plants that did not produce blooms remained in a basal leaf form (Table 3).

The northern site, near Lac La Biche was the only site where seeds planted in the fall of 2012 germinated. In total, 12 seeds successfully germinated, with 8 germinating in local (recipient) soil and 4 germinating in native (origin) soil (Table 4).

No seeds germinated at current range site (however there were less seeds placed at this site). No germination data were available for the southern site as construction of a large transmission line led to the destruction of the seed plot. The Northern Blazing Star pots (adult corms) at this site were buried by construction, but then recovered and transplanted to a different site near this previous destroyed southern site.

In 2013, seed pucks were placed at each site. They were monitored throughout the summer. Emergence at all three sites for seed pucks that incorporated Northern Blazing Star seed was 0%. This was likely due to the seed puck mixture being too hard; and also low germination rates (<50%) in the local Northern Blazing Star seeds, and 0% germination rates for seed from Minnesota (Table 5). Note that the Minnesota Northern Blazing Star seed germinated faster and more robustly than was expected during stratification in the lab, therefore only seed that didn't germinate during this stratification process was available to be used in the germination petri-dish trials and seed pucks. Emergence at all three sites for seed pucks which incorporated Long-Leaved Bluets was 0%. However, germination rates were better for this species than the Northern Blazing Star (Table 6), and therefore perhaps the seed puck mixture was too hard for these small seeds to overcome.

For the additional 12 seed puck recipes, no germination occurred (Table 7). This may have been caused by the use of low quality Northern Blazing Star seed from Minnesota that did not germinate during the stratification process, instead of the seed puck recipes themselves.

Research is ongoing to determine if seed pucks are a viable option for future assisted migrations.

Out of the four sites established (4 ring by 4 ring) across Alberta, only 2 Local Northern Blazing Star seeds (bare seed) germinated at the current range translocation site in the shady site.

3.1.1.1 Response Measures of Plant Performance

i) Height

From the Permutational ANOVA it was found that both source and site had significant effects on maximum height of plants (Table 8). A pairwise comparison using Tukey's adjustment for multiple inference found that of the Northern Blazing Stars that grew, the current range site had maximum heights significantly greater than those at both the southern and northern translocation sites with no significant difference in maximum heights between the north and south sites (Table 9, Figure 3).

Since source was found to be significant, I performed a Permutation T-Test on the Northern Blazing Star corms that grew to determine if there was a difference in height between the two source locations (i.e. where the Northern Blazing Stars were taken from). From this analysis it was found that corms from the Ukalta source had significantly greater maximum heights than those from Bruderheim at all three translocation sites (Table 10, Figure 4).

ii) Florets

Total number of florets at the central site was far greater than the total number of florets at the southern and northern assisted migration sites. The northern site had the fewest florets out of the three sites (Table 11, Table 12).

When comparing the number of florets summed over all the plants in 2012 (prior to translocation) and in 2013 (after translocation) that grew, it was found that plants translocated to the northern site in 2012 had a 33.3% decrease in total florets by 2013 (54 florets in 2012 vs. 36 florets in 2013). It was also found that plants translocated in 2012 to the southern site had an 18.7% decrease in total florets by 2013 (64 florets in 2012 vs. 52 florets in 2013). In contrast, plants transplanted to the current range site in 2012 had a 70.0% increase in total florets by 2013 (82 florets in 2012 vs. 140 florets in 2013) (Table 11, Figure 5).

4: Next Steps: 2014 field season

During the summer of 2014, autoecological studies will be carried out in natural populations of the Long-Leaved Bluets (Bruderheim and Bellis Lake). These studies will provide valuable information on the habitat-specificity of this species, its population size and reproductive output, thus allowing for a better understanding of its extirpation risk associated with changes in habitat. Seed collection and translocation will occur for this species if permission is obtained.

Sensors for temperature and humidity will be set up at all 12 assisted migration sites.

In the summer, growth measurements and germination rates for Northern Blazing Star will be recorded at each of the 12 translocation sites. From these data more analyses will be conducted to assess the effects of climate change on the Northern Blazing Star and to determine the efficacy of using assisted migration as a conservation tool for a select group of species in Alberta.

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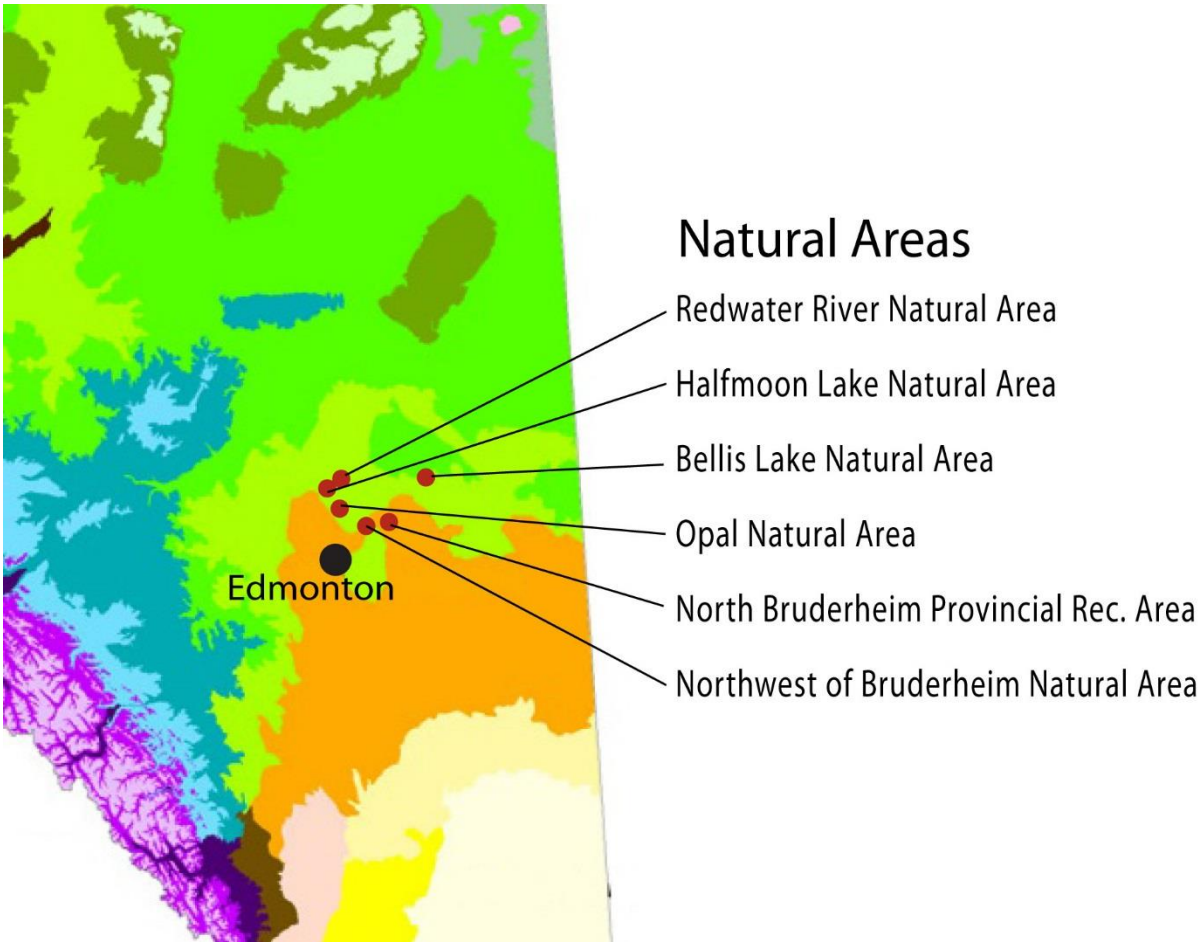

Figure 1: Locations of the six natural areas where population surveys for the Northern Blazing Star were conducted in central Alberta using 500 m line transect searches.

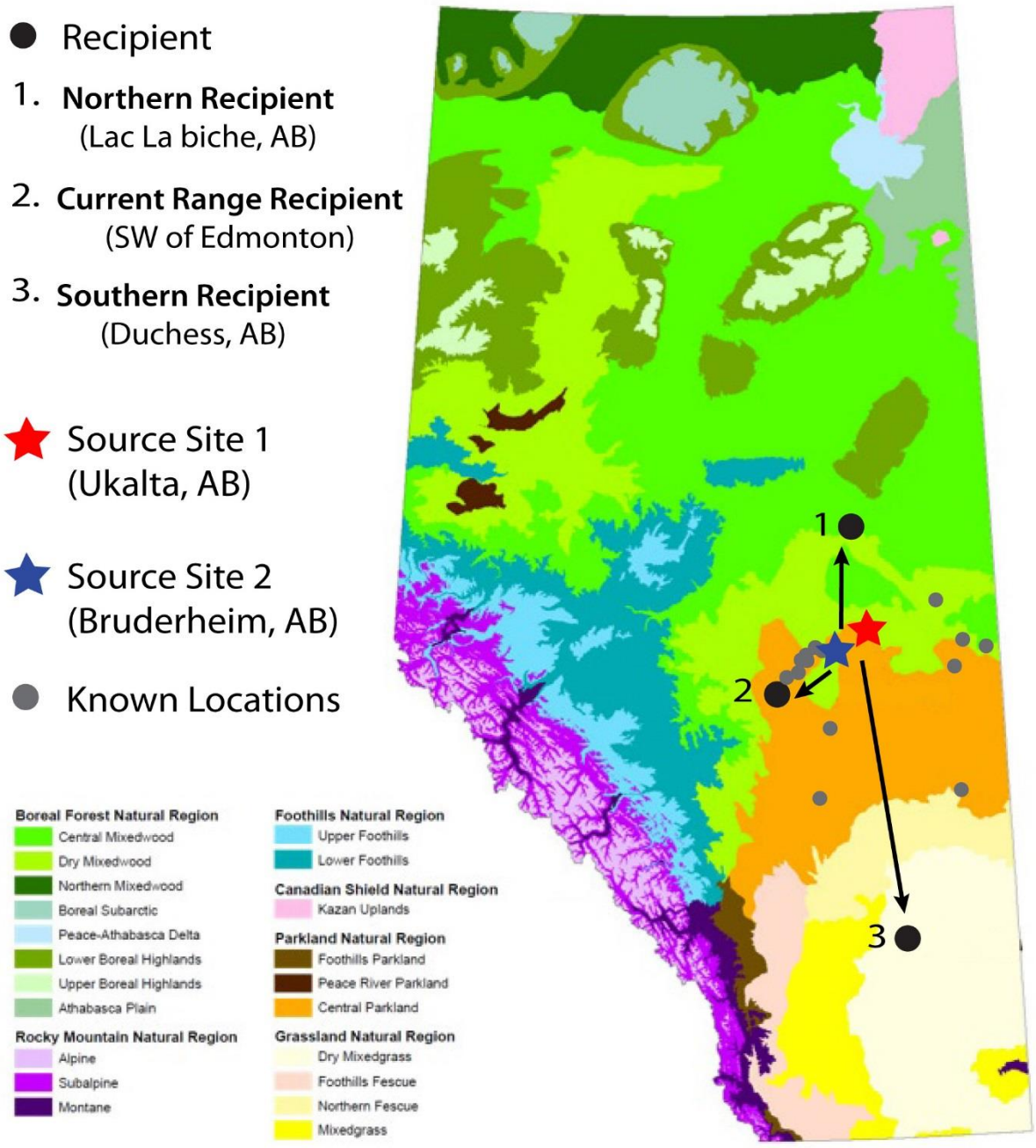

Figure 2: Map of Alberta, showing the two source locations (Ukalta and Bruderheim) and the three translocation sites that were established in 2012.

Table 1: Number of 500 m line transects surveyed in each Natural Area. Note the variation in number of line transects corresponds to access issues due to wet conditions.

Date	Natural Area	# Transects	Length (m)	# Northern Blazing Star Individuals Observed
July 11, 2013	Northwest of Bruderheim	2	500	0
July 12, 2013	Bellis Lake	4	500	2
July 16, 2013	Redwater River	5	500	0
July 19, 2013	Halfmoon Lake	4	500	0
July 24 & 26 2013	North Bruderheim Provincial Recreation Area	7	500	2061
August 1, 2013	Opal	4	500	0

Table 2: Northern Blazing Star statistics based on 1 m^2 quadrat sampling in two Natural Area in Alberta.

Total Northern Blazing Star Plants	Natural Areas	
Measurements	North Bruderheim Provincial Recreational Area	Northwest of Bruderheim
Date	August 9-23, 2013	22-Aug-13
Total this year flowered	92	23
Total basal	174	40
Total last yr flowered	54	4
Total browsed	7	0
Av. # Florets	10.89 (SE=1.33)	9.61 (SE=1.30)
Av fl. height - all hoops (cm)	47.06 (SE=4.11)	58.87 (SE=6.67)
Av. bas. height - all hoops(cm)	17.19 (SE=1.68)	19.23 (SE=1.79)
Av. last yr height - all hoops (cm)	29.33 (SE=3.66)	39.67 (SE=0.33)
Av. browsed ht. (cm) - all hoops	22.27 (SE=2.83)	0.00 (SE=0.00)
Av. plant height - all hoops (cm)	32.32 (SE=2.89)	32.89 (SE=4.54)
Av. max height (cm)	42.07 (SE=3.59)	47.68 (SE=8.14)
Total occupied quadrats	93	17
Av. density (# plants/m2)	0.22 (SE=0.05)	2.42 (SE=0.62)
Transect Length (m)	100	30
# Transects	61	5
Quadrat Interval (m)	5	5
Quadrat size (m^2)	1	1
Total # of quadrats	1215	26
Total plants (browsed, basal, this year flowered)	273	63

Table 3: Northern Blazing Stars' growth at the three 2012 translocation sites.

	Translocation Sites		
Measurements	Northern Recipient (Lac La Biche, AB)	Current Range Recipient (SW of Edmonton)	Southern Recipient (Duchess, AB)
Total # Corms Planted	10	10	10
Total # of Corms that Grew	8	10	10
Total # of Corms that grew in basal Form	5	4	6
Total # Corms that produced blooms	3	6	4
# Corms Planted in Local Soil	5	5	5
# Basal Form in Local Soil	2	2	4
# Corms that produced blooms in Local Soil	2	3	1
# Corms Planted in Native Soil	5	5	5
# Basal Form in Native Soil	3	2	2
# Corms that produced blooms in Native Soil	1	3	3

Table 4: Northern Blazing Star seed germination at the three 2012 translocation sites.

Translocation sites	# Seeds planted in Local Soil	# Seeds planted in Native Soil	# Seeds Germinated in Local Soil	# Seeds Germinated in Native Soil	Total # of Seeds Germinated
Northern Recipient (Lac La Biche, AB)	100	100	8	4	12
Current Range Recipient (SW of Edmonton)	100	0	0	0	0
Southern Recipient (Duchess, AB)	100	100	N/A - seeds destroyed due to construction	N/A - seeds destroyed due to construction	N/A

Table 5: Petri-Dish germinations of Northern Blazing Star seeds from Local Alberta plants (numbers correspond to GPS locations) and those plants from Minnesota (MN). All seeds were placed on filter paper moistened with distilled water within each petri-dish.

Petri-Dishes of Northern Blazing Star	# of Seeds	# Germinated	Germination percent (%)
MN (1)	30	0	0%
MN (2)	30	0	0%
MN (3)	30	0	0%
Local #14,#19,#20	30	15	50%
Local # 19	30	2	6.70%
Local #18, #19	30	9	30%

Table 6: Petri-dish germinations of Long-Leaved Bluets seeds from Bellis Alberta. Petri-dish 1 and 2 refer to petri-dishes where seeds were placed on filter paper moistened with distilled water. The Greenhouse agar petri-dishes 1 and 2 had seed placed on an agar solution and were placed in the greenhouse.

Petri-Dishes of Long-Leaved Bluets	# of Seeds	# Germinated	Germination percent (%)
Petri-Dish 1	30	15	50%
Petri-Dish 2	30	21	70%
Greenhouse (agar petri-dish 1)	30	13	43%
Greenhouse R (agar petri-dish 2)	30	16	53%

Table 7: List of the twelve seed puck recipes. The bracketed numbers indicate how many parts went into each recipe. For instance (2) red clay, (1) wet peat, (1) dry peat means that this recipe incorporated 2 parts red clay, 1 part wet peat and 1 part dry peat. Note that zero germination occurred from these 12 seed puck recipes.

		Germinations of Minnesota Northern Blazing Star Seed		
#	Recipes	07-May-13	11-May-13	17-May-13
1	(2) red clay, (1) wet peat, (1) dry peat	0	0	0
2	(2) red clay, (2) sand, (1) wet peat, (1) dry peat	0	0	0
3	(2) red clay, (1) sand, (1) wet peat, (1) dry peat	0	0	0
4	(2) red clay, (1) sand, (2) wet peat	0	0	0
5	(5) red clay, (3) wet peat	0	0	0
6	(1) red clay, (3) wet peat	0	0	0
7	(1) red clay, (2) sand, (1) wet peat	0	0	0
8	(2) red clay, (1) sand), (2) wet peat, 2.5 ml seaweed	0	0	0
9	(1) red clay, (1) wet peat, 2.5 ml seaweed	0	0	0
10	(3) red clay, (2) wet peat, 2.5 ml seaweed	0	0	0
11	1st batch combo (2.5 kg clay, 8 cups sand, 8 cups peat, 3/4 cup seaweed, 1 cup charcoal)	0	0	0
12	Juffy Pucks	0	0	0

Table 8: Permutational ANOVA output for Northern Blazing Star maximum height based on site (Current range, Southern, Northern), source (Ukalta, Bruderheim), and soil type (Local, Native). For p.values<0.001 "***"

Predictor Variable	DF	Sum Sq R	Pr(Prob)
Site	2	12270	<0.001***
Source	1	9794	<0.001***
Site: Source	2	3181	<0.001***
Soil	1	513	0.099
Site: Soil	2	47	1.000
Source: Soil	1	94	0.372
Site: Source: Soil	2	758	0.102

Table 9: Pairwise comparison output using Tukey's adjustment for multiple inference. Comparisons of maximum height for the Northern Blazing Star made between Northern Recipient Site, Current Range Recipient Site, and Southern Recipient Site. For p.adjust values <0.001 "***"

Site Comparison	p.adjust
Northern Recipient - Southern Recipient	0.092
Current Range Recipient - Southern Recipient	<0.001***
Current Range Recipient - Northern Recipient	<0.001***

Table 10: Permutation T-test output representing the significant difference in Northern Blazing Star maximum heights between those taken from Ukalta and those from Bruderheim at each translocation site. For p.adjust values <0.000 "***", p.adjust values <0.01 "**"

Source Comparison	p.adjust
Northern Recipient Site: Ukalta vs. Bruderheim	0.009**
Current Range Recipient Site: Ukalta vs. Bruderheim	<0.001***
Southern Recipient Site: Ukalta vs. Bruderhiem	0.004**

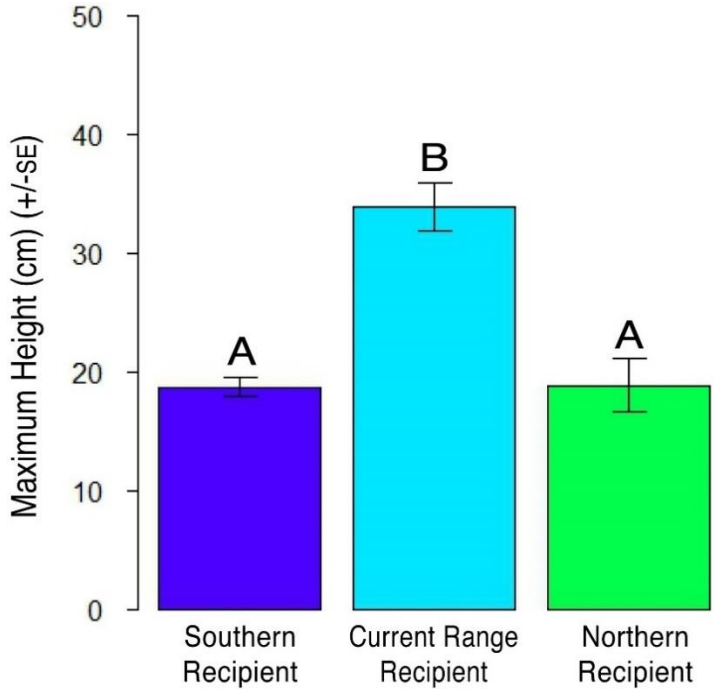

Figure 3: Average maximum height of Northern Blazing Stars' at the three translocation sites. Difference in letters indicates significance.

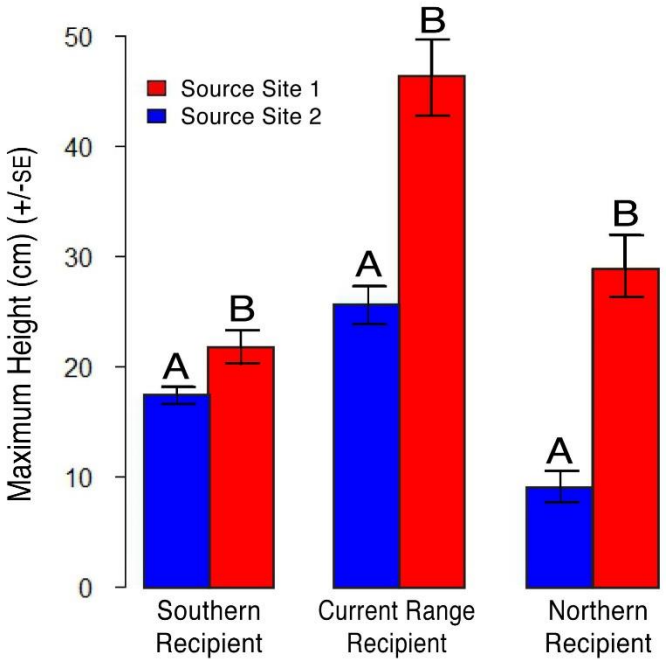

Figure 4: Average maximum height of Northern Blazing Stars at the three 2012 translocation sites, compared between corms from Source Site 1: Ukalta and Source Site 2: Bruderheim

Table 11: Total number of florets for each of the 10 Northern Blazing Stars associated with the three translocation sites. The 2012 column represents the total number of florets from the Northern Blazing Stars at their source location before they were moved to the translocation sites. The 2013 column represents the total number of florets after 1 year of growth for the same 10 Northern Blazing Stars that were moved to the translocation sites. Note that the major cause of this difference is associated with the number of plants that flowered at each site and not how many florets a flowering plant produced.

	Total Number of Florets		Difference (%)
Translocation Site	2012	2013	(2012-2013)/2012 *100
Northern Recipient	54	36	-33.3%
Current Range Recipient	82	140	70.0%
Southern Recipient	64	52	-18.7%

Table 12: Permutation T-test output representing the significant difference in the total number of Northern Blazing Star florets summed over the 10 plants at each translocation site between the years 2012 (before translocation) and 2013 (after translocation).

Year Comparison (Total Florets)	p.adjust
Northern Recipient Site: 2012 vs. 2013	0.996
Current Range Recipient Site: 2012 vs. 2013	0.591
Southern Recipient Site: 2012 vs. 2013	0.999

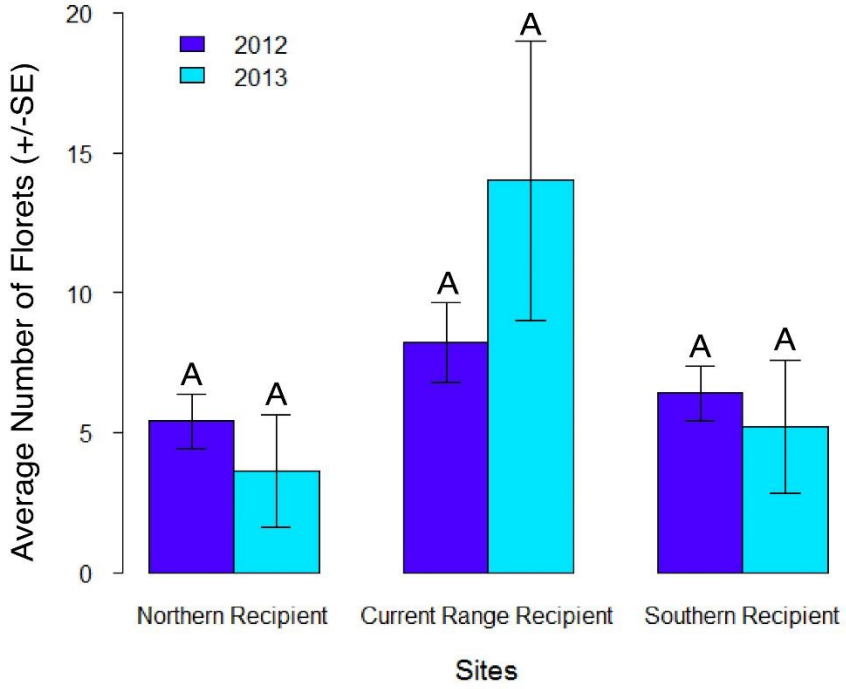

Figure 5: Average Number of Northern Blazing Star florets at each of the three 2012 translocation sites, compared between two years 2012 and 2013. Difference in letters indicates significance.