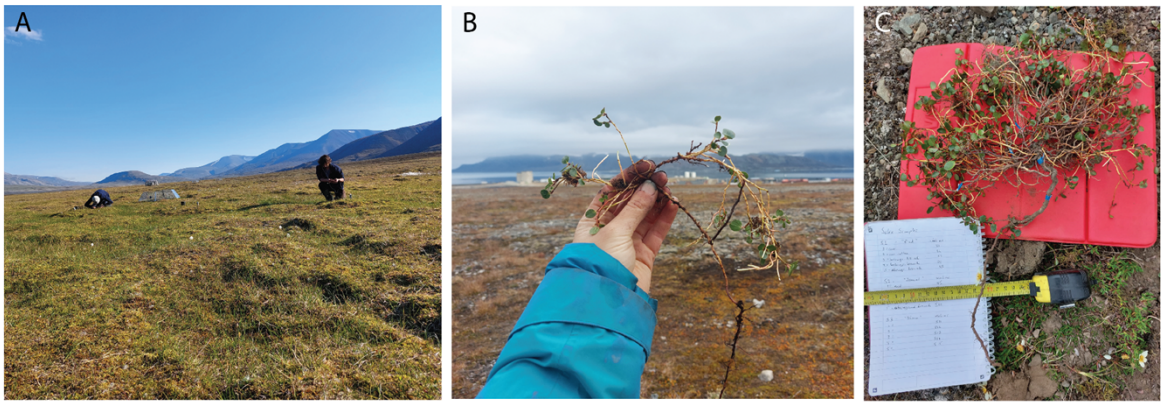
Bring us.. a shrubbery! - Investigating climate drivers of shrub growth on Svalbard

Rúna Magnússon, Svalbard Environmental Protection Fund grant 23/58

"*Struikrover*" is a Dutch word for a bandit or highwayman. It literally means "shrub robber", someone who lurks in the bushes to mug you. But in summer 2024, researchers and students from Wageningen University came to Svalbard as literal "*shrub robbers*" to collect many polar willow shrubs from around Adventdalen, Endalen and Ny-Ålesund.

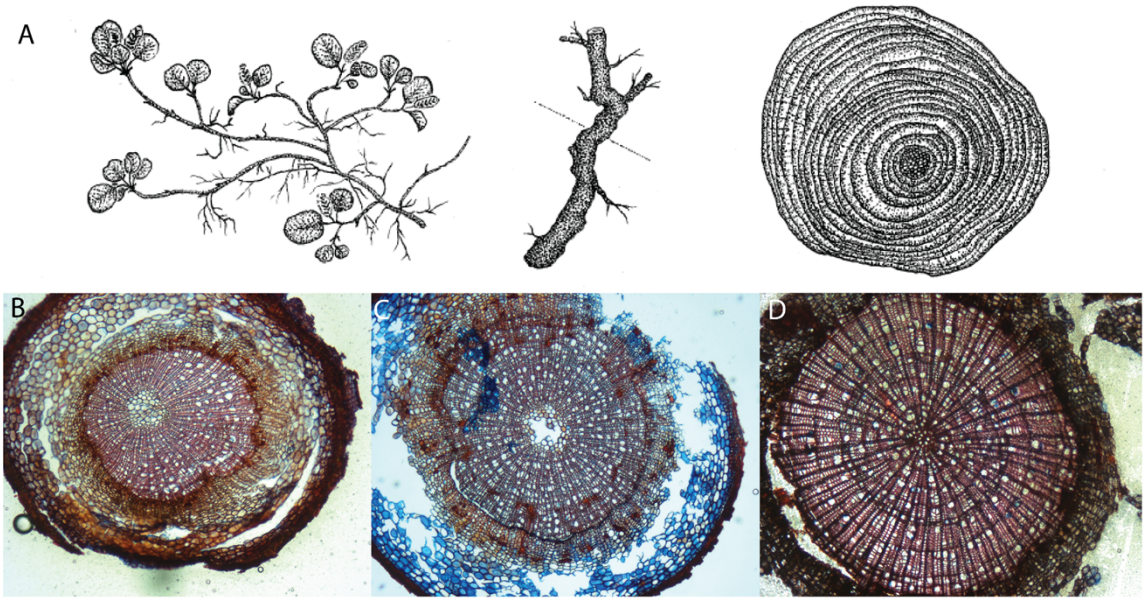


***A** - Sampling polar willow shrubs at a climate manipulation experiment in Adventdalen, MSc students and "*struikrovers*" Dinand Scholten and Bastiaan Leopold of Wageningen University are hard at work. **B** - A very small excavated shrub with Ny-Ålesund in the background. **C** - Typical growth form of polar willow, with a central taproot and laterally branched belowground shoots. Only the ends of the shoot emerge from the ground and bear leaves. Blue tape markers indicate where we cut segments for analysis.*

Why were we so keen on gathering shrubs? Most woody species, trees and shrubs, form wood in regular annual ring shaped patterns that we know as "tree-rings". We have probably all counted the rings of cut-down trunks in the forest at least once in our life to know the trees' age. The size of the ring tells us whether it grew well that year, or not so much. Tree-rings are an archive of the past and have helped scientists uncover the most amazing and unlikely insights. It has for example enabled curators to determine whether Rembrandt paintings were actually Rembrandts, based on the panels, or whether acclaimed Stradivarius violins were actually made by Stradiavius. Hard to claim that Stradivarius built a violin out of a cherry tree that was still alive after he died, which you can demonstrate by matching tree-ring patterns in the wood of a violin or picture frame against historical databases. Tree-rings can tell us when and where sunken shipwrecks were built, and how a historical period of exceptionally low hurricane activity likely enabled the "golden age of piracy" in the Caribbean. Or how climate change may have contributed to the fall of the Roman empire. These and some other amazing examples are described in Valerie Trouet's iconic book on dendrochronology (the study of tree-rings) "Tree Story".

Back to the High Arctic. Svalbard's most abundant "tree" is the tiny, several centimeter tall dwarf shrubs *Salix polaris*, polar willow in English, polarvier in Norwegian. It is possible to measure its tree-rings and several researchers have successfully done so in the past. It

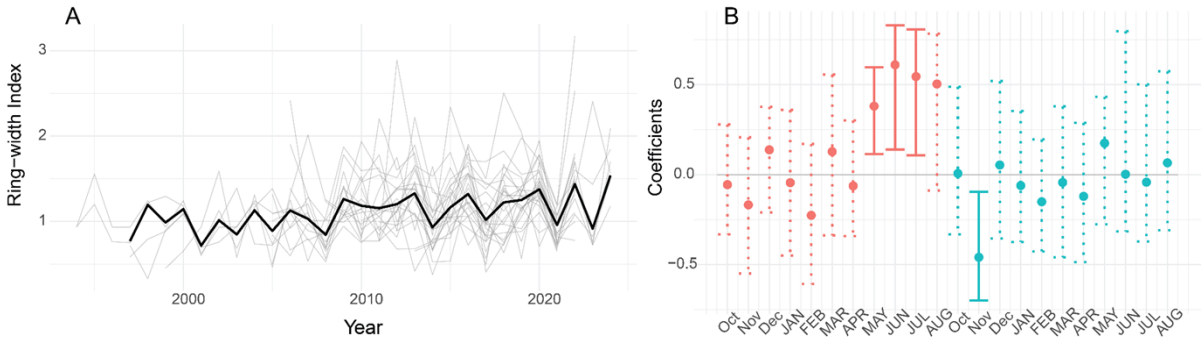
comes with a challenge though; the rings of polar willow are some of the tiniest in the world, often around 50 micrometers. If the shrub experiences difficulty, such as harsh conditions, competition, infection, damage, you name it, it may not form a ring at all. Or sometimes it only grows new wood tissue in specific places along the circumference and length of its system of branches and roots. This poses a challenge to dendrochronologists, because it means we have to deal with partially or entirely missing rings. We have to dig up the whole plant to understand its growth. Damage to the wood or very, very small and poorly defined tree-rings pose additional challenges. Even some of the most seasoned dendrochronologists would consider it madness to try to measure them. What we have to do is collect segments of the stem and roots from multiple parts of the shrub, slice micro-thin cross sections (around 20 micrometers) and enlarge them under a microscope. Then we measure the ring width patterns in several places per section, several sections per shrub, many shrubs per sampling site, and somehow puzzle all of that together. We can tell you, from experience, that you will see a dancing mess of patterns when you close your eyes at night after a day of work.



A - *An overview of how we go from shrub individual, to a stem segment, to a cross-section with discernible tree-rings. Illustration © Rúna Magnússon.* ***B -*** *A cross-section for which the tree-rings are hard to count, because they are very small, asymmetric and poorly defined.* ***C -*** *A cross-section for which the tree-rings are hard to count and potentially less driven by climate factors, since they show damaged tissue.* ***D -*** *Finally, a nicely measurable sample with clear tree-rings. Here we see several very small rings for recent years, then some large rings in the middle. The cross-sections of* ***B****,* ***C*** *and* ***D*** *are several millimeters in diameter including the ring of bark on the outside, and photographed under a microscope.*

But the reward of successfully measuring tree-ring growth of a shrub is sweet; it provides a record of past shrub growth that you can correlate to different climate conditions. This allows us to tell whether the growth of the polar willow is mostly driven by temperature in the summer months, by rainfall, by winter conditions or potentially by snowmelt timing or extreme events. And then, using knowledge from future climate scenarios, we can infer whether shrub growth will be higher or lower in the future. On Svalbard, this is important knowledge, because the polar willow represents a very substantial share of total plant biomass on the archipelago. To have more or less shrubs could also mean more or less

carbon uptake, differences in soils conditions and changes in food availability to herbivores such as the Svalbard reindeer, along with changes in many other ecosystem processes.



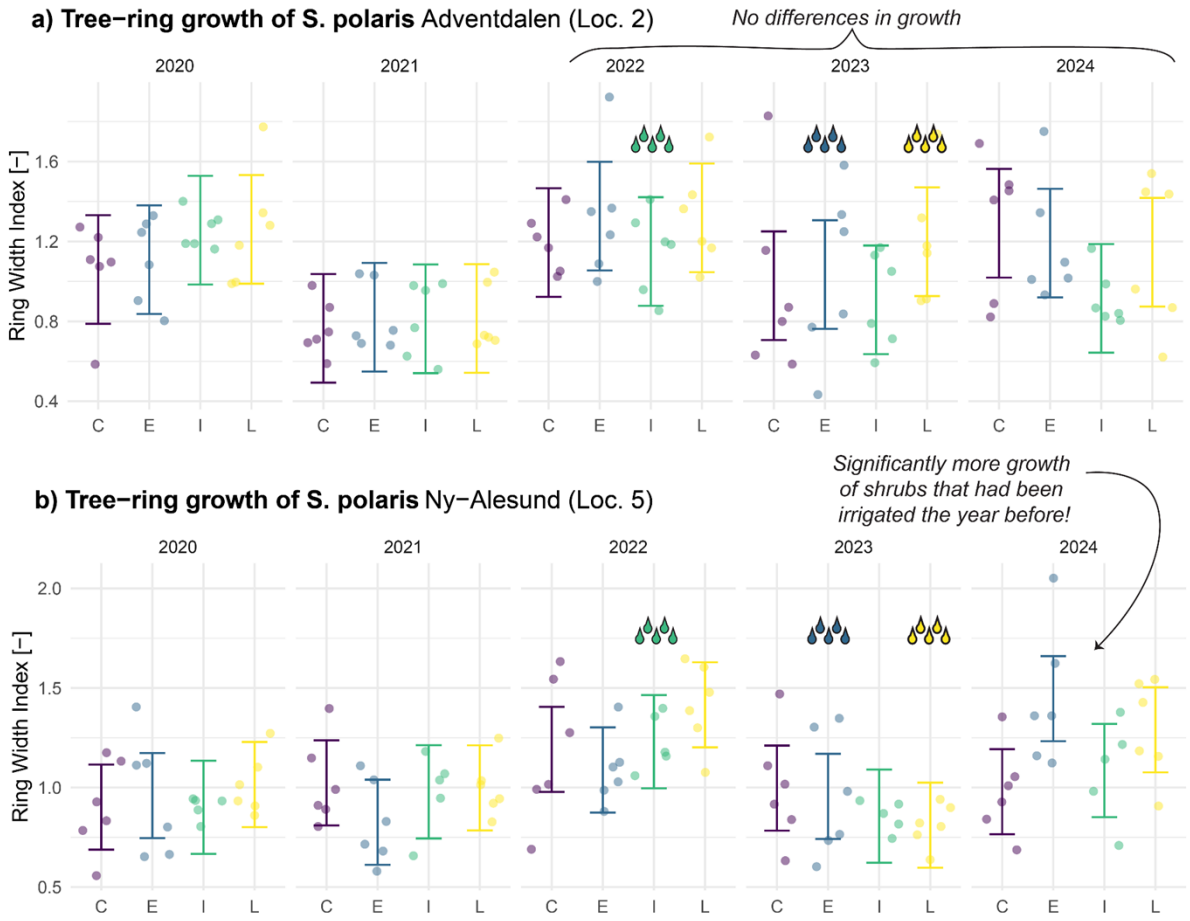
***A** - Relative tree-ring sizes of individual shrubs in grey lines, and the averaged dynamics for one sampling site in black. The relative growth index of each year (positive = more growth, negative = less growth) can be related to the weather conditions in that year. Evidently, there is also quite some variability among shrub individuals. **B** - "Fingerprint" of correlation between the ring width size (as in **A**) and weather conditions in specific months. Red bars show correlations with temperature per month, blue bars for rainfall per month. The months range from October previous to that year's growth, up until August (late summer). Here we see summer temperature (May-July) as a key driver of shrub growth, with some relation to early winter snowfall as well.*

For Svalbard, tree-ring studies generally agree that temperatures in summer are the most important factor for growth of polar willow, and the importance of rainfall (extra moisture) or rain-on-snow (potential damage to the plant due to formation of ice layers) differs from place to place. This suggests that we should expect increasing abundance and biomass of shrubs in a warming climate.

But the climate is changing fast, and we keep observing new extremes that are simply unprecedented in the past. How do you determine a plant's reaction to an extreme event that has never occurred yet? In that case, you have to make it happen, by doing an experiment. Across Svalbard, different kinds of such "climate manipulation experiments" exist; warming experiments with little transparent greenhouses, snow depth manipulations with fences, and many other set-ups. With our grant from the Svalbard Environmental Protection Fund, we were able to sample polar willows in a rainfall experiment that simulates heavy rainfall events in summer that are expected to occur increasingly on Svalbard. The experiment contained unaltered sites, and sites that had received extra rainfall in different years and at different moments in the season, on several locations in Adventdalen, Endalen and Ny-Ålesund. The beauty of using tree-rings in this context, is that it allows you to determine with a lot of certainty whether shrub growth started diverging as a result of the manipulation. You can even determine this in retrospect, after the experiment is finished, since the shrubs have essentially "stored" all the data for you!

Wageningen University MSc student Manon van den Dolder is irrigating a research plot in Endalen. You can imagine the workload involved in collecting and supplying over 10,000L of water this way!

This allowed us to uncover something we could not tell by simply correlating annual shrub growth to past weather data; namely that the polar willow can respond positively to extra rainfall, but only under specific conditions. We saw that only in the driest site in Ny-Ålesund, shrub growth was enhanced by adding rainfall, but the additional growth only happened in the summer after we supplied that extra rainfall. We found that heavy rainfall events can lift drought stress, and that its effects can only become evident in the next summer. Apart from lifting drought stress, heavy rainfall does not seem to affect shrub growth very much. And this makes sense; your house plants also just want to have “enough” water - too dry is not good, but enough is enough and too much is too much. On a warmer future Svalbard, the growth patterns of polar willow will likely be shaped by patterns of warm and moist summers (more growth) and warm and dry summers (less growth).



We sampled shrubs from climate manipulation sites and calculated their ring-width indexes (y-axis). Shrubs were samples from sites that had not received extra rainfall (C, purple), sites that had received extra rainfall in early summer 2023 (E, blue), sites that had received extra rainfall in late summer 2022 (I, green) and sites that had received extra rainfall in late summer 2023 (L, yellow). ***A*** *- We see that in the site in Adventdalen, the growth (ring width index) did not differ after adding extra rain, indicating that rainfall was not an important factor for growth here.* ***B*** *- For the site in Ny-Ålesund, we see that the extra rain in 2022 did not cause any effects on shrub growth, but shrubs that had received extra rain in 2023 grew significantly better in the next year (2024).*

We are now writing up our findings for publication in a scientific journal. In the future, we would like to study wood vessel sizes under the rainfall treatment as well. And lastly, we are applying for research grants to also sample polar willow shrubs from other types of climate manipulation sites on Svalbard, so we can better map the relative importance of changes to temperature, snowpack conditions and other weather conditions for shrub growth on Svalbard. *Tusen takk* to the Svalbard Environmental Protection Fund for enabling us to take this first and exciting step!