Ecological Assessment and Monitoring Program for

Northern Blackberry (*Rubus acaulis*)

in Bighorn National Forest, Wyoming

Prepared for the Bighorn National Forest

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Table of Contents

Figures, Tables, and Appendices

Figures

Tables

Appendices

INTRODUCTION

Northern blackberry or nagoonberry (*Rubus acaulis*) ranges widely across Alaska and northern Canada, but occurs only sporadically south of the Canadian border in Minnesota, Montana, Wyoming, and Colorado. Due to concerns over its long-term survival in the southern Rocky Mountains, this species was recommended for Sensitive designation in US Forest Service Region 2 (Rocky Mountain Region) in 1990 (Marriott et al. 1990). It was officially designated as Sensitive in Region 2 forests in Colorado and Wyoming in 1993 (Estill 1993).

At the time of its designation as Sensitive, *Rubus acaulis* was known in Wyoming from a single population in Yellowstone National Park and a vague, historical record from the Bighorn Range (last observed in 1900). Stephanie Mills and Kathy Zacharkevics, seasonal ecology field technicians with Bighorn National Forest, rediscovered this species in the Bighorn Mountains in 1994 while conducting surveys for the proposed Tie Hack Dam. Zacharkevics conducted a more exhaustive survey in 1995 and located six subpopulations numbering several thousand stems along a 2.4 km (1.5 mile) stretch of Sourdough Creek, southwest of the proposed dam area (Fig. 1).

The Sourdough Creek watershed remains the only known extant location for *Rubus acaulis* on Bighorn National Forest. Under the Bighorn National Forest Management Plan, the Sourdough Creek area is managed with a livestock and timber emphasis, but also receives recreational use (USDA Forest Service 1985). The population dynamics and potential management needs of Northern blackberry are poorly known at present. In 1999, Bighorn National Forest contracted with the University of Wyoming's Natural Diversity Database (WYNDD) to conduct an ecological assessment of the Sourdough Creek watershed and establish a pilot monitoring program to provide information on the population trend of *R. acaulis* at this site. The monitoring protocol is intended to be repeatable, consistent, and cost-efficient and is meant to collect qualitative data on trends rather than testing specific hypotheses about the relationship between environmental variables and the distribution of this species. In addition, WYNDD surveyed potential Northern blackberry habitat in adjacent watersheds to determine if more suitable habitat may be present. The results of these investigations are contained in this report.

METHODS

Ecological Assessment

Information on the habitat and distribution of *Rubus acaulis* was obtained from secondary sources, including WYNDD and Bighorn National Forest files and computer databases, specimens from the Rocky Mountain Herbarium (RM), scientific literature, and knowledgeable individuals. USGS topographic maps, geologic maps (Love and Christiansen 1985), and US Forest Service aerial photographs were used to identify areas of potential habitat for ground survey at Sourdough Creek and other streams on the east slope of the Bighorn Range.

Figure 1. Southeastern Bighorn National Forest Study Area.

Surveys and monitoring were conducted from 12-20 July 1999 (survey routes and monitoring sites are indicated in Appendices B-C). Locations of Northern blackberry were mapped on USGS 1:24,000 quads and USFS 1:24,000 scale aerial photographs and later digitized into a GIS theme in Arc-View (version 3.1). Data on the number of stems, phenology, density, associated species, vegetation type, cover, soil moisture, and other environmental attributes were recorded for each separate subpopulation. Color photographs were taken of plants and their habitat at each site. Information gathered in the field was entered into the computerized Element Occurrence database at WYNDD.

Monitoring of *Rubus acaulis*

Monitoring efforts in 1999 focused on developing and testing techniques for measuring the number and frequency of stems of *Rubus acaulis* in order to provide a baseline for future trend studies. Two permanent monitoring macroplots were established in planeleaf willow/beaked sedge (*Salix planifolia/Carex* [*rostrata*] *utriculata*) communities along the middle reach of Sourdough Creek. These macroplots measured 5 x 16 m and were subdivided into five 1 x 16 m lanes using 50-meter tapes. The lanes were further subdivided into two 1 x 8 m blocks and twenty 0.4 x 1 m grids. Two to four 1 x 8 m blocks and fifty to sixty 0.4 x 1 m grids were selected using a stratified random protocol (Elzinga et al. 1998). Within each block and grid, all stems of Northern blackberry were counted and classified by growth form (reproductive [flowering or fruiting] or vegetative). A 0.2 x 0.5 m Daubenmire frame was also used in the upper right hand corner of each 0.4 x 1 m grid to measure presence or absence of Northern blackberry for frequency monitoring.

Three permanent belt transects measuring 2 x 6 m were established in Engelmann spruce/twinberry forests (*Picea engelmannii/Linnaea borealis*) along the lower reaches of Sourdough Creek. These belts were divided into 2 parallel 1 x 6 m lanes and then subdivided into 3 1 x 2 m plots. The number of reproductive and vegetative stems in all plots were counted, but frequency with Daubenmire frames was not recorded.

Photographic monitoring points were established at 4 locations along the middle and lower reaches of Sourdough Creek. The location of each photo point was recorded on USGS 1:24,000 quads and aerial photographs and was marked by fence posts if permanent landscape features were not available.

Figure 2 (page 7). Aerial photograph of the middle and lower reaches of Sourdough Creek. Scale 1:24,000.

Figure 3. Northern blackberry populations along Sourdough Creek.

RESULTS

Ecological Assessment/Habitat

Sourdough Creek originates on the east slope of Loaf Mountain and flows for approximately 5 km (8 miles) before joining Clear Creek at the present site of the Tie Hack Dam. (Fig. 1). During its course, Sourdough Creek drops from 2987 to 2255 meters (9800 to 7400 feet) and passes through a mosaic of high montane meadows, mountain big sagebrush grasslands, lodgepole pine and Engelmann spruce forests, planeleaf willow thickets, and beaked sedge marshlands (Fig. 2). The creek is bisected by US Highway 16, the main route across the southern Bighorn Range between the cities of Buffalo and Worland.

The Sourdough Creek watershed is managed for multiple use values, with an emphasis on livestock grazing and timber harvest (Bighorn National Forest 1985). Cattle graze the middle reaches of the creek in late July to early August, concentrating mostly in the drier meadows on the north bank. Due to its accessibility, fishermen regularly use the middle reach of the creek and a trail has become established along the north side. Use of the south bank by livestock or fishermen appears low due to the area's uneven terrain and flooded soils. Unofficial but semi-permanent car and trailer campsites are present along the upper reach of Sourdough Creek, but not along the middle to lower reaches. An electric powerline crosses the middle reach of the wetland approximately 0.32 km (0.2 miles) downstream of US Highway 16. Several small clearcuts are present along the divide between Sourdough and Little Sourdough creeks, and a timber sale is currently pending near the head of Sourdough Creek. The watershed was historically flooded to facilitate the transportation of trees cut for railroad ties.

Northern blackberry was found at 10 main sites along the middle to lower reaches of Sourdough Creek in 1999 (Fig 3). Six and one-half of these subpopulations occur in semi-open planeleaf willow/beaked sedge (*Salix planifolia/Carex utriculata* [synonym = *C. rostrata*]) communities on the south bank of Sourdough Creek between 0.5-1.6 km (0.3-1 miles) northeast of US Highway 16. Three and one-half larger colonies are found downstream in Engelmann spruce/twinberry (*Picea engelmannii/Linnaea borealis*) forests starting about 1.6 km (1 mile) northeast of US Highway 16 and extending to the confluence of Little Sourdough Creek (Fig. 3). Despite the presence of some potential habitat, no populations are known from the upper reaches of Sourdough Creek southwest of the highway, the lowermost reach of Sourdough Creek (below Little Sourdough Creek), or the main stem of Little Sourdough Creek (K. Zacharkevics, pers. comm.).

Populations of northern blackberry along the middle reach of Sourdough Creek occur primarily on mossy hummocks with organic-rich soils in planeleaf willow thickets and beaked sedge marshlands (Fig. 4). These soils have a histic epipedon and represent either histisols or inceptisols (aquepts). Although moist, these hummocks are drier than adjacent depressions dominated by beaked sedge, water sedge (*C. aquatilis*), or bluejoint reedgrass (*Calamagrostis canadensis*). Occasionally, small populations may also be found on abandoned beaver dams or lodges that have been colonized by grasses, sedges, and willows. Northern blackberry colonies are usually found within 7 m of the stream bank, although one large occurrence extends nearly 30 meters from the creek on a gently north-dipping, flooded slope. Plants may occur in full sun or partial to complete shade beneath a canopy of shrubby cinquefoil (*Pentaphylloides floribunda* [synonym = *Potentilla fruticosa*]), planeleaf willow, Booth willow (*S. boothii*), Bebb willow (*S. bebbiana*), or Geyer willow (*S. geyeriana*). Vegetation cover is typically 90-95%, with at least 50% of all cover provided by mosses. Associated vascular plant species are listed in Table 1.

Northern blackberry populations along the lower reaches of Sourdough Creek are restricted to streamside terraces under a dense, shady canopy of Engelmann spruce (Fig. 5). Colonies occur on moist, moss-covered sandy-loam hummocks or spruce rootcrowns along the streambank and in drier, sparsely-vegetated, needle-rich loamy-clay soils up to 4 m from the stream. These sites are probably flooded each spring during high water runoff and receive an influx of sandy alluvium. Small populations may also occur on damp, shady soils along isolated sloughs within a short distance of the main stream channel. The understory of these riparian Engelmann spruce forests is dominated by twinberry on drier sites and low-growing planeleaf willow and field horsetail (*Equisetum arvense*) in wetter areas (Table 1). Vegetative ground cover ranges from 5-10% on drier sites to ca 60% along the creek itself. *Rubus acaulis* may occur on both the north and south banks of the creek, but is absent from sites with large rocks or boulders lining the stream.

Rubus acaulis is absent from mesic meadows and willow thickets on the north bank of the middle reach of Sourdough Creek. These sites probably become too dry during the summer months to support blackberry populations and lack the characteristic hummocky topography and high water table of the south bank. Populations are also absent from south-facing shrubby cinquefoil and sagebrush-dominated meadows along the middle to lower reaches of the creek. These latter sites support lush growth of Kentucky bluegrass (*Poa pratensis*), alpine timothy (*Phleum alpinum*), tufted hairgrass (*Deschampsia cespitosa*) and exotic weeds such as white clover (*Trifolium repens*).

Ecological Assessment/Population Size

Based on surveys in 1999, the Sourdough Creek population of *Rubus acaulis* is estimated at approximately 51,000-77,000 stems. Due to the plant's rhizomatous nature, the exact number of genetically distinct individuals is probably much lower (perhaps only in the low thousands). The average number of stems per rhizome is not known and cannot be easily determined without destructive sampling. Stem number may vary seasonally in

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Figure 4 (page 11). Habitat of *Rubus acaulis* in a hummocky planeleaf willow thicket/beaked sedge marsh community on the south bank of the middle reach of Sourdough Creek, Johnson County, Wyoming. WYNDD photograph by Walter Fertig, 17 July 1999.

Fig 4

response to climatic factors or loss of energy reserves following a large flowering year (individual aerial stems survive for only one year).

Sourdough Creek contains 10 main subpopulations of Northern blackberry, each numbering between 25 to 20,000 stems (Table 2). Subpopulations occupy areas ranging in size from 3 square meters to linear patches nearly 0.3 km long (0.2 miles). The total area inhabited by this species along Sourdough Creek is only about 2 hectares (ca 5 acres).

The distribution of Northern blackberry plants along Sourdough Creek is strongly clustered. Density ranges from 27-50 stems per square meter in willow thicket/marsh habitats and 10-48 stems per square meter in riparian Engelmann spruce forests (Appendix B). Large patches of seemingly suitable habitat, however, are unoccupied both within clusters of stems and between subpopulations. Frequency within occupied patches (based on randomly distributed 0.2 x 0.5 plots) ranges from 50-60% in willow thicket/marsh habitat (Appendix B). The patchy distribution of this species may be directly related to its rhizomatous growth form.

Rubus acaulis populations were observed in flower and vegetative condition in mid July 1999. 24-39% of all stems were in flower in willow thicket/sedge marsh habitat, while only 23-27% were in flower in forested areas. Northern blackberry produces an open, cup-shaped flower that is attractive to a broad range of generalist pollinators (although only honeybees were observed visiting flowers in 1999). No fruit production was documented in the Sourdough Creek population in 1999.

Little evidence of herbivory was observed on stems, leaves, or inflorescences during 1999 surveys. Moose are commonly observed in the watershed in the spring (Gary Beauvais, pers. comm.), and may graze or trample some *Rubus* plants in willow thicket and marsh habitats. Cattle graze the middle reach of Sourdough Creek after late July, but seem to congregate mostly in the open meadows on the north side of the creek (away from *R. acaulis* habitat). Kathy Zacharkevics, however, did report some trampling of wetland habitats by cattle in 1995 (pers. comm.). It is not known if grazing is having an impact on fruit production.

<u>Survey for Additional Populations</u>

The variety of habitats occupied by Northern blackberry along the middle to lower reaches of Sourdough Creek suggests that this species should be more widely distributed along streams in the southeastern Bighorn Range. Extensive rare plant and riparian classification surveys by Bighorn National Forest staff in the early to mid 1990s however,

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Figure 5 (page 13). Habitat of *Rubus acaulis* in understory of moist, shady Engelmann spruce/twinberry forest on the south bank of Sourdough Creek. Plants occur on mossy streamside hummocks on sandy alluvium or needle-rich loamy clays and root mounds within 2-3 meters of the creekbank. WYNDD photograph by Walter Fertig 15 July 1999.

Fig 5

Table 1.

Plant Species Associated with Northern blackberry (*Rubus acaulis*)
Along Sourdough Creek

Species	Common Name	Planeleaf willow/ Beaked sedge cty	Engelmann spruce/ Twinberry cty
Aconitum columbianum	Columbian monkshood	X	
Arenaria lateriflora	Bluntleaf sandwort		X
Astragalus alpinus	Alpine milkvetch	X	X
Astragalus americanus	American milkvetch	X	X
Botrychium lanceolatum	Lance-leaved grapefern	X	
Calamagrostis canadensis	Bluejoint reedgrass	X	
Carex aquatilis	Water sedge	X	
Carex canescens	Gray sedge	X	
Carex disperma	Soft-leaved sedge		X
Carex utriculata [*Carex rostrata*]	Beaked sedge	X	
Epilobium angustifolium	Fireweed	X	
Equisetum arvense	Field horsetail	X	X
Eriophorum polystachion	Many-spiked cotton-grass		X
Fragaria virginiana	Virginia strawberry	X	X
Galium boreale	Northern bedstraw	X	
Geranium richardsonii	White geranium	X	
Geum macrophyllum	Large-leaved avens	X	
Linnaea borealis	Twinberry		X
Luzula parviflora	Small-flowered woodrush		
Mertensia ciliata	Ciliate bluebells		
Moneses uniflora	Woodnymph		X
Pedicularis groenlandica	Elephant's-head	X	
Pentaphylloides floribunda [*Potentilla fruticosa*]	Shrubby cinquefoil	X	
Phleum alpinum	Alpine timothy	X	
Picea engelmannii	Engelmann spruce		X
Picea glauca	White spruce	X	
Polygonum viviparum	Alpine bistort	X	
Potentilla gracilis	Slender cinquefoil		X
Pyrola asarifolia	Pink wintergreen		X
Pyrola minor	Lesser wintergreen		X
Rosa sayi	Prickly rose	X	
Salix bebbiana	Bebb willow	X	
Salix boothii	Booth willow	X	
Salix geyeriana	Geyer willow	X	
Salix planifolia	Planeleaf willow	X	
Saxifraga subapetala	Oregon saxifrage	X	
Streptopus amplexifolius	Clasping-leaved twisted-stalk		X
Thalictrum sparsiflorum	Few-flowered meadow-rue	X	
Trifolium repens	White clover	X	X
Veronica wormskjoldii	American alpine speedwell		X

Table 2.

Population Size of Colonies of *Rubus acaulis*
Along Sourdough Creek

Subpop.	Approximate # of Stems	Approximate Size	Habitat
A*	3000-6000	Ca 7 m wide x 0.1 km long stream segment	Planeleaf willow/beaked sedge
B*	3000-6000	25-30 m wide x ca 0.15 km long stream segment	Planeleaf willow/beaked sedge
B1	50-75	1 x 3 m	Planeleaf willow/beaked sedge
C	200	Ca 5 x 10 m	Planeleaf willow/beaked sedge
D	50-100	Ca 5 x 50 m	Planeleaf willow/beaked sedge
D1	25-50	Ca 10 x 30 m	Planeleaf willow/beaked sedge
E*	10,000-15,000	Ca 3 m wide x 0.3 km long stream segment	Planeleaf willow/beaked sedge & Engelmann spruce/twinberry
F	10,000-15,000	Ca 3 m x 0.1 km long stream segment	Engelmann spruce/twinberry
G	15,000-20,000	Ca 6 m x 0.3 km stream segment	Engelmann spruce/twinberry
H	10,000-15,000	Ca 6 m x 0.3 km stream segment	Engelmann spruce/twinberry

* Location of monitoring plots.

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have failed to document additional populations of *Rubus acaulis* on the Forest. Surveys by Zacharkevics and Mills in 1994-95 targeted upper Sourdough, Middle Clear, South Clear, Circle Park, Grommund, Pole, Caribou, and Hesse creeks. In 1999, new surveys were conducted along Little Sourdough, North Fork Crazy Woman, Muddy, Circle Park, South Clear, Little North Fork Crazy Woman, and Doyle, but no populations were found (Appendix C).

Monitoring of *Rubus acaulis*

Pilot monitoring studies in 1999 were conducted to assess baseline abundance, density, and frequency of three *Rubus acaulis* subpopulations along Sourdough Creek (these data are summarized in Appendix B). A variety of plot sizes were employed to test the efficiency and statistical relevance of different plot designs and sampling strategies. Analysis of the preliminary results for stem number and density (Appendix C) indicate that a prohibitively large number of samples would be required for these results to be statistically relevant at a 80, 90, or 95% confidence interval within 5-20% of the sample mean. These data still have some value for elucidating general patterns of density and population size, but due to statistical concerns the numbers should not be extrapolated across the entire population. Frequency data, however, fall within the desired 30-70% range for baseline data, which will allow future shifts in abundance or distribution to be readily observed (Elzinga et al. 1998).

Permanent photographic monitoring stations were established along US Highway 16 and adjacent to each of the three macroplots to record gross vegetation structure. Photos taken in 1999 (Fig. 6 and slides in Appendix D) show that the current vegetation along the middle reach of Sourdough Creek consists of dense thickets of willow and marsh graminoids, while the lower reaches are primarily Engelmann spruce forests. The location and orientation of the photo points is summarized in Table 3.

Table 3
Location of Permanent Photo Monitoring Points Along Sourdough Creek
(See Figure 3)

Photo Point 1. View downstream (NE) of US Highway 16 where it crosses Sourdough Creek. Photo taken from the 7th highway marker post from the northeast side of the road. View is 27° N. Photo depicts planeleaf willow and beaked sedge communities along the middle reach of Sourdough Creek (Fig. 6).

Photo Point 2. View to southeast from fence post on the north bank of Sourdough Creek, directly across from the origin of macroplot A. Photos taken at 130° and 148° to illustrate the condition of the plot and its planeleaf willow/beaked sedge vegetation.

Photo Point 3. View to south from wooden exclosure on the north bank of Sourdough Creek at the base of a large granite outcrop across from macroplot B. Photos taken at 110° and 156° to depict the condition of macroplot B and its willow thicket/beaked sedge communities.

Photo Point 4. View to southeast from fence post on north bank of Sourdough Creek across from macroplot E. Post is located across from a large granite outcrop bordering a small trail and is located at the junction of two large bowl-shaped meadows on the north side of the creek. Photos were taken at 74° and 142° to illustrate the Engelmann spruce/twinberry community.

All slides were taken on 18 July 1999 and included in Appendix D.

Figure 6 (page 17). *Rubus acaulis* photo point 1 depicting habitat condition of the middle reach of Sourdough Creek. Photo is oriented at 27 ° northeast from the 7th road marker on the north side of US Highway 16 (T50N R84W S34 SE4). WYNDD photograph by Walter Fertig, 18 July 1999.

DISCUSSION

Sourdough Creek supports the largest known population of Northern blackberry in Wyoming. Based on ocular surveys and monitoring plots established in 1999, the population along Sourdough Creek is currently estimated at 51,000-77,000 stems. While sizeable, the actual number of genetically distinct individuals is probably much lower. Fortunately, the population does not seem to be highly threatened by existing management activities (logging, livestock grazing, and recreation). Given the small geographic area occupied by these plants, however, *Rubus acaulis* remains vulnerable to large scale habitat loss or disturbance.

Trend data are needed to confirm if the Sourdough Creek population is truly stable and to provide an early warning system should changes in management be needed to ensure the plant's continued survival. Unfortunately, conducting an annual or periodic census of the entire population (counting each individual) is not a practical option due to the plant's low stature, densely brushy habitat, and scattered distribution. Statistically sound, systematic monitoring programs based on a subset of the population may be a more cost-effective means of determining trends.

A pilot monitoring study utilizing randomly located plots of various sizes was established along Sourdough Creek in 1999 to measure the density, distribution, and number of *Rubus acaulis* stems. Although this effort did yield useful population data, the results cannot be extrapolated from the sample plots to the entire *Rubus* population because the sampling intensity was insufficient to ensure statistical significance at even the modest cut-off of an 80% confidence interval within 20% of the population mean (Appendix B). This problem is not easily remedied by merely increasing the sample size, as the number of plots necessary for high statistical confidence may be prohibitively large (see Appendix B, pages 37-38). In addition, this approach is extremely labor-intensive, potentially environmentally destructive (rates of trampling and soil compaction may be high), and will be difficult to replicate due to the problems relocating plot boundaries within the dense underbrush.

A more feasible alternative is to use changes in frequency (the percentage of all possible plots within the sample area occupied by a species) to measure population trends. Frequency studies can be used for any species growth form (including annuals and rhizomatous perennials) and can be measured quickly and easily (Elzinga et al. 1998). The primary disadvantage of frequency is that it is strongly influenced by the size of the sampling unit. If plots are too large, frequency scores will be high and increases in abundance or shifts in distribution will be difficult to detect. Likewise, if plots are too small, frequency values will be artificially low and downward trends could go undetected. These problems can be mitigated by choosing a sample size that ensures a baseline frequency of 30-70% (Elzinga et al. 1998). As with other sampling methodologies, an adequate number of samples are necessary for statistical relevance. Grieg-Smith (1983) recommends 100 frequency plots per macroplot as a minimum target.

Changes in frequency over time can be the result of changes in density, absolute numbers, or spatial arrangement in short-lived organisms (Grieg-Smith 1983). As a result, trends from frequency studies need to be interpreted carefully. Additional information on habitat quality and condition and gross population size from observational studies may still be necessary to inform management decisions (Elzinga et al. 1998).

Frequency was measured at macroplots A and B along Sourdough Creek in 1999 (Appendix B). Baseline frequency values of 50-60% were derived using standard 0.2 x 0.5 m Daubenmire frames, while scores of 60-71% were derived using 0.4 x 1 m plots. Of the two plot sizes, the Daubenmire frame is superior in achieving the desired 30-70% baseline rate recommended by Elzinga et al. (1998). Square plots may also be used in frequency monitoring, although rectangular plots (such as a Daubenmire frames) may be better at capturing sparsely distributed and rare species (Elzinga et al. 1998).

Existing baseline data from the 1999 pilot study could be used to measure future changes in frequency, but will be difficult to replicate because of problems relocating survey lanes and plots in the dense underbrush of Sourdough Creek. An alternative is to establish new transects marked by permanent monuments (Elzinga et al. 1998). These transects could be single lanes 50-100 meters long, or a series of non-overlapping, parallel transects 20-25 m long. Enough transect lanes are needed per macroplot to ensure a minimum of 100 frequency plots (Grieg-Smith 1983). Daubenmire frames could be placed in a stratified random pattern (i.e. one chosen randomly within each 1 meter block on the right or left side of the baseline) or a systematic manner (i.e. the first plot is located randomly in the first meter block and then every subsequent plot is located 1 meter farther along the tape). Such plots should be established at a minimum of five of the known subpopulations of *Rubus acaulis* along Sourdough Creek. Transects should be placed in a stratified random manner to ensure that a mix of occupied and suitable unoccupied habitat is included, thus allowing possible range expansions to be detected. End points of the transects need to be permanently marked and points along the line should also be staked with permanent markers to minimize movement of the line in future visits. GPS readings of transect endpoints should be made to assist in their relocation in case markers are dislodged or lost.

Frequency plots along the transect line can be marked permanently to facilitate future relocation, or treated as temporary plots (in which case new plots will need to be selected randomly on subsequent visits). Permanent marking is initially more time consuming and will require an investment in marker posts and GPS measurements, but offers several important advantages for data analysis. Statistical tests for changes in frequency from permanent plots, such as McNemar's test, are more powerful at detecting small (but potentially significant) changes than standard tests of independent data and may require fewer plots (Zar 1996; Elzinga et al. 1998). McNemar's test is a modification of the standard chi-square 2 x 2 matrix test, but focuses primarily on changes from presence to absence (or vice-versa) in paired data over two time periods. The test employs a simple equation to assess if observed changes are significantly different from a null-hypothesis of no change (Table 4). If permanent plots cannot be efficiently or reliably relocated, the chi-square test is still a useful tool to test the significance of frequency changes over time. For a perennial species like *Rubus acaulis,* as few as 51-156 plots may be sufficient to detect a 10% change in frequency over short time intervals (Elzinga et al 1998, p. 464).

Photo plots can also be a powerful tool for measuring changes in habitat suitability, especially when used in conjunction with quantitative data or detailed observations of plant abundance or distribution. Permanent photo points were established in 1999 to document the current condition of the vegetation along Sourdough Creek. These sites should be revisited every 1-2 years to record any potential changes. It might be informative to take site photos both before and after livestock graze the site to compare the effects of grazing from one year to the next.

Other qualitative studies should be continued on a 3-5 year cycle. The distribution of *Rubus acaulis* should be remapped periodically along Sourdough Creek (preferably using a global positioning system) to detect gross changes. Detailed notes on abundance, density, habitat preferences, and associated species should also be made periodically to confirm if current patterns are being maintained.

Given the relatively broad habitat tolerance of Northern blackberry in the Sourdough Creek drainage and the distribution of similar habitats elsewhere in the Bighorns, the limited distribution of *Rubus acaulis* in Bighorn National Forest remains an enigma. The plant’s rarity could be an artifact of incomplete survey, as the species can be difficult to locate (especially in vegetative condition). It is more likely that Northern blackberry is truly uncommon, but probably not occupying its full potential range. Poor fruit production or dispersal may be severely limiting the plant’s ability to spread to new locations. If this is true, managers might consider transplanting seeds or stems from the Sourdough population to other wetland sites as a means of increasing its numbers and range in the Bighorn Mountains.

It is not known whether *Rubus acaulis* was once more widespread in the Bighorn Range and has been declining due to long-term climate change, habitat loss, or incompatible past management. Evidence from Sourdough Creek, however, suggests that *R. acaulis* is surprisingly resilient to such disturbances as grazing, flooding, tie hacking, clear cutting, and recreation. Qualitative and semi-quantitative monitoring programs, such as those initiated in 1999, will help land managers assess the future trends and management needs of this population.

Table 4
Tests for Determining the Significance of Changes in Frequency

McNemar's Test for Paired Sample Frequency Data

McNemar's test is used to test whether an observed change in frequency at a permanent plot over time is significantly different from the null hypothesis of no change. To use the test, data from two different years are compared in a 2 x 2 matrix in which similarities and differences in frequency values are recorded in the appropriate cells (see below):

	Year 1 Present	Year 1 Absent
Year 2 Present	% present both years	% increase in presence
Year 2 Absent	% decrease in presence	% absent both years

McNemar's test is interested only in the % of cells that increase or decrease in presence between the two years. A chi-square value is determined for these cells using the following formula (Zar 1996):

$$\chi^2 = \frac{(\left|\text{(\% increased presence - \% decreased presence)}\right| - 1)^2}{\text{\% increased presence + \% decreased presence}}$$

Many computerized statistical packages can do this calculation automatically and generate a P value for comparison with the null hypothesis at the desired level of confidence. The P value for the null and χ^2 can also be calculated from a chi-square distribution table (see page 334 of Elzinga et al. 1998), based on the desired α value (typically 0.05 in most studies). The value of χ^2 at 1 degree of freedom (the typical value in 2 x 2 blocks) can then be compared to the null value at the desired α to see if the χ^2 is lower than the null (in which case the null hypothesis is not rejected and the observed difference is not significant) or higher (in which the null hypothesis is rejected).

Chi-Square Test for Independent Data

If frequency plot data from year to year are derived from temporary plots that are randomly selected each year (and thus independent), the chi-square test can be used. See Elzinga et al. (1998, pp. 241-243) for further information on this test.

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Appendix A.

Species Summary for *Rubus acaulis*

Classification:

Scientific Name: *Rubus acaulis* Michx. (Fl. Bor. Am. 1:298. 1803)
Common Name: Northern blackberry, nagoonberry, or dwarf raspberry.
Family: Rosaceae (Rose family).
Synonyms: *Cylactis arctica* (L.) Raf. ssp. *acaulis* (Michx.) Weber (Spackman et al. 1997); *Rubus arcticus* L. ssp. *acaulis* (Michx.) Focke (Hulten 1968).
Phylogenetic Relationships: *Rubus* is one of the largest and most taxonomically complicated genera in the Northern Hemisphere, with 200-700 species recognized (Gleason and Cronquist 1991). *R. acaulis* is one of 5-8 species in the subgenus *Cylactis*, a group that is characterized by herbaceous annual stems with few or no bristles and a low stature (Bailey 1941). Northern blackberry is sometimes treated as a variety or subspecies of *R. arcticus*, a species found primarily in northern Eurasia, Alaska, and the Yukon (Hulten 1968). Species within the subgenus are capable of interbreeding and several putative hybrid taxa have been formally described (eg. *R. alaskensis, R. paracaulis*) (Bailey 1941; Hulten 1968; Porsild and Cody 1980). Weber (1985) recently resurrected *Cylactis* as a genus, a change that seems little warranted given the strong similarities in leaf, floral, and fruit morphology between this group and other subgenera of *Rubus.*

Legal Status: *Rubus acaulis* is listed as Sensitive in US Forest Service Region 2 (Estill 1993). The Sensitive list includes those species identified by the Regional Forester with "significant current or predicted downward trends in population numbers, density, ... or habitat capability" which makes them vulnerable to extirpation (Forest Service Manual 2670.5). Sensitive species are typically managed so as to prevent them from experiencing further declines and becoming listed as Threatened or Endangered under the Endangered Species Act. Northern blackberry is not protected under state law in either Wyoming or Colorado.

Natural Heritage Rank: The network of Natural Heritage programs gives *Rubus acaulis* a rank of G5, indicating that the species is "demonstrably secure, although [it] may be rare in parts of its range, especially at the periphery" (Fertig and Beauvais 1999). Northern blackberry is ranked S1 in both Wyoming and Colorado, indicating that it is imperiled in both states (Spackman et al. 1997; Fertig and Beauvais 1999). Although not especially common, *R. acaulis* is not currently tracked as a species of special concern in Montana (Lesica and Shelly 1991).

Description: Northern blackberry is a strongly rhizomatous perennial herb with non-bristly or prickly annual stems under 12-15 cm tall (Figs. 7-8). Stems are finely pubescent, erect, and bear 2-5 alternate leaves. Leaves are divided into 3 ovate to obovate leaflets, 1-3.5 cm long with serrated margins and blunt or rounded tips. Flowers are usually solitary and equal to or shorter than the leaves. Petals are rose-pink, narrowly spoon-shaped, 10-15 mm long, and erect to spreading (forming a shallow cup). Fruits are red, globe-shaped aggregations of drupelets (blackberries or raspberries) about 1 cm broad (Hitchcock and Cronquist 1961; Hulten 1968; Moss 1983; Dorn 1992; Fertig et al. 1994).

Similar Species: *Rubus pubescens* has white petals 5-8 mm long and sharp-toothed leaflets. Other *Rubus* spp. in Wyoming have woody, prickly-bristly stems over 1 m tall or simple leaves. *Fragaria* spp. have white flowers on leafless stems and have above-ground stolons. Small, vegetative specimens of *Geum macrophyllum* have pinnately compound leaves with 5 or more leaflets (the terminal leaflet being largest) (Fertig et al. 1994).

Figure 7. Line drawing of *Rubus acaulis* from Fertig et al. (1994).

Geographic Range: *Rubus acaulis* ranges from central Alaska and the Northwest Territories to Newfoundland, south to New Brunswick, Minnesota, Manitoba and British Columbia, with scattered populations extending south in the Rocky Mountains to Montana, northern Wyoming, and north-central Colorado (Hulten 1968; Porsild and Cody 1980; Spackman et al. 1997). In Wyoming, this species is restricted to the Yellowstone Plateau and Bighorn Range in Johnson and Teton counties (Figure 9). Locations in Wyoming are summarized in Table 4.

Habitat: Across its range, *Rubus acaulis* occurs in alpine tundra, montane meadows, boggy woods, and marshlands (Hitchcock and Cronquist 1961). Wyoming populations are found primarily in hummocky marshes dominated by *Salix planifolia* and *Carex utriculata* [synonym = *C. rostrata*], margins of boggy beaver dam ponds, and streamsides in shady *Picea engelmannii/Linnaea borealis* forests at elevations of 2257-2350 m (7400-7700 ft). Populations typically occur on organic-rich histisols or inceptisols derived from Quaternary alluvial/colluvial deposits or gneiss bedrock on gentle slopes or flats (Love and Christiansen 1985). Common associated species include *Equisetum arvense, Pedicularis groenlandica, Pentaphylloides floribunda* [synonym = *Potentilla fruticosa*], *Fragaria virginiana, Geum macrophyllum,* and *Thalictrum sparsiflorum*.

Average annual precipitation within the range of *Rubus acaulis* in Wyoming varies from 508-762 mm (20-30 inches) on the east slope of the Bighorn Range to 1016 mm (40 inches) in the Yellowstone Lake area (Martner 1986). Peak precipitation comes in May and June in the Bighorn Range and December-January and June in Yellowstone. Mean annual temperature is 0-2.2° C (32-36° F) in the Bighorns and 0° C (32° F) at Yellowstone Lake. Mean maximum and minimum temperatures in January are -3.3° and - 11.6° C (26° and 6° F) in the Bighorns and - 4.4° and - 17.6° C (24° and 0° F) at Yellowstone Lake, while mean maximum and minimum July temperatures are 23.1-24.2° and 5.5-7.7° C (74-76° and 42-46° F) in the Bighorns and 23.1° and 3.3° C (74° and 38° F) in Yellowstone (Martner 1986).

Population Size and Ecology: *Rubus acaulis* is currently known from 3 extant and 1 vague, historical population in Wyoming. Two populations are known in Yellowstone National Park and at least one was reported as “relatively abundant” in 1997 (Jennifer Whipple, pers. comm.). The Sourdough Creek population in Bighorn National Forest contained an estimated 51,000-77,000 stems in 1999. Because of the rhizomatous nature of *Rubus acaulis*, the actual number of

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Figure 8 (Page 27). Photograph of *Rubus acaulis* from the south bank of Sourdough Creek in the Bighorn Mountains (Johnson County, WY). The flowering plants and adjacent vegetative stems may be part of a single genet found in sandy-mossy soil in a riparian Engelmann spruce grove. WYNDD photograph by Walter Fertig, 15 July 1999.

Fig 8

Figure 9. Wyoming distribution of *Rubus acaulis*.

genetically distinct individuals is probably much lower (perhaps in the low thousands). The Sourdough population is divided into 10 main subpopulations, each ranging in size from 25-20,000 stems. Patches may cover an area of less than 3 square meters or extend almost continuously for nearly 0.3 km (0.2 miles). Density ranges from 10-48 stems per square meter in densely forested habitats to 27-50 stems per square meter in willow thicket/beaked sedge marsh communities. 23-26% of all stems produce flowers in riparian Engelmann spruce habitats, while 24-39% of all stems are reproductive in willow thickets and marshes.

Rubus acaulis can spread asexually by underground rootstalks and sexually by production of fleshy, blackberry-like aggregate fruits. Bailey (1941) suggested that members of the subgenus *Cylactis* may produce functionally unisexual flowers to facilitate cross pollination. Although no evidence of hybridization has been found in Wyoming, *R. acaulis* can hybridize with *R. pubescens*, *R. arcticus*, and *R. stellatus* (*R. arcticus* var. *stellatus*) where their ranges overlap in southern Canada and Alaska (Hulten 1968; Porsild and Cody 1980). Honeybees were observed pollinating *R. acaulis* flowers in the Bighorns in 1999.

<u>Threats</u>: Logging, recreation, and impoundments have been reported as the main threats to *Rubus acaulis* populations in Wyoming. At least one population in Yellowstone National Park is located along a pack trail and may be impacted by trampling. Construction of the Tie Hack Dam was once considered an important threat to the Sourdough Creek population (Fertig 1999), but the reservoir has inundated little, if any, *R. acaulis* habitat. Development of new recreation facilities in conjunction with the dam, however, could lead to some habitat loss or degradation. Past cutting, tie hacking, and grazing along Sourdough Creek seems to have had little impact on this population.

<u>Land Ownership</u>: All known populations of *Rubus acaulis* are on public lands. Two occurrences are protected in Yellowstone National Park. Populations in the Bighorn Range occur on National Forest lands managed for multiple use.

Table 5

Location Information and Demographic Data for Known Populations of *Rubus acaulis* in Wyoming

Bighorn Range

Occurrence # 001
County: Johnson
Legal Description: **T50N R84W S17** (TRS approximate).
Latitude: 44° 18' 11" N (approximate centrum).
Longitude: 106° 59' 49" W (approximate centrum).
Elevation: 7000-9000 ft (2130-2740 m).
USGS 7.5' Quad: Hunter Mesa.
Location: East slope Bighorn Range, “headwaters of Clear Creek and Crazy Woman River”. Tweedy’s exact collection site is unknown.
Area: Size unknown.
Number of Plants: Not known.
Density: Not known.
Evidence of Reproduction: Observed in vegetative condition by Frank Tweedy in July-August 1900.
Evidence of Expansion/Contraction: Not known. Population has not been relocated since 1900.

Occurrence # 003
County: Johnson
Legal Description: **T50N R84W S26** (S2 of SW4 of SE4, E2 of SW4 of SE4, & SW4 of NE4 of SE4), **S34** (SW4SW4 of NE4 of SE4 & NE4NE4 of SE4), **S35** (SE4 of NW4NW4 & W2 of SW4 of NW4).
Latitude: 44° 16' 02" N (centrum)
North: 44° 16' 39" N.
South: 44° 15' 24" N.
Longitude: 106° 56' 05" W (centrum)
East: 106° 55' 15" W.
West: 106° 56' 47" W.
Elevation: 7440-7740 ft (2265-2360 m).
USGS 7.5' Quad: Hunter Mesa.
Location: East slope Bighorn Range, along Sourdough Creek between 0.25 air miles NE of US Highway 16 NE to ca 0.2 air miles NE of the confluence of Sourdough and Little Sourdough creeks, 11-12 air miles SW of Buffalo.
Area: ca 5 acres of occupied habitat along a 1.5 mile stretch of creek. Population consists of 10 primary subpopulations.
Number of Plants: Population estimated at 51,000-77,000 stems in July 1999. The actual number of genetically distinct individuals is, however, much lower.
Density: Clones may be locally dense in areas of suitable habitat, but these patches are often widely scattered.
Evidence of Reproduction: Observed in flower and vegetative condition on July 12-17, 1999.
Evidence of Expansion/Contraction: Originally discovered in August 1994 and still extant in July 1999. The population is now known to be much larger than in 1994, although this is probably due to more thorough survey rather than a population increase.

Yellowstone Plateau

Occurrence # 002
County: Teton
Legal Description: **T50N R113W S28** (NW4NW4). TRS taken from BLM 1:100,000 quad.
Latitude: 44° 16' 48" N (centrum).
North: 44° 16' 50" N.
South: 44° 16' 47" N.

Longitude: 110° 28' 37" W (centrum).
East: 110° 28' 31" W.
West: 110° 28' 40" W.
Elevation: 7465 ft (2275 m).
USGS 7.5' Quad: Heart Lake.
Location: Yellowstone Plateau, banks of small creek draining into the NE shore of Heart Lake, ca 0.4 miles NW of the outlet of Beaver Creek, ca 7.5 miles E of the Lewis Lake Campground.
Area: 2 acres.
Number of Plants: Reported as "relatively abundant" by Jennifer Whipple in 1997.
Density: Not known.
Evidence of Reproduction: Plants observed in flower and vegetative condition on July 7, 1997.
Evidence of Expansion/Contraction: Population originally discovered in late 1970s and still extant in 1997.

Occurrence # 004
County: Teton
Legal Description: **T50N R113W S19** (SW4 of NE4). TRS taken from BLM 1:100,000 quad.
Latitude: 44° 17' 23" N (centrum).
Longitude: 110° 30' 25" W (centrum).
Elevation: 7460 ft (2273 m).
USGS 7.5' Quad: Mount Sheridan.
Location: Yellowstone Plateau, Witch Creek at S end of Heart Lake Geyser Basin.
Area: Not known.
Number of Plants: Not known.
Density: Not known.
Evidence of Reproduction: Plants observed in flower and vegetative condition by Jennifer Whipple on June 28, 1995.
Evidence of Expansion/Contraction: Population has not been relocated since 1995.

Appendix B.

Monitoring Data, 1999
Rubus acaulis (Northern blackberry)

Macroplot A

Date: 14 July 1999
Surveyors: Walter Fertig, Kevin O'Dea, and JoAnn Storlie
Time: 320 minutes.

Location: Macroplot A is located along the south bank of Sourdough Creek ca 0.4 km (0.25 miles) northeast of the crossing of US Highway 16 (Fig. 3 and slides in Appendix D). The plot is marked by a green fence post on the north bank located near the confluence of two small side valleys and ca 0.15 km (0.1 mile) northeast of the powerline. The origin of the plot is marked by an orange-tipped rebar located in a small clearing on the south bank. The long axis of the plot parallels the creek and extends for 16 m from the origin on a 126° E trajectory (the end point is located at the base of a willow clump and is marked by rebar). The short axis of the plot is perpendicular to the creek and extends for 5 m at 42°. The southwest side of the macroplot serves as the baseline, from which five 1 x 16 m plots are formed by 50 m tapes. Lanes are numbered 1-5, starting at the origin.

Procedure: 50 0.4 x 1 m plots were selected using a stratified random procedure. All stems in each plot were counted and classified as either vegetative or flowering. Frequency was measured using a 0.2 x 0.5 m Daubenmire frame placed in the upper right hand corner of each plot and was based on presence/absence of either stem class. A score of 1 was assigned if stems were present, and 0 if stems were absent. Counts of vegetative and flowering stems were also done in two randomly chosen 1 x 8 meter lanes (divided into 1 x 2 m plots) to test the efficiency of larger plots in assessing density. Frequency was not calculated in these plots.

0.4 x 1 meter plots

Lane #	Plot	# of Vegetative Stems	# of Flowering Stems	Total # of Stems	Frequency
1	0.8-1.2 m	10	0	10	1
1	2.8-3.2 m	42	87	129	1
1	3.6-4.0 m	25	41	66	1
1	5.2-5.6 m	0	0	0	0
1	5.6-6.0 m	0	0	0	0
1	8.0-8.4 m	0	0	0	0
1	9.2-9.6 m	0	0	0	0
1	10.4-10.8 m	0	0	0	0
1	13.6-14.0 m	1	0	1	0
2	2.0-2.4 m	37	2	39	1
2	2.8-3.2 m	30	8	38	1

2	3.6-4.0 m	63	69	132	1
2	5.6-6.0 m	2	1	3	0
2	6.0-6.4 m	0	0	0	0
2	6.4-6.8 m	0	0	0	0
2	8.4-8.8 m	0	0	0	0
2	9.2-9.6 m	0	0	0	0
2	10.0-10.4 m	0	0	0	0
2	11.2-11.6 m	0	0	0	0
2	12.4-12.8 m	0	0	0	0
2	13.6-14.0 m	1	0	1	0
2	14.4-14.8 m	0	0	0	0
2	15.2-15.6 m	2	0	2	0
3	3.2-3.6 m	50	17	67	1
3	3.6-4.0 m	87	27	114	1
3	4.8-5.2 m	13	7	20	1
3	5.2-5.6 m	24	2	26	1
3	8.0-8.4 m	0	0	0	0
3	9.2-9.6 m	0	0	0	0
3	11.6-12.0 m	0	0	0	0
3	14.0-14.4 m	3	0	3	1
4	2.0-2.4 m	0	0	0	0
4	2.8-3.2 m	9	0	9	1
4	3.2-3.6 m	38	8	46	1
4	5.2-5.6 m	15	2	17	0
4	6.4-6.8 m	0	0	0	0
4	11.2-11.6 m	3	0	3	1
4	12.8-13.2 m	18	3	21	1
4	14.8-15.2 m	14	0	14	1
4	15.6-16.0 m	13	0	13	1
5	1.2-1.6 m	0	0	0	0
5	3.2-3.6 m	21	0	21	1
5	3.6-4.0 m	32	5	37	1
5	4.0-4.4 m	10	1	11	1
5	8.8-9.2 m	0	0	0	0
5	9.2-9.6 m	1	0	1	1
5	10.4-10.8 m	24	4	28	1
5	10.8-11.2 m	36	17	53	1
5	12.8-13.2 m	37	6	43	1
5	13.2-13.6 m	26	1	27	1

Total	687	308	995	25 (50%)
Mean per plot	13.7	6.2	19.9	
ST Deviation	19.9	16.7	32.5	3.5
Mean per m^2	34.4	15.4	49.8	
% Flowering	30.1			

1 x 8 meter lanes (divided into 1 x 2 meter plots)

Lane # Plot # of Vegetative # of Flowering Total # of Stems

		Stems	Stems	
1	0-2 m	53	31	84
1	2-4 m	58	165	223
1	4-6 m	2	2	4
1	6-8 m	0	0	0
4	8-10 m	22	4	26
4	10-12 m	100	16	116
4	12-14 m	137	28	165
4	14-16 m	11	0	11

Total	383	246	629
Mean per plot	47.9	30.8	78.7
ST Deviation	49.6	55.7	83.5
Mean per m^2	23.9	15.4	39.3
% Flowering	39.1		

Monitoring Data, 1999
Rubus acaulis (Northern blackberry)
Macroplot B

Date: 15 July 1999
Surveyors: Walter Fertig, Kevin O'Dea, and JoAnn Storlie
Time: 270 minutes.

Location: Macroplot B is located along the south bank of Sourdough Creek ca 0.65 km (0.4 miles) northeast of the crossing of US Highway 16 (Fig. 3 and slides in Appendix D). The origin of the plot is 48 m due E of a large, lone white spruce (*Picea glauca*) on the south side of the creek and is marked by a green fence post and short piece of re-bar. The origin is also 128° S of a large, aspen-covered granite outcrop on the north bank of the creek and 162° S of a Forest Service wooden exclosure on the north bank. The 16 m endpoint of the macroplot is oriented 312° NW of the origin and runs perpendicular to the creek. The 5 m end point of the plot is 228° SW and is marked with re-bar (the re-bar is actually at 5.2 m). The south end of the macroplot serves as the baseline, from which five 1 x 16 m plots are formed by 50 m tapes. Lanes are numbered 1-5, starting at the origin.

Procedure: 60 0.4 x 1 m plots were selected using a stratified random procedure. All stems in each plot were counted and classified as either vegetative or flowering. Frequency was measured using a 0.2 x 0.5 m Daubenmire frame placed in the upper right hand corner of each plot and was based on presence/absence of either stem class. A score of 1 was assigned if stems were present, and 0 if stems were absent. Counts of vegetative and flowering stems were also done in 5 randomly chosen 1 x 8 meter lanes (divided into 1 x 2 m plots) to test the efficiency of larger plots in assessing density. Frequency was not calculated in these plots.

0.4 x 1 m plots

Lane #	Plot	# of Vegetative Stems	# of Flowering Stems	Total # of Stems	Frequency
1	1.2-1.6 m	0	0	0	0
1	2.0-2.4 m	0	0	0	0
1	3.2-3.6 m	0	0	0	0
1	3.6-4.0 m	0	0	0	0
1	6.4-6.8 m	37	5	42	1
1	8.4-8.8 m	10	7	17	1
1	9.2-9.6 m	20	5	25	1
1	9.6-10.0 m	25	9	34	1
1	11.6-12.0 m	1	0	1	0
1	13.2-13.6 m	0	0	0	0
1	14.0-14.4 m	0	0	0	0
1	14.4-14.8 m	0	0	0	0
1	15.2-15.6 m	60	24	84	1
2	1.2-1.6 m	0	0	0	0
2	2.8-3.2 m	0	0	0	0
2	4.0-4.4 m	2	0	2	1
2	5.6-6.0 m	20	1	21	1
2	6.4-6.8 m	24	6	30	1
2	7.2-7.6 m	2	0	2	1
2	8.8-9.2 m	13	10	23	1
2	9.2-9.6 m	11	13	24	1
2	11.2-11.6 m	29	5	34	1
2	12.8-13.2 m	13	0	13	0
2	14.4-14.8 m	0	0	0	0
2	15.2-15.6 m	3	0	3	1
3	0.4-0.8 m	0	0	0	0
3	1.6-2.0 m	0	0	0	0
3	2.0-2.4 m	2	0	2	0
3	3.6-3.0 m	4	4	8	1
3	4.4-4.8 m	17	6	23	1
3	8.4-8.8 m	13	1	14	1
3	10.0-10.4 m	28	4	32	1
3	10.8-11.2 m	11	0	11	1
3	11.6-12.0 m	23	3	26	1
3	12.0-12.4 m	11	2	13	1
3	14.4-14.8 m	7	1	8	1
4	0.8-1.2 m	0	0	0	0
4	1.2-1.6 m	0	0	0	0
4	1.6-2.0 m	2	0	2	1
4	2.4-2.8 m	3	0	3	1
4	3.6-4.0 m	14	4	18	1
4	6.0-6.4 m	7	1	8	1
4	7.2-7.6 m	14	2	16	1
4	8.0-8.4 m	3	1	4	1

4	8.8-9.2 m	12	3	15	1
4	10.4-10.8 m	12	5	17	1
4	11.2-11.6 m	22	1	23	0
4	14.4-14.8 m	23	10	33	1
4	15.2-15.6 m	1	0	1	0
5	1.6-2.0 m	0	0	0	0
5	2.0-2.4 m	0	0	0	0
5	3.6-4.0 m	0	0	0	0
5	4.4-4.8 m	5	0	5	1
5	5.6-6.0 m	8	1	9	1
5	6.0-6.4 m	1	0	1	1
5	9.2-9.6 m	16	24	40	1
5	11.2-11.6 m	20	7	27	0
5	12.8-13.2 m	16	14	30	1
5	13.6-14.0 m	14	8	22	1
5	14.8-15.2 m	1	0	1	0

Total	580	187	767	36 (60%)
Mean per plot	9.7	3.1	12.8	
ST Deviation	11.5	5.3	16.8	3.8
Mean per m^2	24.2	7.8	32	
% Flowering	24.4			

1 x 8 m plots (divided into 1 x 2 meter plots)

Lane #	Plot	# of Vegetative Stems	# of Flowering Stems	Total # of Stems
1	0-2 m	0	0	0
1	2-4 m	0	0	0
1	4-6 m	27	21	48
1	6-8 m	40	21	61
2	8-10 m	57	25	82
2	10-12 m	117	26	143
2	12-14 m	41	20	61
2	14-16 m	13	2	15
3	0-2 m	2	0	2
3	2-4 m	31	6	37
3	4-6 m	28	11	39
3	6-8 m	67	25	92
4	0-2 m	2	0	2
4	2-4 m	31	6	37
4	4-6 m	28	11	39
4	6-8 m	25	13	38
5	8-10 m	69	48	117
5	10-12 m	94	38	132
5	12-14 m	87	39	126
5	14-16 m	30	13	43

Total	789	325	1114
Mean per plot	39.5	16.3	55.8
ST Deviation	33.0	14.2	45.7
Mean per m^2	19.7	8.1	27.8
% Flowering	29.2		

Monitoring Data, 1999
Rubus acaulis (Northern blackberry)
Macroplot E

Date: 17 July 1999
Surveyors: Walter Fertig
Time: 180 minutes (total)

Location: Macroplot E is located along the southeast bank of Sourdough Creek, ca 1.8 km (1.1 miles) northeast of the crossing of US Highway 16 (Fig. 3 and slides in Appendix D) and consists of 3 separate 2 x 6 m plots. The approximate location of the plots is marked by a fence post on the north side of the creek (directly opposite the middle plot). Each plot is marked by re-bar at the origin (always the western-most point) and parallels the creek. The southwestern-most plot (E-1 [marked 3A on metal tag]) is located in a grove of Engelmann spruce on the inside curve of a sharp bend in the creek formed by an old beaver dam. The end point of this plot is 20° N of the origin and marked with re-bar. A second plot (E-2) is located downstream near a bend and is located directly across from a prominent granite knob on the north bank. The endpoint of this plot is 24° N of the origin. The final plot (E-3) is at the far northwest end of this same Engelmann spruce grove. The end point of the plot is 15° N of the origin.

Procedure: Two parallel 1 x 6 m lanes were established at each site. The number of vegetative and flowering stems were counted in each lane in 1x 2 m plots. Frequency data were not collected.

2 x 6 m plots

Lane	Plot	# of Vegetative Stems	# of Flowering Stems	Total # of Stems
1 upland lane	0-2 m	20	10	30
1 upland lane	2-4 m	9	1	10
1 upland lane	4-6 m	1	0	1
1 stream lane	0-2 m	50	19	69
1 stream lane	2-4 m	6	2	8
1 stream lane	4-6 m	2	0	2

Total	88	32	120
Mean per plot	14.7	5.3	20.0
ST. Deviation	18.6	7.7	26.2
Mean per m^2	7.3	2.7	10.0
% Flowering	26.7		

2 x 6 m plots

Lane	Plot	# of Vegetative Stems	# of Flowering Stems	Total # of Stems
2 upland lane	0-2 m	33	13	46
2 upland lane	2-4 m	26	8	34
2 upland lane	4-6 m	32	4	36
2 stream lane	0-2 m	61	43	104
2 stream lane	2-4 m	106	36	142
2 stream lane	4-6 m	180	30	210

Total	438	134	572
Mean per plot	73.0	22.3	95.3
ST. Deviation	60.3	16.1	70.9
Mean per m^2	36.5	11.2	47.7
% Flowering	23.4		

2 x 6 m plots

Lane	Plot	# of Vegetative Stems	# of Flowering Stems	Total # of Stems
3 upland lane	0-2 m	40	6	46
3 upland lane	2-4 m	13	3	16
3 upland lane	4-6 m	0	0	0
3 stream lane	0-2 m	24	4	28
3 stream lane	2-4 m	32	8	40
3 stream lane	4-6 m	44	25	69

Total	153	46	199
Mean per plot	25.5	7.7	33.2
ST. Deviation	16.8	8.9	24.2
Mean per m^2	12.8	3.8	16.6
% Flowering	23.1		

Determining the Minimum Number of Plots Necessary for Estimating Population Means of *Rubus acaulis*

To derive meaningful population-wide statistics (such as the number of stems or density), an adequate number of sample plots must be measured. The following formula has been developed to determine the minimum number of sample plots needed for statistical significance, based on the preliminary mean and standard deviation (derived from a pilot study), desired confidence interval, and desired precision level (Elzinga et al. 1998):

$$n = \frac{[Z\propto]^2\ [s]^2}{[B]^2}$$

Where n = the uncorrected sample size estimate; $Z\propto$ = the standard normal coefficient for the desired confidence interval (C.I.) level (95% C.I. = 1.96, 90% C.I. = 1.64, 80% C.I. = 1.28); s = the sample standard deviation; and B = the desired precision level (i.e. the desired % error from the mean multiplied by the sample mean. For example, B for a 5% desired error of a mean of 30.0 = 1.5).

The value for n is then applied to a correction table based on the desired confidence interval (Elzinga et al 1998, pp 349-350) to determine the minimum number of plots required. The minimum number of plots needed for adequate sampling based on 1999 pilot monitoring data is listed below:

Plot	Confidence Interval	Desired % of Mean	Minimum # of Plots
A 0.4 x 1	95%	5%	4866
A 0.4 x 1	95%	10%	1217
A 0.4 x 1	95%	20%	305
A 0.4 x 1	90%	5%	3393
A 0.4 x 1	90%	10%	849
A 0.4 x 1	90%	20%	213
A 0.4 x 1	80%	5%	2011
A 0.4 x 1	80%	10%	503
A 0.4 x 1	80%	20%	125
A 1 x 2	95%	5%	2113
A 1 x 2	95%	10%	520
A 1 x 2	95%	20%	130
A 1 x 2	90%	5%	1448
A 1 x 2	90%	10%	360
A 1 x 2	90%	20%	93
A 1 x 2	80%	5%	883
A 1 x 2	80%	10%	220
A 1 x 2	80%	20%	60

Plot	Confidence Interval	Desired % of Mean	Minimum # of Plots
B 0.4 x 1	95%	5%	3169
B 0.4 x 1	95%	10%	792
B 0.4 x 1	95%	20%	198
B 0.4 x 1	90%	5%	2211
B 0.4 x 1	90%	10%	553
B 0.4 x 1	90%	20%	137
B 0.4 x 1	80%	5%	1335
B 0.4 x 1	80%	10%	333
B 0.4 x 1	80%	20%	86
B 1 x 2	95%	5%	1234
B 1 x 2	95%	10%	310
B 1 x 2	95%	20%	80
B 1 x 2	90%	5%	860
B 1 x 2	90%	10%	215
B 1 x 2	90%	20%	58
B 1 x 2	80%	5%	514
B 1 x 2	80%	10%	126
B 1 x 2	80%	20%	37
E-1 1 x 6	95%	5%	3130
E-1 1 x 6	95%	10%	782
E-1 1 x 6	95%	20%	196
E-1 1 x 6	90%	5%	2285
E-1 1 x 6	90%	10%	556
E-1 1 x 6	90%	20%	137
E-1 1 x 6	80%	5%	1318
E-1 1 x 6	80%	10%	327
E-1 1 x 6	80%	20%	85
E-2 1 x 6	95%	5%	1010
E-2 1 x 6	95%	10%	252
E-2 1 x 6	95%	20%	68
E-2 1 x 6	90%	5%	718
E-2 1 x 6	90%	10%	172
E-2 1 x 6	90%	20%	50
E-2 1 x 6	80%	5%	425
E-2 1 x 6	80%	10%	107
E-2 1 x 6	80%	20%	33
E-3 1 x 6	95%	5%	954
E-3 1 x 6	95%	10%	242
E-3 1 x 6	95%	20%	66
E-3 1 x 6	90%	5%	673
E-3 1 x 6	90%	10%	171
E-3 1 x 6	90%	20%	48
E-3 1 x 6	80%	5%	399
E-3 1 x 6	80%	10%	102
E-3 1 x 6	80%	20%	30

Appendix C.

1995-1999 Survey Routes

for *Rubus acaulis* in Bighorn National Forest

Appendix D.

Slides