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Shift in Icelandic Plant Populations Due to Climate Change: Through the Lens of Natural Dyes

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Abstract

Northern residing plant species are at the highest risk for extinction due to temperature rise related to climate change (Schöb, Manuel, Choler & Veit, 2009). Climate change has also led to a northern shift in the geographic distribution of plant species (Parmesan & Yohe, 2003). This could lead to a necessary alteration in the way natural resources are utilized in arctic countries like Iceland (Lim-Camacho et al, 2017). The purpose of this study is to analyze the way in which Icelandic plant species used in natural dye practices may shift in distribution due to climate change and the potential impact this shift may have on the craft. In this study, six plant species used for natural textile dyeing in Iceland were processed into dyes and applied to Icelandic wool. The dyed wool was then woven into an art piece representative of the findings of this study. Through analysis of previous literature on tundra species used in dyeing, the study concludes that a decrease in species diversity and an increase of invasive plant species will occur due to increased temperatures. An increase of new species could lead to new opportunities in the color palette but the increase of invasive species could lead to extinction of commonly used native species that produce unique colors. While some native species like *Rumex longifolius* will benefit from climate change, other native species will falter. This means that natural dye practitioners in Iceland will begin to see a decrease in the availability of commonly used native species like *Cladonia chlorophaea, Peltigera canina* and *Alchemilla vulgaris* and will have to be more mindful when gathering and using them.

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Introduction

Climate change has caused living systems to shift toward the poles at an average rate of 6.1km per decade (Parmesan & Yohe, 2003). With temperature rise and this polar movement of species, highly adapted organisms already residing in the harsh polar climates will become at risk for extinction and habitat loss as climates in the north become more suitable for southern species (Schöb et al., 2009). Climate change will impact the way in which industries will utilize natural resources (Lim-Camacho et al., 2017). For example, the northern shift in plant and lichen species may result in a change in the way Arctic-adapted species are utilized as resources in industries, like the art of natural dyeing, throughout Nordic countries.

Natural dyeing, the production and use of dyes made from plant or animal material (Stothers, J., 2017), was introduced to Iceland by the Vikings during the settlement of the country (Bjarnadóttir, 2017). Traditionally, the nobles wore fabrics dyed with imported colors like blues and reds from other countries, like Norway, while the public wore mainly yellows and browns produced from the Icelandic flora (Guðrún Bjarnadóttir, personal communication, 2017, Bjarnadóttir, 2017). But when Europe experienced a global cooling period, Icelanders were no longer able to import other colors and began wearing clothes of browns and blacks, produced from heather and rotting plant material (Guðrún Bjarnadóttir, personal communication, 2017). This is an example of how changing climate has affected natural dyeing in the past so it is likely that the change in climate we are now experiencing will also alter the practice in the future.

A study done on plant species specific to the Arctic tundra showed a decrease in species diversity with experimental warming of 1-3°C (Walker et al., 2005). The study showed that this decrease was most likely caused by increasing density of shrubs that block sunlight from lower lying species. The individual success of shrub species led to the outcompeting of other species, resulting in the potential for species extinctions in tundra habitats (Walker et al., 2005). The same study shows that some native tundra species are at risk for extinction due to climate change, lichens being the most affected. Walker's study claims that the reason for population decline in lichen is the lack of sunlight penetrating the dense shrub growth that increases as arctic climates warm. These findings suggest that the two lichens analyzed in this review, *Cladonia chlorophaea* and *Peltigera canina,* are some of the most likely species to die out as temperatures rise. Though increasing temperatures may enhance beneficial processes in these arctic lichens, like nitrogen fixation and photosynthesis, they are still at risk for extinction due to competition by other species for different resources (Nash, 1995).

Four different Icelandic species, *Alchemilla filicaulis, Alchemilla glomerulans, Alchemilla wichurae,* and *Alchemilla glabra* are classified under the native aggregate species *Alchemilla vulgaris* (Kristinsson, 2013). Though it is uncertain how these species will individually react to temperature rise, studies show that *A. vulgaris* prospers in areas of high humidity (Gavrilova & Vitkova, 2010). Iceland's relative surface humidity is projected to decrease when modeled using the International Panel on Climate Change's (IPCC) 5th assessment report (AR5) (Figure 1) (KNMI Climate Change Atlas, 2017). With the projected decrease of relative humidity as temperatures rise, native *A. vulgaris* species could be at risk for extinction.

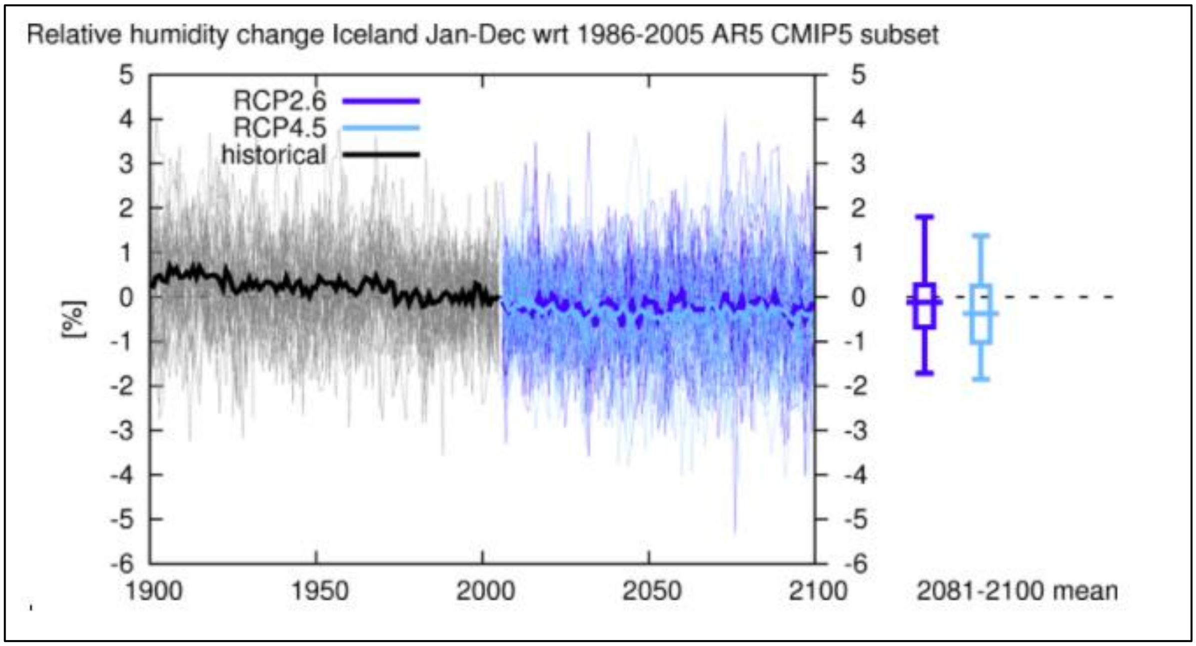

Fig 1: (KNMI Climate Change Atlas, 2017) Figure 2 shows the projected relative near surface humidity based on the IPCC's 5th assessment report. The dark blue shows projections of 2°C warming (RPC2.6) and the light blue shows 4°C warming (RPC4.5). The mean decrease in humidity for RPC2.6 is -0.18% and RPC4.5 averages -0.30%.

Though lichens and other native plants are at high risk for extinction, climatic temperature changes could be beneficial for other native vascular species in Iceland. Wasowicz, Pasierbiński, Przedpelska-Wasowicz, and Kristinsson (2014) show that climatic temperature is highly predictive of where the species populations of vascular plant reside. In this study on current vascular plant distributions, *Rumex longifolius* and species with similar biological traits and habitat locations showed a preference for a milder climate. Therefore, it is likely that as Icelandic climates warm and become milder, plants like *R. longifolius* will find an increase in habitat availability.

Higher temperatures in Iceland will also result in development of new habitats available for invasive species to occupy. A study by Wasowicz Przedpelska-Wasowicz and Kristinsson (2013) showed that there is an average increase of three new species per year into the country with an estimated 26% total increase of new species between the years 2012 and 2050. Their study proved temperature to be a major impacting variable. Using the IPCC's 3rd assessment report for projected climatic changes, Figure 2 shows the impact of invasive species distributions by 2050 in accordance with projected temperatures (Wasowicz et al., 2013). *Lupinus nootkatensis*, whose presence in Iceland was originally established due to human intervention, is an example of an extremely invasive species that will benefit from climate change and whose habitat will grow extensively into Iceland's highlands with warming temperatures (Wasowicz et al., 2013).

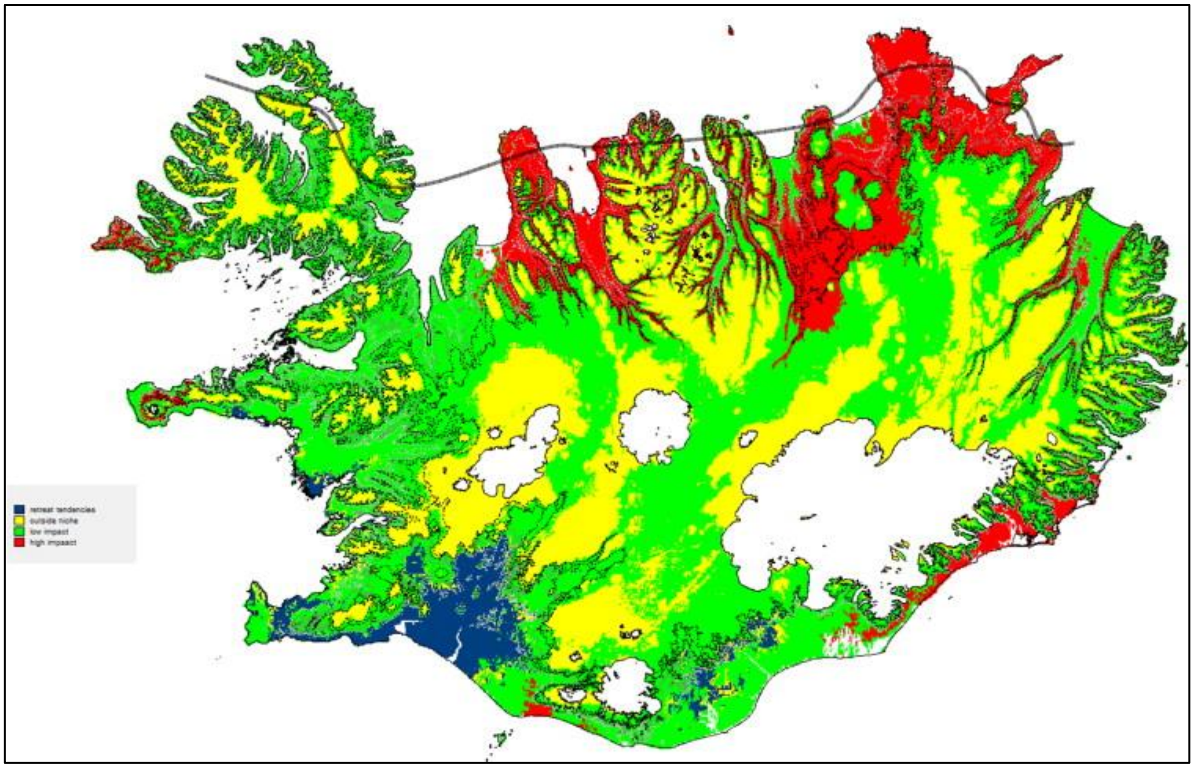

Fig. 2: (Wasowicz, Przedpelska-Wasowicz, Kristinsson. 2013). Figure 2 shows the impact of climate change on alien plant species in regions across the country. The blue represents areas not inhabitable by studied taxa, the yellow areas represent locations outside of the climate niche, the green areas are low impact locations and the red areas show high impact locations.

The purpose of this paper is to analyze the way in which Icelandic plant and lichen species used in natural dye practices may shift in distributions due to climate change. The study predicts that the geographical distribution of native Icelandic plants will change, making them at risk for extinction due to the increase of southern residing species and loss of optimum climatic conditions.

In order to determine the historic distributions of Icelandic plant species, previous literature was reviewed and information on each species' historical distribution was compiled from these resources. In this review, a native species to Iceland is defined by its presence in the country for more than 300 years (Kristinsson, 2013). Though there are many plants used for natural dyeing in Iceland this study evaluates six of the more commonly used species: *L. nootkatensis, A. vulgaris, R. longifolius, P. canina, C. chlorophaea,* and *R. rhabarbarum*. Dyes were made from these species, applied to Icelandic wool, and woven into an artistic representation of the study and its findings to represent the study in an artistic way. This process was chosen to fully explore the craft being analyzed and to engage the audience in a receptive and interesting way not common to natural science research.

2. Methods

2.1 Literature Review

The papers analyzed in this review were found online using science-based databases, ScienceDirect, Science in Context and Science Reference Center. The keywords, "Icelandic plant distributions," "climate change" and "lichen distributions" were searched in the databases. Papers were chosen based on content and peer review. Papers addressing species distributions specific to plants used for natural dyeing were reviewed to determine current conditions and population distributions and the way in which they may change due to temperature rise. Though the papers of this nature analyze many species not used for natural dyes, only species that are used for natural dyes were included in the analysis.

To model projected humidity in Iceland as temperatures rise this study used the KNMI Climate Change Atlas (Figure 1). The following data was entered in the climate model system:

Type: countries

Country: Iceland

Season: first month Jan, length 12 months

Dataset: GCM: CMIP5 (IPCC AR5 Atlas subset)

Variable: relative humidity near the surface, absolute

Output: time series

Scenarios: RCP2.6, RCP4.5

Plot period: 1900-2100

Anomalies: take anomalies wrt 1986-2005

Transparency: blank

2.2 Natural Dyeing

Dyeing Vocabulary:

Weight of Fiber (WOF): This is the weight of the dry fiber to be dyed, typically expressed in grams. The amount of dye required is based on the weight of fibers being dyed (Vejar, 2015).

Mordant: A mordant, such as alum, is a dye fixative used to prevent the fading or bleeding of color. (Vejar, 2015)

Dye bath: This is the amount of time the wool was simmered over a burner in the natural dye after being processed in the mordant.

Copper/Iron bath: Some of the wool samples were simmered in a bath of water saturated with copper and iron. This process changes the pH of the dyes and in turn changes the color of the dyed fibers slightly.

Mindful gathering: This is the process of collecting plant specimens that includes never harvesting the entire plant, being aware of the gathering laws in the area of collection and avoidance of gathering from private land without permission. In addition, mindful gathering includes collection of invasive species first, and never taking protected or endangered species (Vejar, 2015).

Dyeing methods were taught by Ragnheiður Þórsdóttir (personal communication, 2017) and learned from Kristine Vejar's book *The Modern Natural Dyer* (2015). In this study, the fiber dyed was Icelandic wool from the Icelandic company Ístex.

Alum was used as the mordant. Quantities of alum are offered in the following recipes as percentages in terms of WOF. For example if 10 grams(g) of wool was being prepared and the mordant desired was 20% WOF, 2g of alum in water would have been used. The wool was then simmered over a burner in the mordant for 90 to 120 minutes.

In order to make the dyes, plants were collected during the dates of October 21- October 24 in the areas around the towns of Blönduós and Skagaströnd, Iceland. Mindful gathering was practiced during collection (Vejar, 2015). Species were only collected on public land, permissible by the Icelandic Nature Conservation Act (Notes for Visitors: Public Rights, 2017) and no protected species were collected (Kristinsson, 2013). Choice of plant species collected was based upon previous dye research conducted by Maaike Eddinge (2013), Ragnheiður Þórsdóttir (personal communication, 2017) and was dependent upon what species were alive so late in the growing season. Vascular species were identified in the field using the reference Flowering Plants and Ferns of Iceland by Hordur Kristinsson (2013) and the lichens were identified using the reference Encyclopædia Britannica (1998, 2013). The amount of plant material collected was based upon plant availability and the quantity needed to make the dyes. All dyes were made by simmering the plant material in water over a burner for 120 minutes. The copper/iron bath was made by soaking a rusty copper pipe and old iron nails in a pot of water for at least 48 hours. All dyeing recipes were recorded in a field notebook.

The species used for dying, their colors, and the dyeing recipes are as follows:

- *P. canina* (Figure 3):
  (native)

  Dye 1
  WOF: 50g
  Mordant: 20% alum with 2L water for 90mins
  Plant Material: 40g *P. canina* and 1.5L water
  Dye bath: 120min and let sit overnight

  Copper/Iron bath: 25g wool for 30mins

  Dye 2
  WOF: 25g
  Mordant: 20% alum with 1.5L water for 90mins
  Plant Material: 50g *P. canina* and 1L water
  Dye bath: 120min and let sit overnight

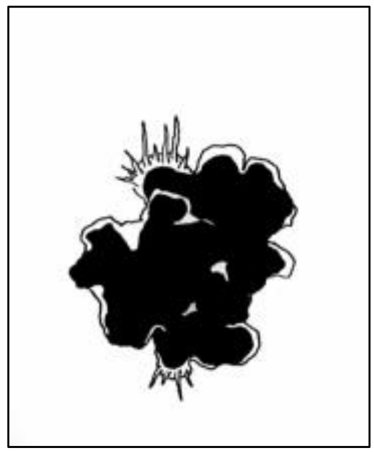

Fig 3: *P. canina*

- *C. chlorophaea* (Figure 4):
  (native)

  Dye 1
  WOF: 25g

Fig 4: *C. chlorophaea*

Mordant: 20% alum with 1.5L water for 90mins

Plant Material: 150g *C. coccifera* and 1.5L water

Dye bath: 120min and let sit overnight

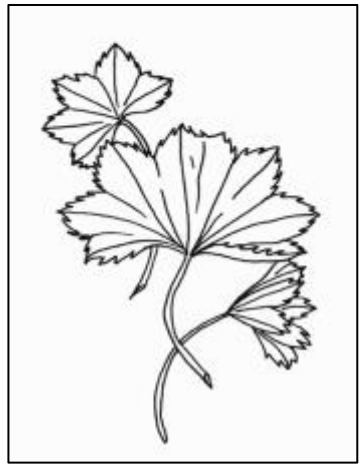

Fig. 5: *A. vulgaris* leaf

- *A. vulgaris* (leaf) (Figure 5):
  (native)

  Dye 1

  WOF (weight of fiber): 10g

  Mordant: 20% alum with 1L water for 90mins

  Plant Material: 20g *A. vulgaris* and 1L water

  Dye bath: 120min and let sit overnight

  Dye 2

  WOF (weight of fiber): 25g

  Mordant: 20% alum with 1.5L water for 120mins

  Plant Material: 20g *A. vulgaris* and 1.5L water

  Dye bath: 120min and let sit overnight

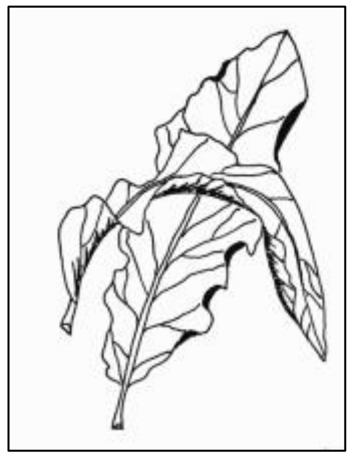

Fig. 6: *R. longifolius* leaf

- *R. longifolius* (leaf) (Figure 6):
  (introduced)

  Dye 1

  WOF: 10g

  Mordant: 20% alum with 1L water for 90mins

  Plant Material: 20g *R. longifolius* and 1.5L water

  Dye bath: 120min and let sit overnight (white wool) 60mins (grey wool)

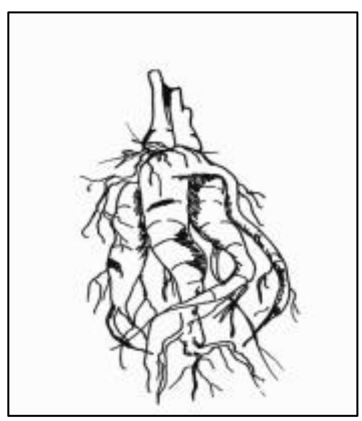

Fig 7: *R. rhabarbarum* (root)

- *R. rhabarbarum* (root) (Figure 7):
  (introduced)

  Dye 1

  WOF: 25g

  Mordant: 20% alum with 1.5L

water for 120mins

Plant Material: 150g *R. rhabarbarum* and 1.5L water

Dye bath: 120min and let sit overnight

- *L. nootkatensis* (leaf) (Figure 8):
  (introduced)

  Dye 1

  WOF: 7g

  Mordant: 15% alum with 1L water for 120mins

  Plant Material: 54g *L. nootkatensis* 1L water

  Dye bath: 120min and let sit overnight

  Copper/Iron bath: 3.5g wool for 30min

  Dye 2

  WOF: 50g (white wool) 10g (grey wool)

  Mordant: 20% alum with 3L water for 90mins

  Plant Material: 54g *L. nootkatensis* 2L water

  Dye bath: 120min and let sit overnight (white and grey wool)

  Copper/Iron bath: 25g wool for 30min

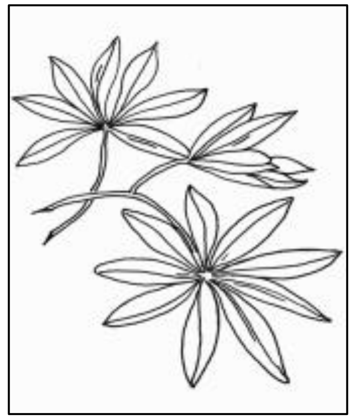

Fig 8: *L. nootkatensis* leaf

2.3 Weaving

Weaving Vocabulary:

Warp: The warp is the part of the weave that runs vertically and, in this piece, is made of white cotton thread.

Weft: The weft is the wool yarn running horizontally along the warp. In this piece the naturally dyed fibers make up the weft.

Plain weave technique: The plain weave technique is the method of pulling the weft thread over one warp thread and under the next, then back over the following warp thread and continuing this pattern down the tapestry.

The naturally dyed fibers were woven into a tapestry on a frame loom. The loom was warped with off white cotton thread and the dyed wool was woven into the warp using the plain weave technique. Thirteen warp threads, each a fourth of an inch apart, made up the length of the weave. The warp was weft with the dyed wool using a tapestry needle for 14 inches. Loose threads were then woven into the back of the tapestry. The weave was then cut off the loom and tied off along the bottom, allowing fringe. The top was finished and tacked down using a sewing needle and thread.

* Illustrations (Figures 3-8) by Molly Pluenneke

3. Results

The results of the previous literature review are as follows:

There will be a decrease in species diversity in the Arctic tundra as temperatures rise (Walker et al., 2005). The species most at risk for extinction due to climate change are lichens, such as *C. chlorophaea* and *P. canina* in this review. (Walker et al., 2005). Because of the decrease of relative humidity projected with temperature rise (Figure 1), *A. vulgaris* species could be at risk for habitat loss (Gavrilova & Vitkova, 2010, KNMI Climate Change Atlas, 2017). Plants with similar biological traits and habitat locations to *R. longifolius* will experience an increase in habitat availability (Wasowicz et al., 2014). With the increased temperature and the northern shift of species in Iceland, new habitats will become available for invasive species such as *L. nootkatensis* (Figure 2).

The colors produced by the dyeing process of each species are represented in Figure 9. In order of appearance on the tapestry from top to bottom, they are: *P. canina*, *C. chlorophaea*, *A. vulgaris*, *R. longifolius*, *R. rhabarbarum* and *L. nootkatensis.*

4. Discussion

4.1 Artistic representation of study- *"Iceland Fall 2017"* (Figure 8)

Figure 9 is a weave of naturally dyed Icelandic wool representing the study in an artistic way and providing a visual representation of the findings. This process was chosen to fully immerse the researcher into the craft being analyzed and to engage the audience in a receptive and interesting way that is uncommon to natural science research. Each species is represented in the piece by the color the plants produce when processed into dyes.

The first two colors in the weave are made from *P. canina* and *C. chlorophaea,* respectively. They are the thinnest sections of color in the weave and there are gaps in the piece where the warp is left unwefted. This represents the danger of extinction these species face with rising temperatures (Walker et al., 2005).

The next color results from the species *A. vulgaris*. Its potential struggle due to decreased humidity as temperatures rise is also represented by gaps in the piece where the warp is left unwefted (Gavrilova & Vitkova, 2010, KNMI Climate Change Atlas, 2017). The next species represented is *R. longifolius*. Here, the warp is only weft on the edges of the tapestry. This represents the current distribution of *R. longifolius,* which currently resides along populated coastal areas (Kristinsson, 2010). This species will benefit from increased temperatures as its habitat availability increases (Wasowicz et al., 2014). Species' benefit derived from temperature rise is represented by the occasional drift of the weft from its "original distribution" at the sides of the tapestry to the center of the tapestry.

The next color is from the root of *R. rhabarbarum*. This is an alien species to Iceland, noninvasive and originally brought to Iceland for cultivation (Wasowicz et al., 2013, Kristinsson, 2010). Because of this, its presence in the tapestry is minimal yet there is no falter in the weft representing the stability of its population in Iceland, even with rising temperatures.

The final harsh yellow color is from the species *L. nootkatensis.* It occupies almost half of the tapestry. The species is both invasive and will benefit from rising temperatures (Wasowicz et al., 2013). Because of this it takes up a majority of the piece.

Starting from the top of the tapestry, various pockets of colors can be seen in sections other than the ones that represent their species. This is because with a more traditional, colder climate, diversity of plant species is high. As the piece continues towards *L. nootkatensis* dyed wool, there is less variation of colors within sections and when *L. nootkatensis* dyed strands are reached in the piece, there is almost no variation present. This is representative of the way in which species diversity in Iceland will decrease as temperature rises and invasive, adaptable plants increase in population (Wasowicz et al., 2013, Walker et al., 2005).

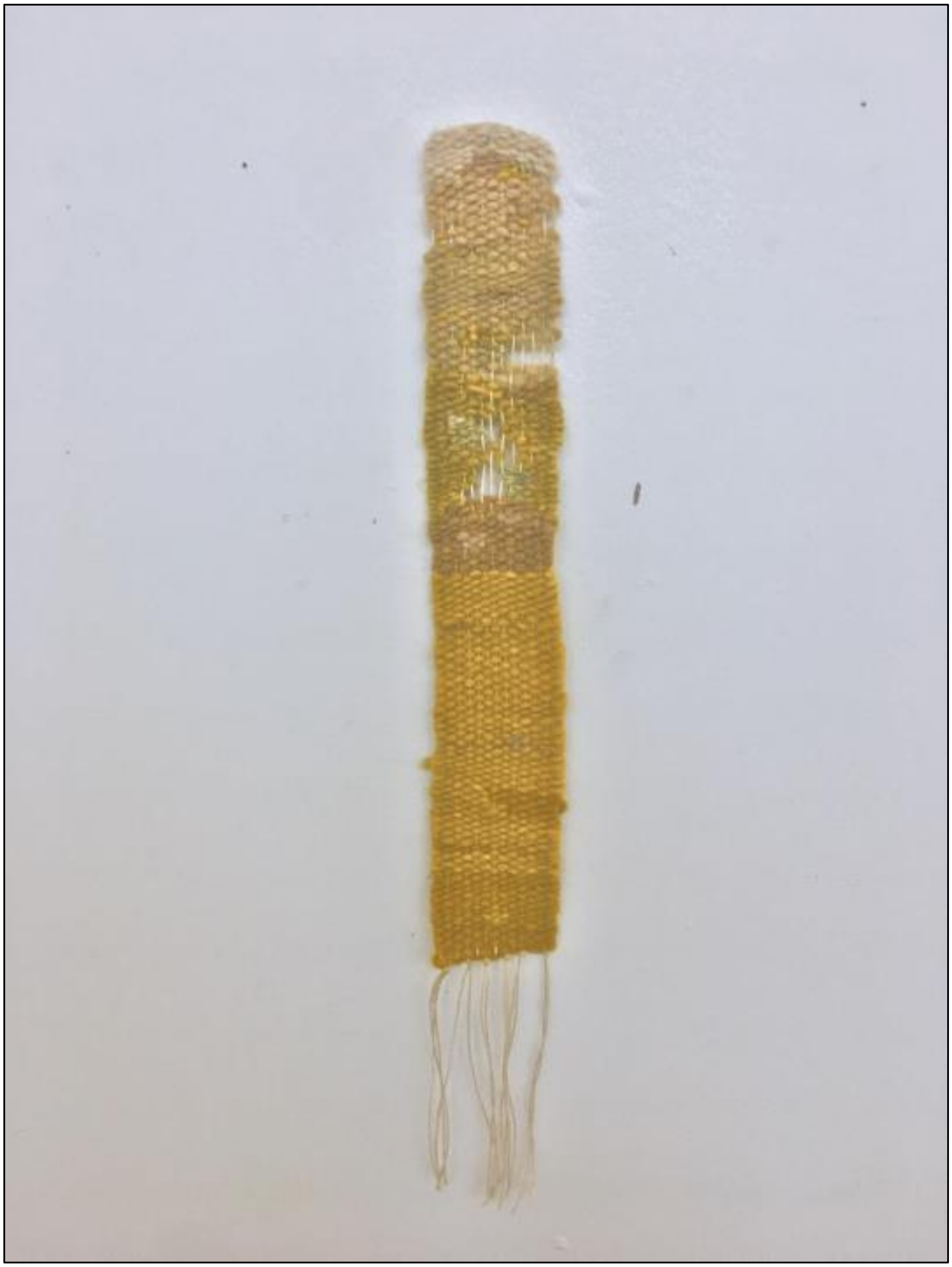

Fig 9: "Iceland Fall 2017" by Molly Pluenneke

4.2 Conclusions

As temperatures rise due to climate change, plant distributions will shift globally with populations in the north being some of the most significantly affected (Parmesan & Yohe, 2003, Schöb et al., 2009). This study explored the ways in which the shift in plant distributions will change due to temperature rise, specifically plants used for natural dyes in Iceland.

Lichen species like *P. canina* and *C. chlorophaea* will be the most at risk for extinction due to competition from larger shrub species (Walker et al., 2005). With the decrease of relative humidity projected with temperature rise (Figure 1), *A. vulgaris* species could be at risk for habitat loss. (Gavrilova & Vitkova, 2010, KNMI Climate Change Atlas, 2017) while other native species like *R. longifolius* will prosper in a warmer climate. Climate change will allow alien species to move into habitats within the country and begin competing for resources with native species. Many alien species like *L. nootkatensis* will also benefit from warming and expansion of their habitats (Wasowicz et al., 2013). This increase of new species into Iceland and the possible extinction of some native species will change the availability of plants used to make natural dyes and could potentially alter the color palette available to natural dye practitioners in Iceland.

Due to the overall decrease in diversity, natural dye artists in Iceland will begin to experience more difficulty in finding wider varieties of colors due to the lack of access to different species. Species traditionally used will begin to decrease in abundance. Specifically, the lichens will be the most at risk for extinction so natural dyers should be mindful of this when gathering during the collection processes. Invasive species should be gathered first and at risk species should be gathered sparingly, if at all (Vejar, 2015). The increase of non-native species could lead to new opportunities in the color palette found in Iceland but the increase of invasive species could lead to extinction of commonly used native species that produce beautiful and unique colors.

This study hypothesized that native species in Iceland will be altered in their distributions and at possible risk for extinction due to the increase of southern residing species and loss of optimum climatic conditions. Though all the species analyzed will most likely experience climate change induced alterations in their population and distribution, some, like *P. canina, C. chlorophaea* and *A. vulgaris,* will be at risk for habit loss and extinction. The results showed that some native species like *R. longifolius,* will likely benefit from a milder climate.

4.3 Future Research and Study Limitations

This review only focused on six plant species used to make Icelandic natural dyes. There are far more species in the country that are commonly used and an analysis of these plants should be done for more comprehensive evaluation. Plant collection and dyeing should also be done earlier in the growing season to obtain better coloring from the younger plants as well as to achieve a more diverse color palette. Experimental testing should be done in the future on just the natural dye-specific species to get more accurate results for the way in which they will react with increased temperatures.

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