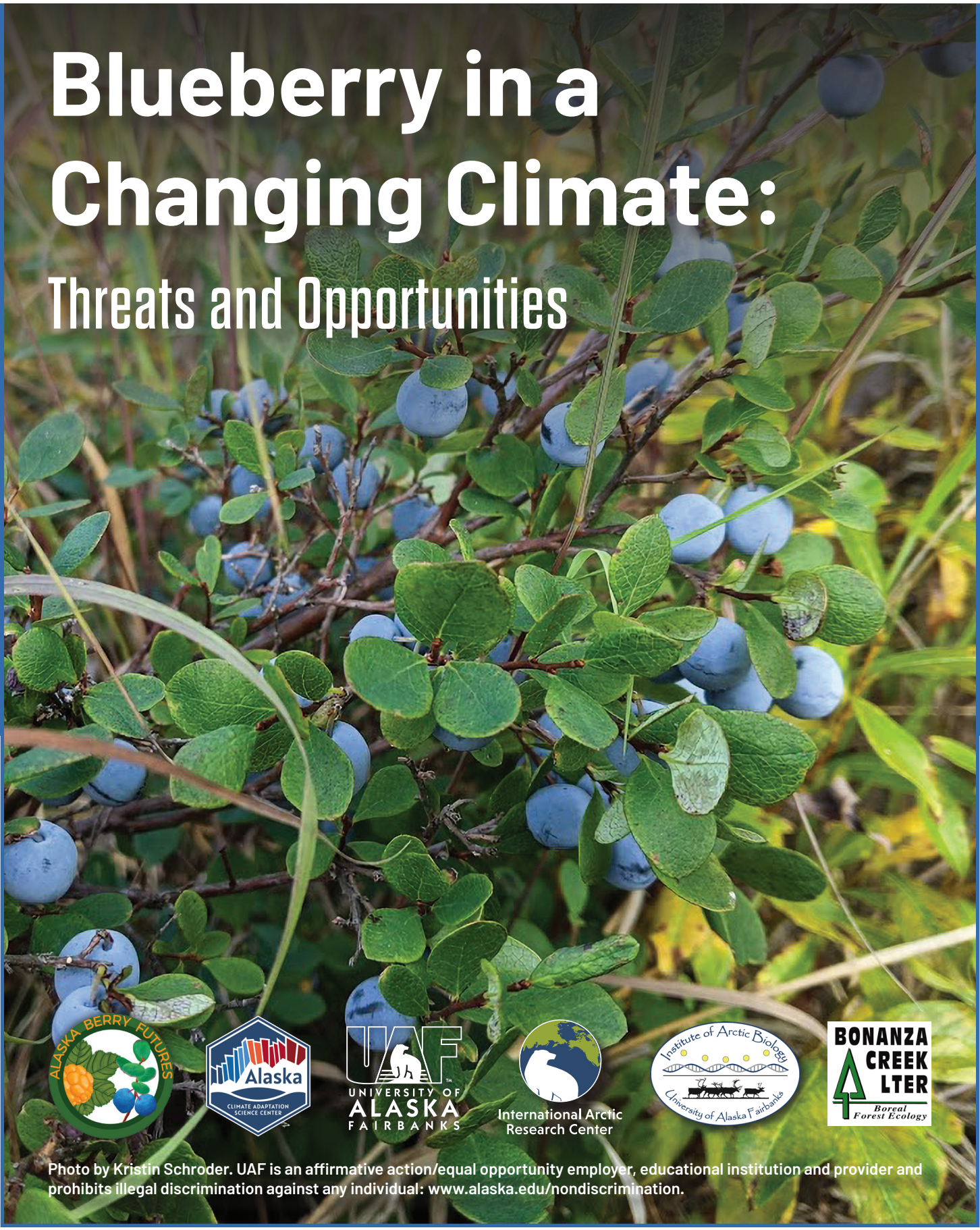
BERRIES IN ALASKA'S CHANGING ENVIRONMENT SERIES: *VACCINIUM ULIGINOSUM*

Blueberry in a Changing Climate:

Threats and Opportunities



ALASKA BERRY FUTURES

Alaska Climate Adaptation Science Center

UAF University of Alaska Fairbanks

International Arctic Research Center

Institute of Arctic Biology, University of Alaska Fairbanks

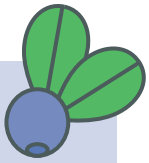
Bonanza Creek LTER, Boreal Forest Ecology

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 of fruit. For Alaska Native peoples, berries are an important part of the culture, reflected in stories and recipes. Berry picking is a tradition 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 the "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. 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 look at growth, flowering, pollination, fruits and seeds, mutualists (like fungi that help plants obtain nutrients), herbivores, and pathogens, briefly discuss human use, and highlight threats and opportunities for each aspect of the plant life cycle under a changing climate.



TEXT: Christa P.H. Mulder, Laura Weingartner, Lindsey V. Parkinson, and Katie V. Spellman

GRAPHICS AND PHOTOS:
Lauren Bird, Molly Putman, Pamela K. Diggle, Emily Sousa, Kristin Schroder, Lindsey V. Parkinson, and Adrienne Smyth

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:
Nikoosh Carlo, Malinda Chase, Maggie Demers, Nancy Fresco, Mario Muscarella, Elena Sparrow

Suggested citation: Suggested citation: Mulder, C.P.H., L. Weingartner, L.V. Parkinson, L. Bird, M. Putman, E. Sousa, P. Diggle, K.V. Spellman, and A. Smyth, (2023). Bog Blueberry in a Changing Climate: Threats and Opportunities. Berries in Alaska's Changing Environment Series: *Vaccinium uliginosum*. Institute of Arctic Biology and International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, Alaska, USA.

BOG BLUEBERRY

This issue focuses on bog blueberry (scientific name: *Vaccinium uliginosum* L., in the Ericaceae family). It goes by many common names, including northern bilberry and bog whortleberry in English, and by many Indigenous names: *jak zheii, jak naalyuu* (Gwich'in)[1]; *asriaviik* (Inupiaq)[3]; *Kigutangirnaq* (Inuktut)[4]; *qiuq, curaq* (Yup'ik)[5]; *cuawak* (Alutiiq/ Sugpiaq)[6]; *ugiidgin* (Unangam Tunuu/ Aleut)[7]; *ts'éekáxk'w* (Lingít)[8]; *nilyagh* (Deg Xinag)[9]; *gega, gegashla* (Dena'ina)[10]; *gege, nelyaage* (Denaakk'e)[11]; *gigi gheli* (Ahtna).[12] It is one of the most popular wild berries for harvesting across North America and northern Europe.[13–15]

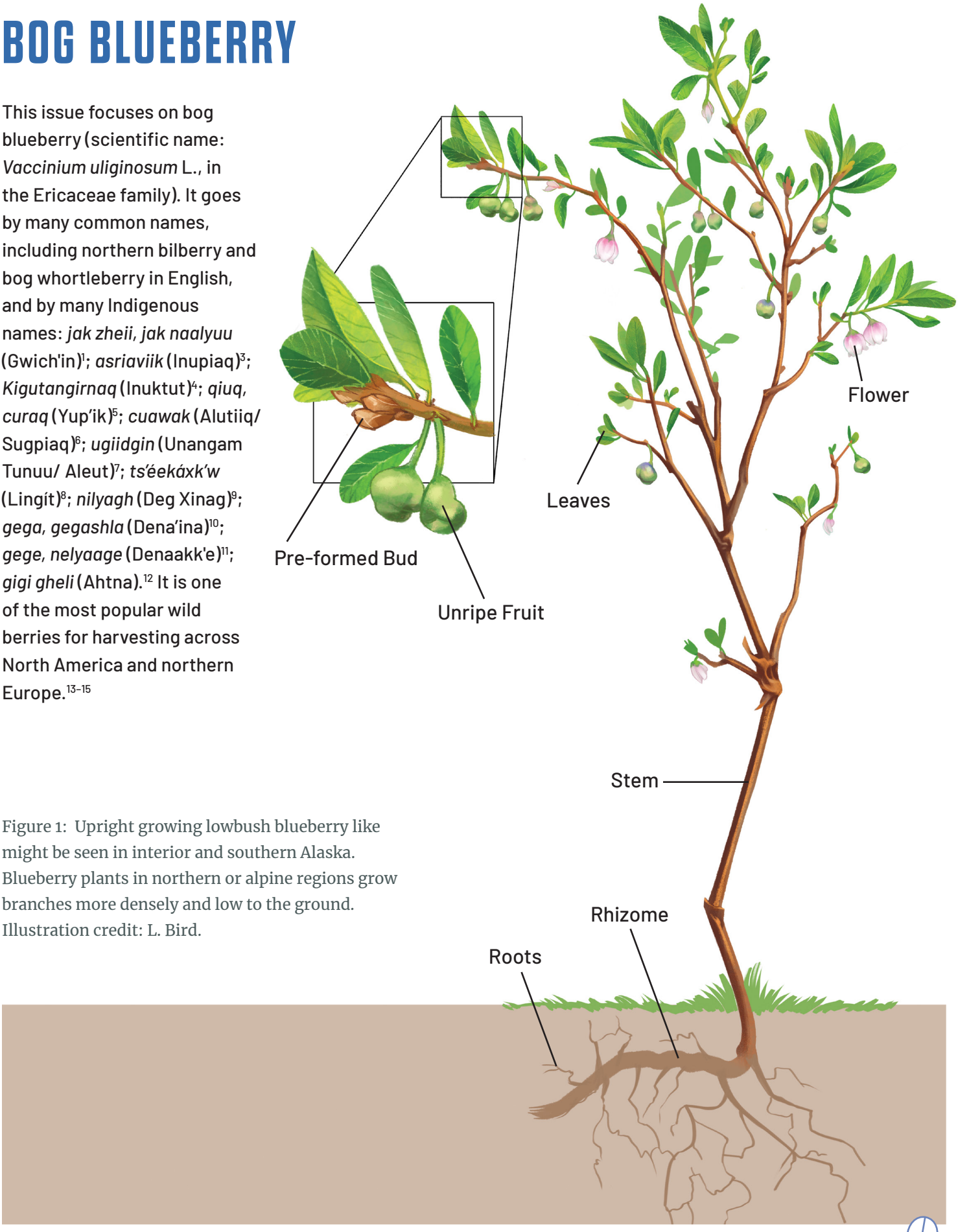


Figure 1: Upright growing lowbush blueberry like might be seen in interior and southern Alaska. Blueberry plants in northern or alpine regions grow branches more densely and low to the ground. Illustration credit: L. Bird.

GROWTH

Bog blueberry is a slow-growing **deciduous** species. It has horizontal stems, called rhizomes, that grow about 6 – 8 inches (15 – 45 cm) below the soil surface (Figure 1). Shoots emerge from the rhizomes and produce branches above the ground. The aboveground portion is the tip of the iceberg: the biomass belowground is almost 10 times more than what is visible aboveground.[16] Blueberries have shallow root systems that reach about halfway down to the permafrost table,[17] with most of the root biomass (~65%) in the top 2 inches (5 cm) of the soil.[16]

The buds at the ends of the branches produce flowers while new shoots and branches develop from the uppermost buds on the sides of older branches, resulting in a highly branched structure.[18] A single plant can form patches up to ~100 ft^2 (10 m^2)[16,19] in size, and in some locations an entire berry patch is one individual.[18,20]

Single shoots (**ramets**) can live ~60-90 years[18,21] while patches of genetically identical shoots all connected by underground rhizomes (a single clonal individual called a **genet**) that are > 1000 years old have been found (oldest estimate = 1390-1880 yrs old).[22] Bog blueberry plants are highly variable in height and growth form: in harsh environments such as alpine tundra they are prostrate (spread along the ground) and < 4 inches (10 cm) tall, while in better protected areas they grow upright to over 4ft. (1.3 m) tall (Figure 1), growing tallest within the forest where it competes for light with other tall shrubs.[2,23] Severe shading by other plants can reduce photosynthesis and growth in bog blueberry.[24]

The production of a bog blueberry leaf bud starts about a year before the buds open and the leaves expand.[18] The tiny buds overwinter on the plant (Figure 1) and start to develop again when the air is warmed and the ground thaws.[26,27] In Interior Alaska leaves emerge over the course of a few days in late May or early June[28] and start to senesce (turn red and brown) around the time that fruits ripen, usually in late July – early August; in other parts of the state this is delayed by a few weeks.

The leaves are large and steeply inclined near the top of the plant, while the lower leaves are smaller and angled more horizontally; this allows the top leaves to take advantage of low sun angles while allowing light to reach the lower leaves.[25]

Bog blueberry buds have a high freezing resistance compared to other dwarf shrubs during much of the winter period and also have a moderately high tolerance of being encased by ice.[29–31] However, as it warms in spring frost hardiness is reduced and temperatures as high as 12 °F (-11 °C) can kill buds.[20]

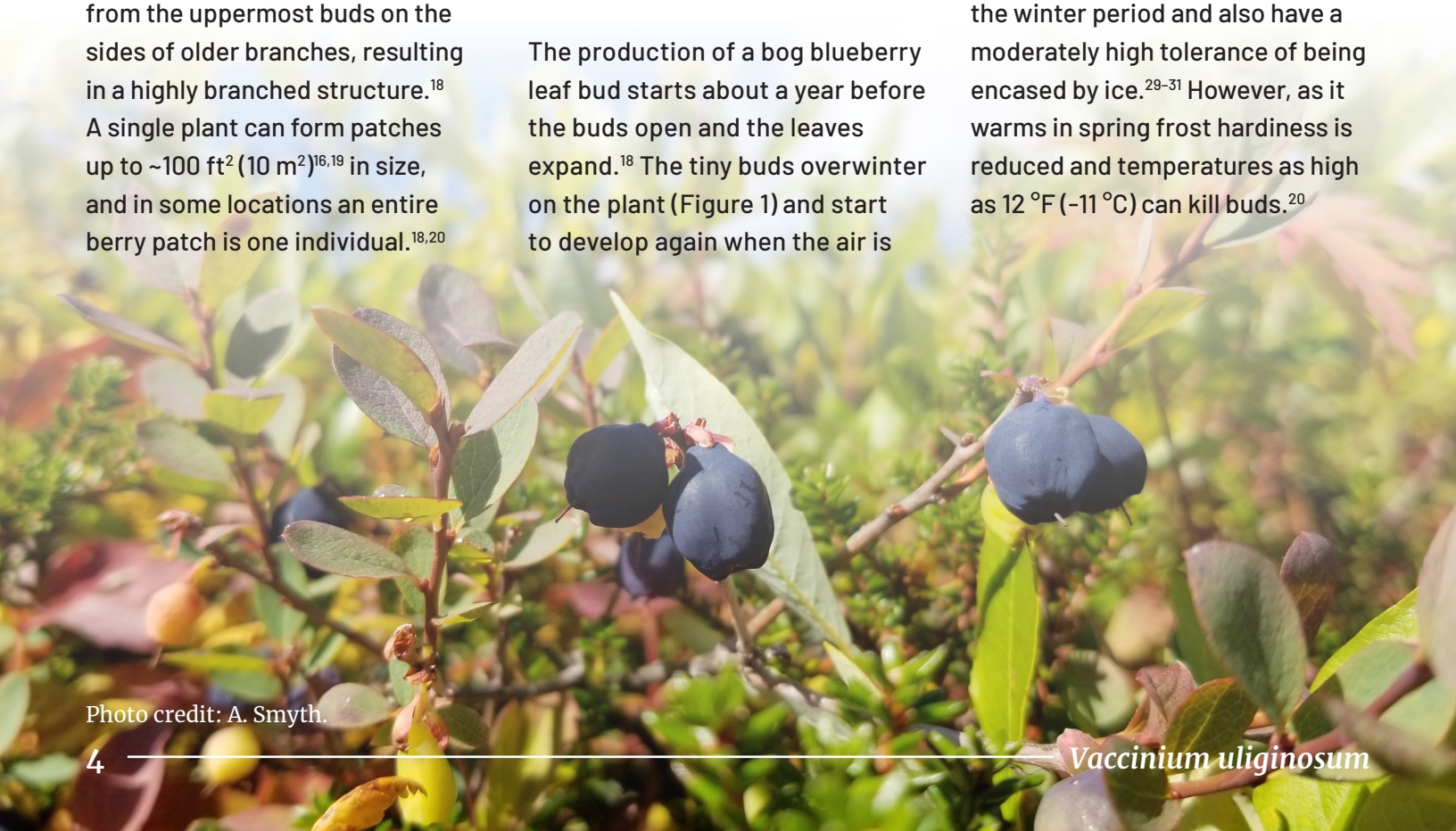


Photo credit: A. Smyth.

Bog blueberry 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.[32–34] The extent to which plants put energy into vegetative reproduction vs. seeds differs by latitude, with the lowest investment in seeds at high latitudes (the Arctic) and highest investment in seeds at lower latitudes (alpine areas).[32]

Bog blueberry can survive light to moderate forest fires and resprout from the stems or rhizomes (belowground stems), to take advantage of the abundant light and nutrients.[35–37] As many blueberry pickers know, in the boreal forest blueberries are often most abundant 5 to 15 years following a fire.[38]

> **"...two years after a fire has burned through the area, berries will often be found in abundance."**
>
> *– Adapting to Climate Change in the Middle Kuskokwim.*

THREATS TO GROWTH FROM CLIMATE CHANGE

Shrub expansion: Shrubs such as alder, birch, and willow are invading tundra in large parts of the state.[2,47–49] Bog blueberry has a very widespread distribution across Alaska while alder (*Alnus* species) are more limited in range and are currently absent from most of the area north of the Brooks Range and sections of the Seward Peninsula[50] (Figure 2). However, alders are expanding rapidly[51,52] and are likely to compete strongly with bog blueberry for light and, to a lesser extent, for nutrients. If alders expand into areas where they are currently absent, this may result in greatly reduced blueberry growth and fruit production.[24,53]

Fire intensity, extent, and frequency are increasing in Interior Alaska.[54–56] Severe (hot) fires that burn through the organic mat of the forest floor will kill the plants, including the seed bank, and recolonization will depend on seed dispersal by animals from unburned or less intensely burned areas.[36,57]

Increased precipitation can lead to fewer leaves per stem, increased leaf thickness, and decreased stem growth.[44,45] Precipitation during the growing season is expected to increase across most regions of the state[46] but because permafrost dynamics and plant communities are also expected to change, it is difficult to predict how water availability, and thus blueberry growth, may be affected.

Increased saltwater: Flooding by saltwater due to storms near the coast can result in severe dieback of dwarf shrubs such as bog blueberry.[58] The Yukon-Kuskokwim Delta in southwest Alaska is particularly vulnerable due to its large, flat coastal plain.[58,59]

Reduced snow cover in spring: Snow cover protects shrubs from harsh winter conditions. While much of the state will see more snow (see opportunities below), in some locations more of spring precipitation will fall as rain rather than snow, reducing snow accumulation before temperatures are consistently above freezing. Wind is also predicted to increase in the early months of the year (approx. January – April) in large parts of the state,[43] resulting in greater variation in snow cover (some patches with little snow, some with a lot), especially in open areas.

OPPORTUNITIES FOR INCREASED GROWTH

Like other Alaskan shrubs, bog blueberry responds positively to **warmer temperatures.**[60] Increased shrub growth may be helped by warmer soil temperatures or increased soil nutrient cycling.[63] It is one of the species contributing to shrub expansion in Russia,[61] and is likely to expand and do well in Alaska in areas where taller shrubs are not expanding.

Increased fire extent and frequency may result in increased growth. While high intensity fires may kill blueberry shrubs and seeds (mentioned above), light to moderate fire intensity may benefit growth and fruit production by removing trees and tall shrubs that compete for light.[64]

Snow accumulation has been increasing in coastal areas (but not in more interior regions).38 This may make coastal areas more suitable for blueberries as snow can protect plants from drying out in winter, reduce frost damage to buds, and increase water availability in spring.[20,40–42]

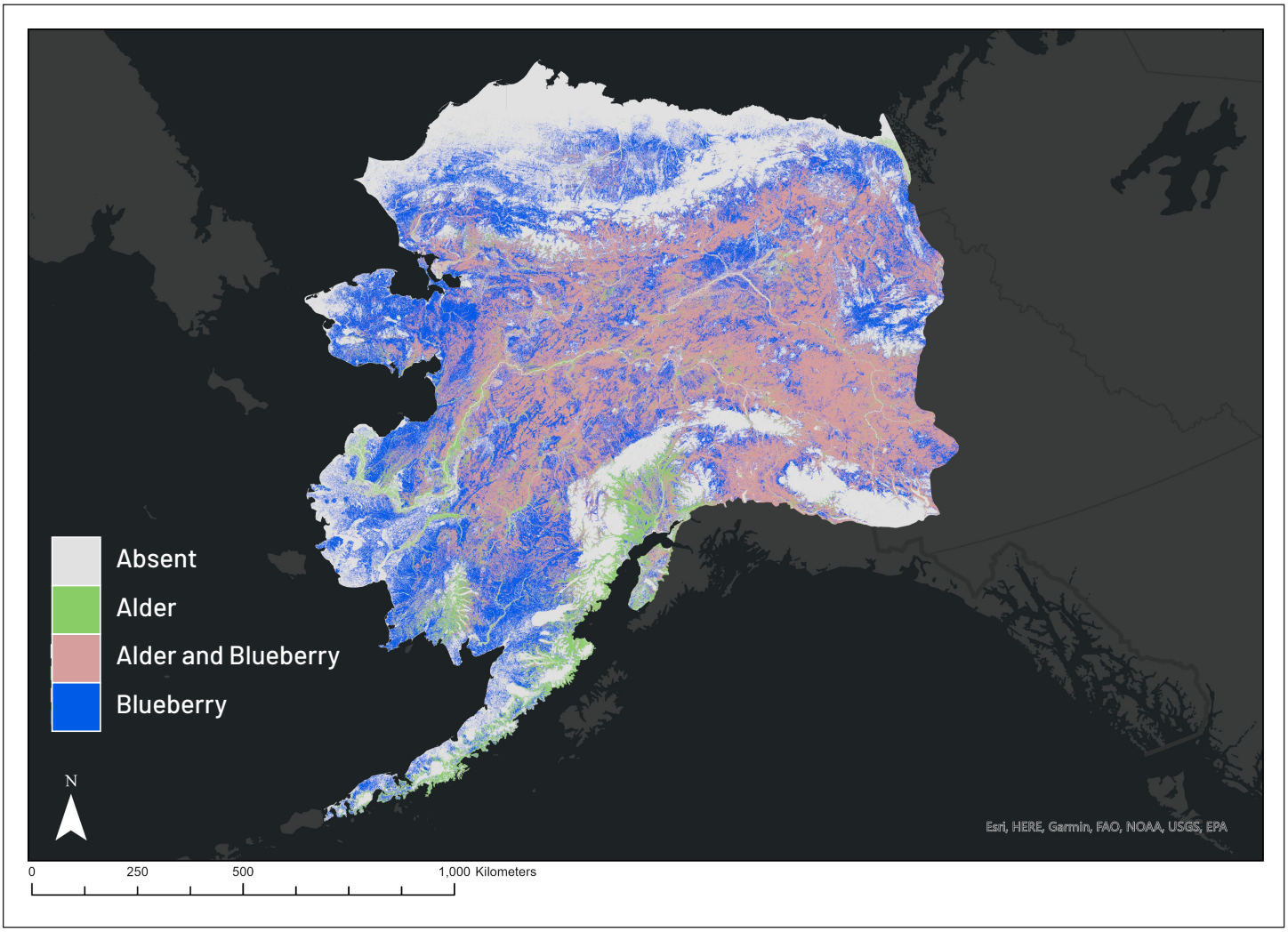


Figure 2. Bog blueberry and alder shrub distribution. Blueberry plants in areas currently free of alder (in blue), such as most of the North Slope and Seward Peninsula, may have problems in the future as the alder shubs expand their range. Map: E. Sousa, Data: Nawrocki et al. 2021.[50]

FLOWERS

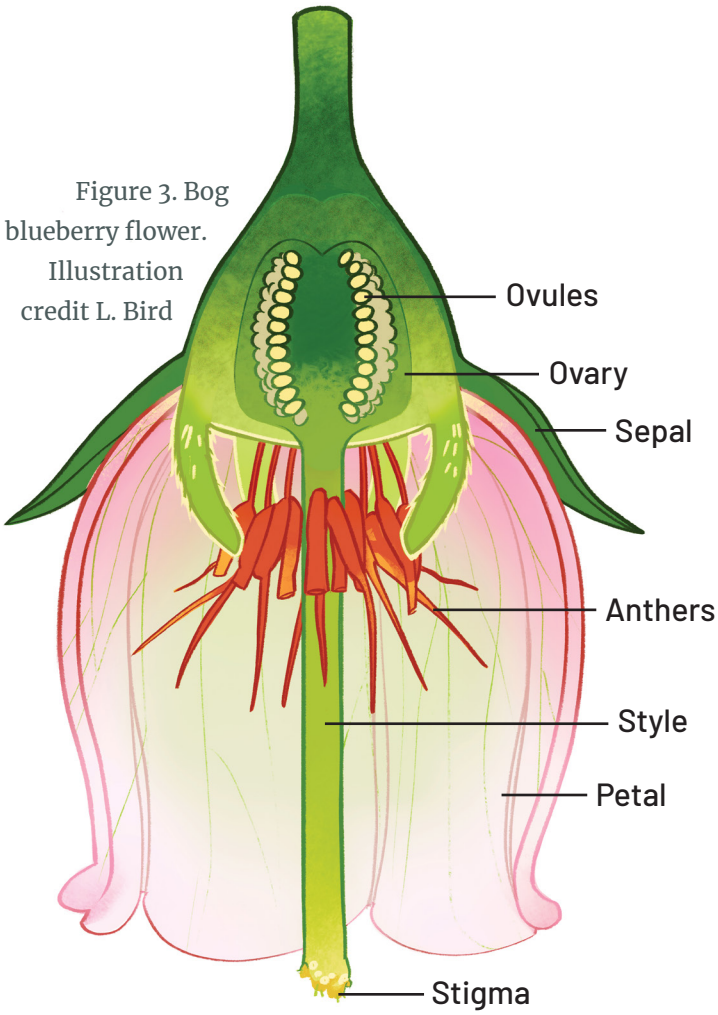


Figure 3. Bog blueberry flower. Illustration credit L. Bird

Flower buds are initiated about a year before they bloom (Figure 4). Flowers are pink to white and bell-shaped. They grow singly or in small clusters, with an average of 8-9 flowers per shoot.[33] Blueberry flowers are hermaphroditic, meaning they have both male and female reproductive organs within the same flower (Figure 3). The flower hangs from the branch with the opening facing down and the 8-10 anthers (where the pollen is produced) well above the stigmas (where the pollen lands; Figure 3). Each flower contains dozens of ovules (estimates range from ~45 to ~85 per flower[18,37]), so fruits can contain dozens of seeds.

The timing of flowering in spring is driven by a combination of air temperature and timing of snow melt / ground thaw, and snow melt and has been found to vary from year to year by up to 3 weeks.[26,27,30]

Figure 4. Scanning electron microscope image of inside a flower bud in August of the year before the flower opens. The bud is about 1 mm in diameter. Image credit: P. Diggle.

Bog blueberry flower. Photo credit: A. Smyth.

POLLINATION

Bog blueberry flowers are pollinated by insects; the pollen they deliver travels down the style to the ovary, where it fertilizes the ovules to produce seeds (Figure 3). The most common pollinators are solitary bees, bumblebees (*Bombus* spp.), and syrphid flies (family Syrphidae, also known as hoverflies or flowerflies).[19,65–67] These insects vibrate the anthers to release the pollen (buzz pollination), and usually move pollen to another flower within 10 ft (3 m).[66] In addition to pollen, bog blueberries offer nectar made up of glucose and fructose.[68]

Bog blueberry flowers open earlier than many species that grow in the same area, but they may compete for pollinators with cloudberry (*Rubus chamaemorus*) or the much less common bog (or small) cranberry (*Vaccinium oxycoccus*).[66] However, blueberry flowers are likely more rewarding than either of these species,[65,68] so they are unlikely to suffer much competition from them.

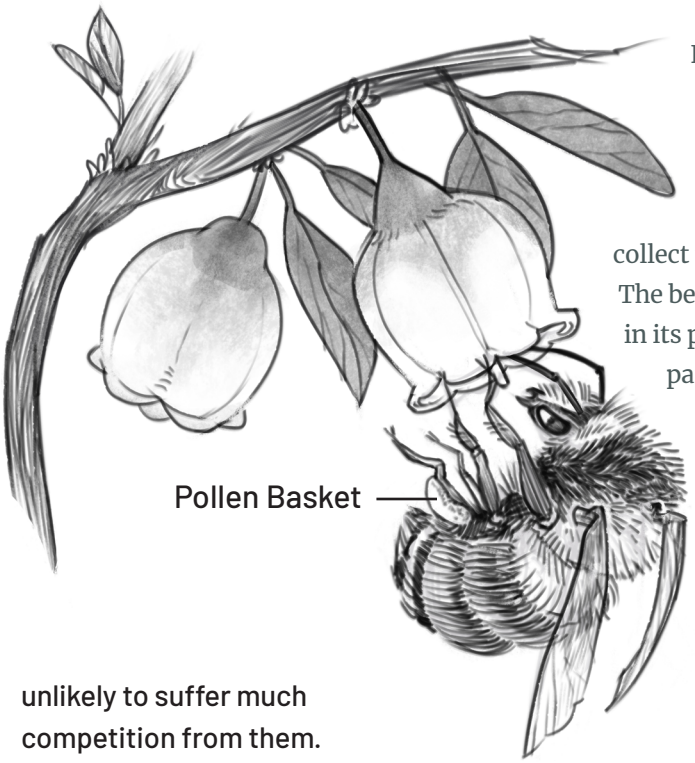


Figure 5. A yellow head bumble bee (*Bombus flavifrons*) prepares to buzz a bog blueberry flower in order to collect the pollen that falls out. The bee transports the pollen in its pollen basket, a special part of the body for just this task. Imagine it as a tiny pocket or basket located on the back legs of a bee. Illustration credit: L. Bird

To get to the nectar, bumblebees hang upside down while grasping the petals with their legs (Figure 5) and insert their long, hairy tongue into the flower.[68] Because bog blueberry is one of the quite early flowering species, many of the bumblebee visitors are queens (which emerge first), and the food supplied by bog blueberry is probably important for the establishment of bee colonies in springtime.[68]

Pollinators are abundant in warm, open habitats such as areas where the forest was burned in the past decades.[37] In cooler or shadier habitats, like black spruce or alpine zones, a lack of pollinators may be a problem. Blueberry flowers can self-pollinate but doing so severely reduces the production of fruits and seeds compared to flowers that are out-crossed (receive pollen from another genetic individual).[33,65,69]

THREATS TO POLLINATION FROM CLIMATE CHANGE

Spring has been coming earlier in communities across Alaska, and snowmelt is expected to advance by 2 – 4 weeks across large parts of the state by the end of the century.[39] If the **timing of ground thaw** advances more than the timing of pollinator emergence, then there may not be enough pollinators for full seed set.

Increased rain during the pollination period (May or June) may reduce pollination.[46]

Expansion of shrubs into tundra[47–49] can reduce flowering[53] and pollinator activity.[2,37]

OPPORTUNITIES FOR INCREASING POLLINATION

Warmer soil temperatures may increase pollinator survival over the winter, and warmer spring temperatures may increase pollinator activity in the early summer when blueberries are flowering.[65,70,71]

FRUITS & SEEDS

Figure 6. Ripe blueberries and leaves changing color in fall. Photo credit: K. Schroder.

The fruits of blueberry shrubs are dark blue to dark purple with a powdery surface (Figure 6). Their size can vary considerably, from 3⁄16 inch (0.5 cm) to 3⁄8 inch (1 cm) in diameter.[19] It takes about 45 - 55 days following fertilization for fruits to ripen.[26] Berries are usually hidden by the leaves and they do not last long on the plants as they are quickly attacked by fungi and rot.[44] The surface of the berries is covered with a thin layer of wax that protects berries from UV light; this natural sun protection has an SPF comparable to that of commercial sunscreen.[72]

Fruit production is highest in areas with high light, which helps explain why tundra plants tend to produce more berries than plants in the boreal forest, and why recently burned forest sites tend to have particularly high fruit production.[2, 37,73,74] Warm summers with sufficient rain may also lead to high berry production 1-2 years later.[74] In lowland black spruce boreal forest, a lack of nutrients may also limit berry production.[37]

THREATS TO FRUIT PRODUCTION FROM CLIMATE CHANGE

As described in the growth section, **expansion of tall shrubs** will likely lead to competition for light,[47–49] reducing fruit production in blueberries[2]. Berry pickers in Nunavik (northern Canada) and Georgetown and Nondalton in western Alaska have reported that other shrubs are taking over areas where blueberries used to grow.[75–77]

> **"...the wet summers make it hard to harvest [blueberries] before they fall off or rot"**
>
> *– Participant, Alaska's Berries in a Changing Climate Listening Session, 12/9/2021*[132]

Fungi generally thrive **under warmer and wetter conditions**, so there may be an increase in fungal activity that leads to a higher proportion of fruits rotting.[78,79]

OPPORTUNITIES FOR GREATER FRUIT PRODUCTION

Warmer winters (but not summers) are associated with an increase in berry production.[60]

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

SEED DISPERSAL & GERMINATION

Seeds are dispersed by birds such as Canada geese and spruce grouse (Figure. 7),[18,81,82] by small mammals such as red-backed voles,[83] and by larger mammals such as arctic foxes, gray wolves, and black bears.[84–86] In a good blueberry year, blueberries can make up almost half of the diet of black bears in Interior Alaska in fall.[86] Bog blueberry seeds are vulnerable to heat and fungal rot, so they don't stay viable for long and do not form a large seed bank.[16,32,87,88] They need a cool or cold period before they can germinate to ensure they don't start to grow in the fall, when seedlings cannot survive.[16,88,89] To successfully establish themselves, bog blueberry seeds need small disturbances or open patches with good conditions like high moisture and soils with high organic content.[18,34] Because of this, reproduction from seed is most common in highly disturbed areas.[32]

Figure 7. Ptarmigan among blueberry plants. Photo credit: K. Schroder.

THREATS TO SEED GERMINATION FROM CLIMATE CHANGE

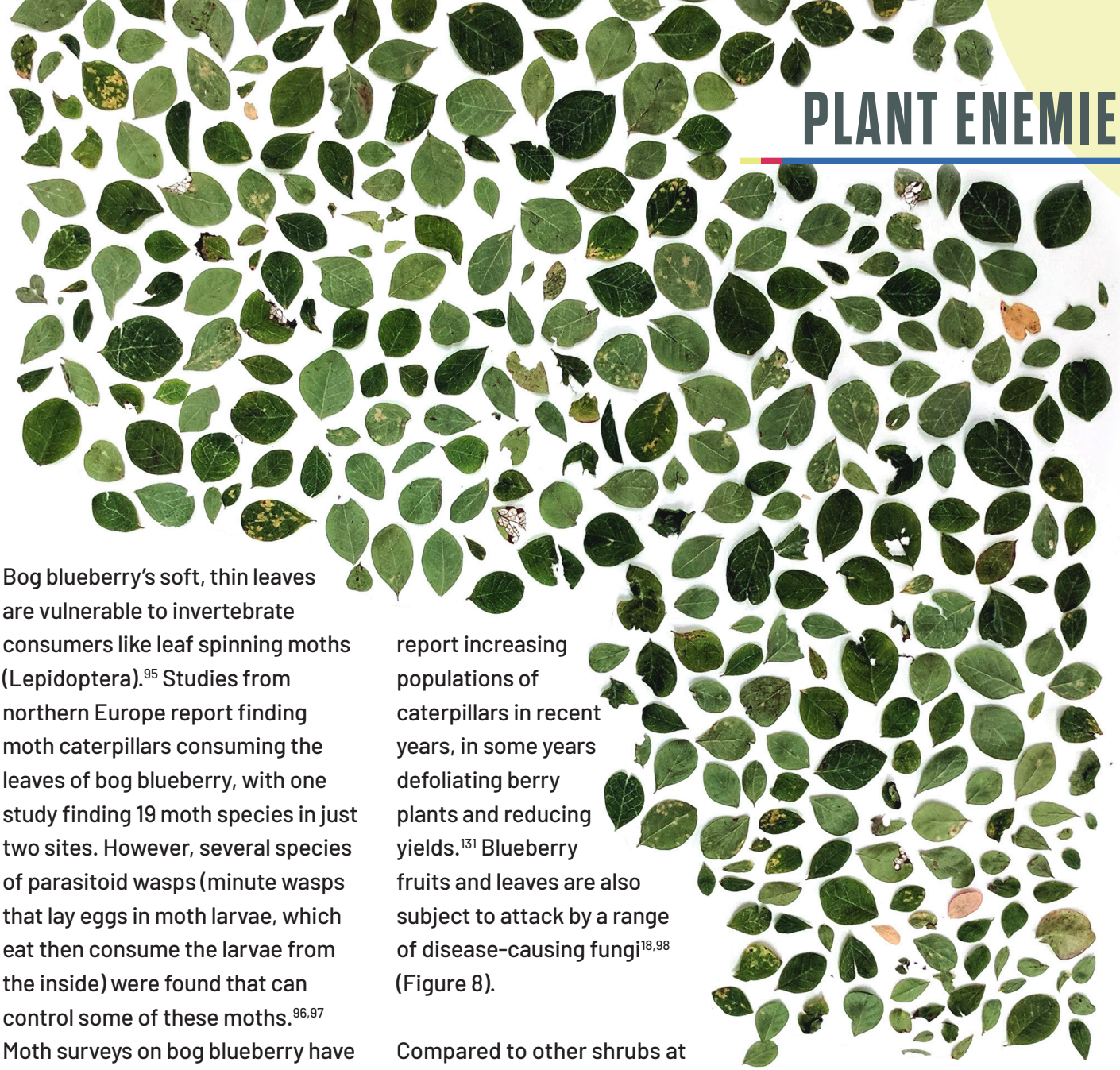
Warmer temperatures may make seeds more vulnerable to **fungal attacks**.[87] More **intense forest fires**[90,91] that burn through the organic mat of the forest floor will kill the plants,[36,57] including the seed bank, making re-establishment entirely dependent on seeds brought in by animals.[92] This may be exacerbated by increasing size of areas burned.[93]

PLANT FUNGAL ASSOCIATES

Bog blueberry roots have ericoid **mycorrhizae**, a group of fungi that help the plant obtain water and nutrients.[94] This is especially important because bog blueberry has shallow roots. Roots also have dark septate endophytes, another type of fungus that helps cycle nutrients from old, dying roots to young, active roots.[94] Together, these fungi allow bog blueberry to grow in areas with low nutrients (like tundra or black spruce forest) where many other species cannot survive.

Shading has been found to reduce the ericoid **mycorrhizae** and dark septate endophytes[24], so the shrub expansion mentioned previously will likely reduce the ability of blueberry plants to obtain the water and nutrients they need.

PLANT ENEMIES



Bog blueberry's soft, thin leaves are vulnerable to invertebrate consumers like leaf spinning moths (Lepidoptera).[95] Studies from northern Europe report finding moth caterpillars consuming the leaves of bog blueberry, with one study finding 19 moth species in just two sites. However, several species of parasitoid wasps (minute wasps that lay eggs in moth larvae, which eat then consume the larvae from the inside) were found that can control some of these moths.[96,97] Moth surveys on bog blueberry have not been completed in Alaska, but extensive invertebrate damage is commonly observed on leaves (Figure 8), and berry pickers in the Matanuska-Susitna Valley report increasing populations of caterpillars in recent years, in some years defoliating berry plants and reducing yields.[131] Blueberry fruits and leaves are also subject to attack by a range of disease-causing fungi[18,98] (Figure 8).

Compared to other shrubs at northern latitudes, bog blueberry twigs and leaves are moderately palatable to mammals.[99] Large mammals like moose, caribou and Sitka deer consume twigs and leaves,[100–102] while smaller mammals such as voles, snowshoe hares, and collared lemmings consume leaves, shoot tips, and small twigs in winter or spring.[103–105]

THREATS FROM INSECTS AND PATHOGENS

Warmer and wetter conditions are likely to increase populations of insects and pathogens that attack leaves, stems, flowers and seeds.[106–109]

Figure 8.
a) Damage to blueberry leaves from invertebrate consumers and pathogens. Photo credit: L. Parkinson.

b) Left photo: Extensive leaf damage by insects on *Vaccinium uliginosum*. Photo credit: A. Smyth

HUMAN USE

People extensively use bog blueberries in sub-arctic and arctic regions. Berries are found throughout Alaska, Canada, northern Russia, Scandinavia, and China, and are used by Indigenous Peoples including Athabascan, Inuit, and Yup'ik.[75,110–113] Over half of all households in surveyed Alaskan communities (Figure 9) use wild blueberries with a significant portion of the harvest in each community getting shared.[121] Bog blueberries are picked as part of the annual berry harvest across most of the state but they make up the majority of the berry harvest in Interior Alaska (Figure 9). The berries are commonly eaten fresh or frozen, and are also used in a variety of foods including akutaq (nivagi in Dena'ina), baked goods, jams, and jellies, for both personal consumption and commercial use.[114–119] The berries are valued as a source of food, for their medicinal properties, and the act of picking berries is a great way to enjoy time outside and an important cultural activity for Alaska Native communities.[120,125]

Picking blueberries in Kotzebue, Alaska. Photo credit: C. Mishler / Alamy Stock Photo

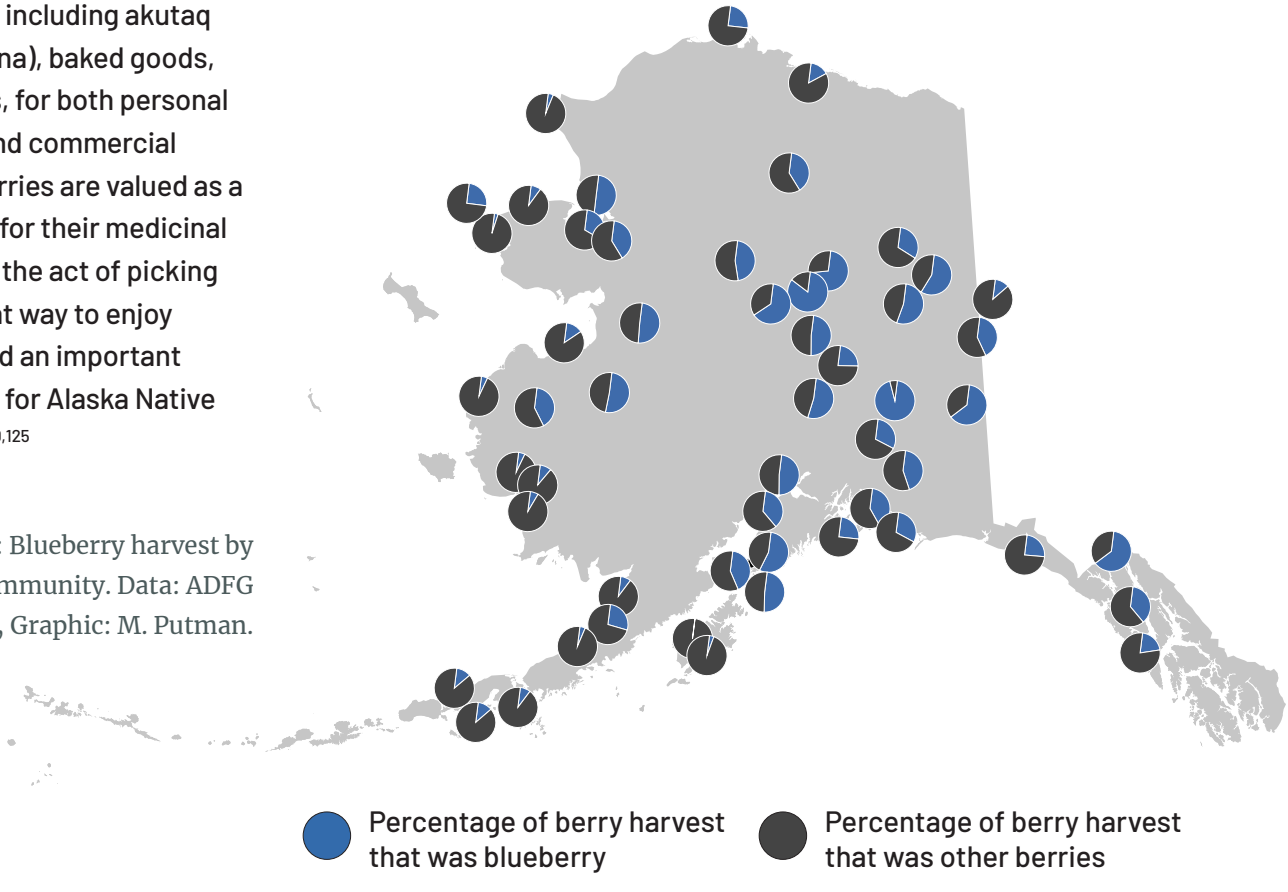


Figure 9: Blueberry harvest by Alaskan community. Data: ADFG 2013-2018, Graphic: M. Putman.

Bog blueberries are a very healthy food due to their extraordinarily high levels of antioxidants from anthocyanins and other phenolic compounds,[122–124] with especially high levels at higher latitudes.[125] They also have high levels of vitamin C.[126] Health benefits associated with bog blueberry consumption include prevention of cancer, vascular, and neurodegenerative diseases,[127,128] reduction of the risk of type 2 diabetes[129] and anti-inflammatory properties.[123,128]

CLIMATE IMPACTS ON HUMAN USE

Concerns about bog blueberry plants are mentioned in at least 16 climate adaptation plans from communities across Alaska.[46]

Increased smoke exposure from more frequent and larger fires may change fruit quality, but these changes are likely either neutral or positive (increase in anthocyanin production) (L. Weingartner, unpubl. data). Changes in timing of when blueberries ripen and where the plants grow may disrupt current harvest cues and travel practices. In some communities, climate change is thought to have changed the distances required to travel for harvesting blueberries.[80]

> **Growing up, you weren't supposed to pick blueberries until first frost. But now they are ripe before first frost; they are ripening earlier over time**
>
> *– Elizabeth Mears, Unalaska*

Photo credit: K. Schroder.

SUMMARY

Blueberry faces multiple threats from a warming world. However, there is a lot we still don't know, especially how damage by herbivores and pathogens will change. The threats depend on the region of the state and in some areas, fruit production may increase while in others, it may be possible to take action to maintain good berry production.

> **We are working on building food forests, [...] focusing on native berry species. This is for food security as well as to preserve berry species from other climate or development impacts. This also creates a space for elders to harvest in a safer area**
>
> *– Genelle Winter, Metlakatla*

Photo credit: A. Smyth

BUILDING RESILIENCE TO CHANGES IN BLUEBERRIES

In areas where snow depth in winter is being reduced (e.g., in coastal areas), snow fences may help protect plants by creating a thick insulative layer. Removing overstory species that are shading the plants, especially in areas where shrubs are expanding, can reduce competition for light. Maintaining patches free from shrub or canopy cover and in different locations with different microclimates (north facing slopes to produce in hot dry years, south facing slopes to produce in cool years). Honeybees may be able to provide a supplementary source of pollinators where native pollinators are scarce, though more research is needed.[130] Pruning and browse can increase or maintain fruit production year-to-year.[131] In areas where bog blueberry has thrived, cultivated species such as honeyberry (*Lonicera caerulea*) and saskatoonberry (*Amelanchier alnifolia*) also thrive and could supplement wild bluberry harvests.

KEY KNOWLEDGE GAPS

We don't know how insect herbivore populations, especially moths (Lepidoptera) will change with warmer and wetter conditions. We don't know whether parasitoid wasps currently control these moth populations or whether they could do so in the future.

We don't know how warmer and wetter conditions will affect damage by fungi to adult plants and seeds.

We don't know where in Alaska the expansion of shrubs includes expansion of blueberries or if it means increased competition for blueberries. The species-level shrub cover is difficult to detect using remote survey techniques, and field surveys would help.

Blueberries 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

Carpel - female part of a flower; contains stigma (pollen collector), ovary (fruit or seed to be), and style (piece connecting stigma and ovary)

Deciduous - an adjective for plants that have leaves that last for one season only

Genet - a group of genetically identical plants, each of which is called a ramet, produced through asexual reproduction

Microbes - microorganisms such as bacteria and fungi

Mycorrhizae - a beneficial fungal partner that grows around many plant roots

Ramet - a single aboveground stem from a clonal plant

Stamen - pollen producing, male part of a flower

ENDNOTES

1. Gwich'in Social and Cultural Institute. Gwich'in Topical Dictionary: Gwichyah Gwich'in & Teetl'it Gwich'in Dialects, 6th ed.; 2009.
2. Siegwart Collier L. 2020. Climate change impacts on berry shrub performance in treeline and tundra ecosystems. Doctoral thesis, Memorial University of Newfoundland.
3. *Iñupiatun Uqaluit Taniktun Sivuniŋit: North Slope Iñupiaq to English Dictionary*. Iñupiatun Uqaluit Taniktun Sivuniŋit. https://inupiaqonline.com/ (accessed 2023-03-01).
4. *Uqausiit: The Inuktut Grammar Dictionary*. https://uqausiit.ca/ (accessed 2023-05-26).
5. Jacobson SA. 2012. *Yup'ik Eskimo Dictionary: Volume 1 (of 2)*, 2nd ed. Alaska Native Language Center.
6. Leer J, C Anahonak, A Moonin, D Tabios, S Moonin, D Anahonak, 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.
7. Bergsland K. 1994. *Aleut Dictionary: An unabridged lexicon of the Aleutian, Pribilof, and Commander Islands Aleut language.* Alaska Native Language Center, https://uafanlc.alaska.edu/Online/AL950B1994a/bergsland-1994-aleut_dictionary-smaller.pdf, (accessed 2023-03-01).
8. Edwards K. 2009. *Dictionary of Tlingit*. Sealaska Heritage Institute. https://www.sealaskaheritage.org/sites/default/files/Tlingit_dictionary_web.pdf (accessed 2023-2-24).
9. Kari J. 1978. *Deg Xinag: Ingalik Noun Dictionary*. Alaska Native Language Center. https://uafanlc.alaska.edu/Online/IK974K1978a/kari-1978-deg_xinag_dictionary.pdf (accessed 2023-5-25).
10. Kari J. 1974. *Kenai Tanaina Noun Dictionary*. Alaska Native Language Center. https://uafanlc.alaska.edu/Online/TI972K1974i/kari-1974-kenai_tanaina_noun_dictionary.pdf (accessed 2023-2-23).
11. Jones, 1978. E. *Junior Dictionary for Central Koyukon Athabaskan*. National Bilingual Materials Development Center.
12. Kari J, M Buck. 1975. *Ahtna Noun Dictionary*. Alaska Native Language Center. https://uafanlc.alaska.edu/Online/AT973BK1975/AT973BK1975.pdf
13. 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.
14. Hiirsalmi H, A. Lehmushovi. 1993. Occurrence and utilization of wild *Vaccinium* species in Finland. *International Symposium on Vaccinium Culture.* https://doi.org/10.17660/ActaHortic.1993.346.43.
15. Turtiainen M, K Salo, O Saastamoinen O. 2011. Variations of yield and utilisation of bilberries (*Vaccinium myrtillus* L.) and cowberries (*V. vitis-Idaea* L.) in Finland. *Silva Fennica* 45: 115.
16. Calmes, MA, JC Zasada. 1982. Some reproductive traits of four shrub species in the black spruce forest type of Alaska. *Canadian Field-Naturalist* 96: 35–40.
17. Hewitt RE, DL Taylor, H Genet, AD McGuire, MC Mack. Below-ground plant traits influence tundra plant acquisition of newly thawed permafrost nitrogen. *Journal of Ecology* 107: 950–962.
18. Jacquemart A-L. 1996. *Vaccinium uliginosum* L. *The Journal of Ecology 84*: 771-785.
19. Holloway P. 2006. *Managing wild bog blueberry, lingonberry, cloudberry and crowberry stands in Alaska*. Natural Resources Conservation Service: Fairbanks, Alaska.
20. Palacio, S. A Lenz, S Wipf, G Hoch, C Rixen. 2015. Bud freezing resistance in alpine shrubs across snow depth gradients. *Environmental and Experimental Botany 118*: 95–101.

21. Shevtsova A, A Ojala, S Neuvonen, M Vieno, E Haukioja. 1995. Growth and reproduction of dwarf shrubs in a subarctic plant community: annual variation and above-ground interactions with neighbours. *Journal of Ecology* 83: 263–275.

22. De Witte LC, GFJ Armbruster, L Gielly, P Taberlet, J Stöcklin. 2012. JFLP markers reveal high clonal diversity and extreme longevity in four key arctic-alpine species: longevity of arctic-alpine clonal plants. *Molecular Ecology* 21: 1081–1097.

23. 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.

24. Olsrud, M, A Michelsen. 2009. Effects of shading on photosynthesis, plant organic nitrogen uptake, and root fungal colonization in a subarctic mire ecosystem. *Botany 87*: 463–474.

25. Karlsson PS. 1985. Effects of water and mineral nutrient supply on a deciduous and an evergreen dwarf shrub: *Vaccinium uliginosum* L. and *V. vitis-idaea* L. *Ecography* 8: 1–8.

26. Mulder CPH, KV Spellman. 2021. Flower and leaf phenology of interior alaska forbs and shrubs as observed near Fairbanks Alaska from 2013 to 2015. https://doi.org/10.6073/PASTA/AE8B2F7626FD96A24BF347AD5E8BA733.

27. Wipf S. 2010. Phenology, growth, and fecundity of eight subarctic tundra species in response to snowmelt manipulations. 2010. *Plant Ecology* 207: 53–66.

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

29. Martin M, K Gavazov, C Körner, S Hättenschwiler, C Rixen. 2010. Reduced early growing season freezing resistance in alpine treeline plants under elevated atmospheric CO_2. *Global Change Biology* 16:1057–1070.

30. Wheeler JA, G Hoch, AJ Cortés, J Sedlacek, S Wipf, C Rixen. 2014. Increased spring freezing vulnerability for alpine shrubs under early snowmelt. *Oecologia* 175: 219–229.

31. Preece C, GK Phoenix. 2014. Impact of early and late winter icing events on sub-arctic dwarf shrubs. *Plant Biology* 16: 125–132.

32. Alsos IG, S Spjelkavik, T Engelskjøn. 2003. Seed bank size and composition of *Betula nana*, *Vaccinium uliginosum*, and *Campanula rotundifolia* habitats in Svalbard and northern Norway. *Canadian Journal of Botany* 81: 220–231.

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

34. 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.

35. 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.

36. Nelson JL, E Zavaleta, FS Chapin. 2008. Boreal fire effects on subsistence resources in alaska and adjacent Canada. *Ecosystems* 11: 156–171.

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

38. Mack MC, KK Treseder, KL Manies, JW Harden, EAG Schuur, JG Vogel, JT Randerson, FS Chapin. 2008. Recovery of aboveground plant biomass and productivity after fire in mesic and dry black spruce forests of Interior Alaska. *Ecosystems* 11: 209–225.

39. Lader R, JE Walsh, US Bhatt, PA Bieniek. 2020. Anticipated changes to the snow season in Alaska: elevation dependency, timing and extremes. *International Journal of Climatology* 40: 169–187.

40. Kuprian E, VF Briceño, J Wagner, G Neuner. 2014. Ice barriers promote supercooling and prevent frost injury in reproductive buds, flowers and fruits of alpine dwarf shrubs throughout the summer. *Environmental and Experimental Botany* 106: 4–12.

41. Wipf S, C Rixen. 2010. A Review of snow manipulation experiments in arctic and alpine tundra ecosystems. *Polar Research* 29: 95–109.

42. Scott P, W Rouse. Impacts of increased winter snow cover on upland tundra vegetation: a case example. 1995. *Climate Research* 5, 25–30.

43. Redilla K, ST Pearl, PA Bieniek, JE Walsh. 2019. Wind climatology for Alaska: historical and future. *Atmospheric and Climate Sciences* 9*:* 683–702.

44. Phoenix GK, D Gwynn-Jones, TV Callaghan, D Sleep, JA Lee. 2001. Effects of global change on a sub-arctic heath: effects of enhanced UV-B radiation and increased summer precipitation: *Journal of Ecology 89*: 256–267.

45. Parsons AN, JM Welker, PA Wookey, MC Press, TV Callaghan, JA Lee. 1994. Growth responses of four sub-arctic dwarf shrubs to simulated environmental change. *Journal of Ecology 82*: 307-318.

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

47. 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.

48. 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.

49. 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.
50. Nawrocki TW. 2021. Continuous foliar cover of vegetation for North American Beringia. https://doi.org/10.5281/zenodo.4770218.
51. Larking T, E Davis, R Way, L Hermanutz, A Trant. 2021. Recent greening driven by species-specific shrub growth characteristics in Nunatsiavut, Labrador, Canada. *Arctic Science* 7: 781–797.
52. Lantz TC, SE Gergel, GHR Henry. 2010. Response of green alder (*Alnus viridis* subsp. *fruticosa*) patch dynamics and plant community composition to fire and regional temperature in north-western Canada. *Journal of Biogeography 37*: 1597–1610.
53. May J, S Oberbauer, SL Unger, MJ Simon, KR Betway, RD Hollister. 2021. Shading decreases and delays NDVI and flowering of prostrate arctic shrubs. *Arctic Science* , AS-2020-0043.
54. 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.
55. Kasischke ES, DL Verbyla, TW 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.
56. 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. *Science Reports* 12: 4901.
57. 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.
58. Lantz TC, SV Kokelj, RH Fraser. 2015. Ecological recovery in an arctic delta following widespread saline incursion. *Ecological Applications* 25: 172–185.
59. Terenzi J, MT Jorgenson, CR Ely. 2014. Storm-surge flooding on the Yukon-Kuskokwim Delta, Alaska. *Arctic 67*: 360-374.
60. Natali SM, EAG Schuur, RL Rubin. Increased plant productivity in alaskan tundra as a result of experimental warming of soil and permafrost. 2012. *Journal of Ecology* 100: 488–498.
61. Shevtsova I, B Heim, S Kruse, J Schröder, EI Troeva, LA Pestryakova, ES Zakharov, U Herzschuh. 2020. Strong shrub expansion in tundra-taiga, tree infilling in taiga and stable tundra in central Chukotka (North-Eastern Siberia) between 2000 and 2017. *Environmental Research Letters* 15: 085006.
62. Koller EK, MC Press, TV Callaghan, GK Phoenix. 2016. Tight coupling between shoot level foliar N and P, leaf area, and shoot growth in arctic dwarf shrubs under simulated climate change. *Ecosystems* 19: 326–338.
63. Mekonnen ZA, WJ Riley, LT Berner, NJ Bouskill, MS Torn, G Iwahana, AL Breen, IH Myers-Smith, MG Criado, Y Liu, ES Euskirchen, SJ Goetz, MC Mack, RF Grant. 2021. Arctic tundra shrubification: a review of mechanisms and impacts on ecosystem carbon balance. *Environmental Research Letters 16*: 053001.
64. Messier C, S Parent, Y Bergeron. 1998. Effects of overstory and understory vegetation on the understory light environment in mixed boreal forests. *Journal of Vegetation Science* 9: 511–520.
65. 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.
66. Van Rossum F, NJ Vereecken, E Brédat, D Michez. 2013. Pollen dispersal and fruit production in *Vaccinium oxycoccos* and comparison with its sympatric congener *V. uliginosum. Plant Biology* 15: 344–352.
67. Stubbs CS, FA Drummond, EA Osgood. 1994. *Osmia ribifloris biedermannii* and *Megachile rotundata* (Hymenoptera: Megachilidae) introduced into the lowbush blueberry agroecosystem in Maine. Journal of the Kansas Entomological Society 67: 173-185.
68. Jacquemart AL. 1993. Floral visitors of *Vaccinium* species in the High Ardennes, Belgium. *Flora* 188: 263–273.
69. Jacquemart AL, 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.
70. 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.
71. 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.
72. Trivedi P, K Karppinen, L Klavins, J Kviesis, P Sundqvist, N Nguyen, E Heinonen, M Klavins, J Jaakola, J Väänänen, J Remes, H Häggman. 2019. Compositional and morphological analyses of wax in northern wild berry species. *Food Chemistry* 295: 441–448.
73. Boulanger-Lapointe, N, J Gérin-Lajoie, L Siegwart Collier, S Desrosiers, C Spiech, GHR Henry, G. 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.
74. Krebs CJ, R Boonstra, K Cowcill, AJ Kenney. 2009. Climatic determinants of berry crops in the boreal forest of the southwestern Yukon. *Botany 87*: 401–408.
75. 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. 2015 *Human Ecol* 43: 379–394.

76. 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).

77. Brubaker M, C Balluta, S Flensburg, J Skarada, R Drake, J Berner, J Warren, J Williamson, O O'Domin, T Smith, K Murphy, L Verbrugge. Climate change in Nondalton, Alaska: Strategies for Community Health.

78. Zhu XQ, CL Xiao. 2015. Phylogenetic, morphological, and pathogenic characterization of *Alternaria* species associated with fruit rot of blueberry in California. *Phytopathology* 105: 1555–1567.

79. Hilário S, G Pinto, P Monteiro, L Santos, A Alves. 2023. The impact of two *Diaporthe* species on *Vaccinium corymbosum* physiological performance under different water availability scenarios. *European Journal of Plant Pathology* 166: 161–177.

80. Brubaker M, J Bell, H Dingman, M Ahkivgak, D Whiteman, R Drake. 2014. *Climate Change in Atqasuk, Alaska: Strategies for Community Health.* Alaska Native Tribal Health Consortium . http://www.anthc.org/chs/ces/climate/climateandhealthreports.cfm (accessed 2023-04-28).

81. Ellison L. 1966. Seasonal Foods and chemical analysis of winter diet of Alaskan spruce grouse. *The Journal of Wildlife Management 30*: 729-735.

82. Green AJ, Á Lovas-Kiss, RA Stroud, N Tierney, AD Fox. Plant dispersal by Canada geese in arctic Greenland. *Polar Research* 37: 1508268.

83. 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.

84. Gable TD, SK Windels, JG Bruggink, 2017. Estimating biomass of berries consumed by gray wolves. *Wildlife Society Bulletin* 41: 129–131.

85. Graae BJ, Pagh S, HH Bruun. 2004. An experimental evaluation of the arctic fox (*Alopex lagopus*) as a seed disperser. *Arctic, Antarctic, and Alpine Research* 36: 468–473.

86. Hatler DF. Food habits of black bear in Interior Alaska. 1972. *Canadian Field-Naturalist* 86: 17–31.

87. Graae BJ, IG Alsos, R Ejrnaes. The impact of temperature regimes on development, dormancy breaking and germination of dwarf shrub seeds from arctic, alpine and boreal sites. *Plant Ecology 198*: 275–284.

88. Vander Kloet SPV, NM Hill. 1994. The paradox of berry production in temperate species of *Vaccinium*. *Canadian Journal of Botany* 72: 52–58.

89. Baskin CC, P Milberg, L Andersson, JM Baskin. Germination studies of three dwarf shrubs (*Vaccinium*, Ericaceae) of northern hemisphere coniferous forests. *Canadian Journal of Botany* 78: 1552–1560.

90. Johnstone JF, TS Rupp, M Olson, D Verbyla. Modeling impacts of fire severity on successional trajectories and future fire behavior in Alaskan boreal forests. *Landscape Ecology* 26: 487–500.

91. Weber MG, MD Flannigan. Canadian boreal forest ecosystem structure and function in a changing climate: impact on fire regimes. 1997. *Environmental Review* 5: 145–166.

92. 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.

93. Kasischke ES, D Williams, D Barry. 2002. Analysis of the patterns of large fires in the boreal forest region of Alaska. *International Journal of Wildland Fire* 11: 131-144.

94. Yang H, S Zhao, C Liu, L Bai, M Zhao, L Li. Diversity and characteristics of colonization of root-associated fungi of *Vaccinium uliginosum*. *Science Reports* 8: 15283.

95. Lozan A, K Spitzer, J Jaroš. 2012. Isolated peat bog habitats and their food connections: parasitoids (Hymenoptera: Ichneumonoidea) and their lepidopteran hosts. *Journal of Insect Conservation* 16: 391–397.

96. Spitzer K, J Jaroš, A Bezdék. 2003. Leaf-spinning moths (Lepidoptera) feeding on *Vaccinium uliginosum* L. along an ecological gradient of central European peat bogs. *Entomologica Fennica* 14: 46-52.

97. Ellis WN. *Plant Parasites of Europe: Leafminers, Galls and Fungi*. https://bladmineerders.nl/ (accessed 2023-1-13).

98. Cipollini ML, EW Stiles. 1993. Fungi as biotic defense agents of fleshy fruits: alternative hypotheses, predictions, and evidence. *The American Naturalist* 141: 663–673.

99. Christie KS, JP Bryant, L Gough, VT Ravolainen, RW Ruess, KD Tape. 2015. The role of vertebrate herbivores in regulating shrub expansion in the Arctic: a synthesis. *BioScience* biv137.

100. LeResche RE, JL Davis. 1973. Importance of nonbrowse foods to moose on the Kenai Peninsula, Alaska. *The Journal of Wildlife Management* 37: 279-287.

101. Crête M. GJ Doucet. 1998. Persistent suppression in dwarf birch after release from heavy summer browsing by caribou. *Arctic and Alpine Research 30*: 126–132.

102. White KS, GW Pendleton, E Hood. 2009. Effects of snow on Sitka black-tailed deer browse availability and nutritional carrying capacity in Southeastern Alaska. *Journal of Wildlife Management 73* : 481–487.

103. Hambäck PA, P Ekerholm. 1997. Mechanisms of apparent competition in seasonal environments: an example with vole herbivory. *Oikos 80*: 276-288.

104. Wolff JO. 1978. Food habits of snowshoe hares in Interior Alaska. *The Journal of Wildlife Management* 42: 148-153.

105. Jensen SP, Doncaster CP. 1999. Lethal toxins in non-preferred foods: how plant chemical defences can drive microtine cycles. *Journal of Theoretical Biology 199*: 63–85.

106. Demain J, B Gessner, J McLaughlin, D Sikes, T Foote. 2008. Increasing insect reactions in Alaska: is this related to changing climate? *Nature Precedings* 1-1.

107. Jepsen JU, SB Hagen, RA Ims, NG Yoccoz. 2008. Climate change and outbreaks of the geometrids *Operophtera brumata* and *Epirrita autumnata* in subarctic birch forest: evidence of a recent outbreak range expansion. *Journal of Animal Ecology* 77: 257–264.

108. Pureswaran DS, A Roques, A Battisti. 2018. Forest insects and climate change. *Current Forestry Reports* 4: 35–50.

109. Strengbom J, G Englund, L Ericson. 2006. Experimental scale and precipitation modify effects of nitrogen addition on a plant pathogen. *Journal of Ecology* 94: 227–233.

110. Ballew C, A Ross Tzilkowski, K Hamrick, ED Nobmann. 2006. The contribution of subsistence foods to the total diet of Alaska natives in 13 rural communities. *Ecology of Food and Nutrition* 45: 1–26.

111. Herman-Mercer N, P Schuster, K Maracle. 2011. Indigenous observations of climate change in the Lower Yukon River Basin, Alaska. *Human Organization* 70: 244–252.

112. 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.

113. Yarborough DE. 2014. Improving northern bilberry (*Vaccinium uliginosum*) production. *Acta Horticulturae* 1017: 223–229.

114. Gray B. 2011. *The Boreal Herbal: Wild Food and Medicine Plants of the North*. Aroma Borealis Press, Whitehorse, Yukon, Canada.

115. Jones A, A Jones. *Plants That We Eat: Nauriat Nigiñaqtuat: From the Traditional Wisdom of the Iñupiat Elders of Northwest Alaska*, 2nd ed.; University of Alaska Press: Fairbanks, 2010.

116. Cascio J. Alaska Blueberries. *UAF Cooperative Extension*. https://cespubs.uaf.edu/index.php/download_file/1237/.

117. Kari PR. 1987. *Tanaina Plantlore, Dena'ina k'et'una*, 2nd ed., rev. National Park Service, Alaska Region: Anchorage, Alaska, 1987.

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

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

120. Redwood DG, ED Ferucci, MC Schumacher, JS Johnson, AP Lanier, LJ Helzer, L Tom-Orme, MA Murtaugh, ML Slattery. 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.

121. Alaska Department of Fish and Game (ADFG). *Community Subsistence Harvest Information System.* www.adfg.alaska.gov/sb/CSIS/ (accessed 2023-02-08).

122. Colak N, H Torun, J Gruz, M Strnad, I Hermosín-Gutiérrez, S Hayirlioglu-Ayaz, FA Ayaz. 2016. Bog bilberry phenolics, antioxidant capacity and nutrient profile. *Food Chemistry* 201: 339–349.

123. Grace MH, D Esposito, KL Dunlap, MA Lila. 2014. Comparative analysis of phenolic content and profile, antioxidant capacity, and anti-inflammatory bioactivity in wild Alaskan and commercial *Vaccinium* berries. *Journal of Agricultural and Food Chemistry* 62: 4007–4017.

124. Rodgers Dinstel R, J Cascio, S Koukel. 2013. The antioxidant level of Alaska's wild berries: high, higher and highest. *International Journal of Circumpolar Health* 72: 21188.

125. Kellogg J, J Wang, C Flint, D Ribnicky, P Kuhn, EG De Mejia, I Raskin, MA Lila. 2010. Alaskan wild berry resources and human health under the cloud of climate change. *Journal of Agricultural and Food Chemistry* 58: 3884–3900.

126. Fediuk K, N Hidiroglou, R Madère, HV Kuhnlein. 2002. Vitamin C in Inuit traditional food and women's diets. *Journal of Food Composition and Analysis* 15: 221–235.

127. Neto CC. 2007. Cranberry and blueberry: evidence for protective effects against cancer and vascular diseases. *Molecular Nutrition & Food Research* 51: 652–664.

128. Olas B. 2018. Berry phenolic antioxidants – implications for human health? *Frontiers in Pharmacology 9*.

129. Lin D, M Xiao, J Zhao, Z Li, B Xing, X Li, M Kong, L Li, Q Zhang, Y Liu, H Chen, W Qin, H Wu, S Chen. 2016. An overview of plant phenolic compounds and their importance in human nutrition and management of Type 2 diabetes. *Molecules 21*: 1374.

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

131. Rader AH. *Blueberries—Wild and Citified*. It Grows in Alaska. https://itgrowsinalaska.community.uaf.edu/2020/04/16/blueberries-wild-and-citified/ (accessed 2023-04-28).

132. Alaska's Berries in a Changing Climate Listening Sessions, hosted by the Alaska Tribal Resilience Network and Alaska Berry Futures Project, both part of the Alaska Climate Adaptation Center. Held December 9, 2021, January 24, 2022, and February 9, 2022

Photo credit: A. Smyth

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 (G17ACO0213) 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)