# Black Sand Extended Growing Season Length Experiment Protocols Document

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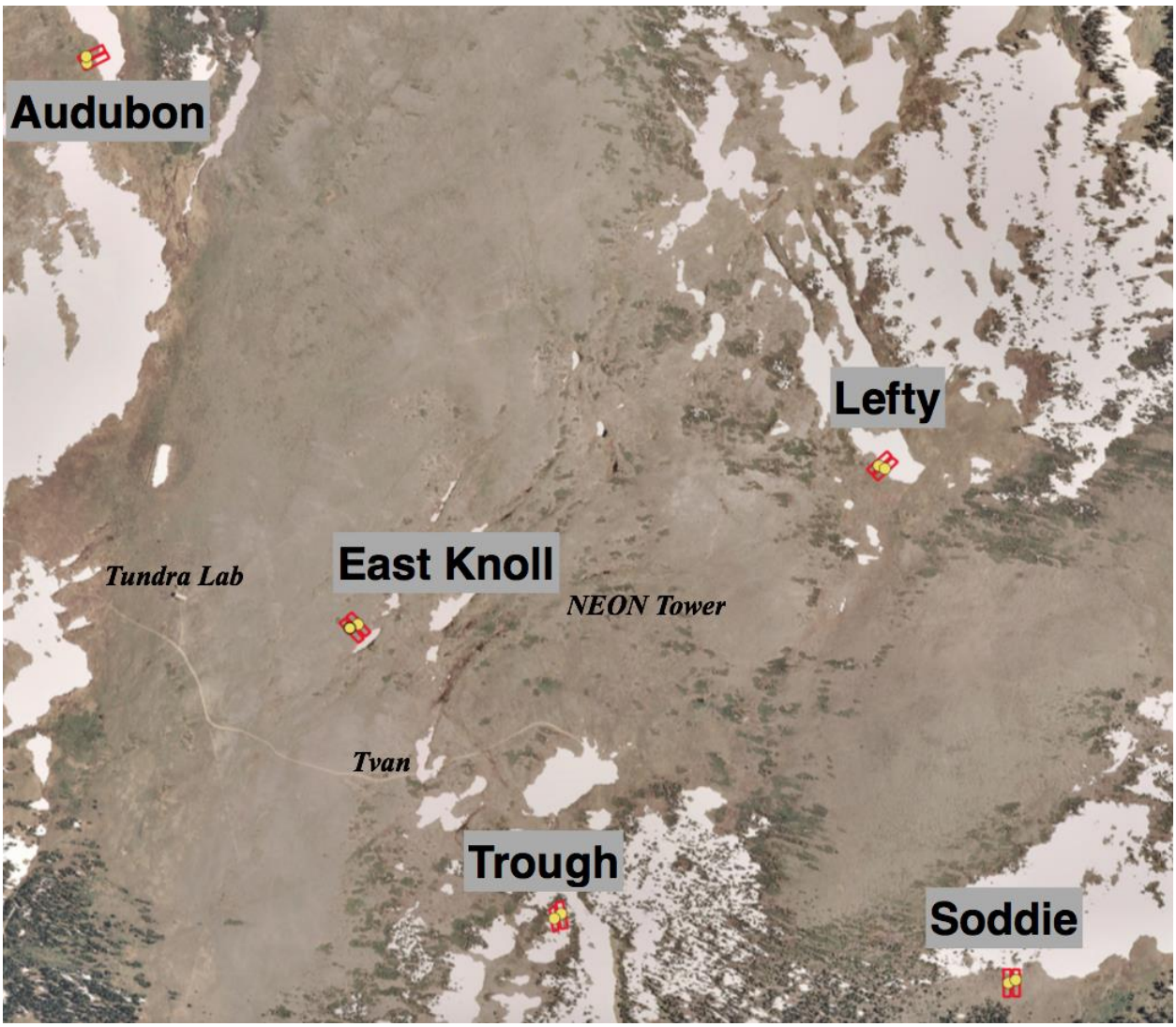
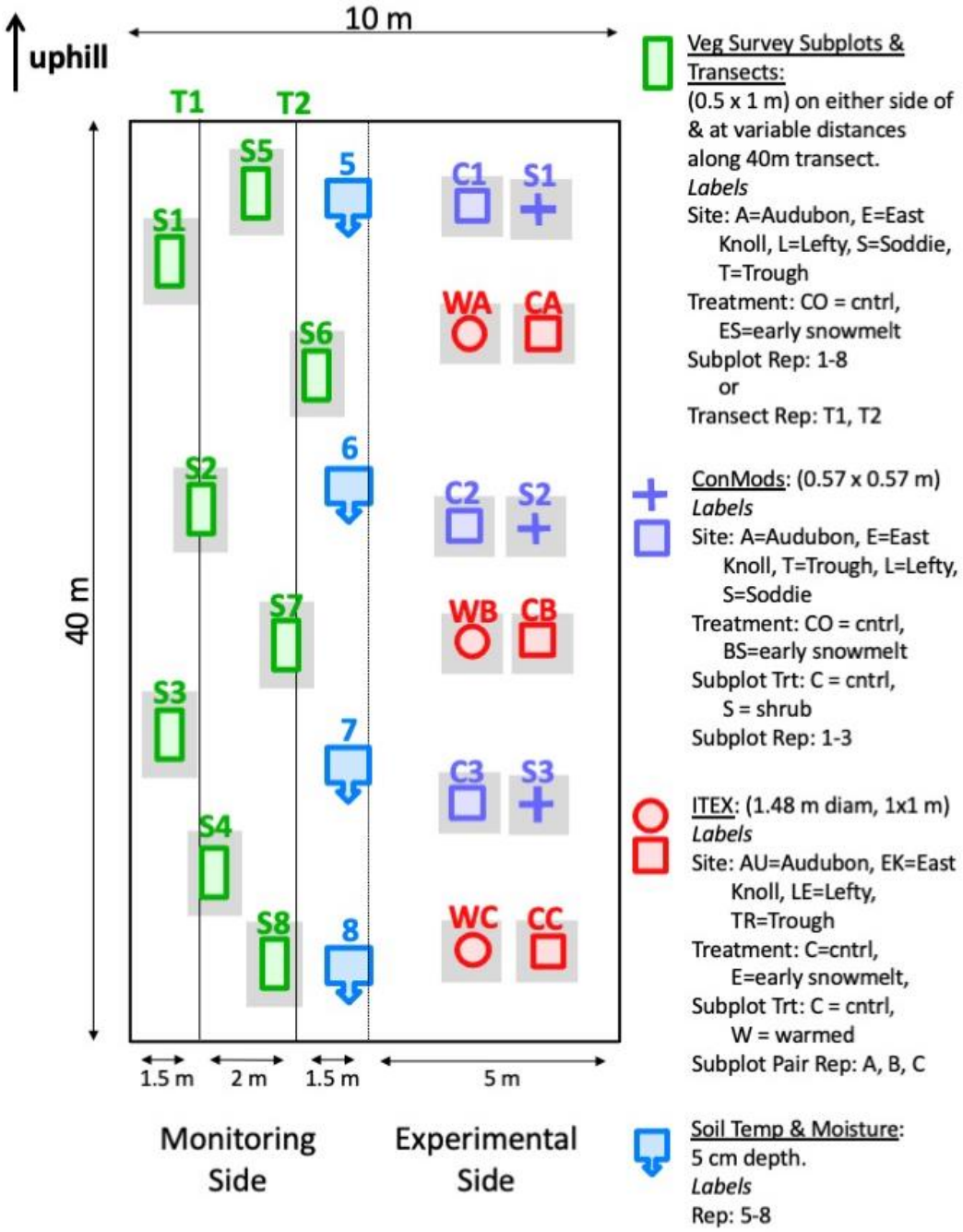
# I. Experimental Design

SITE MAP



PLOT MAP




## II. Sand, Snow & Soil Methods

BLACK SAND APPLICATION (spring and summer)

*Author(s):* Chiara Forrester
*Updated by:* Jane G. Smith on 1/27/2020 – added application dates for 2018 & 2019
JGS Spring 2021 – added applications dates for 2020
JGS 1/21/2022 – added applications dates for 2021

*Sand Information and Purchasing*
Product Link:
https://shop.waxie.com/mStorefrontTest/itemDetail.do?item-id=8077&order-quantity=1&customer-item=910550&order-uom=&warehouse-id=37&item-number=910550
Amount per plot: 500 lbs (10 boxes) = 567 g/m^2

*Sand addition date determination (spring and summer):*
Spring (early snowmelt treatment plots: 1) be in touch with Jen about snow conditions and see when they are doing the snow survey and do it around then, 2) follow the weather and watch for storms – try to do it after a storm.

Summer (control plots): Spread sand in plots in late June to early July.

*Sand application methods*:
Line up 5 boxes equally spaced along each side of the plot. Spread by hand (throwing) into plot (10 areas visualized per plot to achieve even distribution). Do not step in the plot to spread sand.

*Sand application safety:*
People spreading the sand should wear gloves and something to cover their airways (buffs or bandanas work) – the sand can be sharp and is easy to breathe in.

*Snow depth measurements:*
Snow depth was recorded from date of sand application in early snowmelt plots until both control and early snowmelt plots were completely snow-free. Snow depth was recorded 2-3 times per week

*Sand addition dates:*

| Year | Treatment | Audubon | East Knoll | Lefty | Soddie | Trough |
|---|---|---|---|---|---|---|
| 2018 | Early Snowmelt | 5/7/18 | 5/7/18 | 5/7/18 | 5/8/18 | 5/8/18 |
| | Cntrl | 7/16/18 | 7/16/18 | 7/16/18 | 7/16/18 | 7/16/18 |
| 2019 | Early Snowmelt | 6/3/19 | 5/23/19 | 6/3/19 | 5/23/19 | 6/3/19 |
| | Cntrl | 8/21/19 | 8/19/19 | 8/19/19 | 8/21/19 | 8/19/19 |
| 2020 | Early Snowmelt | 5/18/20 | 5/12/20 | 5/18/20 | 5/18/20 | 5/18/20 |
| | Cntrl | 8/17/20 | 8/3/20 | 8/17/20 | 8/22/20 | 8/22/20, 8/23/20 |
| 2021 | Early Snowmelt | 5/4/21 | 5/4/21 | 5/4/21 | 5/4/21 | 5/6/21 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Cntrl | 7/15/21 | 6/30/21 | 6/30/21, 7/15/21 | 7/8/21 | 7/15/21 |
| | | | | | | |
| | | | | | | |

### SOIL TEMPERATURE AND MOISTURE SENSORS

*Author(s):* Jen Morse

*Methods:* 4 Meter Group Teros 12 soil sensors per plot were installed in the black sand and control plots in late August and early September of 2018. Each set of 4 sensors has an associated Campbell cr300 data logger, battery and solar panel.

Sensors are installed at 5cm depth at generally 5,15,25,35 meters from top of plot, but with slightly with modified distances to correspond with vegetation plots ST5-ST8, ad sensors are labeled 5-8 (rather than 1-4) to coincide with vegetation plots ST5, ST6, ST7, ST8.

Sensors take a measurement every 30 seconds and record every hour the following variables: Volumetric Water Content (VWC), Soil Temperature, Electrical Conductivity

Sensor wires are encased in flexible aluminum conduit between ground surface and logger to prevent damage from small mammals.

## III. Vegetation Methods

### WHOLE PLOT SPECIES RICHNESS

*Author(s):* Jared Anderson-Huxley
*Updated by:* JG Smith on 01/27/2020
JG Smith in 2022

The whole plot species richness survey is intended to be conducted only in the first and last years of the experiment.

*Methods:* We used timed searches to quantify species richness in each 10 x 40 m plot. Prior to searching, plots were visually divided into three equal sections: top 0-13 m, middle 13-26 m, and bottom 26-40 m. Each section was searched by a team of 2-3 people for 15 person-minutes (e.g. 5 min search for a team of 3), moving from the bottom section to the top section, for a total of 45 person-minutes per plot. All team members participated in the identification of

species in the plot; one team member additionally served as the data recorder. If a species could not be identified immediately, it was marked with a flag and returned to after the search concluded. For any species that could not be identified in the field, we followed the UNKNOWN SPECIES COLLECTION protocol.

*Specific year notes:* Due to time limitation during the first year of the experiment (2018), no specimens of unknow species were collected. Temporary names were assigned to unidentifiable species and a description of the plant was written at the bottom of the relevant datasheet.

*Estimated time:* 30 minutes per plot for teams of 2-3 people (15 min for actual sampling with a team of 3, 15 min for transition time + identifying/collecting unknowns)

*Equipment List:*

- Binder with plot map, data sheets and unk. specimen collection sheets
- Hori hori & transparent tape for unknown sp collection
- Pencil
- Clipboard
- Stopwatch/phone
- Plant guide

*Dataset(s):* Plant Species Richness
*Dataset years:* 2018

## SPECIES COMPOSITION

*Author(s):* Jared Anderson-Huxley, Jane G. Smith
*Updated by:* Jane G. Smith on 01/27/2020
JGS on 03/10/2021
JGS on 01/21/2022

*Methods:* Species composition in transects and subplots was measured using a point-intercept method, in which the identity of every species touching a pin flag at a designated point was recorded. At each point, species hit were recorded in the order, top to bottom, that they touched the flag. If a species touched the flag multiple times it was only recorded once, at its highest point of contact. If the flag reached the ground surface, i.e. did not pierce a dense patch of plant growth at the bottom, ground surface substrate (bare ground, litter or rock) was recorded as the lowest hit in 2018-19. From 2020 onward, ground surface was recorded only when nothing else was hit.

All senesced plant biomass that was clearly from a previous year's growth was identified as 'litter'. In 2018, if both live biomass and litter were hit at a single sampling point, they were recorded in the order they were hit, top to bottom. In 2019, if both live biomass and standing

dead litter were hit at a single sampling point, live biomass was always recorded as the uppermost hit. In 2020 onward, if both live biomass and litter were hit at a single sampling point, only live biomass hits were recorded; litter was recorded as hit only when no live biomass was hit. For all years, if both standing dead and decumbent litter were hit at a single point, litter was only recorded once.

Coarse woody debris (CWD) was not differentiated from 'litter' until 2020 onward.

'Lichen' was recorded only for lichen growing on soil, not rock. 'Rock' included fragments at least 3 cm in diameter or generally large enough to prevent something from growing; anything smaller was identified as 'bare.'

Any species that could not be identified in the field was assigned a temporary name. A specimen of the unknow species was collected from outside of the plot and brought back to the lab for identification (see UNKNOWN SPECIES COLLECTION).

*Specific year notes:*
Due to time limitation during the first year of the experiment (2018), no specimens of unknow species were collected. Temporary names were assigned to unidentifiable species and a description of the plant was written at the bottom of the relevant datasheet.

Additionally, methods used in 2018 but changed in 2019:

- Aboveground biomass arising from a plant clearly rooted outside of the sampling subplot, was not counted as hit.
- At a particular sampling point, if the end of the flag "pierced" the middle of a broad plant leaf, ground surface substrate below was not recorded.
- Anything composed of rock was recorded as 'rock' regardless of size (e.g. small-sized rocky gravel was also labeled 'rock').

*Estimated time:* 1.5 hours per 1 transect for a team of 2 people
30 minutes per subplot for a team of 2 people

*Equipment List:*

- Binder with plot map, data sheets and unk. specimen collection sheets
- Hori hori & transparent tape for unknown sp collection
- Plant guide
- Pencil
- Clipboard
- Pin flag
- Transect tape, 50 m (transect)
- String for repairs (transect)
- 1m x 0.5m quadrat with string grid (subplot)
- Replacement nails

## A. Transect Species Composition

The purpose of the transect species composition is to examine changes in species composition across community types.

*Methods:* In the monitoring side of each plot (left-side when facing uphill), we established two 40 m transects running parallel to the plot edge (see PLOT MAP). Transects 1 and 2 are 1.5 m and 3.5 m, respectively, from the left edge of the plot (facing uphill). Transect start and end points were permanently marked with rebar, and nails were installed at 10 m intervals along a straight line in between, all connected by a taut string. A tape measure was stretched along the length of string, i.e. between the rebar, contacting all nails in between, in order to keep sampling consistent across years. Transects were labeled by site, experimental treatment, and transect number, e.g. transect 2 in the early snowmelt treatment plot of the East Knoll site is called 'E ES T2'.

Starting 10 cm down from the upper transect rebar, species composition was measured by recording the identity of every species touching a pin flag dropped straight down to the left of the string (facing uphill) every 20 cm. See SPECIES COMPOSITION for more methods details.

In 2018-19, if the transect crossed a shrub or conifer, we recorded the species identity and the start and stop points of intersection along the transect. This data was recorded at the bottom of transect species composition datasheets in the 'shrub start/stop' section.

*Suggested Improvements:*

- The string along each transect does not last even through a single summer field season and the nails at 10 m intervals in between the rebar marking the transect ends are frequently pulled out of the ground. During the string and nail replacement process, as well as over the winter due to freeze-thaw, the exact position of the string inevitably shifts, thus moving the exact placement of the sampling points. The transect species composition data will not be perfectly replicated in its spatially explicitness through time, unless the string is replaced with something more permanent and durable. Additionally, it is unlikely that the measuring tape start point is perfectly replicated every year, especially with a measuring tape that starts at 30 cm, further altering the location of sampling points.
- In 2020 we replaced nails with 12" galvanized, spray-painted nails that will stay in place better and be more visible. Because the string running the length of the transect lasts less than a season and basically just ends up creating a bunch of tundra trash, we stopped stringing transects in 2020. We used landscape staples to secure the measuring tape in the proper place near each nail along the transect. This method worked well.

*Dataset(s):* Transect species composition

*Dataset years:* 2018, 2019, 2020, 2021

## B. Subplot Species Composition

The purpose of subplot species composition is to examine how species composition changes within community types.

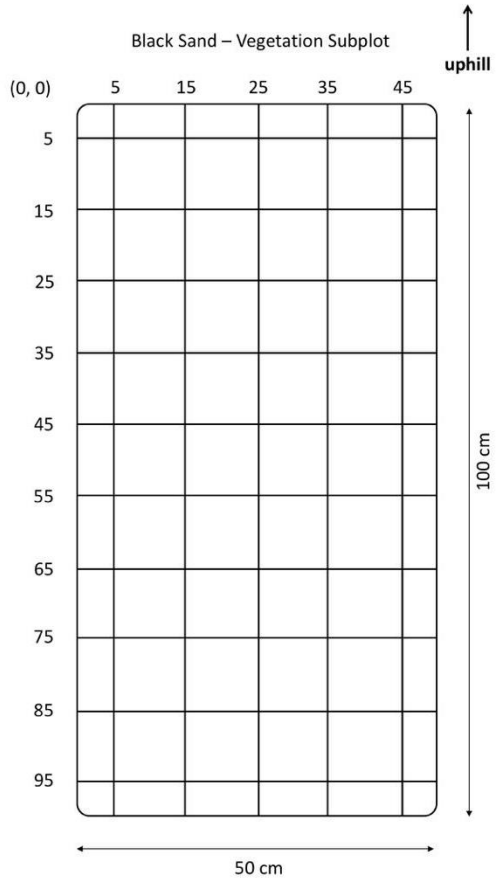
*Methods:* Along each transect we established four 1 x 0.5 m subplots, for a total of 8 subplots per plot, in areas where the vegetation composition reflected that of the whole plot. Subplots were oriented so that the 1 m subplot edges were parallel with the 40 m plot edges and transects, and the 0.5 m subplot edges were parallel with the 10 m plot edges. Subplots were paired between treatment and control plots so as to have similar dominant species present, e.g. in treatment subplot 1 and control subplot 1. Subplots 1-4 are located on transect 1 and 5-8 on transect 2, with 1 and 5 always located at the top (most uphill) of their respective transects with subplots descending numerically from the top to the bottom (most downhill) of the plot (see PLOT MAP). Subplots are labeled by site, experimental treatment, and subplot number, e.g. subplot 7 in the control plot at Audubon was called 'A CO 7'. All four plot corners are marked with nails, and 2 extra nails with whiskers attached were also used to mark opposite corners to make plots more visible. In 2020 all nails and whiskers were replaced with 12" galvanized nails, painted a bright color, that will stay in place better, be more visible and generate less trash to be left in the tundra.

Subplot species composition was measured using a 1 x 0.5 m quadrat with a 10 x 10 cm interior string grid that included 50 intersection points. Grid intersection points are numbered so that, looking uphill, the grid origin (0, 0) is in the upper left-hand corner. Grid points start at 5 cm horizontally and vertically from the origin and continue at 10 cm intervals (see vegetation subplot diagram). We recorded the identity of every species touching a pin flag dropped straight down in the upper left corner of 50 grid intersection sampling points. See SPECIES COMPOSITION for more methods details. Species found present in the subplot that were not hit at any of the grid intersection points were recorded separately at the bottom of the field data sheet.

*Specific year notes:* In year one (2018), the string grid in our pvc quadrat frames was held in place using duct tape. This poor design lead to the string's loosening up and shifting in position over the course of the summer.

In 2019, we found that almost none of the 1 x 0.5 m PVC grid frames fit perfectly over the four subplot corner nails, likely because with all the rocks in the ground it is impossible to place nails exactly where desired. Therefore, PVC frames were placed so that corners were as equally close to all four corner nails in the ground, i.e. frames were centered within or around the four nails.

*Dataset(s):* Subplot species composition
*Dataset years:* 2018, 2019, 2020, 2021




## WOODY SPECIES DEMOGRAPHY

*Author(s):* Jared Anderson-Huxley

*Methods*: To sample woody species demography, we mapped, marked, and measured every *Salix* and conifer growing inside plot boundaries. Individuals were mapped on an x-y coordinate system with the top left-hand corner when facing uphill as the origin (0 m, 0 m). Individuals were marked with a common garden tag labeled with the site, experimental treatment, individual identity (*Salix* or conifer), and a number based on the order of discovery within the plot, e.g. the 5$^{th}$ *Salix* discovered in the early snowmelt treatment plot at the Trough site was labeled 'T BS S 5'. To approximate volume, we recorded canopy height, length and width of each woody plant. Height was measured as the distance from the ground to the highest point on the woody individual. Length was measured as the longest axis across the plant canopy. Width was measured as the canopy axis perpendicular to the length axis at the midpoint of the length axis. Measurements were typically made using a meter stick or tape measure, however, some exceptionally tall conifers required the use of a marked snow pole for measuring height.

In both plots at the Soddie site, some conifers were growing so close together they could not be individually distinguished. We termed these clumps "krumholtz" and labeled them with a "K", not a "C", in the data. Krumholtz were mapped with the x-y coordinates of the clump boundaries to delineate a polygon of their basal area. To determine krumholtz average heights, we measured height every 25cm along the longest axis of the polygon. Some parts of the krumholtz were so tall they required visual estimations of their height in reference to a snow pole. Krumholtz volume was calculated by multiplying the clump basal area by its average height.

*Suggested Improvements:*

- Tags were attached to branches and stems using relatively thin gauge wire. Replacing these with thicker gauge wire would ensure that no tags are lost over the winter.
- Width estimates could be improved if they were measured as the longest distance across the woody individual while perpendicular to the length axis, instead of as the distance across the woody from the midpoint of the length axis while perpendicular to the length axis. Finding the midpoint of the length axis is difficult and requires more subjective judgement than determining the longest distance perpendicular to the length axis. While this change would likely overestimate the actual volume of the salix, it would improve the precision of our estimates of salix volume across time.
- Our estimates of krumholtz and conifer height over 3m should not be trusted. Using a hypsometer (or a similar device) to measure the height of tall trees would greatly improve the accuracy and precision of these measurements. Alternatively, these larger individuals could be given a "T" label (for tree) and diameter-at-breast height measured.
- Future samplers should scan plots (15 minutes?) to identify any woody individuals that may be new or were not marked in the previous year.

*Specific year notes:*

*Estimated time:* The amount of time varied wildly between plots. Some plots had very few (East Knoll, Lefty) or no woody individuals (Audubon). These sites were all sampled in a single day. Others (Trough, Soddie) had numerous woody individuals and took 2+ days for each site. However, woody demography resampling will likely go much faster in future years, as most woody individuals have already been mapped and marked.

*Equipment List:*

- Binder with plot map, data sheets and unk. specimen collection sheets
- Pen/pencil
- Clipboard
- Meterstick
- Transect tape
- Marked snow pole
- Hypsometer
- Gardening tags and gauge wire (to replace missing tags)

*Dataset(s):*
*Dataset years:* 2018

## CON-MODS

*Author(s):* Laurel Brigham

*Methods:* In the alpine tundra, shrubs modify wind distribution of snow, increasing snowpack on the leeward side of shrubs. In order to mimic this abiotic effect of shrubs, snow-retention structures call connectivity modifiers, hereafter referred to as con-mods, were deployed in black sand experiment plots in September 2018. In each of the ten 10 x 40 m plots, there are 3 con-mod "shrub" subplots paired with 3 control (no con-mod) subplots. Con-mods were place on the experimental side of plots (on the right side when looking uphill), a minimum of 1 m distance from all existing observational and experimental plots. The con-mods are constructed using rebar and hardware cloth to form an X[1]; they are 30.5 cm tall and each panel of the X is 40 cm, forming a subplot that is 0.57 m x 0.57 m (0.32 $m^2$) (Fig. X). The con-mod control subplots are placed to the left of the con-mods at a similar elevation and are also 0.57 m x 0.57 m (0.32 $m^2$). All control subplots are marked with nails at their corners. Efforts were made to have similar vegetation composition in each con-mod "shrub" and control subplot replicate pair.

Figure X. A con-mod located in a black sand plot.

*Naming convention:*

Each subplot is named using an alpha-numeric code that denotes the site, the plot treatment, the con-mod subplot treatment, and the con-mod subplot pair replicate, where pair 1 is found at the top of the plot (upslope) and pair 3 is found toward the bottom of the plot.

**Site** (A=Audubon, E=East Knoll, T=Trough, L=Lefty, S=Soddie)

**Plot Treatment** (CO=control, BS=early snowmelt)

**Subplot Treatment** (con-mod present = S(hrub), con-mod absent = C(ontrol))

**Subplot** Pair Rep: (1-3)

Example: ACOS3 is the con-mod subplot at the bottom of the control plot at Audubon.

## ITEX

*Author(s):* Chiara Forester

*Methods:* During the summer of 2018, ITEX warming experiment subplots were established within each 10 x 40 m plot. Subplot locations were chosen to contain the most similar plant community composition between and within early snowmelt and control plots at a site. In each treatment plot (early snowmelt or control) there were three warming subplots, each paired with a control (ambient temperature) subplot.

Warming chambers, designed like those used in the International Tundra Experiment (ITEX), were used to increase growing season temperature. ITEX chambers are conical, measuring 1.48 m in diameter, and cut from Sunlite HP 0.040" x 5' x 10' sheets (see ITEX chamber diagram below). Chambers were installed immediately following snowmelt and removed (stored until next field season) after the first snowfall that sticks in the Fall.

Species composition was measured in ITEX plots using a 1 x 1 m quadrat frame containing a 10 x 10 cm grid for a total of 100 sampling points. Plants interceptions recorded at each point were identified following the SPECIES COMPOSITION methods described above.

*Naming convention:*

Each subplot is named using a code that denotes the site, the plot treatment, the subplot warming treatment, and the subplot pair replicate, where pair A is found at the top of the plot (upslope) and pair C is found toward the bottom of the plot.

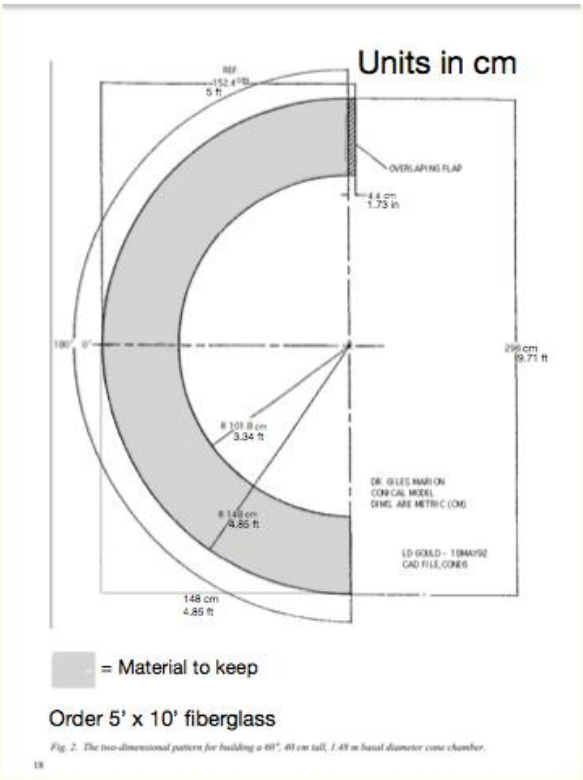
**Site** (AU=Audubon, EK=East Knoll, TR=Trough, LE=Lefty, S=Soddie)
**Plot Treatment** (E=early snowmelt, C = control)
**Subplot Treatment** (W = warmed, C = control)
**Subplot** Pair Rep: (A-c)

*Specific year notes:*

In 2018, some ITEX chambers blew away (but were successfully retrieved) during the strong winds in Fall. Larger landscape staples will be used in 2019 to try and prevent chambers blowing away.

ITEX plots were not established at the Soddie site until 2019, after which time they were surveyed annually only for species composition.

ITEX chamber design:




## ANPP HARVEST

*Author(s):* Jane G. Smith
*Updated by:* Jane G. Smith on 01/27/2020; JGS on 10/29/2021

*Methods:* We began aboveground plant biomass harvesting in 2019 to get an estimate of aboveground net primary productivity (ANPP). In each 10 x 40 m plot, aboveground biomass was clipped from eight 20 x 20 cm harvesting subplots located approximately 1-3 m above (2019) or below or to the left or right when looking uphill (2021) of each of the eight subplots, in an area with plant cover representative of that within the subplot. Clipped biomass from each harvesting subplot was separated into 'live' and 'litter' in 2019. In 2021 only live biomass was harvested. After harvesting, biomass was put in paper bags and dried in the oven at 60 C for at least a week before weighing.

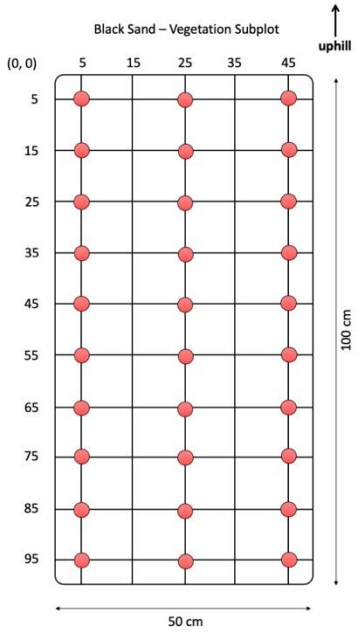
*Specific year notes:*
*Datasets:* ANPP
*Data years:* 2019, 2021

## CANOPY HEIGHT

*Author(s):* Jane G. Smith

*Updated by:* Jane G. Smith on 10/29/2021

*Methods:* Canopy height was measured shortly after peak biomass in the eight 1 x 0.5 m species composition subplots within each 10 x 40 m plot. Within each subplot, the same pin flag and point-intercept grid frame used for species composition were used to measure the height of the highest point of interception of live (current year's growth) vegetation with a pin flag placed vertically at 30 points in each subplot. The 30 points consisted of the 10 points along the first, third and fifth rows parallel to the 1 m sides of the subplot (red dots in diagram). At points where only plant litter (previous year's growth) or no plant biomass was hit, a height of 0 cm was recorded.




*Specific year notes:*
*Datasets:* Canopy Height
*Data years:* 2021

## NDVI

*Author(s):* Jane G. Smith
*Updated by:* Jane G. Smith on 10/29/2021

*Methods:* NDVI was measured weekly, weather allowing, in the eight 1 x 0.5 m species composition subplots within each 10 x 40 m plot, using a Trimble GreenSeeker handheld crop sensor. Initially we tried to make measurements within two hours of solar noon (around 1 pm), but this proved difficult with mid-day storms and, based on some testing, did not seem to produce significantly different measurement values than taking measurements at any other time of day. The GreenSeeker detects NDVI across an area approximately 0.5 m wide when held 4 feet above the ground. Since subplots are 0.5 m wide, the GreenSeeker was held 4 feet above each subplot while scanning along its 1 m length. Each subplot was scanned at least 3 times to make sure readings were consistent before recording the reading.

*Specific year notes:*
*Datasets:* NDVI
*Data years:* 2021

## UNKNOW SPECIES COLLECTION

*Author:* Jane G. Smith

*Method* (from Niwot_UnkSpecimenCollectionGuidelines.docx):

Any species that cannot be identified in the field should be collected for identification back in the lab. To collect a specimen, find ***at least two*** individuals of the same species growing near-by, ***outside of*** the plot. Try to find specimens with good leaves and flowers (and rhizomes, where relevant).

Use a hori hori to extract the aboveground and as much of the belowground biomass as possible of an intact individual. Remove soil from the plant and use ***transparent***, not satin, tape to attach it to an unknow specimen page (NWT_UnkSpecimen.docx). Try not to tape over key characteristics, i.e. ligule, leaf, inflorescence. Fill in all the information on the unknow specimen sheet (date, site, plot, unknow code name, community, growth form, growth habit, rhizomatous, notable characteristics, what you think it is and why).

The specimen can be given any code name, as long as it is unique. Include the code name on the unknown specimen collection sheet and the relevant species composition data sheet. If the same unknow species is found in another plot, you do not need to collect another specimen; just use the same code name in the sp comp datasheet and add the name of the new plot and site to the same unknown specimen sheet.

If you think you know what something is but want to collect a specimen just to make sure, give it the code name of the six letter code of the species you think it is followed by a question mark, e.g. 'CARALB?' Also make a new category on the sp comp data sheet with the same code name.

Specimens should be stored in the relevant project field binder. In the lab, try to identify the species, making detailed notes on the unknow specimen sheet about the characteristics you find that support its identity. Above your notes, include your name and the date on which you made them. After a specimen has been positively identified, go back to the sp comp datasheet and indicate what the unknow species is. Also, update unknow species in the data if it has already been entered.

After the field season is finished and unknown specimens have been identified, they should be stored in the lab Unknow Specimens binder for the relevant project.

*Specific year notes:*

In year one (2018) no unknown species were collected. For any unidentifiable species, a temporary name was assigned and description of the plant was written at the bottom of the datasheet.