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Snowpack profiles

Motivation

Snow conditions have pronounced impacts on conditions experienced by plants and animals during winter. Climate change increases the frequency of mild winters and winter rain, resulting in ice layers. Ice layers prevent movement of small mammals and hamper herbivores access to food. Changes of snow conditions are therefore expected to have large consequences to herbivore population dynamics. The snow pack measurements are connected to monitoring of the rodent community and their associated mustelid predators, and are a part of COAT Varanger's small rodent module.

State variables:

- CT2 snow depth
- CT3 snow structure
- CT4 ice thickness

Reference(s) to method: We conduct measurements of snow profiles based on a protocol written by Jean-Charles Gallet.

Spatial study design

The snowpack profile measurements are conducted COAT Varanger's intensive locations; Komagdalen and Vestre Jakobselv. At both locations, snowpack profiles are measured according to three designs:

1. River valley sections: Snow pits are dug associated with 15*15 quadrats in heath and meadow habitats were small rodents are trapped in early summer and each fall each year. Recco-bricks have been placed at the precise location for the snow pits and are located a few meters outside the 15*15m quadrats. When willow thickets are present, the recco is placed at a similar distance of the thicket edge as the outer edge of the quadrat (but in no case inside any thicket). The spot selected for recco has approximately similar vegetation, microtopography etc as the quadrat (i.e. snow conditions at this site should be representative for snow conditions of the quadrate.

2. Camera trap monitoring of lemmings: Snowpack measurements are made at a subset of sites where the camera traps are placed both in lemming summer habitat (hummock tundra) and in winter habitat (snow beds). See description for "lemming block" sections in the study design protocol for COAT. The pit should be dug at the recco-brick that is placed 15m sideways relative to the position of the camera trap to avoid disturbance of the snow pack close to the trap.

3. Weather station transect: Six snow pits are dug along a transect from the COAT weather station in willow thicket belt (Torvhaugen) to the station at discontinuous vegetation zone (Reinhaugen).

A complete list of siteIDs included in the current data collection is included in the Appendix. The sites are include in GPS-files “small_mammal_cameras_2019.gpx”, “intensive quadrats Varanger 2019.gpx”, and “Snowprofiles_VJ_weather stations transect.gpx” stored in the COAT Box folder Fieldwork/Varanger GPS files for fieldwork. Specific coordinates for the snow pits within site are given in a separate file “recco_coordinates_COAT_Varanger_2024.gpx”. These were marked with recco detector bricks during 2019-2023, but the recco brick setup is no longer in use.

Temporal study design

At heath, meadow, and hummock tundra sites one snow pit is dug in late March. At sites along the weather station transect snow profiles are recorded throughout the winter approximately at one month’s interval, with focus on early winter.

Procedure

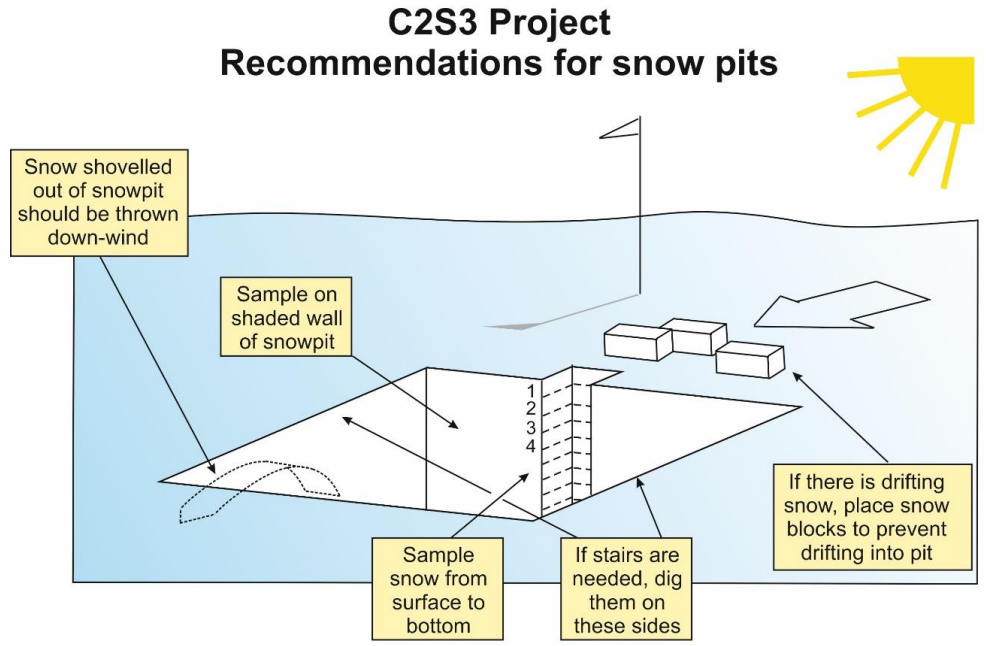
Dig a **large enough** snow pit so that you can conduct your sampling comfortably, and without touching or hitting the snow wall accidentally. If the pit is deeper than 1 m, a good idea is to make a step that can be used as a shelf to place sampling containers/tools onto. It is critical to **excavate the snow pit properly**. Taking 5 more minutes to properly excavate the snow will also help you to better distinguish layers and do better measurements.

The snow extracted from the pit should be disposed at a good distance on the **downwind side**, to avoid having it slump or drift back into the pit. On windy days, you may want to place snow blocks on the surface, one meter upwind of the snow pit, to deflect drifting snow from the snow pit. **Avoid trampling the snow surface between those blocks and the snow pit itself**.

The face of the snow pit to be examined and/or sampled should be on the **Sun-shaded side**, so when digging, take into account the Sun's movement across the sky during your work. (See figure below).

If the bottom is covered with continuous ice layer, it is not necessary to dig through the ice.

After digging the snowpit, record first the temperature profile (this starts to change quickly, so it’s important to do it first). Thereafter, record the snowpit depth, layer structure, bottom vegetation, and presence of ice in the bottom. Finally record the snow density.



Equipment needed

- Shovels
- GPS, pencils, datasheets
- Snow profile kit (black pelicases) containing:
    - Digital thermometer to measure snow temperature
    - A snow cutter with 100 cm^3 capacity to measure snow density
    - Digital weighing scale with a maximum load of 2000 g and a precision of ± 1 g
    - Folding rulers (1 and 2 m, plastic) to record snow depth
    - Several plastic and one stainless steel spatula(s)
    - Two brushes
    - A snow saw and a knife
- Penetrometer
- Recco detector

Information recorded in the field

Information is recorded in a field data sheet called “fieldsheet_snowpits_COAT_2020”, stored in the COAT Box folder Protocol/data sheets for writing data in field.

General information about the site: site ID (or GPS coordinates if not an established site); date and time before and after the snow pit observations; surface meteorological conditions: air temperature 1m above the surface, sky conditions (clear sky or clouds), wind speed and direction, precipitation, presence of fog; the total depth of the snow pit; bottom vegetation in terms of presence of grass and moss (just as groups) and the species/genera of shrubs (Vaccinium spp., Empetrum nigrum, Betula nana and Salix); presence of ice in the bottom (no ice, patchy ice, continuous ice). Basal ice thickness in cm.

Snow pack temperature profile: Start at the air/snow surface, and take temperature measurements every 5 cm near the surface (down to 20 cm below surface), and then every 10 cm. The last measurement should be at the bottom (snow/ground interface).

Remember to place your thermometer at the shade of your body for example (also protect it from the wind), so you get a good estimate of air temperature. Sun and wind affect temperature measurement. Note any additional comments about things that could affect your observations.

Layer structure: Put a ruler on the face of the pit to record the depth of the measurements and stratigraphy, the 0 cm level being at the bottom of the snow pit (0 = soil). For each layer, note

- the depth it starts and ends
- snow hardness using the hand test (see table below)
- Snow hardness using the penetrometer. Three replicates per layer at the same depth. Record the depth where you took the measurements. Set the penetrometer to "c-pk".
- snow grain size (fine (< 0.5 mm), medium (0.5-1.0 mm), coarse (> 1.0 mm)
- Further information about the snow type if possible (e.g. fresh snow, crust, hoar, wind affected snow, ice…)

Term	**Hand hardness test**	**Code**	**Symbol**
Very soft	Fist	F	
Soft	4 fingers	4F	
Medium	1 finger	1F	
Hard	Pencil[1]	P	
Very hard	Knife blade	K	
Ice	Ice	I	

Snow density: Density (i.e. weight for a fixed volume snow sample) should be measured in <u>each stratigraphically distinct layer</u>, unless a layer is too thin, or discontinuous, or too hard or loose to be sampled. Use the sampling tools provided, which include a 100 cm^3 cutter.

Begin by weighing the empty cutter on the scale, and record its weight or press the zero button on the scale so you do not take into account the weight of the cutter. Weight the samples within the cutter on the scale. Snow density often ranges from 50 kg m^{-3} for fresh light snow to 450-550 kg m^{-3} for wind pack or melt refrozen layers (however values as low as 20 kg m^{-3} exist).

If there are large disparities in the snow density within the same layer, take separate measurements. If you encounter a thick snow layer (e.g., 20 cm), you can take several measurements (top/middle/bottom of the layer) at different positions in the layer. Record also the depth of the snow sample (0 cm at the bottom of the snowpit).

<u>Data processing</u>

All field observers are in charge of typing their data into digital format (unless otherwise agreed with the data set responsible, in this case Nigel Yoccoz). The data is split into several files, according to measurement type. Accordingly, the data is typed using several templates:

"template_general_info _snowpits_COAT.xlsx"

"template_snowprofile_snowpits_COAT.xlsx"

"template_temperature_snowpits_COAT.xlsx"

“template_density_snowpits_COAT.xlsx”

“template_pressure_snowpits_COAT.xlsx”

These are stored in the COAT Box folder Protocol/Data typing templates. A new file is created for each year, locality and data type; for example “VJ_2017.txt”. The template file includes additional information on how to record specific types of observations in the template. Follow the datasheet exactly; use exactly the same column names, large/small letters, for factorial values do not add new categories etc.

After completing a data file in excel, it should be saved as txt-file. Thereafter (unless otherwise agreed), data files are sent to dataset responsible who will quality-check them and store them in COAT data portal.

Training requirements and specialized skills

All new observers should get introduction to the used instruments, and preferably dig their first snowpits together with more experienced observers. They should also calibrate their snow-hardness scale (i.e. hand test measurements), preferably with a snow researcher/geophysicist.

To obtain reliable estimates of snow hardness, it is important to press the penetrometer into the snow applying a relatively constant strength. Use a moment in the start of the field season to train taking these measurements. Take several measurements in the same layer and compare the results to get a feeling how the penetrometer should be pressed into the snow to get similar values. Repeat a few times for softer and harder layers.

Appendices

List of sites where the snow profiles should be done annually at Vestre Jakobselv.

Locality	Section	Site	Comment
Vestre Jakobselv	Torvhaugdalen	vj_to_m_a	
		vj_to_m_b	
		vj_to_m_c	
		vj_to_m_d	
		vj_to_hn_a	
		vj_to_hn_b	
		vj_to_hn_c	
		vj_to_hn_d	
	Bearalveaijohka	vj_be_m_a	
		vj_be_m_b	
		vj_be_m_c	
		vj_be_m_d	
		vj_be_m_e	
		vj_be_hn_a	
		vj_be_hn_b	
		vj_be_hn_c	
		vj_be_hn_d	
		vj_be_hn_e	
	Jakobselv	vj_vj_m_a	
		vj_vj_m_b	
		vj_vj_m_c	
		vj_vj_m_d1	
		vj_vj_hn_a	
		vj_vj_hn_b	
		vj_vj_hn_c	
		vj_vj_hn_d1	
	Reinhaugen	vj_re_hu_1	
		vj_re_hu_4	
	Gåsevannan	vj_ga_hu_1	
		vj_ga_hu_5	
	Skoarrajohka	vj_sk_hu_1	
		vj_sk_hu_6	
	Tranemyra	vj_tr_hu_3	
		vj_tr_hu_6	
		vj_tr_hu_1	

List of sites where the snow profiles should be done annually in Komagdalen. Additional snow profiles can be dug if time allows, start by adding one snow-pit in the middle of the sections ko and km (meadow and heath sited d).

Locality	Section	Site	Comment
Komagdalen	komagdalen_ovre	ko_ko_m_a	
		ko_ko_m_e	
		ko_ko_hn_a	
		ko_ko_hn_e	
	komagdalen_midtre	ko_km_m_a	
		ko_km_m_e	
		ko_km_hn_a	
		ko_km_hn_e	
	sandfjorddalen	ko_sa_m_a	
		ko_sa_m_d	
		ko_sa_m_f	
		ko_sa_hn_a	
		ko_sa_hn_d	
		ko_sa_hn_f	
	Ryggfjellet	ko_ry_hu_1b	
		ko_ry_sn_1	
	Gargas	ko_ga_hu_2	
		ko_ga_sn_2b	Until 2022
		Ko_ga_sn_6	Since 2023
	Hubejohka	ko_hu_hu_2b	
		ko_hu_hu_5	
	Kjøltindan	ko_kj_hu_4b	
		Ko_kj_sn_22	

List of sites where the snow profiles should be done several times per winter

Region	Site
Vestre Jakobselv	vj_wst_1
	vj_wst_2
	vj_wst_3
	vj_wst_4
	vj_wst_5
	vj_wst_6