BERRIES IN ALASKA'S CHANGING ENVIRONMENT SERIES: *VACCINIUM VITIS-IDAEA*

Lowbush cranberry in a Changing Climate:

Threats and Opportunities

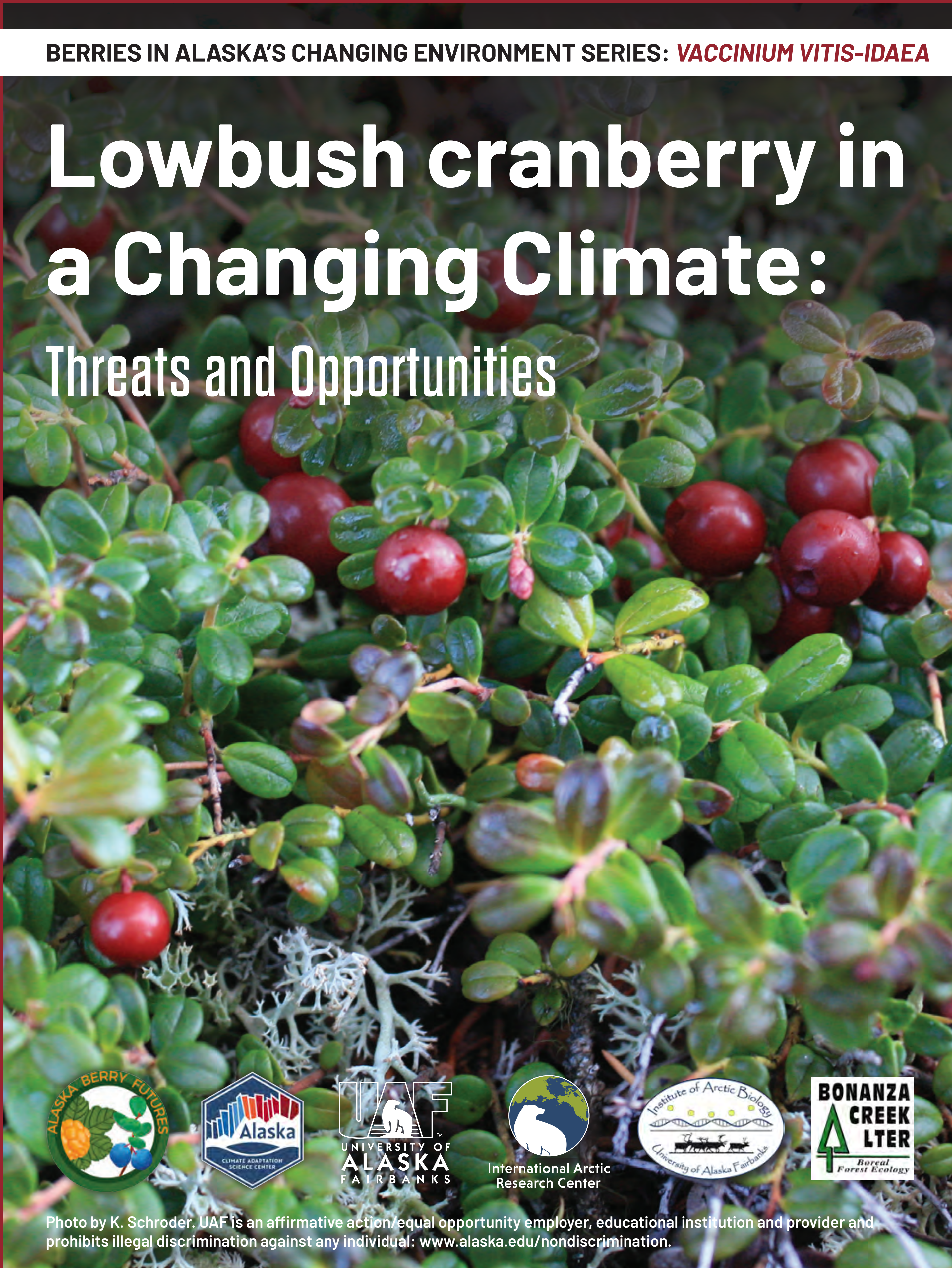


Photo by K. Schroder.

WELCOME!

In late summer, berry picking is on the to-do list of many Alaskans. Alaska's wild berries provide delicious and highly nutritional food, and for communities not connected to the road system they are a crucial source fruit. For Alaska Native peoples, berries are an important part of the culture, reflected in stories and recipes. Berry picking is a traditional and recreational activity for rural and urban Alaskans alike. But all across the state people have observed changes in the timing and predictability of fruiting for many berry species, and wonder if a changing climate is having an influence. A shifting climate has led to many changes that could influence berry species, including rising temperatures, longer growing seasons, shorter snow-covered seasons, and altered precipitation patterns. It can also lead to changes in the pollinators that our berry plants depend on, and in the populations of the animals and **microbes** that consume or protect the plants. The effects of those changes are complicated, and the overall impact can be positive or negative.

In "Berries in Alaska's Changing Environment" series, we examine what we know about the impacts of climate change on our berry species based on scientific research and observations by community members across the state. We identify potential threats to the growth, health, and fruit production of each species. We also look at opportunities: ways that Alaskans may be able to preserve or even expand the availability of fruits. And third, we identify gaps in our knowledge that limit our current abilities to predict what will happen with our berry species. Some potentially unfamiliar words are bold, colored, and defined in the **glossary** at the end of the booklet. We hope this information will inspire berry lovers to find ways to take advantage of opportunities, protect what we have, and adapt when that is not possible.

The series will briefly discuss human use and then look at growth, flowering, pollination, fruits and seeds, mutualists (like fungi that help plants obtain nutrients), herbivores, and pathogens, and highlight threats and opportunities for each aspect of the plant life cycle under a changing climate.

TEXT: Lindsey Parkinson, Christa Mulder, Kristin Schroder, Katie Spellman

GRAPHICS AND PHOTOS:
Ann Ruggles, V. Mononen, Katie Spellman, KC Nattinger, Molly Putman, Lauren Bird, Hannah Foss, Emily Sousa, Kristin Schroder, Eileen Schaub, Christa Mulder

MORE INFORMATION:
For more information and to download copies of this booklet visit the Alaska Berry Futures website at *https://casc.alaska.edu/changingberries*

ADVISORY AND REVIEW TEAM:
M. Chase, N. Fresco, C. Nichols, D. Osbourne, T. Schwoerer, E. Sparrow, K. Spellman

Suggested citation: Parkinson, L.V., C.P.H. Mulder, K. Schroder, L. Bird, M. Putman, H. Foss, E. Sousa, and K. Spellman. (2024). Lowbush Cranberry in a Changing Climate: Threats and Opportunities. Berries in Alaska's Changing Environment Series: *Vaccinium vitis-idaea*. Institute of Arctic Biology and International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, Alaska, USA.

LOWBUSH CRANBERRY

Lowbush cranberry (scientific name: *Vaccinium vitis-idaea* L., in the Ericaceae family) goes by many names across Alaska including: *kikmiññaq* (Iñupiaq)[1]; *kenegtaq* (Alutiiq/Sugpiaq)[2]; *kiika-x* (Unangam Tunuu)[3]; *natł'at* (Gwich'in)[4]; *nenhtl'it*, *nenhtl'i* (Deg Xinag); *neentł'ee, dinaałkk'aza* (Denaakk'e)[5]; *netl', kwntsan'* (Upper Kuskokwim)[6]; *hey gek'a*, *k'inhildi* (Dena'ina)[7]; *dáxw* (Lingít)[8]; *sk'ag cháay* (Haida);[9] as well as lingonberry, partridgeberry, and cowberry (English). It is a popular berry to harvest in northern Alaska and northern Europe.

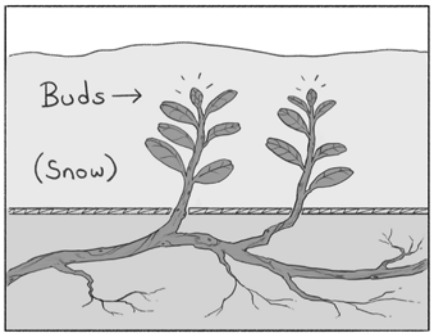
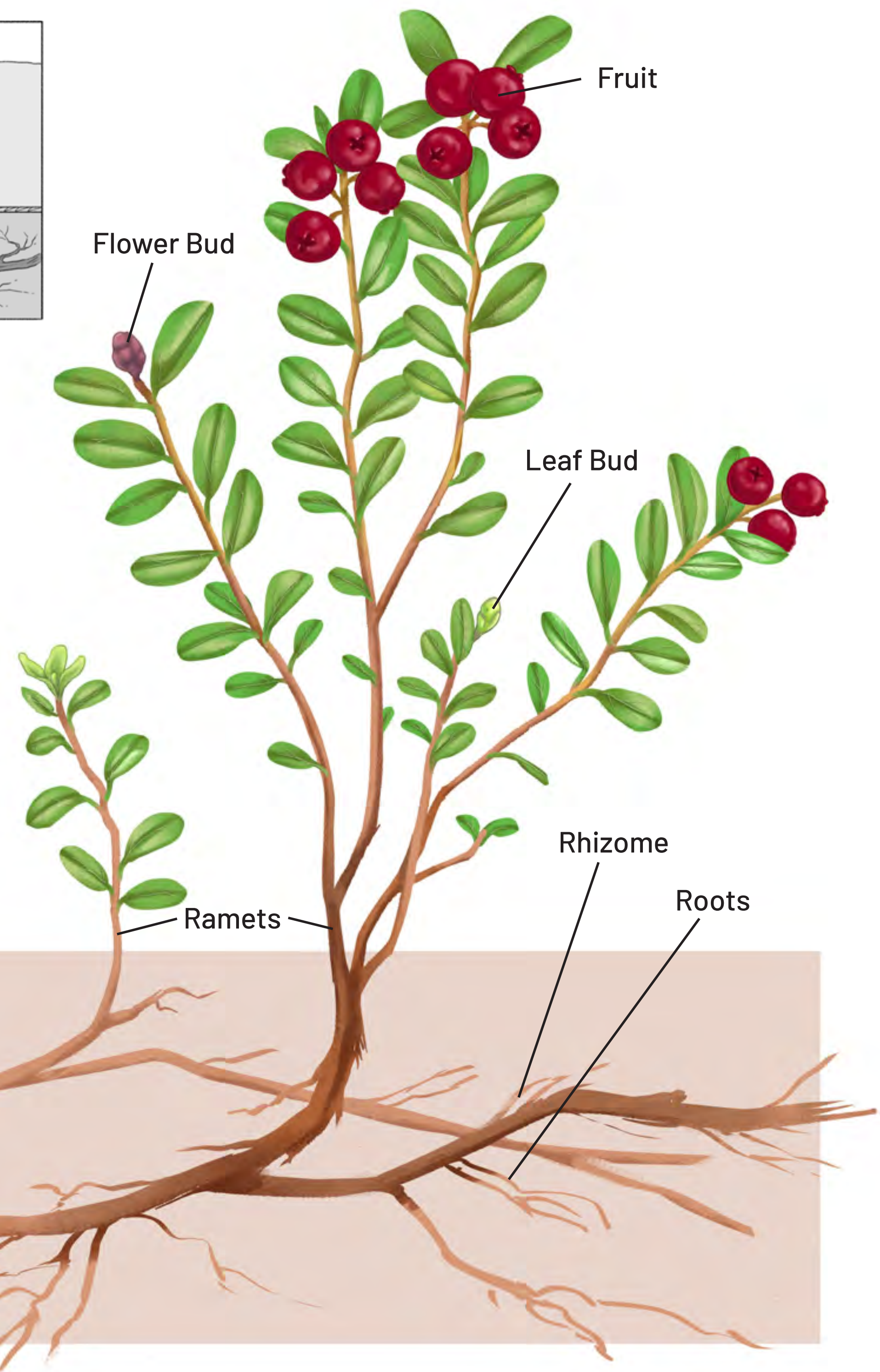


Figure 1: Above: Lowbush cranberry (*Vaccinium vitis-idaea*) in spring, when the overwintered flower and leaf buds are starting to expand. Right: Most ramets (stems) grow from existing underground rhizomes (underground stems) instead of from seeds. Illustration credit: L. Bird and H. Foss



HUMAN USE

Lowbush cranberries are commonly picked throughout their range, and are an important source of traditional food and medicine within many cultures, including the Indigenous peoples of North America and throughout Eurasia.[46] In Alaska, the berries are valued as a source of food, for their medicinal properties, and the act of picking berries is an important cultural activity for many communities.[1,7,78–81] Lowbush cranberries are picked as a portion of the berry harvest across most of the state (Figure 2). The berries are often harvested after the first frost, as they are said to be sweeter then; the overwintered berries are also sometimes gathered in the spring following snowmelt.[1,7]

While some enjoy the tart flavor of the berries raw, they are typically combined with sugar or used in other dishes[1,7] such as *akutaq* (*nivagi* in Dena'ina), baked goods, jams, and jellies, for both personal consumption and commercial use.[82] In arctic Alaska, Iñupiaq families enjoy berries mixed with meats and seal oil. Or one can

CLIMATE IMPACTS ON HUMAN USE

At least eleven Alaskan communities mention lowbush cranberry in their climate adaptation plans. Many are particularly concerned with changes in the variability of timing and abundance of harvests.[49]

Changes in the timing of berry ripening could affect when people can harvest the fruit, potentially affecting traditional harvest schedules and the availability of the fruit for eating and storage. The Native Village of Georgetown mentioned in their climate adaptation plan that increased shrub cover has decreased visibility and access to berries.[88]

"I like going berry picking not just to get big pails of berries but because you are out alone. [...] Calm and just enjoying yourself. [...] Small children, they usually come along but you don't have to worry that they will go out of sight. They are more free, it's good therapy."

– Berry picker, Inuit Nunangat[79]

Berry picker near Chitina, Alaska.
Photo credit: A. Ruggles

Berry picker near Fairbanks, Alaska. Photo credit: A. Ruggles

make *Ittukpalak*, a dish of whipped fish eggs and berries.[1]

Lowbush cranberries are considered true superfoods. They have the highest level of antioxidants of 16 berry species tested in Interior and South Central Alaska (see also **anthocyanin**).[83] Peter Kalifornsky of the Dena'ina is recorded as saying: "The old people said that there is more nourishment in the lowbush cranberry than in any other berry."[7]

Wild cranberries are rich in nutrients and antioxidants including phosphorus, calcium, magnesium, potassium, and carotene,[13] as well as vitamins A, C, E, and polyphenols.[84] Due to their high tannin, benzoic acid, and anthocyanin content, the fruits have a long shelf life (over 8 weeks under refrigeration).[46] The pharmaceutical industry uses the plant as a source of arbutin, which is used in the treatment of intestinal disorders.[13,85]

Eating lowbush cranberries has been linked to the prevention of neurodegenerative disorders.[84] Many other studies have indicated the health benefits of the fruit, including anti-inflammatory, antioxidant, and anticancer activities.[84] This is particularly important where access to fresh foods is scarce, such as in rural Alaskan and Canadian communities.[86,87]

> **Elders also say to wait to pick until after first frost, but now the berries are ripe before that point.**
>
> *– Stephen Payton, Seldovia, Alaska's Berries in a Changing Climate Listening Session, Feb. 2022*

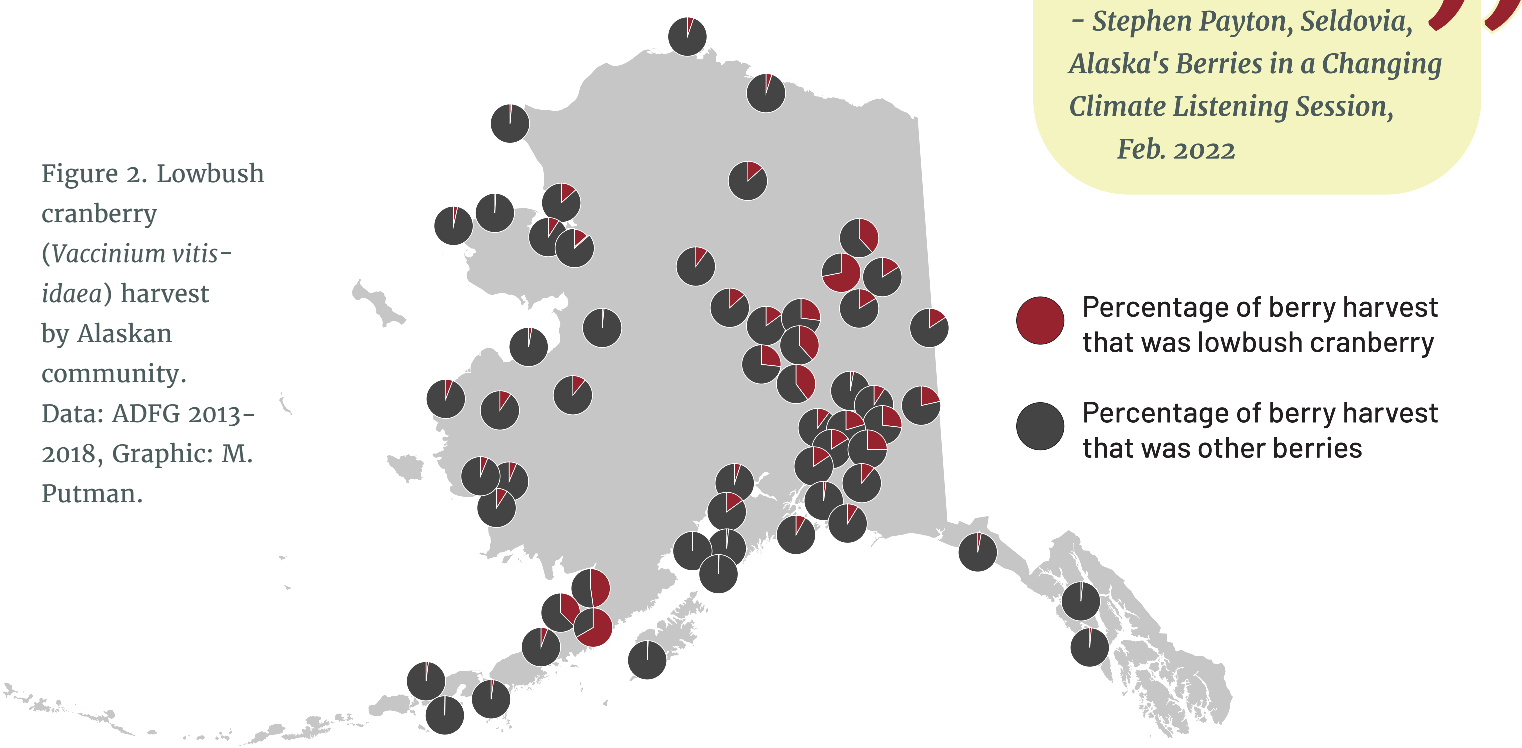


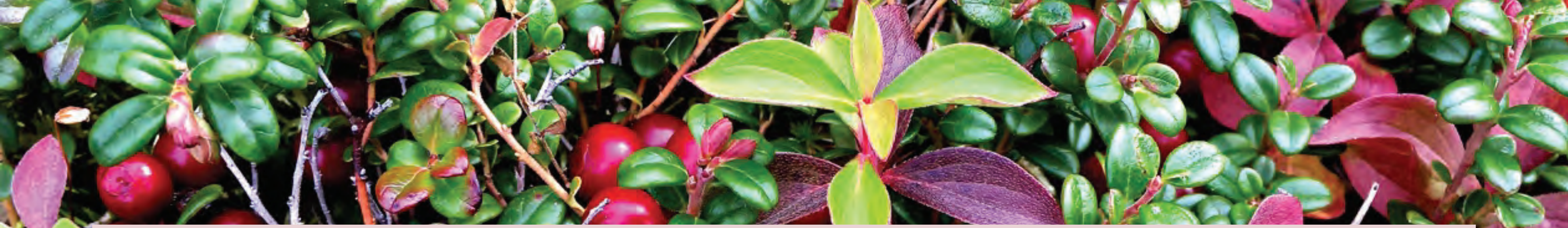
Figure 2. Lowbush cranberry (*Vaccinium vitis-idaea*) harvest by Alaskan community. Data: ADFG 2013-2018, Graphic: M. Putman.

GROWTH

Lowbush cranberry is an evergreen shrub that grows low to the ground, often forming thick mats. The plant grows outwards through underground stems called rhizomes (Figure 1). Nearly 80% of the plant is underground, made up of rhizomes and roots.[10] Shoots emerge from the rhizomes and can range from 2 to 6 inches (5 to 15 cm) in height aboveground. Each shoot is called a **ramet** and all the ramets that are connected underground are called a **genet** — because they are one big genetically identical individual, a clone.

Leaf buds are produced at the tips of some of the ramets while other ramets produce flower buds (Figure 1). The lowbush cranberry plant starts making a leaf bud about a year before the leaves actually grow, so the leaves overwinter in bud form before they start developing again in spring.[11] In summer the leaves are bright to dark green. The plant's optimum temperature for photosynthesis is 50 - 65° F (10 - 18° C), but even at these temperatures lowbush cranberry leaves photosynthesize slowly compared to deciduous plants (plants with leaves that last one season) such as the closely

Figure 3. Winter reddened leaves of lowbush cranberry. Photo credit K. Schroder.



THREATS TO GROWTH FROM CLIMATE CHANGE

Though lowbush cranberry plants can withstand extreme temperatures, the plants may be sensitive to a sudden change in temperature (cold or warm) if it comes during a season when they are not historically exposed to it. Experimental studies have shown that when the stems are suddenly exposed to cold temperatures, like losing snow cover after an early or **mid-winter warming event**, buds can be damaged and shoots can even die.[24,25] Sudden loss of snow cover may lead to more UV exposure than the plant is prepared for, which can hurt the plant (like a strong sunburn) if they are not able to generate protective compounds (internal plant sunscreen).[26,27]

Low-growing cranberry shrubs are vulnerable to **shrubification**, when taller shrubs like willows and alders expand into areas where they are currently absent.[28,29] These shrubs are able to quickly adjust to changes in temperature and nutrient availability to get bigger and expand their range (Figure 4),[30] and this is likely to result in reduced cranberry growth and fruit production.[28,31]

Fire intensity, extent, and frequency are increasing in interior Alaska.[32–34] Severe (hot) fires that burn through the organic mat of the forest floor will kill both mature plants and seeds in the soil, and recolonization will depend on seeds brought in by animals from unburned or less intensely burned areas.[22,35]

related bog blueberry.[12] Leaves last 2 to 4 years[13–15] and are incredibly tough. In the fall they produce high levels of **anthocyanins** (CPH Mulder, unpublished data) which turn them red (Figure 3). It's not known exactly why some evergreen plants redden in winter, but it may provide protection from UV light so that they can continue to function during the shoulder seasons (spring and fall).[16]

Lowbush cranberry plants build up their frost hardiness (resistance to cold) each time they go through a freeze-thaw cycle in the fall. By December lowbush cranberry leaves in Interior Alaska can survive temperatures down to -80 °C (-112 °F).[17] In early spring, when plants are protected from temperature extremes by a layer of snow, lowbush cranberry leaves are able to use the light that filters through the snow to start photosynthesizing.[18] This unusual trait gives them an advantage over deciduous plants, which are still leafless at this time.

Lowbush cranberries can reproduce vegetatively (by producing shoots that become independent) and sexually (by seeds). In most places vegetative reproduction is very common and sexual reproduction is rare.[19,20]

Lowbush cranberries can survive light to moderate forest fires and resprout from the stems or rhizomes (belowground stems, Figure 1), to take advantage of the abundant light and nutrients available after a fire.[21–23]

Photo credit: A. Ruggles.

OPPORTUNITIES FOR INCREASED GROWTH

When combined with herbivory, **warming** may help evergreen shrubs. Several studies have found a strong increase in dwarf evergreen shrubs in response to warming.[37] In addition, herbivores may promote evergreen shrubs because they preferentially browse shrubs like willow, which have more nutritious leaves.[38,39] **The plants are resistant to high temperatures**: leaf and stem tissue can survive temperatures as high as 118 °F (48 °C). The same adaptations that make them resistant to extreme cold may also protect them from extreme heat.[17] **Greater snowfall in winter**, which is predicted for the interior and northern regions of the state,[40] does not appear to hurt the plants, and may help them by increasing winter soil temperatures.[30,41]

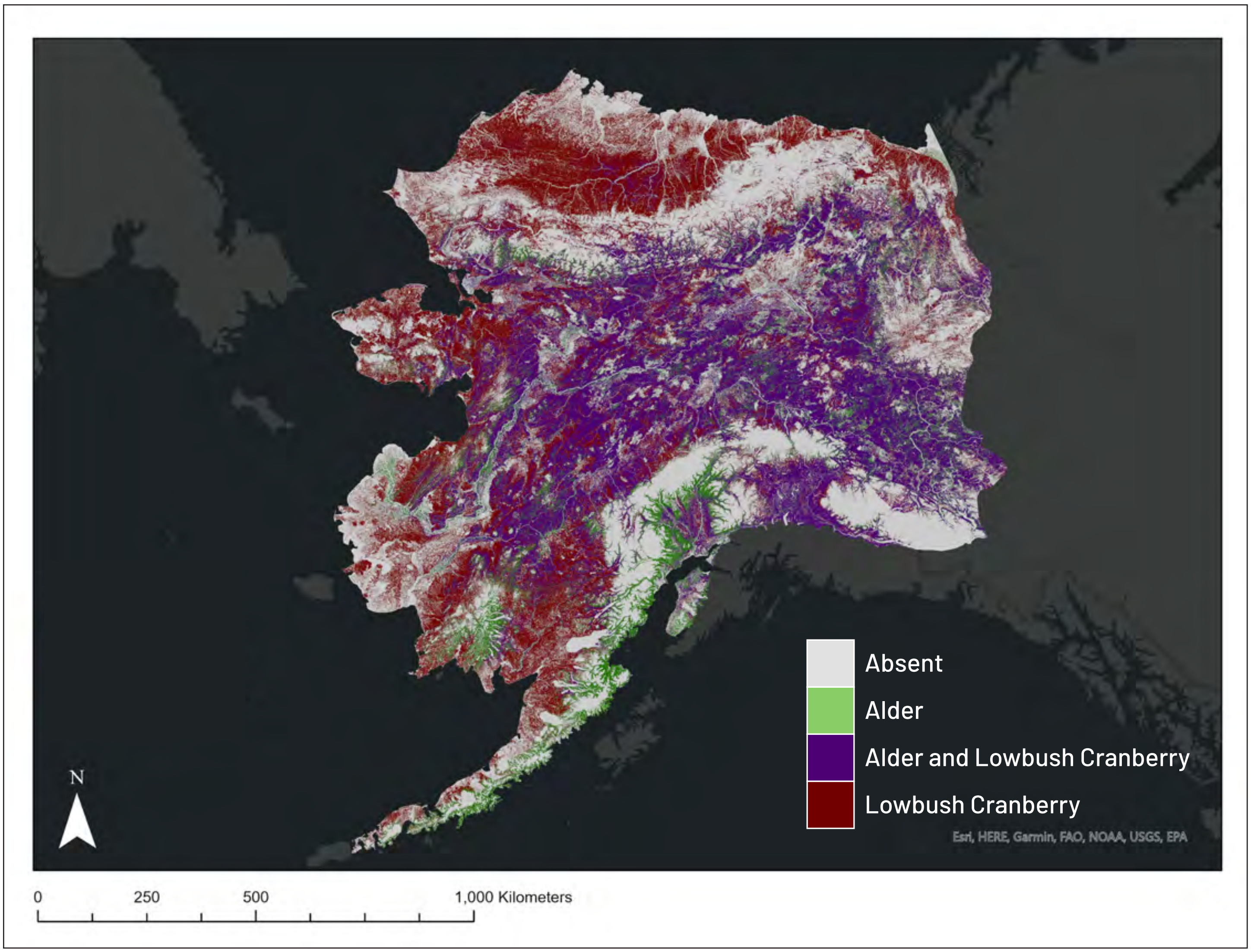
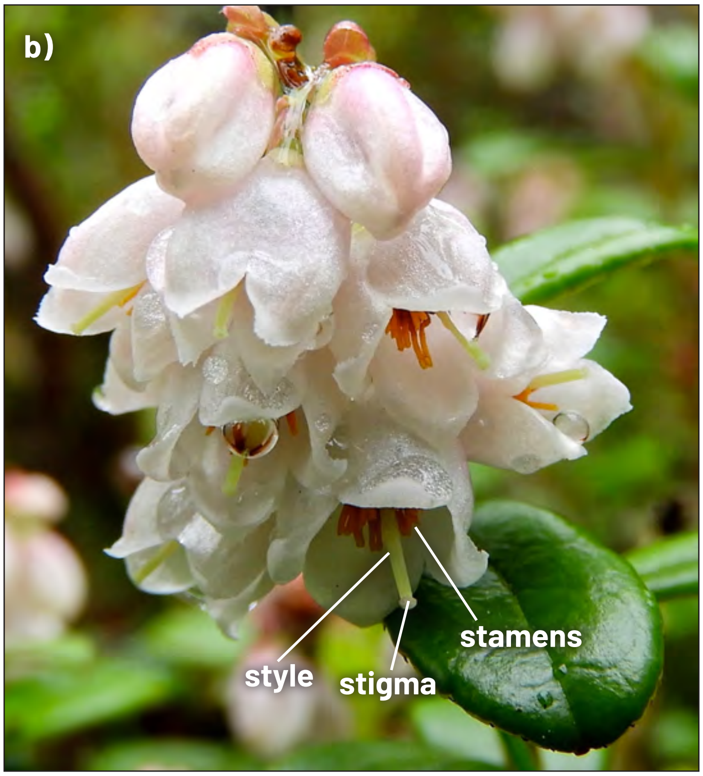


Figure 4. Current lowbush cranberry and alder (*Alnus* species) shrub distribution. Lowbush cranberry plants in areas now free of alder (in red), such as most of the North Slope and Seward Peninsula, may have problems in the future as the alder shrubs expand their range. Map: E. Sousa, Data: Nawrocki et al. 2021.[36]

It takes 3-6 years for a lowbush cranberry stem to mature before it starts producing flower buds at the tips of some of the shoots.[13,14,42] Fewer than half of the shoots produce flower buds (most others produce leaf buds).[13] Each bud includes multiple flowers, which together are called an inflorescence (Figure 5). Flower buds initially begin to develop the year before they bloom (Figure 5a).[11] The start of flower bud growth depends on the date of soil thaw, but regardless of when bud growth starts, once they reach a certain developmental stage they usually "pause" development and wait for winter.[11] The buds overwinter and resume growing and finally flowering the following spring as the plant ramps up growth.[11] Lowbush cranberry flowers appear in May or June.[43] Peak flowering in Interior Alaska ranges from mid to late June, and up to 3 weeks later in more northern regions.[44,45] After flowering, a ramet stops growing from the tip; the stem won't get any taller.[13]

Lowbush cranberry inflorescences contain 1-9 flowers (average 4–5), with the youngest flowers at the tips (Figure 5).[23] Individual flowers are a whitish-pink bell-shape approximately 4 – 6 mm in length.[13,46] Lowbush cranberry flowers are hermaphroditic, meaning that they contain both male and female reproductive organs within each flower. Each flower contains 8 – 10 stamens (male parts, where the pollen is produced) and a **carpel** (female part including stigma, style and ovary) (Figure 5b).[47] The ovary (Figure 8) contains dozens of ovules and therefore can produce dozens of seeds.[47]

Figure 5. a) Scanning electron microscope image of a lowbush cranberry flower inflorescence in July of the year before the flower opens. Individual buds at different stages of development (most developed toward the bottom) can be seen. Image credit: E. Schaub.



b) Lowbush cranberry inflorescence with the youngest flowers (still in bud) at the top. The stigmas can be seen extending beyond the stamens. Pollen lands on the stigma and travels down the style to the ovary to fertilize the ovules. Photo credit: A. Ruggles.

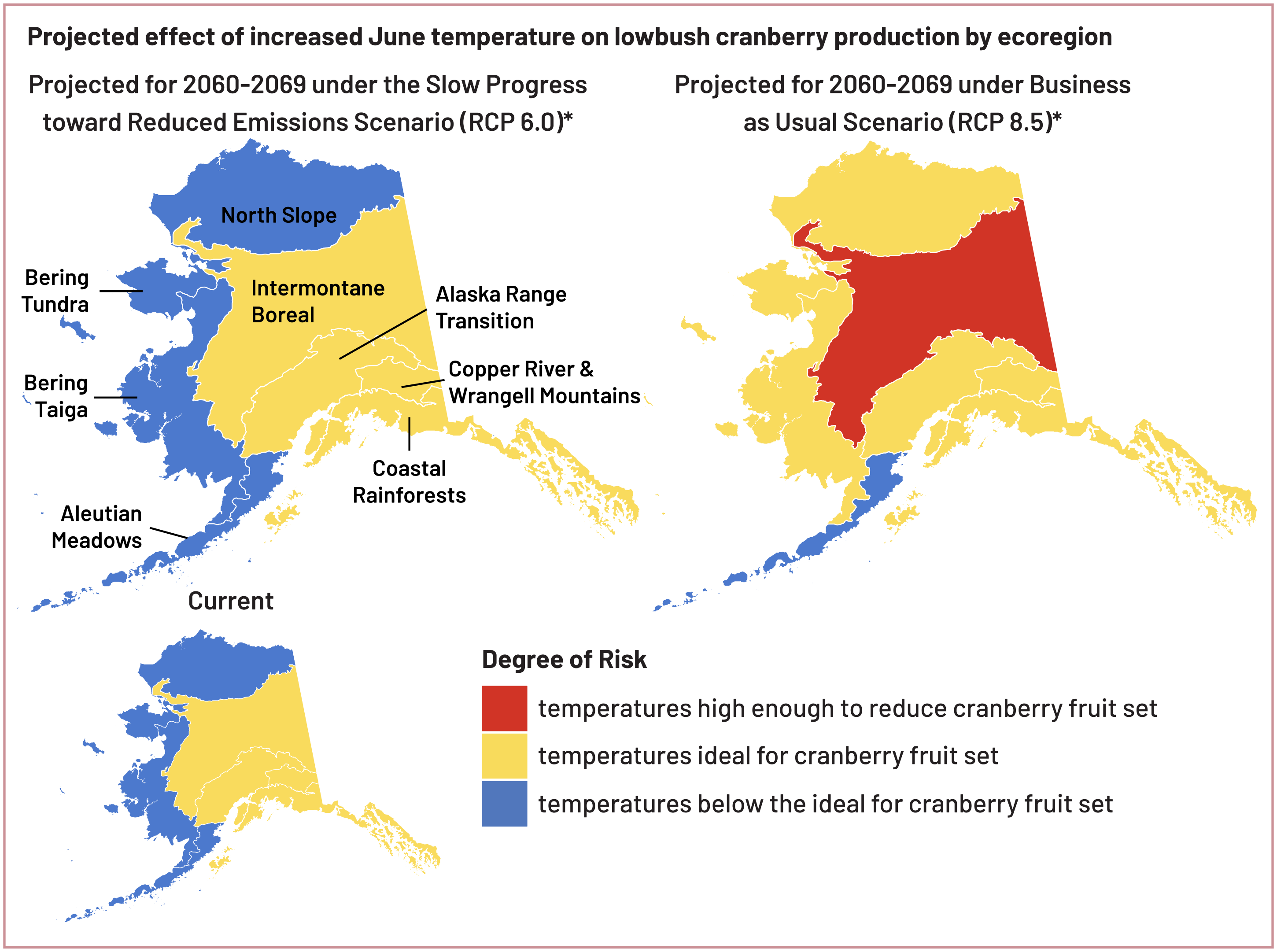


Figure 6. Current and projected maximum daily temperatures during lowbush cranberry flowering. Projections are based on Intergovernmental Panel on Climate Change (IPCC) Representative Carbon Pathways 6.0 and 8.5 for 2060-2069. Interior Alaska is at risk of reaching temperatures above 77 °F (25 °C) in June which can cause a lower proportion of lowbush cranberry flowers to become fruits. However, western and northern Alaska may enter the ideal temperature range by the 2060's depending on the level of global greenhouse gas emissions.

OPPORTUNITIES FOR INCREASED FLOWER PRODUCTION

Temperatures of 59 – 68 °F (15 – 20 °C) are optimum for the development of flowers into fruit (fruit set).[48] The coastal regions of Alaska may see a rise in the fruit set of lowbush cranberries, as they are increasingly likely to have temperatures in this range in June, when lowbush cranberries flower (Figure 6).

Figure 7. A lowbush cranberry flowering in August. The flowers seen here should have bloomed the next spring and will not set fruit. Photo credit: CPH Mulder.

THREATS TO FLOWER PRODUCTION

Fruit set decreases when **temperatures are above 77 °F (25 °C)** during flowering.[48] While most of Alaska is unlikely to get that hot in June, even with climate warming, the Interior may start to see negative effects from high temperatures if no efforts to reduce greenhouse gas emissions are undertaken and temperatures rise as predicted (Figure 6).[49]

Spring icing: In a study in Sweden, when winter warming melted snow but then froze again to cover the plants in ice for weeks or months two winters in a row there was a significant decrease in the number of flowers.[50] This is unlikely to be an issue in Southeast Alaska or the Aleutians, but it may be become a problem in some other parts of the state.

Flowering at the wrong time: Developing lowbush cranberry buds sometimes open early, as a second set of flowers in August or September (Figure 7). These are probably flower buds the plant produced earlier in the summer that developed too far. While the exact cause is not known, this late flowering is likely associated with warm spring temperatures and a longer growing season.[51] No berries can grow from this second flowering (there is not enough time) and the ramet will produce fewer or even no flowers the next summer.[13,14,52]

POLLINATION

Pollination of lowbush cranberry. A bumblebee visiting a lowbush cranberry flower. Photo credit: V. Mononen, CC by NC-2.0 DEED.

Vaccinium shrubs like cranberry and blueberry produce pollen tetrads, four pollen grains grouped together (Figure 9). Insect pollinators are necessary for lowbush cranberries to produce fruit; plants without access to pollinators produce almost no berries.[13,53]

The most important lowbush cranberry pollinators (carrying over 1,000 pollen tetrads per insect) are in the order Hymenoptera (a subgroup of insects), and includes native bees in the genera *Bombus*, *Andrena*, and *Dialictus*.[53] These insects vibrate the anthers (buzz pollination) to release the pollen.[54] Non-native bee species *Apis mellifera* (honey bees) and *Bombus occidentalis* (western bumble bee) are pollinators in regions where cranberries are present but are unlikely to be important in most parts of Alaska.[53] In addition, syrphid flies (Syrphidae, a.k.a. hover flies or flower flies) pollinate to a lesser extent. Since mosquitoes can't buzz the anthers they are not effective pollinators.

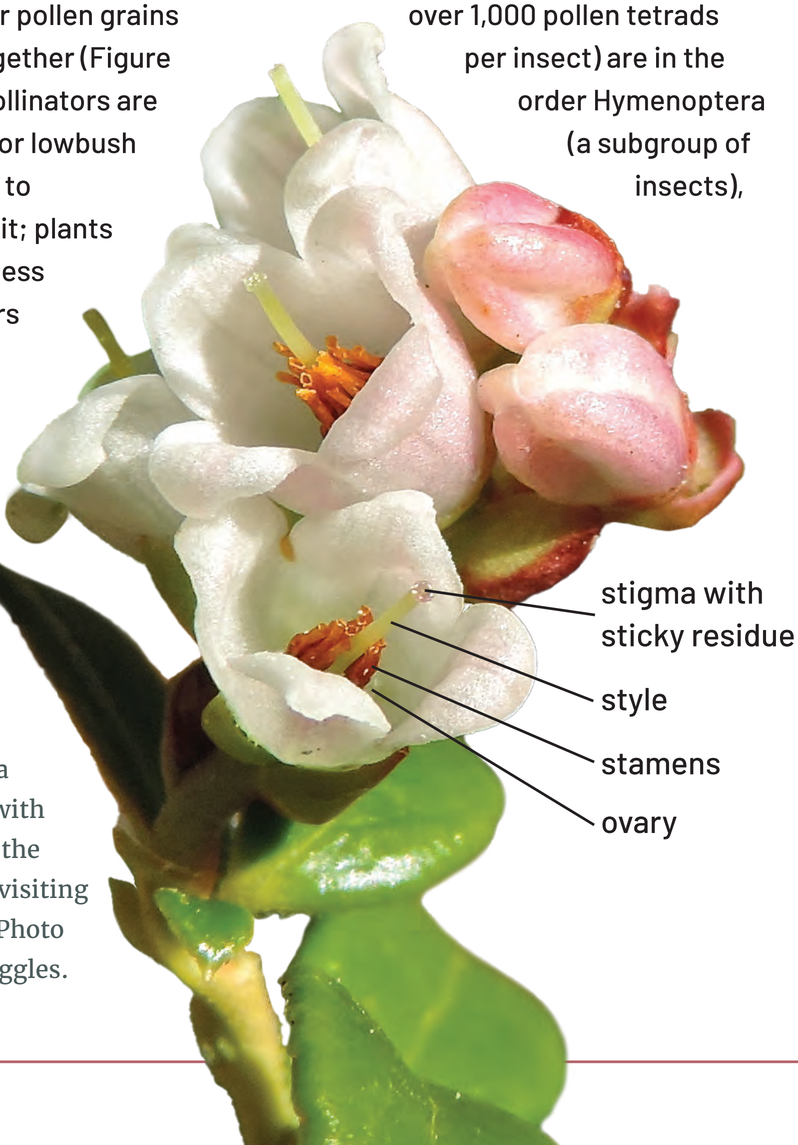
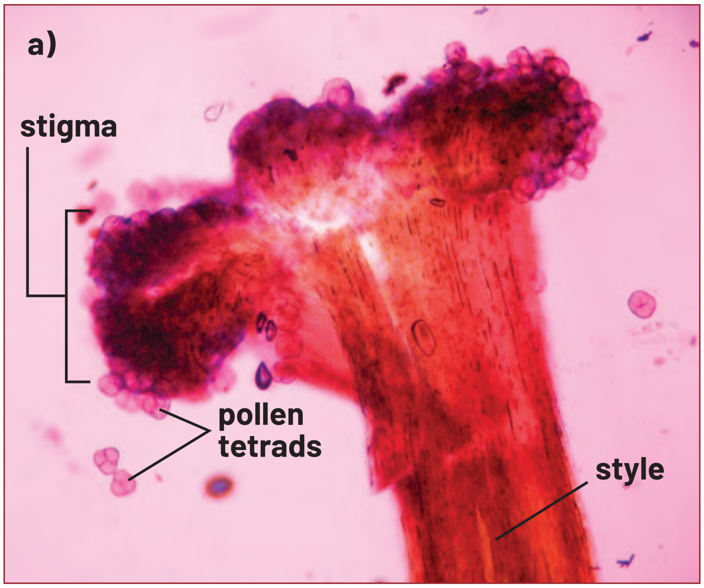


Figure 8. A lowbush cranberry flower with a stigma wet with fluid to trap the pollen from visiting pollinators. Photo credit: A. Ruggles.

Lowbush cranberry flowers probably need at least ten pollen tetrads (40 pollen grains) to be well-pollinated (able to fertilize all the ovules and turn them into seeds).[55] Flowers that receive this much or more pollen are not pollen-limited, meaning if they do not produce a



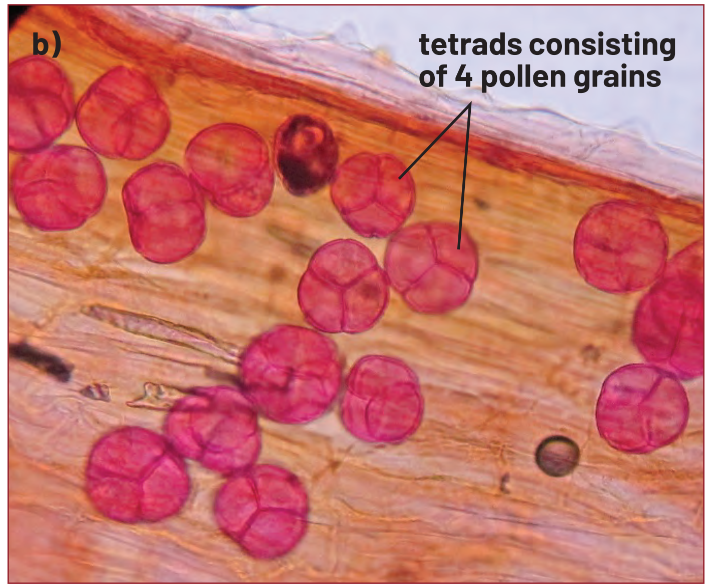


Figure 9. Pollination of lowbush cranberry. a) The pollen-catching part of a *Vaccinium* flower (stigma) with dozens of pollen tetrads. The pink color comes from a dye that makes the pollen easier to see. This stigma would be considered well-pollinated. Photo credit: K. Spellman. b) A close-up of the pollen tetrads: four pollen grains sticking together (the fourth grain is hidden in this view). Photo credit: K. Spellman.

berry it is because of something other than lack of pollen.

The majority of lowbush cranberry flowers begin producing a small amount of nectar once the flower opens.[56] It is the sugar-filled nectar that draws bees and other pollinators to the flowers for pollination. In addition to nectar, pollen grains are an important reward for many pollinators since they are an excellent source of protein.[56]

In warm, open habitats such as areas where the forest was burned in the past decades, pollinators are abundant and a lack of pollination is not a problem.[23] Several studies have found that under normal conditions lowbush cranberry fruit production is likely not pollen-limited,[53,57,58] although lowland sites are likely more pollen-limited than upland sites in Interior Alaska.[23] In cooler or shadier habitats where pollinators are not abundant, like black spruce forest or alpine zones, lowbush cranberries produce few fruits. The better pollinated the flowers, the bigger the berries and more seeds each berry contains.[13,48,57]

Lowbush cranberries flower later in the season than cloudberry or blueberry when there are more pollinators around[44], so they may not suffer from mismatches between flowering times and pollinator activity the same way that species that flower earlier can.

THREATS TO POLLINATION FROM CLIMATE CHANGE

As mentioned earlier, **expansion of taller shrubs** into tundra[59–61] can reduce growth and flowering of lowbush cranberries (Figure 4).[28,31] However, it can also reduce pollinator activity since insects are less active when it is cooler and shadier.[23,28]

Increased rain during the flowering period (June) may reduce pollination because the insects don't fly in bad weather.[49] In Interior Alaska precipitation in June is expected to increase by ~50% but in other places it is either not increasing or not by very much.[49]

OPPORTUNITIES FOR INCREASING POLLINATION

Warmer soil temperatures may increase pollinator survival over the winter, and warmer spring temperatures may increase pollinator activity.[62–64]

FRUITS AND SEEDS

About 30% of lowbush cranberry flowers get pollinated and survive to become berries in Interior Alaska (though this likely varies a lot from year to year).[23]

Lowbush cranberry fruits are spherical, 0.25-0.35 in (6-9 mm) in diameter[47], and dark red when ripe. The number of ripe fruit per **ramet** ranges from about 1-6.[23] Generally, fruit yields are greater on peat than on mineral soil, and shade reduces fruit yields.[46] In Interior Alaska, most fruits are ripe by late August or September (pers. obs.), or roughly 78 to 84 days following flowering.[46] Fruits ripen 2-3 weeks later in more northern regions. Time of flowering is the main driving factor in ripening time.[43]

Low fruit set may be caused by factors including cold temperatures, rain, hail, or drought during flowering.[13,46] Once unripe fruit have developed, they may be destroyed by temperatures below 26 °F (-3.5 °C).[46] However, this is not a big danger: even historical records from Utqiaġvik, Alaska rarely show temperatures this cold in June or July.[49]

The average number of seeds per lowbush cranberry fruit varies widely between sites, from 7 to 20 seeds per berry.[13] A seed weighs the same as almost two raindrops.[65] More seeds make bigger berries and after a severe

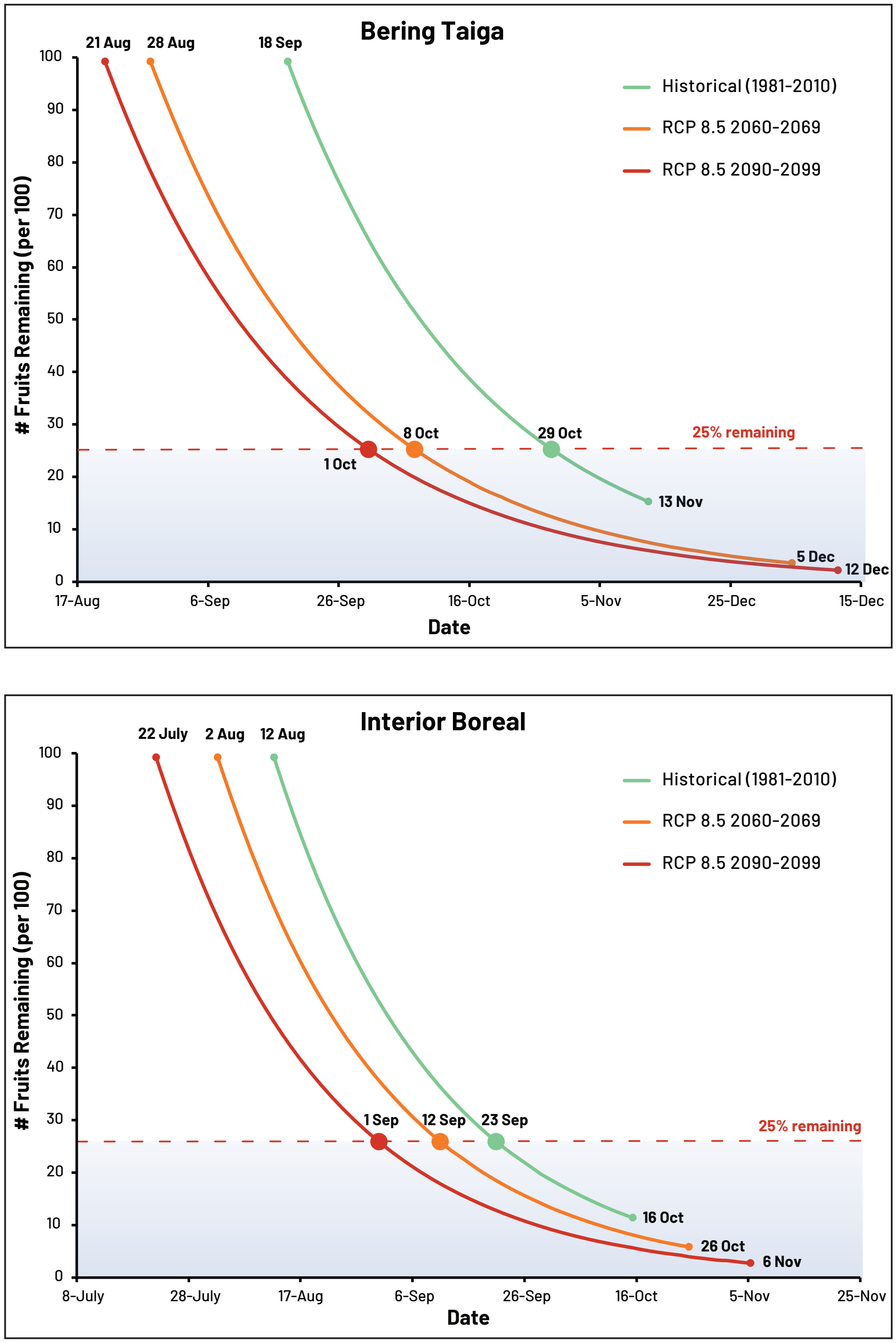


Figure 10. Predicted changes in timing of fruit loss in the Bering Taiga and Interior Boreal ecoregions (Fig. 5) due to shifts in the start and end of the growing season.[91] Green lines show the % fruits remaining under historical conditions, while the orange and deep red lines show the % fruits remaining by the middle and end of the century. Projections are based on the Intergovernmental Panel on Climate Change (IPCC) Representative Pathway 8.5. The large dots point to the dates by which 25% of fruits are still remaining under each of the scenarios. Image credit: C. Mulder and M. Putman.

fire seeds are the primary way lowbush cranberry shrubs can re-establish.

In Interior Alaska approximately 10% of the lowbush cranberry fruits are still on the plant by the time it begins to snow, while in the Bering Taiga ecoregion about 15% are still on the plant.[66] The majority of berries that make it through the summer (70 – 80%) are still good to eat throughout the fall[66], and are still edible when the snow melts in spring.[5,7,13,46] Many other berries in Alaska, such as blueberries and cloudberries, do not survive the winter, which makes lowbush cranberry an important winter food source to many creatures (Figure 9).[66]

THREATS TO FRUIT FROM CLIMATE CHANGE

Earlier springs will lead to berries ripening earlier with a greater chance that fruits will be removed before the snow falls, especially in the years with **later onset of snow in winter** (Figure 10). Also, **more precipitation** may cause more fruits to rot (Mulder, unpubl. data). These combined threats will not necessarily cause a reduction in fruits produced but they may reduce the number of cranberries available for animals in the winter and spring, when other sources of food are scarce.[66]

OPPORTUNITIES FOR GREATER FRUIT PRODUCTION

Warmer winters (but not summers) are associated with an increase in berry production in Interior Alaska.[41] The greatest predicted warming in Alaska is generally in winter, which can mean more snowfall in the Interior and North Slope regions.[40,67] The First Nations communities in Nunavik, Canada link greater snow fall to higher berry production.[68]

As mentioned in the growth section, **low intensity** fires that return more often can clear the taller plants away and increase light availability, which can lead to increased fruit production in future seasons.

SEED DISPERSAL AND GERMINATION

Figure 11. Lowbush cranberries from the crop of a ptarmigan that was shot in April 2018 in Scammon Bay, Alaska. The ground at the time was snow covered. Photo credit: K.C. Nattinger.

Lowbush cranberry fruits are an important food source for many species of wildlife, including grouse, ptarmigan, ravens, black and brown bears, foxes, mustelids, and a variety of small mammals and songbirds.[13,46,69–71] Many wildlife species feed on fruit that stays on the bush throughout winter and spring (Figure 11).[46] Berries are also an essential food for birds migrating northward in the spring, including Canada geese.[46]

Most "new" cranberry plants are vertical stems that grow up from existing underground rhizomes (Figure 1).[13,14] Growing from seed is rare in clonal plants, including lowbush cranberry, though there may be "windows of opportunity" for seeds to germinate and grow after disturbances like a wildfire or when colonizing the rotting wood of a fallen tree.[20] A study in Norway found that birds pooping on stumps after logging were one such example of seed dispersal and growth for lowbush cranberry and other *Vaccinium* species.[72]

HERBIVORES AND PATHOGENS

Figure 12a. Evidence of insects and pathogens from Fairbanks, AK. *Exobasidium vaccinii* (lingonberry gall) growing pseudo-flowers (pink structure) over two lowbush cranberry ramets. Photo credit: L.V. Parkinson.

The tough, long-lived leaves of the lowbush cranberry are much better at resisting **herbivores** and **pathogens** than some other berry species, like blueberry. Lowbush cranberry plants are susceptible to infection by several pathogens and during wet growing seasons, infection by the fungus *Exobasidium vaccinii* (a.k.a. lingonberry gall) is common[13] (Figure 12a). Lingonberry gall is found on both European and North American lowbush cranberry plants. It causes the leaves to thicken and form cups, eventually leading to leaf and stem death.[76] The pink fungus makes fake **pseudo-flowers** which attract pollinators that then spread the fungal spores (Figure 12a).[77]

The fungus *Lophodermium hypophyllum* is also found on Alaskan plants.[13] Additionally, *Phomopsis columnaris* may cause stem death, and *Ophiognomonia alni viridis* can cause a “sooty” appearance on leaves.[76,38] Many additional pathogens have been identified affecting lowbush cranberry shrubs throughout Canada and Fennoscandia, but

Figure 12b. Evidence of insects and pathogens from Fairbanks, AK. Suspected *Geometer* moth larva on lowbush cranberry flowers. Photo credit: L.V. Parkinson

have not yet been identified in Alaska.[13]

Cranberry shrubs are an important browse for moose, caribou, arctic hare, and snowshoe hare in Alaska.[46] The evergreen foliage is an important component of the winter diet of moose and caribou in regions where snow accumulation is light.[46]

Invertebrate herbivores of *V. vitis-idaea* remain understudied in Alaska. Insects are the suspects behind pink, yellow, and black leaf spots, sometimes seen on lowbush cranberry plants.[76] Larvae (likely moths) can live within the flowers during early summer, consuming the reproductive flower parts (L. Parkinson, pers. obs.). Additionally, significant insect damage to overwintering *V. vitis-idaea* flower buds has been observed (Figure 11d; K. Schroder unpublished data).

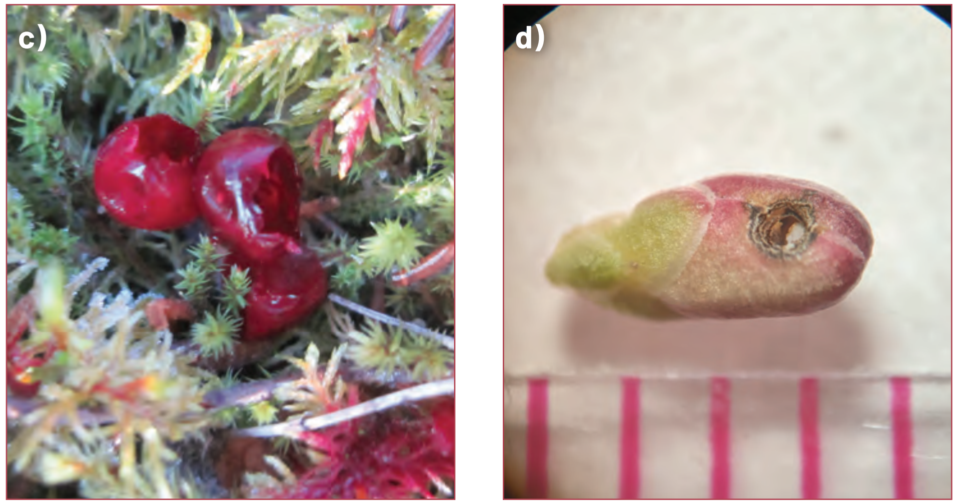


Figure 12. Evidence of insects and pathogens from Fairbanks, AK. c) lowbush cranberries eaten by ants. Photo credit: C.P.H. Mulder. d) flower bud damaged by insects. Photo credit: K. Schroder.

THREATS FROM INSECTS AND PATHOGENS

Expected increases in the number and diversity of **invertebrate herbivores** and other plant enemies (Figure 12) is a likely threat to all steps of the lowbush cranberry life cycle. The **loss of berries surviving into the winter** (Figure 10)may change which animals are eating berries, and thus how far seeds are dispersed.

PLANT FUNGAL ASSOCIATES

Lowbush cranberry roots host **ericoid mycorrhizae** species, a group of fungi that attach and insert themselves directly into the cells of plant roots.[73] Through this close connection, the mycorrhizal fungi help plants get nitrogen and phosphorus from the soil in return for sugars from the plant.[74] Around 150 species have been discovered in Alaskan tundra partnering with lowbush cranberry and other related plant species.[75] Ericoid mycorrhizae can collect metal ions that are toxic to the plant, effectively shielding the plant from chemicals that would otherwise negatively affect photosynthesis.[74]

SUMMARY

Lowbush cranberry faces multiple unknowns from a warming world which makes it difficult to say how it will grow in the future compared to now. Some of the expected changes are predicted to increase berry production, others to decrease it, and for still others we don't know enough to make predictions. We do know that most likely fewer berries will survive into the winter which could have effects up the food chain. Other threats depend on the region of the state but in many cases it may be possible to take preemptive action to maintain good berry spots.

> **"[I am] using other species and new recipes to adapt to what is abundant."**
>
> *- Charlotte Westing, Cordova, Alaska's Berries in a Changing Climate Listening Session, Dec. 2021*

Photo credit
K. Schroder

BUILDING RESILIENCE TO CHANGES IN LOWBUSH CRANBERRIES

Cutting back shrubs that are overtaking the lowbush cranberry patches can increase the availability of light and nutrients.

Increasing floral neighbors by interplanting with flowers that pollinators are attracted to could increase pollinator diversity and visitation to nearby lowbush cranberry flowers. Transplanting clumps of lowbush cranberry to gardens and farms and starting plants from seed have been successful strategies in Alaska. Amending the soil with peat has been key to these efforts.[90]

Mulching trials (adding a layer of organic material like leaves or straw on top of the soil around plants) in Finland resulted in increased fruit yields both in cultivated fields and in wild stands of lowbush cranberries.[46] Mulching can help to protect soil from drying, roots from freezing, and reduce the growth of weeds or other competitive plants.

KEY KNOWLEDGE GAPS

Insect communities are already changing across Alaska and will likely continue to change as the climate warms.[89] We don't know how changes in insect populations and species ranges (of both plants and invertebrates) will change the impacts of herbivores on lowbush cranberry.

We don't know how climate change is affecting the abundance of important pollinators such as solitary bees or syrphid flies.

We don't know how warmer and wetter conditions will affect damage by **fungal pathogens** to plants and seeds.

Lowbush cranberries grow across a huge range of environments. We don't know whether there are plants growing in some locations that might be well suited to the future conditions in other locations.

GLOSSARY

Anthocyanin - natural plant pigments that make red, blue, and purple colors in many fruits and vegetables. They are antioxidants, thought to be good for humans to eat.

Carpel - female part of a flower; contains stigma (pollen collector), ovary (develops into the fruit with seeds), and style (piece connecting stigma and ovary)

Herbivore - an animal that eats primarily plants

Genet - a group of genetically identical plants (ramets) in one area, all originating from asexual reproduction of a single ancestor

Microbe - a microscopic organism or microorganism — especially bacteria

Mycorrhizae - beneficial fungal partners that grow around many plant roots

Pathogens - bacteria, fungi, or viruses that cause disease

Pseudo-flowers - colorful, flower-shaped structures made by some fungi to trick insects into spreading fungal spores instead of pollen

Ramet - a single aboveground stem from a clonal plant

ENDNOTES

1. Jones A. 2010. *Plants That We Eat: Nauriat Nigiñaqtuat: From the Traditional Wisdom of the Iñupiat Elders of Northwest Alaska*, 2nd ed.; University of Alaska Press: Fairbanks.
2. Leer J, C Anahonak, A Moonin, D Tabios, S Moonin, D Anahonak D, M Anahonak. 2007. *Nanwalegmiut Paluwigmiut-Llu Nupugnerit: Conversational Alutiiq Dictionary, Kenai Peninsula Alutiiq*, 8th ed.; National Bilingual Materials Development Center and the Alaska Native Language Center.
3. Bergsland K. 1994. *Aleut Dictionary: An Unabridged Lexicon of the Aleutian, Pribilof, and Commander Islands Aleut Language*; Alaska Native Language Center.
4. Gwich'in Social and Cultural Institute. 2009. *Gwich'in Topical Dictionary: Gwichyah Gwich'in & Teetl'it Gwich'in Dialects*, 6th ed.
5. Jones E. 1978. *Junior Dictionary for Central Koyukon Athabaskan*; National Bilingual Materials Development Center.
6. Collins R, Petruska B. 1979. Dinak'i (Our Words): Upper Kuskokwim Athabaskan Junior Dictionary. https://uafanlc.alaska.edu/Online/UK964CP1979/UK964CP1979-Upper_Kuskokwim_%20Dictionary.pdf.
7. Kari PR. *Tanaina Plantlore Dena'ina K'et'ua: An Ethnobotany of the Dean'ina Indians of Southcentral Alaska.*; National Park Service Alaska Region: Anchorage, Alaska.
8. Edwards K. 2009. *Dictionary of Tlingit*; Sealaska Heritage Institute.
9. Lachler J. 2010. *Dictionary of Alaskan Haida*; Sealaska Heritage Institute.
10. Persson H. 1978. Root dynamics in a young Scots pine stand in central Sweden. *Oikos 30*, 508–519.
11. Schaub EP, Mulder CPH, Diggle PK. 2021. Preforming floral primordia converge on a narrow range of stages at dormancy despite multiple effects of temperature on development. *New Phytologist 233*, 2599–2613.
12. Karlsson PS. 1985. Photosynthetic characteristics and leaf carbon economy of a deciduous and an evergreen dwarf shrub: *Vaccinium uliginosum* L. and *V. vitis-idaea* L. *Ecography 8*, 9–17.
13. Holloway P. 1981. Studies of Vegetative and Reproductive Growth of Lingonberry, *Vaccinium vitis-idaea* L., University of Minnesota, Saint Paul.
14. Ritchie JC. 1955. *Vaccinium vitis-idaea* L. *Journal of Ecology* 43, 701.

15. Karlsson PS. 1992. Leaf longevity in evergreen shrubs: variation within and among European species. *Oecologia 91*, 346–349.

16. Hughes NM. 2011. Winter leaf reddening in 'evergreen' species. *New Phytologist*, 190, 573–581.

17. Von Riedmüller-Schölm, HE. 1974. The temperature resistance of Alaskan plants from the continental boreal zone. *Flora*, 163, 230–250.

18. Lundell R, T Saarinen, H Åström, H Hänninen. 2008. The boreal dwarf shrub *Vaccinium vitis-idaea* retains its capacity for photosynthesis through the winter. *Botany 86*, 491–500.

19. Fröborg H. 1996. Pollination and seed production in five boreal species of *Vaccnium* and *Andromeda* (Ericaceae). *Canadian Journal of Botany 74*, 1363–1368.

20. Eriksson O, H Fröborg. 1996. "Windows of opportunity" for recruitment in long-lived clonal plants: experimental studies of seedling establishment in *Vaccinium* shrubs. *Canadian Journal of Botany 74*, 1369–1374.

21. Narita K, K Harada, K Saito, Y Sawada, M Fukuda, S Tsuyuzaki. 2015. Vegetation and permafrost thaw depth 10 years after a tundra fire in 2002, Seward Peninsula, Alaska. *Arctic, Antarctic and Alpine Research* 47, 547–559.

22. Nelson JL, ES Zavaleta, Chapin FS. Boreal fire effects on subsistence resources in Alaska and adjacent Canada. *Ecosystems 11*, 156–171.

23. Parkinson LV, Mulder CPH. 2020 Patterns of pollen and resource limitation of fruit production in *Vaccinium uliginosum* and *V. vitis-idaea* in Interior Alaska. *PLOS ONE 15*, e0224056.

24. Bokhorst S, JW Bjerke, FW Bowles, J Melillo, TV Callaghan, GK Phoenix. 2008. Impacts of extreme winter warming in the sub-arctic: growing season responses of dwarf shrub heathland: plant responses to extreme winter warming. *Global Change Biology 14*, 2603–2612.

25. Bokhorst S, JW Bjerke, LE Street, TV Callaghan, GK Phoenix 2011. Impacts of multiple extreme winter warming events on sub-arctic heathland: phenology, reproduction, growth, and CO^2 flux responses: impacts of multiple extreme winter warming events. *Global Change Biology 17*, 2817–2830.

26. Saarinen T, R Lundell. 2010. Overwintering of *Vaccinium vitis-idaea* in two sub-arctic microhabitats: a reciprocal transplantation experiment. *Polar Research 29*, 38–45.

27. Solanki T, PJ Aphalo, S Neimane, SM Hartikainen, M Pieristè, A Shapiguzov, A Porcar-Castell, J Atherton, A Heikkilä, TM Robson. 2019. UV-screening and springtime recovery of photosynthetic capacity in leaves of *Vaccinium vitis-idaea* above and below the snow pack. *Plant Physiology and Biochemistry 134*, 40–52.

28. Siegwart Collier, L. 2020. Climate Change Impacts on Berry Shrub Performance in Treeline and Tundra Ecosystems. Doctoral thesis, Memorial University of Newfoundland.

29. Lévesque E, L Hermanutz, J Gérin-Lajoie, T Bell, S Boudreau, A Cuerrier, J Jacobs, C Laroque, C Lavallée, LS Collier. 2012. Trends in vegetation dynamics and impacts on berry productivity. *Nunavik and Nunatsiavut: from Science to Policy. An Integrated Regional Impact Study of Climate Change and Modernization. ArcticNet Inc Quebec City*, 223–247.

30. Chapin FS, GR Shaver. 1996. Physiological and growth responses of arctic plants to a field experiment simulating climatic change. *Ecology* 77, 822–840.

31. May JL, SF Oberbauer, SL Unger, MJ Simon, KR Betway, RD Hollister. 2022. Shading decreases and delays NDVI and flowering of prostrate arctic shrubs. *Arctic Science 8*, 967–978.

32. Kasischke ES, MR Turetsky. 2006. Recent changes in the fire regime across the North American boreal region—spatial and temporal patterns of burning across Canada and Alaska. *Geophysical Research Letters 33*, L09703.

33. Kasischke ES, DL Verbyla, TS Rupp, AD McGuire, KA Murphy, R Jandt, JL Barnes, EE Hoy, PA Duff, M Calef, MR Turetsky. 2010. Alaska's changing fire regime: implications for the vulnerability of its boreal forests. *Canadian Journal of Forest Research 40*, 1313–1324.

34. Buma B, K Hayes, S Weiss, M Lucash. 2022. Short-interval fires increasing in the Alaskan boreal forest as fire self-regulation decays across forest types. *Scientific Reports 12*, 4901.

35. Racine CH, LA Johnson, LA Viereck. 1987. Patterns of vegetation recovery after tundra fires in northwestern Alaska, U.S.A. *Arctic and Alpine Research 19*, 461–469.

36. Nawrocki TW. 2021. Continuous foliar cover of vegetation for North American Beringia. https://doi.org/10.5281/zenodo.4770218.

37. Shevtsova A, E Haukioja, A Ojala. 1997. Growth response of subarctic dwarf shrubs, *Empetrum nigrum* and *Vaccinium vitis-idaea*, to manipulated environmental conditions and species removal. *Oikos, 78*, 440.

38. Vowles T, RG Björk. 2019. Implications of evergreen shrub expansion in the Arctic. J*ournal of Ecology, 107* 650–655.

39. Vowles T, B Gunnarsson, U Molau, T Hickler, L Klemedtsson, RG Björk. 2017. Expansion of deciduous tall shrubs but not evergreen dwarf shrubs inhibited by reindeer in Scandes Mountain Range. *Journal of Ecology 105*, 1547–1561.

40. Littell J, S McAfee, G Hayward. 2018. Alaska snowpack response to climate change: statewide snowfall equivalent and snowpack water scenarios. *Water 10*, 668.

41. Natali SM, EAG Schuur, RL Rubin. 2012. Increased plant productivity in Alaskan tundra as a result of experimental warming of soil and permafrost. *Journal of Ecology 100*, 488–498.

42. Fernqvist I. 1977. Results of experiments with cowberries and blueberries in Sweden. *Acta Horticulturae 61*, 295–300.

43. Mulder CPH, KV Spellman. 2019. Do longer growing seasons give introduced plants an advantage over native plants in interior Alaska? *Botany 97*, 347–362.

44. Mulder C, KV Spellman. Flower and leaf phenology of interior Alaska forbs and shrubs as observed near Fairbanks Alaska from 2013-2015. https://doi.org/10.6073/PASTA/AE8B2F7626FD96A24BF347AD5E8BA733.

45. Spellman KV, CPH Mulder. 2016. Validating herbarium-based phenology models using citizen-science data. *BioScience 66*, 897–906.

46. Tirmenstein D. *Vaccinium vitis-idaea*. Fire Effects Information System. https://www.fs.fed.us/database/feis/plants/shrub/vacvit/all.html (accessed 2021-12-01).

47. Aiken, SG. 2007. *Flora of the Canadian Arctic Archipelago*. Canadian Museum of Nature, National Research Council Canada, Eds.; NRC Research Press: Ottawa.

48. Hjalmarsson I. 1997. Pollination and fruit set in lingonberries (*Vaccinium vitis idaea*). *Acta Horticulturae 446*, 97–100.

49. Mulder CPH, LV Parkinson, K Shroder. 2023. Data underlying graphs and climate statements in the berries in Alaska's Changing Climate series. https://casc.alaska.edu/changingberries.

50. Preece C, TV Callaghan, GK Phoenix. 2012. Impacts of winter icing events on the growth, phenology and physiology of sub-arctic dwarf shrubs. *Physiologia Plantarum 146*, 460–472.

51. Diggle PK, CPH Mulder. 2019. Diverse developmental responses to warming temperatures underlie changes in flowering phenologies. *Integrative and Comparative Biology 59*, 559–570.

52. Mulder CPH, Iles DT, RF Rockwell. 2017. Increased variance in temperature and lag effects alter phenological responses to rapid warming in a subarctic plant community. *Global Change Biology 23*, 801–814.

53. Davis AN, PS Holloway, JJ Kruse. 2003. Insect visitors and potential pollinators of lingonberries, *Vaccinium vitis-vidaea* subsp. minus, in sub-arctic Alaska. *Acta Horticultarae 626*, 433–438.

54. Moquet L, L Bruyère, B Pirard, A-L Jacquemart. 2017. Nectar foragers contribute to the pollination of buzz-pollinated plant species. *American Journal of Botany 104*, 1451–1463.

55. Spellman KV, LC Schneller, CPH Mulder, ML Carlson. 2015. Effects of non-native *Melilotus albus* on pollination and reproduction in two boreal shrubs. *Oecologia 179*, 495–507.

56. Stephens D. 2012. Pollination ecology and the floral rewards of *Vaccinium myrtilloides* and *V. vitis-idaea* (Ericaceae). Thesis, University of Saskatchewan, Saskatoon, Canada.

57. Jacquemart A-L, JD Thompson. 1996. Floral and pollination biology of three sympatric *Vaccinium* (Ericaceae) species in the Upper Ardennes, Belgium. *Canadian Journal of Botany 74*, 210–221.

58. Koch V, L Zoller, JM Bennett, TM Knight. 2020. Pollinator dependence but no pollen limitation for eight plants occurring north of the Arctic Circle. *Ecology and Evolution 10*, 13664–13672.

59. Tape K, M Sturm, C Racine. 2006. The evidence for shrub expansion in northern Alaska and the pan-Arctic. *Global Change Biology 12*, 686–702.

60. Pearson RG, SJ Phillips, MM Loranty, PSA Beck, T Damoulas, SJ Knight, SJ Goetz. 2013. Shifts in arctic vegetation and associated feedbacks under climate change. *Nature Climate Change 3*, 673–677.

61. Myers-Smith IH, BC Forbes, M Wilmking, M Hallinger, T Lantz, D Blok, KD Tape, M Macias-Fauria, U Sass-Klaassen, E Lévesque, S Boudreau, P Ropars, L Hermanutz, A Trant, LS Collier, S Weijers, J Rozema, SA Rayback, NM Schmidt, G Schaepman-Strub, S Wipf, C Rixen, CB Ménard, S Venn, S Goetz, L Andreu-Hayles, S Elmendorf, V Ravolainen, J Welker, P Grogan, HE Epstein, DS Hik. 2011. Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities. *Environmental Research Letters 6*, 045509.

62. Urbanowicz C, RA Virginia, RE Irwin. 2018. Pollen limitation and reproduction of three plant species across a temperature gradient in Western Greenland. *Arctic Antarctic and Alpine Research 50*, S100022.

63. Suzuki S, G Kudo. 2000. Responses of alpine shrubs to simulated environmental change during three years in the mid-latitude mountain, northern Japan. *Ecography 23*, 553–564.

64. Kudo G, S Suzuki. 2003. Warming effects on growth, production, and vegetation structure of alpine shrubs: a five-year experiment in northern Japan. *Oecologia 135*, 280–287.

65. *How heavy is 0.3 grams? | The Measure of Things*. https://www.themeasureofthings.com (accessed 2023-04-28).

66. Mulder CPH, KV Spellman, J Shaw. 2021. Berries in winter: a natural history of fruit retention in four species across Alaska. *Madroño 68*, 487–510.

67. Stuefer SL, DL Kane, KM Dean. 2020. Snow water equivalent measurements in remote arctic Alaska watersheds. *Water Resources Research 56*, e2019WR025621.

68. Cuerrier A, ND Brunet, J Gérin-Lajoie, A Downing, E Lévesque. The study of Inuit knowledge of climate change in Nunavik, Quebec: A mixed methods approach. *Human Ecology 43*, 379–394.

69. West SD. 1982. Dynamics of colonization and abundance in Central Alaskan populations of the northern red-backed vole, *Clethrionomys rutilus*. *Journal of Mammalogy 63*, 128–143.

70. Krebs CJ, K Cowcill, R Boonstra, AJ Kenney. 2010. Do changes in berry crops drive population fluctuations in small rodents in the southwestern Yukon? *Journal of Mammalalogy 91*, 500–509.

71. Munro RHM, SE Nielsen, MH Price, GB Stenhouse, MS Boyce. 2006. Seasonal and diel patterns of grizzly bear diet and activity in West-Central Alberta. *Journal of Mammalalogy 87*, 1112–1121.

72. Arnberg MP, MA Patten, K Klanderud, C Haddad, O Larsen, SMJG Steyaert. 2023. Perfect poopers; passerine birds facilitate sexual reproduction in clonal keystone plants of the boreal forest through directed endozoochory towards dead wood. *Forest Ecology and Management 532*, 120842.

73. Dighton J. 2009. *Encyclopedia of Microbiology: Mycorrhizae*. Academic Press.

74. Smith SE, DJ Read. 2010. *Mycorrhizal Symbiosis*. Academic Press.

75. Walker JF, L Aldrich-Wolfe, A Riffel, H Barbare, NB Simpson, J Trowbridge, A Jumpponen. 2011. Diverse Helotiales associated with the roots of three species of arctic Ericaceae provide no evidence for host specificity. *New Phytologist 191*, 515–527.

76. Roy BA, CPH Mulder. 2014. Pathogens, herbivores, and phenotypic plasticity of boreal *Vaccinium vitis-idaea* experiencing climate change. *Ecosphere 5*, art30.

77. Roy BA. 1993. Floral mimicry by a plant pathogen. *Nature 362*, 56–58.

78. Redwood, DG, ED Ferucci, MC Schumacher, JS Johnson, AP Lanier, LJ Helzer, L Tom-Orme, MA Murtaugh, ML Slattery. 2008. Traditional foods and physical activity patterns and associations with cultural factors in a diverse Alaska Native population. *International Journal of Circumpolar Health* 67, 335–348. https://doi.org/10.3402/ijch.v67i4.18346.

79. Boulanger-Lapointe N, J Gérin-Lajoie, L Siegwart Collier, S Desrosiers, C Spiech, GHR Henry, L Hermanutz, E Lévesque, A Cuerrier. 2019. Berry plants and berry picking in Inuit Nunangat: traditions in a changing socio-ecological landscape. *Human Ecology* 47, 81–93.

80. Pilz D. 2006. *Nontimber Forest Product Opportunities in Alaska*; US Department of Agriculture, Forest Service, Pacific Northwest Research Station.

81. Thornton TF. 1999. Tleikwaaní, the "berried" landscape: the structure of Tlingit edible fruit resources at Glacier Bay. *Journal of Ethnobiology 19*, 27–48.

82. *Alaska Made Products*. https://www.commerce.alaska.gov/dcra/akmadeproducts (accessed 2023-04-28).

83. Leiner RH, PS Holloway, DB Neal. 2008. Antioxidant capacity and quercetin levels in Alaska wild berries. *International Journal of Fruit Science 6*: 83-91.

84. Kowalska K. 2021. Lingonberry (*Vaccinium vitis-idaea* L.) fruit as a source of bioactive compounds with health-promoting effects—a review. *International Journal of Molecular Sciences 22*, 5126.

85. Shamilov AA, VN Bubenchikova, MV Chernikov, DI Pozdnyakov, ER Garsiya. 2020. *Vaccinium vitis-idaea* L.: chemical contents, pharmacological activities. *Pharmaceutical Sciences 26*, 344-362.

86. Murray G, PC Boxall, RW Wein. 2015. Distribution, abundance, and utilization of wild berries by the Gwich'in people in the Mackenzie River Delta region. *Economic Botany 59*, 174-184.

87. Hupp J, M Brubaker, K Wilkinson, J Williamson. 2015. How are your berries? Perspectives of Alaska's environmental managers on trends in wild berry abundance. *International Journal of Circumpolar Health* 74, 28704.

88. Koopman M. *Native Village of Georgetown: Climate Change Vulnerability Assessment | GEOS Institute and Georgetown Tribal Council*. https://www.cakex.org/documents/native-village-georgetown-climate-change-vulnerability-assessment (accessed 2023-04-28).

89. Demain J, B Gessner, J McLaughlin, D Sikes, T Foote. 2008. Increasing insect reactions in Alaska: is this related to changing climate? *Allergy and Asthma Proceedings 30*, 238-243.

90. Holloway, P. 1984. Lingonberry Cultivation. *Agroborealis* 16(2). https://georgesonbotanicalgarden.org/wp-content/uploads/2021/05/1984.Holloway.lingon.pdf.

91. Lader, R., J.E. Walsh, U.S. Bhatt, P.A. Bieniek. 2020. Anticipated changes to the snow season in Alaska: Elevation dependency, timing and extremes. *International Journal of Climatology* 40: 169-187.

Photo credit: K. Schroder

Funding Acknowledgement: This report is part of the Alaska Berry Futures project of the Institute of Arctic Biology and International Arctic Research Center at the University of Alaska Fairbanks. Major funding is provided by the US Geologic Survey through the Alaska Climate Adaptation Science Center (G17AC00213) and additional support is provided by Arctic Harvest- Public Participation in Scientific Research project (NSF Award AISL-1713156) and the Bonanza Creek Long Term Ecological Research program (NSF Award DEB-163476 and USDA USFS award RJVA-PNW-01-JV-1161952-231)