

Tree Line Research in Gates of the Arctic NP A Follow-up to Robert Marshall's Research

By Terry Droessler and Judy Alderson

When wilderness explorer Robert Marshall travelled in the central Brooks Range in the 1930s, he combined his enthusiasm for the scenic and wilderness values of the area with a scientific interest in the ecological relationships there. As a result, Marshall undertook tree growth studies in the North Fork of the Koyukuk, Alatna, and John River drainages in what today is Gates of the Arctic National Park and Preserve (Retzlaf and Marshall 1931, Marshall 1933, 1970, 1979, Glover 1986, Brown 1988).

Current interest in global change and the need for long-term data relating to climate change have led two agencies to investigate the potential use of Marshall's data for determining change at tree line in the central Alaskan arctic. Tree line is defined in this study as the northernmost trees that were located.

During summer 1990, the U.S. Environmental Protection Agency and NPS combined resources to sample sites at tree line within Gates of the Arctic NP. White spruce (*Picea glauca*, Voss) at tree line is sensitive to climate and may respond to global climate change. To detect field evidence of white spruce tree growth and tree line responses to climate, tree line location was mapped and tree cores were extracted to determine tree age and annual increment. Previous work by Marshall helped identify specific research sites. The tree increment cores collected, together with observations of tree line migration, should enable quantitative statements of tree growth and tree line migration response to recent past (post 1900) climate. The tree cores currently are being analyzed and results as well as observations will be published when completed.

The relationship between tree line location and climate has been based on correlational studies. There are several temperature-based guidelines that correlate with tree line location. For example, correspondence between the 10 deg. C. July isotherm and tree line location is discussed in Tranquillini (1979),



Boreal Mountain (left) and **Frigid Crags Mountain** (right) form the namesake "gates" in Gates of the Arctic NP. In this photo, looking south, the North Fork of the Koyukuk River flows in from the left and Ernie Creek flows in from the right. Tree lines on both waterway drainages were sampled, as shown on the map.

Arno (1984), Larsen (1988), and Young (1989).

The greatest climate warming is expected to occur at higher latitudes. According to predictions from General Circulation Models (GCMs) warming in the higher latitudes may be at least twice the global average (Houghton and Woodwell 1989). An increase in temperature would shift the 10 deg. C. July isotherm higher in latitude and altitude. If temperatures do increase and moisture is not limiting, tree line may advance in latitude and altitude at a faster rate, or advance where it previously was limited by climate. Previous studies of

tree line in other areas in Gates of the Arctic have shown stable to advancing tree lines (Densmore 1980, Goldstein 1981, Odasz 1983, Cooper 1986, Lev 1987).

White spruce at tree line on the south slope of the Brooks Range and isolated clusters of balsam poplar (*Populus balsamifera*, L.) trees on the north slope commonly reproduce by vegetative means only (Lev 1987, Edwards and Dunwiddie 1985). Increased temperature may allow trees to flower and set viable seed. Migration rates could increase dramatically because seed dispersal distances are far greater than branch or root vegetative reproduction dispersal distances.

Marshall's Historical Records

The Robert Marshall Papers, archived at the Bancroft Library, U/Cal/Berkeley, contain ecological observations and tree growth data that Marshall collected on field trips. Marshall kept detailed field journals, including time and distance records and descriptions of where data were collected. The data include various ecological observations in addition to increment core tracings and diameter distribution and stocking information.

Marshall collected tree growth and sample plot information at and "below" tree line. He hypothesized tree growth to be limited by moisture, solar radiation, or temperature, and that tree line was not exclusively constrained by climate. Rather, he thought spruce trees may not have had sufficient time since the last glaciation to migrate to a climate controlled tree line.

Marshall attempted to advance tree line by planting white spruce seed plots beyond tree line (Marshall 1970). Paired plots were planted in 3 drainages, Grizzly, Kinnorutin and Barronland Creeks (located in Gates of the Arctic NP), to see if seeds would germinate and grow. Seed was sown on mineral soil (all vegetation removed) on one plot and on existing vegetation on a paired plot. For example, the 1930 Grizzly Creek planting (about 12 miles north of tree line) used

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seed collected approximately 4 miles south of tree line. Marshall suggested that if the seeds germinated and grew, he was advancing tree line by about 3000 years (based on the estimated 50 years to reach seed bearing age and a seed dispersal distance of 1000 to 1200 feet, roughly a migration rate of one mile in 250 years).

The Grizzly Creek planting site was revisited in 1938 by Marshall and no sign of seed germination was found. Sam Wright visited the Kinnorutin Creek and Barrenland Creek sites in August 1966 and again found no sign of trees (Wright 1969, 1973, 1988). A likely explanation is that the seed origin was inappropriate (Minnesota and Michigan) and seed viability was unknown for 2 of the 3 seed sources. The seed also may have been sown above climate controlled tree line.

The Barrenland Creek planting site was revisited by Sam and Billie Wright in 1968. They obtained 100 4-year-old white spruce seedlings from Dr. Leslie Vierck at the Forestry Sciences Lab in Fairbanks (Wright 1973, 1988) and planted them in one of Marshall's original Barrenland Creek plots. Sam Wright revisited the planting site in August 1989 and found 5 living seedlings, approximately 2 inches taller than at planting (S. Wright personal communication, Wright 1988). That there were any surviving seedlings after 21 years indicates the potential for trees to survive north of current tree line (the planting site is approximately 3 miles north of current tree line). That the trees were essentially the same size as at planting indicates a physiological limitation on photosynthesis. Wright (1988) ends a chapter entitled "Tree Planting" with the following:

"At present, in the arctic wilderness north of timberline, there is now a small grove of seedlings which have jumped three thousand years."

Tree Line Sample Locations

Marshall provided detailed descriptions of tree line locations where he extracted tree cores. Figure 1 shows 6 of Marshall's tree line sites chosen for this study.

Data Collection

For the 1990 field work, tree line sampling sites were located from a helicopter and by hiking. The helicopter was used to hover at low altitude and circle up drainages beyond tree line to help insure that the northernmost trees were located. Hiking from both the north and south helped insure that trees hidden by alder and willow brush were located.

Once located, the tree line position was recorded on topographic maps and photographs of trees were taken. Approximately 20 trees, 5 cm or larger at 1.5 m above the base, were cored at each site. Cores were extracted at the base and at 1.5 m height, stored in straws, and labeled for later measurement. The increment cores are currently being measured and analyzed; results will be published upon completion.

Management Implications

Baseline tree growth and tree line location data will help advance our understanding of a unique resource, the forest-tundra ecotone. It will also be important for monitoring future climate-induced tree growth and migration changes. Current and recent past white spruce demographics will be essential for interpreting response to recent past climate and for predicting possible future changes. Marshall's descriptions of tree line position in the 1930s provide one baseline for



Looking north at the northernmost trees on Loon Creek.

comparison. The data collected in the summer of 1990 will provide a current baseline for comparison.

Tree data may be useful as part of the international effort to study global change. The importance of arctic areas for global change research is becoming recognized. Regional assessments and studies can be coordinated and correlated through tree line work such as this, and through work planned in the Noatak National Preserve to the west of Gates of the Arctic. Predictions of tree growth and tree line migration response to future climate scenarios throughout the region may be possible.

Tree line information may be useful for park specific or regional retrospective analyses and future resource management interpretative efforts. The potential impact on wildlife that show preference for forested versus brush/tundra areas exemplifies the use of tree line location information. In the near future, sparsely forested areas at the south of tree line may become heavily forested, thereby enlarging habitat ranges for northern woodland wildlife species.

Future Research and Monitoring

The acquisition of a portable Global Positioning Sys-

tem (GPS) would allow mapping of tree line and other features of the park in 3 dimensions and provide precise measurements for tree line advances or retreats. Because tree core information already has been collected, this would involve revisiting the sites with a portable GPS unit, standing next to each tree or feature of interest, and locking in the position with a GPS receiver. A single GPS unit will determine position within approximately 15 meters, multiple units within one meter. The accuracy of GPS equipment depends on the grade of the satellite signals available for civilian use at a given time (controlled by the Department of Defense and called selective availability.)

Many factors acting separately or synergistically have been hypothesized as controlling tree line location. Identifying the physiological limitation(s) for sexual reproduction, seed germination, seedling survival, and tree growth and maturation at sites varying in slope, aspect, drainage, etc., is critical for modeling the response of tree line in specific drainages and regions to climate change.

The tree line environment is subject to natural cycles on various time scales and to anthropogenic influences that may confound the effect of global warming. Determining the effect of rising CO₂ levels from rising temperature levels may prove challenging. If temperature is a critical factor, tree line may advance beyond the continental divide to the north slope, reducing tundra areas to the higher elevations of the continental divide.

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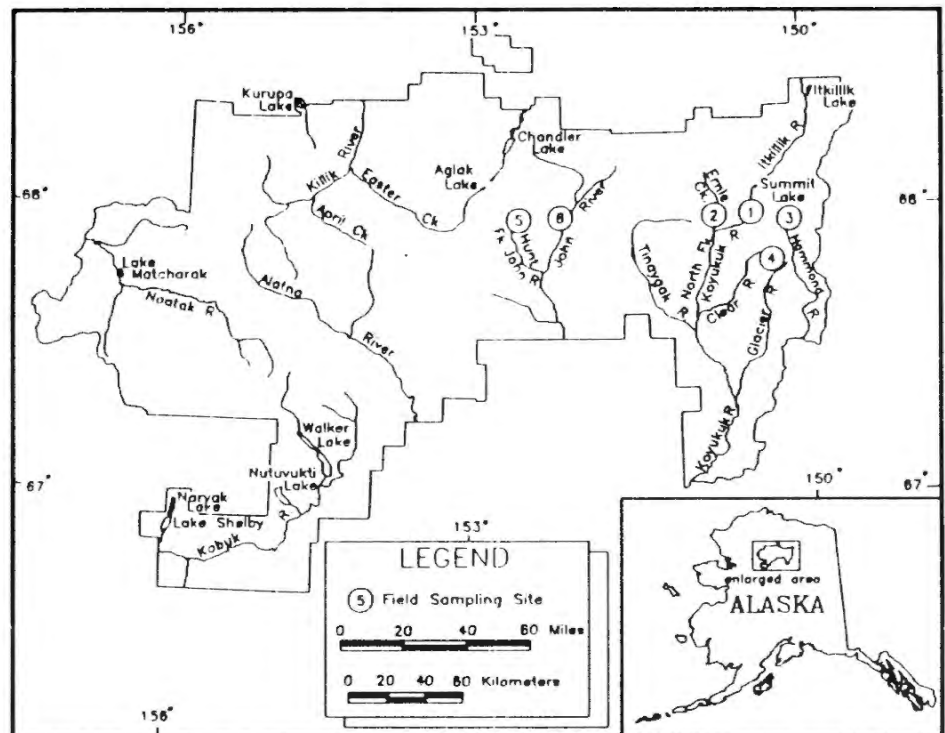


Figure 1. Map of Gates of the Arctic National Park and Preserve showing the position of tree line study sites in the park. 1) North Fork of the Koyukuk River, 2) Ernie Creek, 3) Hammond River, 4) Clear River, 5) Loon Creek and 6) John River.

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