Section 2

Study Site and Measurement Plan for Northern Old Black Spruce (NOBS) Study Area, Thompson, Manitoba, Canada

NOBS

Directions to Site

From Thompson, Manitoba

1. Leave Thompson northwest on Road 391, crossing the Burntwood River and passing the airport.
2. Continue west on Road 391 for approximately 36 km past Gillam (Road 280).
3. The trailhead to NOBS is visible on the south side of the road just before the crest of the hill. Trailhead is marked with red/white striped flagging, and an orange utility garage sits just inside the forest.
4. Follow trail to the power line right-of-way (approx. 4 km) and make a left at power line.
5. Travel east along the power line right-of-way until trail enters the forest again (approx. 1 km). Entry point is marked with red/white striped flagging.
6. Continue south along trail past the power station to the research huts and flux tower (approx. 3 km).

Note: The trail from Road 391 to the site is largely paved with spruce planks. It is best traveled by Argo™ when wet and ATV when dry. It is not hard to follow and can be walked in about 1½ hours.

NOBS

Major Cover Types

Major cover types encountered in BigFoot study site

1. Muskeg (open-canopy black spruce)
2. Black spruce (closed-canopy black spruce)
3. Aspen
4. Wetlands
5. Jack pine

Cover type qualifiers

1. Burned
2. Unburned

Cover type descriptions

Muskeg

Acronym:	MSKG
Overstory:	dominated by black spruce often mixed with tamarack
Understory:	sparse to heavy cover of Labrador tea, *Vaccinium* spp., and willow spp.
Ground cover:	predominately sphagnum with feathermoss and reindeer lichen
Vegetation structure:	ground cover hummocky; canopy sparse; trees often stunted (1–6 m tall)
Land form:	flat, low-lying, occasionally flooded
Comments:	Muskeg is very abundant in NOBS. There exists a gradual transition between muskeg and closed-canopy black spruce–feathermoss forests; demarcation is unavoidably arbitrary.

Black spruce

Acronym:	BLSP
Overstory:	dominated by black spruce occasionally mixed with eastern larch (Tamarack). Low-level occurrence of balsam poplar and jack pine
Understory:	sparse coverage of Labrador tea, *Vaccinium* spp.
Ground cover:	predominately feathermoss
Vegetation structure:	ground cover flat (not hummocky); canopy closed; trees not stunted (6–9 m tall)

Land form:	flat, low-lying, but never flooded
Comments:	This cover type is very abundant in NOBS. Transition between muskeg and closed-canopy black spruce–feathermoss forests is gradual; demarcation is unavoidably arbitrary.

Aspen

Acronym:	ASPN
Overstory:	dominated by trembling aspen. Low-level occurrence of white spruce, balsam poplar, black spruce, and jack pine
Understory:	green alder and hazel spp.
Ground cover:	very little moss or forbs present
Vegetation structure:	canopy closed, trees often tall (12–15 m), hazel and alder often forming second closed canopy at 1–2 m
Land form:	uplands
Comments:	Several patches occur at NOBS, but they are small and infrequent.

Wetland

Acronym:	WTLD
Overstory:	scattered bog birch and eastern larch
Understory:	open water lined with willow, Labrador tea, and marsh grasses
Ground cover:	mosses
Land form:	flooded lowlands, creek margins, and beaver ponds
Comments:	This is a difficult community to describe because it includes both flooded peatlands (oligotrophic fens dominated by aquatic sphagnum spp., *Vaccinium*, and Labrador tea) as well as the marshy borders of creeks and beaver ponds (marshes containing willows and sedges). Despite the range of plant communities in this cover type they are grouped together because of their similar structure.

Jack pine

Acronym:	JKPN
Overstory:	dominated by jack pine. Low-level occurrence of white spruce, balsam poplar, black spruce, and trembling aspen

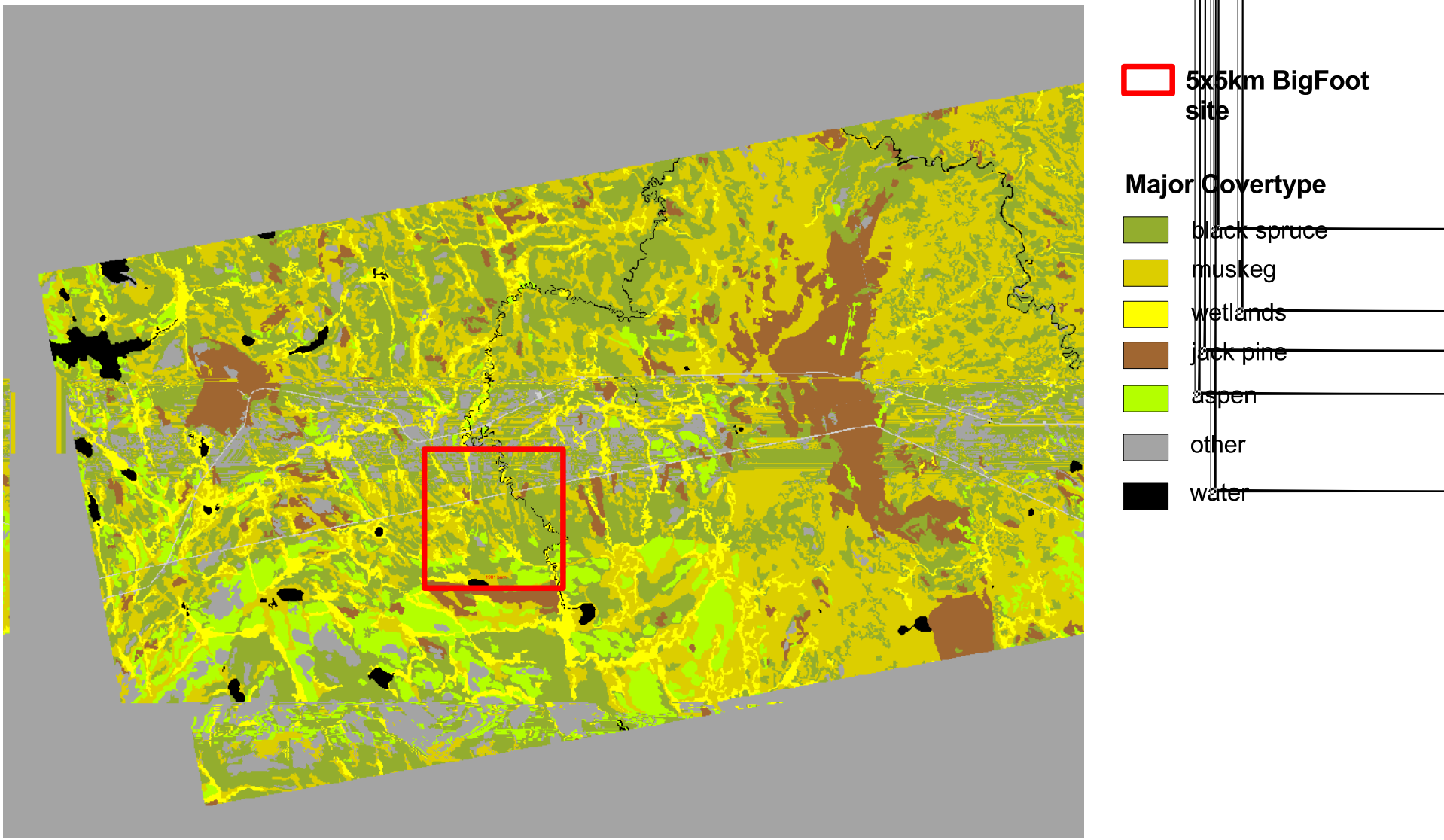
Understory:	sparse coverage of Labrador tea, *Vaccinium* spp., and occasional patches of green alder
Ground cover:	sparse to complete coverage by reindeer lichen; sparse coverage by feathermoss
Canopy architecture:	canopy closed, trees often tall (10–12 m tall)
Land form:	uplands, sandy soils
Comments:	This cover type is very rare at NOBS except for regeneration stands in a 1981 burn at the southern edge of the site.

Cover type qualifiers and additional comments

A large fire burned a 150-km^2 area on the southern boundary of the NOBS BigFoot study area in 1981. A few of the extensive plots on the south end of the 5 x 5 km grid occur in this burn. These plots are classified according to their current plant community (i.e., MSKG, BLSP, WTLD, ASPN, or JKPN), but their status as burned will also be recognized as a cover type qualifier, since the burn influences the species composition, LAI, f_{APAR}, and NPP.

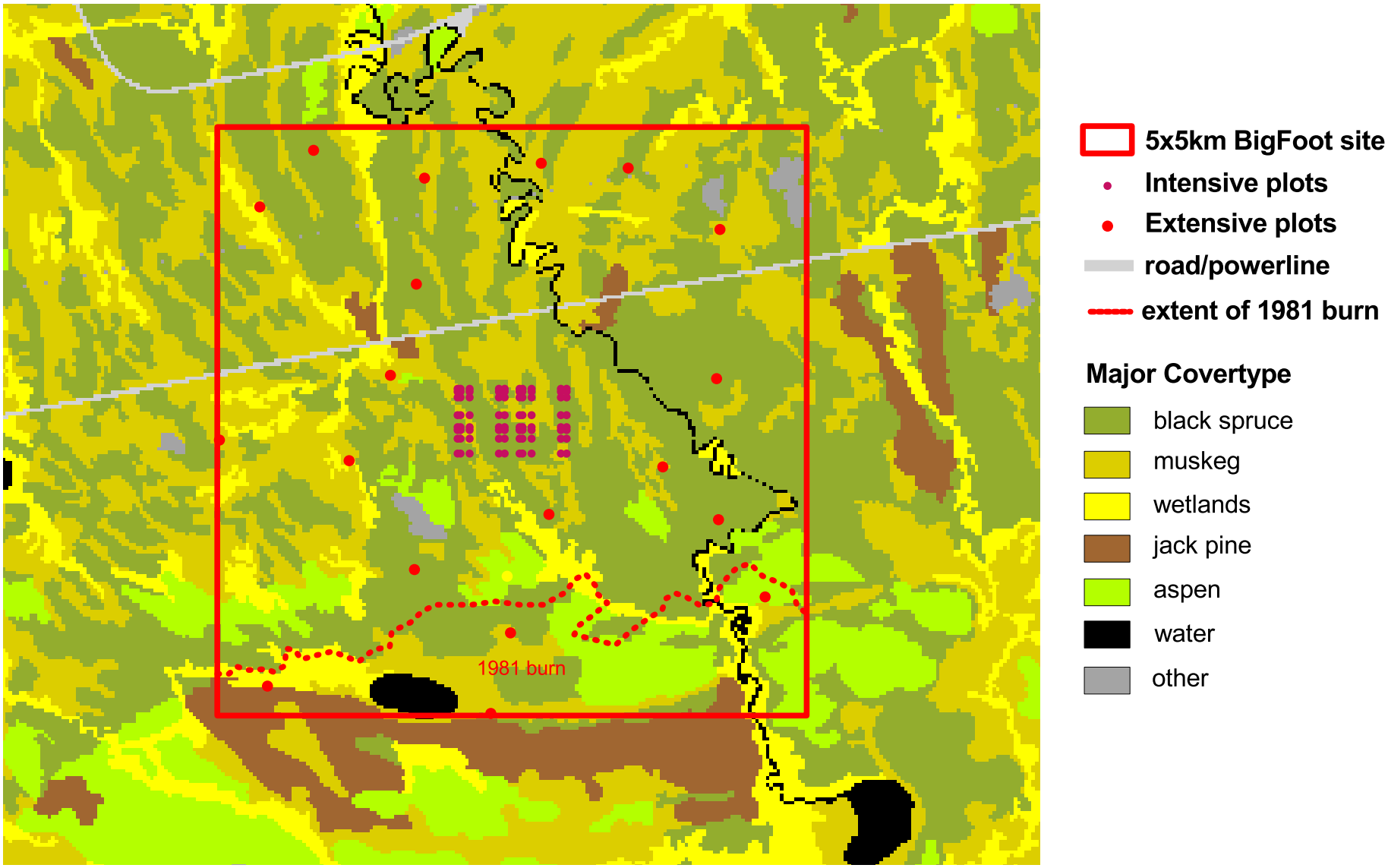
Cover type maps (see Figures 2.1 and 2.2) for the NOBS BigFoot study area were constructed from aerial photography by the Manitoba Department of Natural Resources (MDNR) in 1988 and are available as rastor maps from the BOREAS Information System (BORIS) database (Beth Nelson, BOREAS Data Manager, NASA Goddard Space Flight Center). Figures 2.1 and 2.1 are derived from a high-quality map that recognizes more than 100 vegetation cover types. Based on our on-ground experience, the map is accurate. Table 2.1 shows how the five BigFoot cover types correspond to cover types recognized by the Manitoba Department of Natural Resources map.

Figure 2.1. Major land cover types for the NOBS study area and surrounding region.



BOREAS data product created from aerial photography (1988) by the Manitoba Department of Natural Resources; modified to show major land cover classifications.

Figure 2.2. Location of study plots in the NOBS Bigfoot study site.



BOREAS data product created from aerial photography (1988) by the Manitoba Department of Natural Resources; modified to show major land cover classifications.

Table 2.1. Relationship between the five BigFoot NOBS cover types and the cover types recognized in the Manitoba Department of Natural Resources (MDNR) map. Number of pixels refers to number of pixels in the 5 x 5 km BigFoot study area

BigFoot cover type	MDNR subcategories	Cover type*	Number of MDNR pixels
BLSP	black spruce w/pine	BS/JP	16
		BS/JP/TA	45
	black spruce w/broad leaves	BS/TA	42
		BS/BA	55
		BS/WS/TA	47
		BS/WB	44
		WS/TA	43
	black spruce	BS	12
		BS/EL	17
MSKG	muskeg w/trees	treed muskeg	101
	open muskeg	clear muskeg	103
WTLD	open mupe		

NOBS

Plot Placement Rationale

Positioning of intensive sampling grid

The intensive sampling grid, or flux tower footprint, will consist of 80 individual plots arranged in a systematic spatial cluster design (Figures 2.2 and 2.3). Each plot is 25 x 25 m. The 80-plot grid extends 925 m east to west and 550 m north to south. The purpose of the intensive sampling grid is to characterize the land cover, species composition, LAI, f_{APAR}, and NPP for the footprint of the tower and determine the degree and scale of spatial autocorrelation among land cover type, LAI, f_{APAR}, and NPP.

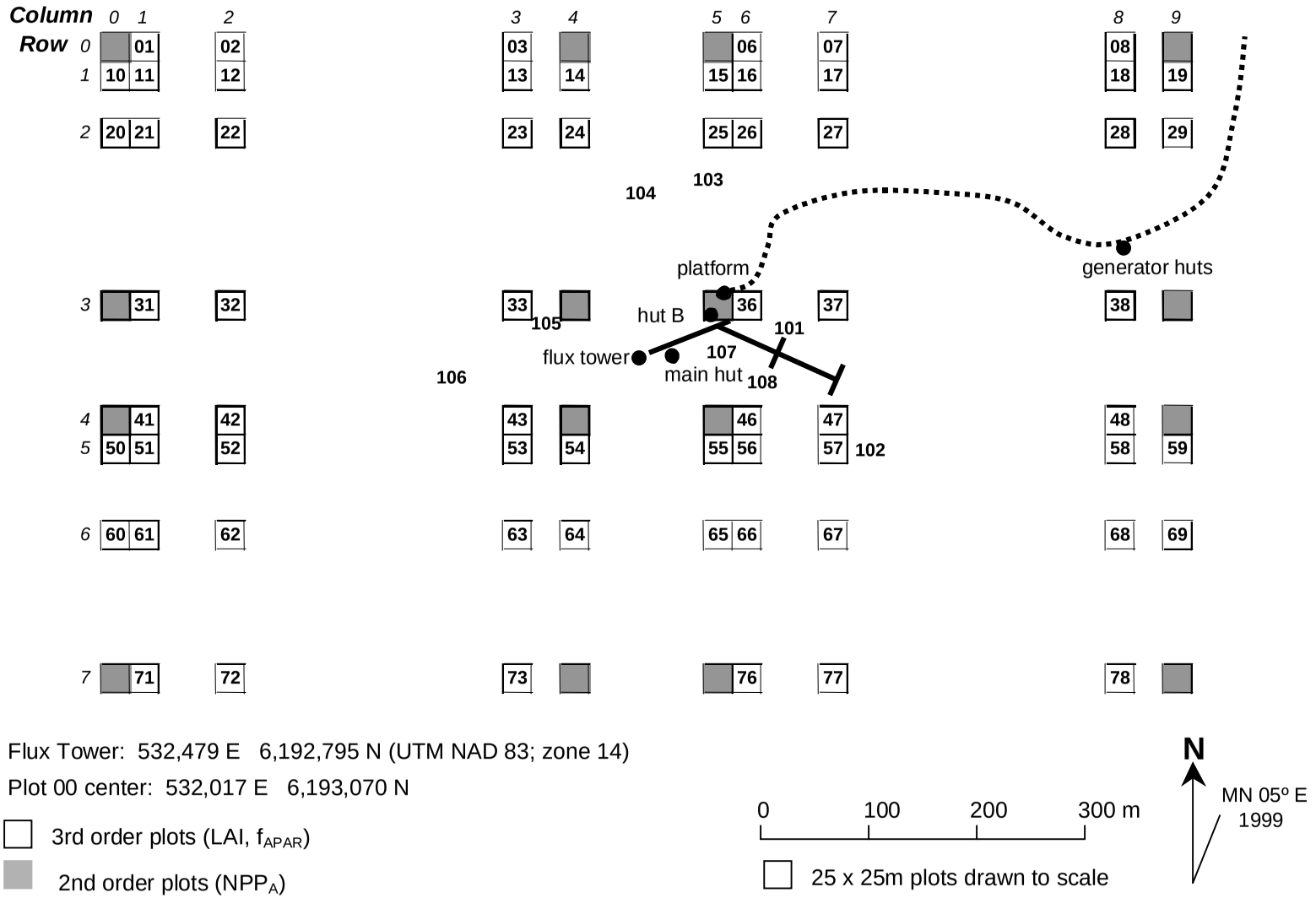
The intensive sampling grid at the NOBS site will be centered on the eddy flux tower. Positioning of the intensive sampling grid in this manner will not place any plots too close to the flux tower (nearest plot >50 m away).

Positioning of extensive sampling plots

The extensive sample plots will consist of twenty 25 x 25 m plots randomly stratified throughout the 5 x 5 km study area (Figure 2.2). The purposes of the extensive sample plots are to verify that cover type-specific characteristics hold over multi-kilometer distances and to address surface features that influence the 25-km^2 MODIS surface but are not necessarily present within the tower footprint.

The 5 x 5 km study area will be centered on the flux tower. The 20 external plots will be randomly stratified throughout the 5 x 5 km study area such that plots are at least 600 m from each other. Four of the original 20 locations were repositioned to new locations because they were in lakes, creeks, or nonrepresentative land cover types. Aquatic ecosystems are an important component of the northern boreal landscape, but characterizing these ecosystems is beyond the scope of this project.

Figure 2.3. Location of intensive study plots surrounding NOBS flux tower.



NOBS

Sampling Intensity Among Plots

According to the BigFoot sampling design, each of the 25 x 25 m plots will be sampled at one of three levels of intensity. For the NOBS site, the distribution of sampling intensity among plots will be as follows:

Sampling Intensity	Vegetation Characteristics	Number of plots (of 108 total plots)
3rd order	Vegetation cover, species composition, plant biomass, leaf area index (LAI), and f_{APAR}	56
2nd order	3rd-order measurements + aboveground net primary productivity (NPP_A)	44
1st order	2nd-order measurements + belowground net primary productivity (NPP_B)	8

Assignment of second-order plots

All 20 of the extensive plots (plot numbers 80–99) will be assigned second-order status. In addition, 24 of the 80 intensive plots will be assigned second-order status. The 24 second-order plots will be chosen from the 80 intensive plots to maximize their distance from each other and minimize autocorrelation among plots.

Assignment of third-order plots

Excluding the second-order plots, the remaining 56 plots in the intensive plot grid will be third-order plots.

Assignment of first-order plots

Eight plots will be assigned first-order status for belowground NPP measurements because of the labor costs associated with the measurement of fine root NPP. Four separate plots will be sampled to estimate fine root NPP for a given cover type; the eight plots are evenly distributed between the two most abundant cover types.

At the NOBS site, four first-order plots will be located in closed-canopy black spruce, and four first-order plots are located in open-canopy black spruce muskeg. Since these plots were initiated prior to establishing the BigFoot sampling grid, they do not share a position with any of the BigFoot plots 00–99 and are labeled 100–107. (See Table 2.2.)

Table 2.2. NOBS plot locations and descriptions

Plot Number	UTM zone 14 NAD 83 Easting*	UTM zone 14 NAD 83 Northing	Cover type**	Sampling intensity	Comments***
00	532016.653	6193070.418	MSKG	2	
01	532041.653	6193070.418	BLSP	3	
02	532116.653	6193070.418	BLSP	3	
03	532366.653	6193070.418	BLSP	3	
04	532416.653	6193070.418	BLSP	2	
05	532541.653	6193070.418	MSKG	2	
06	532566.653	6193070.418	MSKG	3	
07	532641.653	6193070.418	BLSP	3	
08	532891.653	6193070.418	BLSP	3	
09	532941.653	6193070.418	BLSP	2	
10	532016.653	6193045.418	MSKG	3	
11	532041.653	6193045.418	BLSP	3	
12	532116.653	6193045.418	BLSP	3	
13	532366.653	6193045.418	BLSP	3	
14	532416.653	6193045.418	BLSP	3	
15	532541.653	6193045.418	MSKG	3	
16	532566.653	6193045.418	MSKG	3	
17	532641.653	6193045.418	BLSP	3	
18	532891.653	6193045.418	BLSP	3	
19	532941.653	6193045.418	BLSP	3	
20	532016.653	6192995.418	BLSP	3	
21	532041.653	6192995.418	BLSP	3	
22	532116.653	6192995.418	BLSP	2	
23	532366.653	6192995.418	BLSP	2	
24	532416.653	6192995.418	BLSP	3	
25	532541.653	6192995.418	BLSP	3	
26	532566.653	6192995.418	BLSP	3	
27	532641.653	6192995.418	BLSP	2	
28	532891.653	6192995.418	BLSP	2	
29	532941.653	6192995.418	BLSP	3	
30	532016.653	6192845.418	BLSP	2	
31	532041.653	6192845.418	MSKG	3	
32	532116.653	6192845.418	BLSP	3	
33	532366.653	6192845.418	BLSP	3	
34	532416.653	6192845.418	BLSP	2	
35	532541.653	6192845.418	MSKG	2	
36	532566.653	6192845.418	MSKG	3	
37	532641.653	6192845.418	MSKG	3	
38	532891.653	6192845.418	BLSP	3	
39	532941.653	6192845.418	BLSP	2	
40	532016.653	6192745.418	BLSP	2	
41	532041.653	6192745.418	BLSP	3	
42	532116.653	6192745.418	MSKG	3	
43	532366.653	6192745.418	BLSP	3	
44	532416.653	6192745.418	BLSP	2	
45	532541.653	6192745.418	BLSP	2	
46	532566.653	6192745.418	BLSP	3	
47	532641.653	6192745.418	MSKG	3	
48	532891.653	6192745.418	BLSP	3	

Table 2.2 (continued)

Plot Number	UTM zone 14 NAD 83 Easting*	UTM zone 14 NAD 83 Northing	Cover type**	Sampling intensity	Comments***
49	532941.653	6192745.418	BLSP	2	
50	532016.653	6192720.418	BLSP	3	
51	532041.653	6192720.418	BLSP	3	
52	532116.653	6192720.418	MSKG	3	
53	532366.653	6192720.418	BLSP	3	
54	532416.653	6192720.418	BLSP	3	
55	532541.653	6192720.418	BLSP	3	
56	532566.653	6192720.418	BLSP	3	
57	532641.653	6192720.418	MSKG	3	
58	532891.653	6192720.418	BLSP	3	
59	532941.653	6192720.418	BLSP	3	
60	532016.653	6192645.418	BLSP	3	
61	532041.653	6192645.418	BLSP	3	
62	532116.653	6192645.418	MSKG	2	
63	532366.653	6192645.418	BLSP	2	
64	532416.653	6192645.418	BLSP	3	
65	532541.653	6192645.418	BLSP	3	
66	532566.653	6192645.418	BLSP	3	
67	532641.653	6192645.418	BLSP	2	
68	532891.653	6192645.418	BLSP	2	
69	532941.653	6192645.418	BLSP	3	
70	532016.653	6192520.418	BLSP	2	
71	532041.653	6192520.418	BLSP	3	
72	532116.653	6192520.418	BLSP	3	
73	532366.653	6192520.418	BLSP	3	
74	532416.653	6192520.418	BLSP	2	
75	532541.653	6192520.418	BLSP	2	
76	532566.653	6192520.418	BLSP	3	
77	532641.653	6192520.418	BLSP	3	
78	532891.653	6192520.418	MSKG	3	
79	532941.653	6192520.418	BLSP	2	
80	529994.213	6192634.148	MSKG	2	
81	530337.153	6194614.408	WTLD	2	
82	530403.203	6190541.898	WTLD	2	in 1981 burn
83	530793.113	6195093.608	BLSP	2	
84	531094.123	6192458.308	WTLD	2	
85	531444.823	6193184.088	MSKG	2	
86	531640.823	6191580.828	BLSP	2	
87	531666.063	6193958.858	BLSP	2	
88	531735.323	6194857.528	MSKG	2	
89	532297.153	6190311.528	MSKG	2	in 1981 burn
90	532407.583	6191502.858	ASPN	2	
91	532462.233	6190995.528	MSKG	2	in 1981 burn
92	532725.933	6194986.678	MSKG	2	
93	532791.023	6192003.328	BLSP	2	
94	533463.453	6194942.678	BLSP	2	
95	533755.243	6192407.348	MSKG	2	

Table 2.2 (continued)

Plot Number	UTM zone 14 NAD 83 Easting*	UTM zone 14 NAD 83 Northing	Cover type**	Sampling intensity	Comments***
96	534213.713	6193154.978	BLSP	2	
97	534226.783	6191956.048	BLSP	2	
98	534241.553	6194421.418	MSKG	2	
99	534622.943	6191301.818	ASPN	2	in 1981 burn
100	to be determined	to be determined	MSKG	1	NPP_B plot established 10/98 (not part of grid)
101	to be determined	to be determined	MSKG	1	NPP_B plot established 10/98 (not part of grid)
102	to be determined	to be determined	MSKG	1	NPP_B plot established 10/98 (not part of grid)
103	to be determined	to be determined	MSKG	1	NPP_B plot established 10/98 (not part of grid)
104	to be determined	to be determined	BLSP	1	NPP_B plot established 10/98 (not part of grid)
105	to be determined	to be determined	BLSP	1	NPP_B plot established 10/98 (not part of grid)
106	to be determined	to be determined	BLSP	1	NPP_B plot established 10/98 (not part of grid)
107	to be determined	to be determined	BLSP	1	NPP_B plot established 10/98 (not part of grid)
GPS base	532541.913	6192844.748			

* UTM = Universal Transverse Mercator; NAD = North American Datum.

** MSKG = muskeg; BLSP = black spruce; WTLD = wetland; ASPN = aspen.

*** NPP_B = belowground net primary production.

NOBS

Vegetation Characteristics to be Measured

Table 2.3. Vegetation sampling methodology for NOBS

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
1) Moss mass	Feathermoss and sphagnum	Visual estimate of % ground cover in subplots is multiplied by average mass of moss per unit area (measurement no. 16)	5	0.25–4.00 m^2 (depending on moss patch size)	Midsummer	
2) Understory mass	Labrador tea, rose spp., *Vaccinium* spp.	Clip at base, dry, and weigh all understory in subplot	5	0.25 m^2	Midsummer	
3) Small tree mass	Black spruce and larch <2.5 cm DBH*	Count stems and basal diameter in subplots and scale to tree mass w/ allometric equations	5	1–25 m^2 depending on tree density (enough to get 4 trees/ subplot)	Midsummer	
4) Large tree above-ground mass	Black spruce, larch >2.5 cm DBH*	Variable-radius plots to count stems by size; stem counts scaled to tree mass w/ allometric equations	1	Variable-radius prism plot	Pre- and post-growing season	
5) Coarse root mass	Tree roots >2 mm in diameter	Variable-radius plots to count stems by size; stem counts scaled to root mass w/ allometric equations	1	Not applicable	Midsummer	Derived from the same prism sweep data above

Table 2.3 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
6) Fine root mass	Root 2 mm or less in diameter	The inside of clear tubes inserted into ground are periodically viewed with a digital camera. Area of fine roots seen in images are scaled to mass/area	5 tubes	2-D image totaling about 30 cm^2	4 times seasonally	Size cutoff and scaling factors depend on further methods development
7) Moss growth	Feathermoss and sphagnum	Vertical growth measured in subplots; growth through plastic mesh for feathermoss, past vertical wire gauges for sphagnum	0–8	moss screens = 0.01 m^2; sphagnum gauges clustered in 0.25-m^2 clumps	Gauges set at either spring thaw or fall freeze; growth measured 1 and/or 2 years later	Number of mesh plots or wire gauges dependent on ground cover composition
8) Understory stem growth	New stem of Labrador tea, rose spp., *Vaccinium* spp.	Based on bud scarring, new stem growth is separated from the understory biomass samples and weighed	5	0.25 m^2	After growing season for which NPP is calculated	Sampled from the same plots used to determine small tree mass

Table 2.3 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
9) Small tree wood growth	Annual stem and branch growth of spruce and larch <2.5 cm DBH	Radial increment of tree determined from stem cores or disks; increment scaled to stem growth w/allometric equations	4	1–25 m^2, depending on tree density (enough to get 4 trees/subplot)	After growing season for which NPP is calculated	Sampled from the same plots used to determine small tree mass
10) Large tree stem growth	Annual stem and branch growth of spruce and larch >2.5 cm DBH	Radial increment of trees counted in prism sweep determined from cores taken at BH; Increment scaled to stem growth w/ prism factor and allometric equations	1	Variable-radius prism plots	After growing season for which NPP is calculated	Same trees used to determine aboveground biomass
11) Foliage NPP	Leaves senesced from (and presumed grown in) canopy over one growing season New foliage produced	Litter traps: foliage detritus = new foliage production (2) Allometric equations used to estimate new foliage	5	0.25-m^2 litter traps	Litter collected over the growing season for which NPP is calculated	In deciduous plots, leaflitter is annual foliar production. In evergreen plots, steady stasis between foliar growth & senescence must be assumed

Table 2.3 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
12) Coarse root NPP	Annual growth in roots >2 mm in diameter	Calculated as an allometric function of aboveground stem growth (measure no. 10)	1	Variable-radius prism plots	After growing season for which NPP is calculated	Same trees used to determine aboveground biomass
13) Fine root NPP	Fine root tips <2 mm	The insides of clear tubes inserted into ground are periodically viewed with a digital camera; increase in area of fine roots is scaled to biomass using mass/area constants	5 tubes	2-D image totaling about 30 cm^2	4 times seasonally	Σ new fine root length for each root diameter class x mass/area coefficient
14) LAI (optical)	½ total leaf area in canopy per unit ground area	Measured at points in plot using LAI 2000 (LAI computed from sunlight attenuation as it passes through canopy)	5	Point samples	4 times seasonally	
15) LAI (allometry)	½ total leaf area in canopy per unit ground area	Foliar mass (determined allometrically from prism sweeps) is scaled to area using specific leaf area (area/mass)	1	Variable-radius prism plots	Any time	In deciduous stands, litterfall can be used to estimate LAI

Table 2.3 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
16) f_{APAR}	Fraction of light absorbed by canopy	Measured at points in plot using LAI 2000 (computed from same measurement as LAI)	5	Point samples	4 times seasonally	
17) Vegetation cover	Vertical projection of vegetation to ground area	Mean crown completeness using digital true-color camera	5	1 m^2	Midsummer	
18) Moss mass per ground area	Dry mass of moss per unit ground area at 100% coverage	Moss samples are collected from a fixed area in which moss grows with 100% coverage; living tissue is separated, dried, and weighed	5		Midsummer	This is used to scale moss coverage to moss mass. Sitewide averages will suffice

Table 2.3 (continued)

Measurement	Example	Method	Subplot number	Subplot size	Timing	Comments
19) Specific leaf area	Leaf area per unit leaf mass by species	For broad leaves, fresh leaves are weighed and measured with a leaf area meter; for needle leaves, leaf volume is determined gravimetrically, converted to area using shape-specific geometric constants		5 trees of each dominant species	Midsummer	Sitewide averages
20) Leaf nitrogen concentration	% nitrogen by mass of leaves from dominant tree species	Fresh leaves are dried, digested by Kjeldahl incubation, and colormetrically analyzed for nitrogen		5 trees of each dominant species	Midsummer	Sitewide averages

* DBH = diameter at breast height.

NOBS

Subplot Placement

The 25 x 25 m plot is the experimental unit. In the final analyses, each plot produces only *one* value for each characteristic parameter measured. When appropriate, multiple fixed-area subplots will be used to sample variation within each plot. The subplots are positioned in the 25 x 25 m plot such that

1. they are spatially stratified throughout the plot and not clustered in one area,
2. they are simple and convenient to deploy in the field, and
3. they do not interfere with one another.

The subsamples will be located in a regular pattern in each plot based on the cardinal compass directions. The protocol for the subplot placement of subsamples at NOBS is illustrated in Figure 2.4 and described in Table 2.4.

Figure 2.4. Placement of NOBS subsamples.

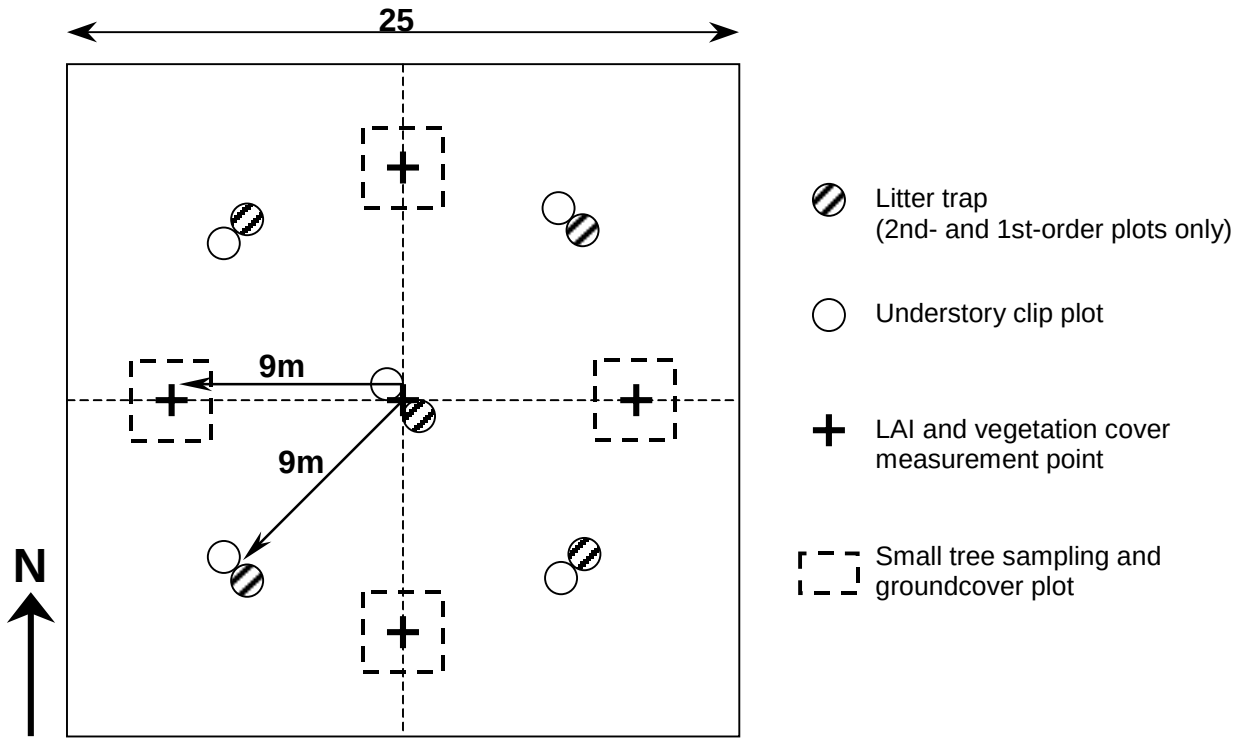


Table 2.4. Subplot placement protocol for NOBS

Subplot	Number of subplot	Position in 25 x 25 m plot
Understory clip plots	5	One positioned near plot center and four more positioned 9 m NW, NE, SE, and SW from plot center
Litter traps (2nd- and 1st-order plots only)	5	Placed adjacent to the understory clip plots
Small tree stem survey plots	4	Four fixed-area subplots centered at points 9 m N, S, E, and W from plot center
Moss groundcover survey plots	1	Visual survey made from plot center
Variable-radius plots	1	One prism plot made from plot center
LAI and vegetation cover sample points	5	One positioned near plot center and four more positioned 9 m N, S, E, and W from plot center
Minirhizotrons (1st-order plots only)	5	Placed adjacent to the understory clip plots (or anywhere they can be installed)
Feathermoss growth plots	0–8	Up to eight feathermoss screens stratified among the patches of pure feathermoss
Sphagnum growth wires	0–5	Up to five sets of sphagnum growth wires stratified among the sphagnum hummocks in the plot

NOBS

Tentative 1999 Field Calendar

Month	Week	Day of year	Measurements
May	2–4	130	Survey in plots, install moss gauges and litter traps, measure LAI, and take root images Snow melts mid-April
June	4	174	Measure LAI and vegetation cover, take root images
Aug.	1–3	211	Measure LAI and vegetation cover, take root images, sample understory, begin surveying trees Full flush occurs at this period
Oct.	1–2	271	Measure LAI and vegetation cover, take root images, finish surveying trees, clip moss

In the summer of 2000, a new set of LAI measurements, root images, litter collections, and moss growth measurements will be taken on similar dates. Tree surveys will not need to be repeated. Tree cores will be collected at the end of the year 2000 growing season to estimate aboveground NPP.

NOBS

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