2007 Expedition to Yamal Peninsula Region, Russia

Donald A. Walker, Howard E. Epstein, Elina Kaarlejärvi, Patrick Kuss, Marina O. Leibman, Nataliya G. Moskalenko, George V. Matyshak
Locations

- Nadym
- Laborovaya
- Vaskiny Dachi
Members of the Expedition

Nadym

Laborovaya and Vaskiny Dachi
Logistics

Laborovaya

Vaskiny Dachi

Field camp at Laborovaya
Nadym

ND-1, forest site
ND-2, CALM grid

Forest and hummock tundra (northern boreal forest)
• Nadym-1, sandy fluvial terrace, 20-40 kya
• Nadym-2, sandy fluvial terrace, deep organic, 60-80 kya
• Both sites lichen-rich due to lack of recent reindeer grazing
• Both sites are sandy
Southern tundra (subzone E)
• Heavily grazed by reindeer
• Mesic tundra with clayey vs. sandy substrate
Vaskiny Dachi

VD-1, Terrace IV  
VD-2, Terrace III  
VD-3, Terrace II

Typical tundra (subzone D)
- Terrace IV - clayey marine plain, 130-117 kya
- Terrace III - mixed clay and sand fluvial marine terrace, 75-25 kya
- Terrace II - sandy fluvial terrace, 25-10 kya
- Heavily grazed by reindeer
Vaskiny Dachi

- Unique permafrost conditions
- Landslide successional sequences
- Willows on old landslides
Typical sampling strategy (1)

- 5 50-m transects
- 5 10x10-m plots
- 1 soil pit
- Adjustments for homogeneous zonal vegetation
Typical sampling strategy (2)

Plot and transects

Soil pits
Data collected (1)

Transects

- Species cover (Buckner sampler)
- Forest structure, (Point-centered quarter method, density, basal area, biomass)
- Leaf area index (LAI-2000)
- NDVI (PSII)
- Active layer thickness (thaw probe)
Data collected (2)

Study plots (relevés)

- Species cover (all species, cover estimates)
- Site descriptions (vegetation structure, photos, geology, thaw depth, etc.)
- LAI and NDVI
- Biomass (harvest, 20 x 50-cm plots)
- iButtons for N-factor determination

Biomass harvest

iButton
Data collected (3)

Soil pits
- 1–2 soil pits at each site
- Descriptions according to US soil taxonomy (G. Matyshak)
- Methane and trace-gas production

Soil samples from each relevé
- Will be analyzed at UAF for physical and chemical properties
Data Report

- Background for the project,
- General descriptions of each locality with photographs,
- Maps of the sample sites,
- Summary of sampling methods
- Tabular summaries of data
- Soil descriptions with photos
- Photos of each study plot
- Contact information for participants
- Species lists
- Appendices with methods
- Available in hard copy and online (pdf)
- Raw data files available from Alaska geobotany center
Other data collected but not included in the data report

- Permafrost temperature logger information
- CALM data at Nadym and Vaskiny Dachi
- Thesis projects of Gubarkov, Khomutov, Orekhov and others
- Soil chemical and physical analyses

30-m borehole near Nadym CALM grid
Cover/Biomass Report

• The importance of biomass and cover data
• The current problems with tundra biomass and cover data
• The approaches used on the Yamal transect
• Results
The importance of cover and biomass data

Needed for:
- interpreting space-based spectral data (NDVI),
- developing ecosystem-permafrost relationships (N-factor),
- detecting long-term changes to land-cover,
- detecting changes in forage quality.

*Walker et al. 2003, JGR, 108 D2 8169.*
Numerous studies have shown a general trend of increased NDVI in the Arctic, but...

"Should we believe in the NDVI trend? There are no "ground truth" measurements of photosynthesis at northern high latitudes over the same period, and so the accuracy of the trend cannot be established unambiguously.... It will be a challenge for ecologists to explain how photosynthesis could possibly have increased by approximately 10% from 1981 to 1991." (Inez Fung, 1997)
“What does NDVI really mean in tundra systems... particularly for reindeer and caribou?”

Some areas with low NDVI have high forage quality for reindeer.

Bright green areas may be dominated by species such as alder or dwarf-birch, which have abundant toxic secondary plant compounds that protect them from grazing.
Some problems with existing biomass data

- Vegetation type often unknown.
- Soil and site factor information missing.
- Harvest methods not documented.
- Not georeferenced.
- Replication not documented.
- Not linked to NDVI, LAI, or other cover properties of the vegetation.
- Definitions of biomass components unclear.

*e.g.* Not a clear definition of where the soil surface is or what is dead component of biomass.
Cover data are even worse...

- Usually cover is estimated.
- Unable to replicate the data.
- Very few good quantitative methods (e.g. point frames).
- Most are very time consuming.

Buckner point-intercept sampler
- Developed for mining reclamation studies.
- Quick, objective, easy to replicate.

Biomass standards needed

International CBMP workshop proposed to standardize vegetation sampling procedures.

Yamal methods are fully documented in Appendix D of the data report.
Plant functional types
Categories based largely on plant growth forms, used in modeling efforts.

- evergreen shrub
  - stem
  - live foliar
  - attached dead foliar
  - reproductive
- deciduous shrub
  - stem
  - live foliar
  - attached dead foliar
  - reproductive
- graminoid
  - live
  - attached dead
- forb
- equisetum
- bryophyte (mosses & liverworts)
  - live
  - dead
- lichen
  - live
  - dead
- algae
- litter (all unattached dead plant parts)
- soil and roots (belowground)
Biomass along the Yamal transect

- Climate trend for tundra and understory and tundra vegetation: 2000–2300 g m⁻² at Nadym to about 1000–1300 g m⁻² at Vaskiny Dachi.
- Total biomass determined by allometric equations (Zianis 2005), adds another 4,121 g m⁻² ± 851 g m⁻² to Nadym forest site.
- Sandy soils have 250–350 g m⁻² less biomass than comparable clayey sites, with much more lichen biomass and less mosses and graminoids.
- Lichen biomass was especially large in the ungrazed sandy areas near Nadym – over 1000 g m⁻² in two areas studied at Nadym compared to less than 250 g m⁻² in sandy areas where reindeer grazing has occurred annually.
Comparison of biomass and cover data

- Less correspondence between the cover data and the climate gradient.
- Cover data do appear to show general correspondence with the trends of the hand-held LAI and NDVI values at the same sites (Epstein et al. talk).
Comparison with North America
Arctic Transect


<table>
<thead>
<tr>
<th>Standing Crop</th>
<th>North America</th>
<th>Yamal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subzone D</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daedhorse</td>
<td>410</td>
<td>Vaskiny Dachi-1</td>
</tr>
<tr>
<td>Franklin Bluffs</td>
<td>490</td>
<td>Vaskiny Dachi-2</td>
</tr>
<tr>
<td>Sagwon MNT</td>
<td>610</td>
<td>Vaskiny Dachi-3 (sand)</td>
</tr>
<tr>
<td><strong>Subzone E</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagon MAT</td>
<td>730</td>
<td>Laborovaya-1</td>
</tr>
<tr>
<td>Happy Valley</td>
<td>730</td>
<td>Laborovaya-2 (sand)</td>
</tr>
<tr>
<td><strong>Boreal Forest</strong></td>
<td></td>
<td>Nadyr-2a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nadyr-2b (sand)</td>
</tr>
</tbody>
</table>
Thermal effects of biomass to permafrost: the $n$-factor

Most biomass determinations do not consider the dead moss as part of the biomass.

Whether it is considered part of the plant biomass or soil, it is the most critical to insulating the permafrost in summer and must be considered in developing meaningful models of permafrost-ecosystem interactions.

“What is biomass?”
n-Factor:

Ratio of the sum of degree-day temperatures at the soil surface to the sum of degree-day temperatures in the air:

\[ n = \frac{DDT_{soil}}{DDT_{air}} \]

Summer \( n_s \): uses thawing degree days
Winter \( n_w \): uses freezing degree days
Summer and winter $n$-factor: placement of iButtons

<table>
<thead>
<tr>
<th>SUMMER</th>
<th>WINTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle</td>
<td>Circle</td>
</tr>
<tr>
<td>TDD$_a$</td>
<td>FDD$_a$</td>
</tr>
<tr>
<td>TDD$_m$</td>
<td>FDD$_m$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tundra</th>
<th>Tundra</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDD$_a$</td>
<td>FDD$_a$</td>
</tr>
<tr>
<td>TDD$_m$</td>
<td>FDD$_m$</td>
</tr>
</tbody>
</table>

Summer $n_m = \frac{TDD_m}{TDD_a}$
Winter $n_m = \frac{FDD_m}{FDD_a}$

Legend:
- Data logger
- Live vegetation
- Soil organic mat
- Mineral soil
- Snow cover

Anja Kade et al., 2006, *Permafrost and Periglacial Processes*
$n$-factor of tundra and patterned ground features along the North American Transect

Walker et al., 2008 submitted, *JGR - Biogeosciences*
Conclusions

• The baseline of information collected along the Yamal transect is helping us gain a more complete understanding of the relationships between vegetation, climate, reindeer, permafrost, and key biophysical variables.

• The data will be extremely useful for monitoring long-term changes at the sites where data were collected.

• Biomass clearly increases with temperature along the gradient and the values correspond well with standing crop data from the NAAT.

• There are clear substrate effects on plant functional-type abundance, with sandy sites having less total biomass, but more lichens.

• Nadym is effectively an area where reindeer have been excluded for many years and may be a good area to contrast with the rest of the transect, where reindeer are ubiquitous.

• International standards of biomass and cover measurements are needed to detect change.
Acknowledgements

• We greatly appreciate the efforts of Marina Leibman and Nataliya Moskalenko, at the Earth Cryosphere Institute in Moscow, who were responsible for the logistics for this major undertaking.
• Many people at ECI especially Academician Vladimir Melnikov, Elena Slagoda, Dimitri Drozdov, Olga Ponomareva, Olga Opokina, Anatoly Gubarkov, and Artyom Khomutov, Pavel Orekov helped with the expedition.
• Lev Bogatyrev and Gosha Matyshak helped immensely by providing the space and drying ovens for the biomass studies.
• Evgeny Chuvilin provided space in his cold room for our biomass samples.
• This project was funded by the NASA Land-Cover Land-Use Change project No. NNG6GE00A.