Dinosaur National Monument
Survey Design and Site Selection Report

Defining the Upland Resources for Monitoring

Discussions with DINO resource management staff identified big sagebrush and grassland communities as the main priority for long-term monitoring. Grasslands occur as an early successional stage of big sagebrush communities after fire, and hereafter, these communities will be referred to as "sagebrush". Sagebrush communities within the park unit are grazed, burn regularly, and are often invaded by aggressive exotic species. DINO is interested in monitoring sagebrush because of these management issues, and more specifically, would like compare grazed and ungrazed sagebrush areas. There is also interest in stratifying by Wyoming big sagebrush and mountain big sagebrush since they appear to respond differently to fire.

DINO resource managers are also interested in monitoring pinyon juniper (PJ) ecosystems because of their abundance in the park unit. The goal of monitoring PJ is to provide information on the natural variability of upland resources as well as early warning of system degradation.

Accessibility

Steep slopes ($\geq$ 50%) and areas isolated due to steep slopes (e.g., mesa tops) have been deemed inaccessible for NCPN upland monitoring. Additionally, NCPN does not rely on boat access for upland monitoring, and therefore, we create an accessibility map based on road and trail access. Numerous private inholdings exist within the DINO boundary, and discussion with DINO staff determined which areas could be used for access and which areas must be avoided. All private inholdings were excluded from the sampling frame.

The original map was based on a roads and trails layer created by DINO resource management staff. After additional discussion with DINO staff members, we included access to Pearl Park, the Iron Springs area, and the area south of Brown's Park. We visited the area north of the Yampa River during scouting field work, but decided that this area should be considered inaccessible because an issue with a private land owner made access possible only through lengthy hikes.

Accessibility in DINO was derived using the NCPN Landscape Accessibility Model (Figure 1), which deemed 50.0% of the park unit as accessible. Directions and specific instructions were created for areas with special access concerns in DINO to assist field crews with future visits.

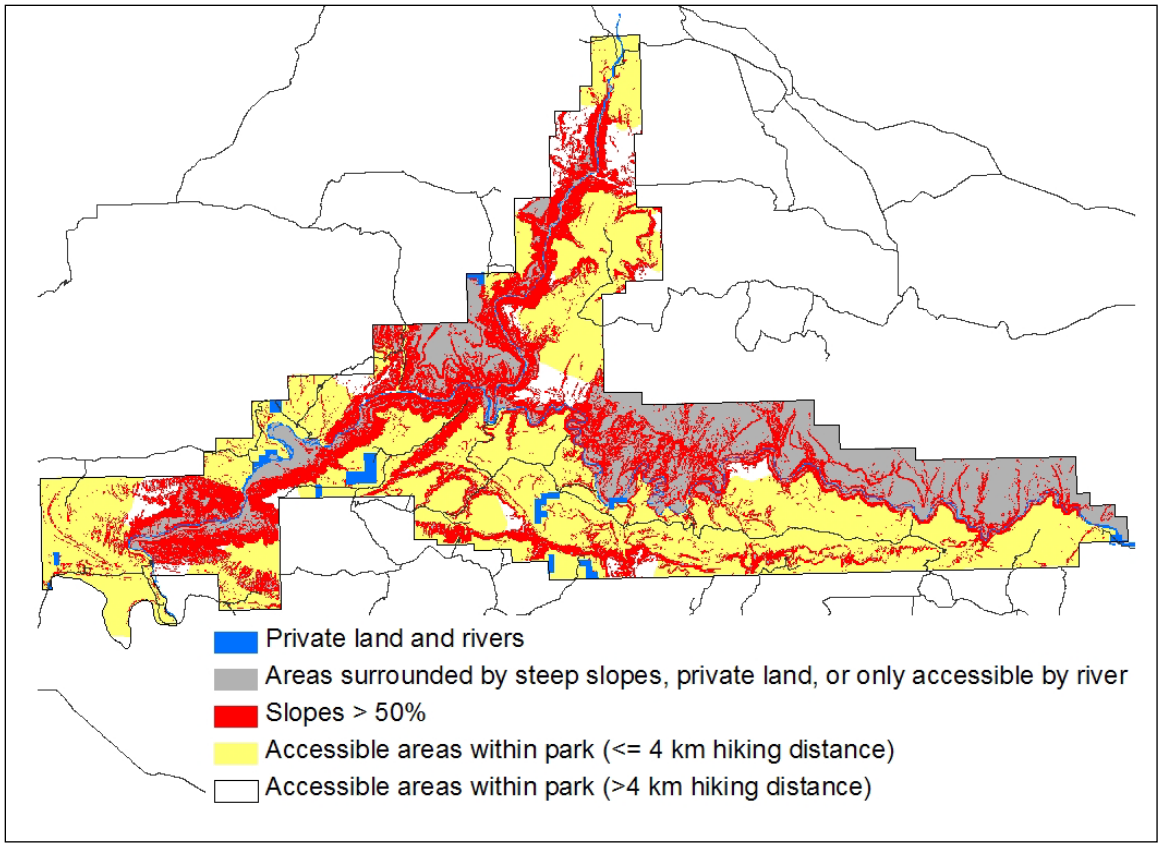

Figure 1. Accessible areas of Dinosaur National Monument.

Other Management Considerations

Grazing Allotments

As of 2009, there are 10 active grazing allotments in DINO (Figure 2) covering an area of 23,544 ha (approximately 28% of the total park unit area). Resource managers would like to have a better understanding of how grazing affects sagebrush ecosystems in DINO and have determined that this should be the main priority of upland monitoring. It also appears that big sagebrush ecosystems may react differently to grazing depending on elevation and the associated changes in precipitation and temperature.

Stratifying upland monitoring by grazing could be complicated, as some grazing allotments may expire in the near future while other may be grazed indefinitely. The timing and intensity of grazing may vary between allotments and the long-term history of grazing on DINO land is poorly documented. We know that historically the entire park unit was grazed, and there is no way to document which currently ungrazed areas were altered by grazing in the past. Most allotments allow grazing in spring and summer, however, Green River is grazed February through March and Blue Mountain (Mantle) is grazed all year long. An additional problem is cattle trespass on land outside of the established allotments. DINO has a history of private landowners cutting fences and grazing where they are not permitted. How all of these issues may affect monitoring data is not known, however, they should be considered when interpreting monitoring results.

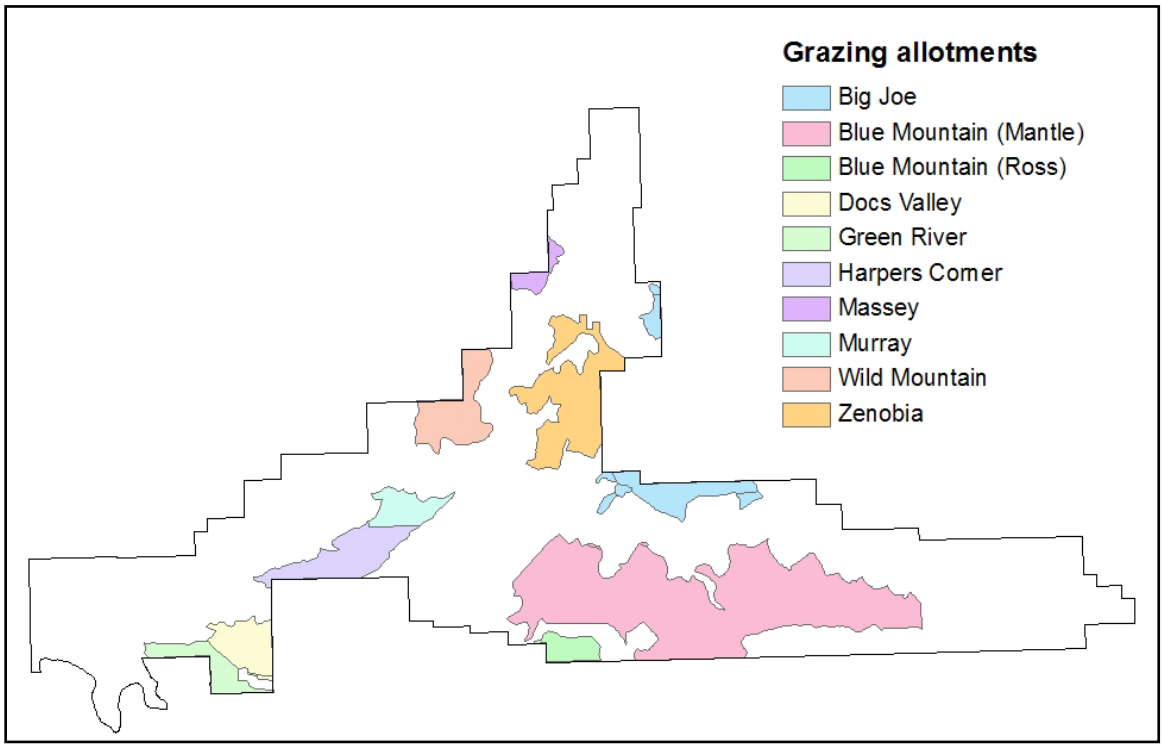

Figure 2. Grazing allotments in Dinosaur National Monument.

Fire History

Both sagebrush and PJ ecosystems in DINO are prone to natural fires which play an important role in succession as well as in the spread of exotic plant species. These areas have a complex fire history, and the available spatial data is incomplete. Due to the complex nature of fires within the park unit, the lack of predictability of where fires will occur, and incomplete historical data, long-term monitoring sites will not be stratified by fire history. Fire may have an important role in understanding landscape dynamics of sagebrush and PJ, however, and these data may be used in correlational assessments of monitoring data to help understand possible causes of trends.

Delineating the Target Population

Defining Target Vegetation Communities

Inspection of the DINO vegetation map (Coles et al. 2008) and field visits to the park unit determined the vegetation associations corresponding to the target communities for monitoring. The vegetation map units associated with sagebrush and PJ are listed in Table 1.

Wyoming big sagebrush is the 2nd most abundant vegetation type in DINO found primarily at lower elevations (<6500 ft). Large areas of Wyoming big sagebrush are found on benches south of the Yampa River and near the Quarry, Split Mountain, Rainbow Park, and Gates of Lodore. Mountain big sagebrush is mainly found at higher elevations (>6500 ft) that occur south of the Yampa River and near Harpers Corner Drive, Zenobia, and Pot Creek. Vegetation map unit 31 includes both Wyoming and mountain big sagebrush while vegetation map unit 32 includes only mountain big sagebrush. Vegetation map units 16, 20, and 73 include other successional stages of big sagebrush ecological sites such as grasslands and sagebrush invaded by PJ. Vegetation map unit 68 includes alternative weedy states of big sagebrush sites.

PJ occurs over the greatest area of DINO and is represented by many different vegetation associations.

Defining Target Soils and Ecological Sites

A new soil survey for DINO was recently published (USDA NRCS 2007). Although the soils portion is complete, additional work remains to remedy differences between the ecological sites used in Utah and the old range sites used in Colorado. We expect that the old Colorado range site descriptions will no longer be used and that the existing Utah MLRA (Major Land Resource Area) 34 and 47 ecological site descriptions will be updated and added to. It is unclear, however, when this update will be completed, and until then, we will continue to use the outdated Colorado range site descriptions.

Using the NRCS soil map units, ecological sites currently associated with sagebrush are listed in Table 2. Soil map units containing soil components with greater than 10% area of potential sagebrush ecological sites were included in the tables. Ecological site Semidesert Sand (214UT) was included in Table 2 because Wyoming big sagebrush was observed growing in areas predicted as this ecological site.

PJ is not well differentiated by ecological sites in the DINO Soil Survey and occurs across the landscape on a variety of different landforms and soil components (Table 2). Soil components associated with PJ have the ecological site name “Pinyon-Juniper”, however, no effort has been made to distinguish between the different types of PJ ecological sites that exist within DINO. Further discussion with DINO resource managers is necessary to limit the area of PJ monitored.

Table 1. Community types and corresponding vegetation map units for Dinosaur National Monument.

Community type	Vegetation Map Unit	Vegetation Map Unit Name
Big sagebrush /herbaceous	31	Sagebrush/Rabbitbrush shrubland
	32	Sagebrush/Antelope bitterbrush shrubland
	47	Sagebrush/spiny hopsage/ black greasewood shrubland
	68	Weedy herbaceous vegetation
	73	Native Grasslands
PJ	8	PJ/Sparse understory woodland
	9	PJ/True mountain mahogany
	10	PJ/Herbaceous woodland
	11	PJ/Mixed desert shrub woodland
	13	PJ/Soil crust woodland
	14	PJ/Little-leaf mountain mahogany shrubland & woodland
	15	PJ/Black sagebrush woodland
	16*	PJ/Sagebrush woodland
	17	PJ/Curlleaf mountain mahogany
	20*	Rocky mountain juniper/Sagebrush woodland
	21	Rocky mountain juniper/Three-leaf sumac woodland
	40	Black sagebrush shrubland and cushion plant herbaceous

* may be more similar to sagebrush ecological sites

Table 2. Estimated area (ha), potential sagebrush production (%), and associated soil map units for ecological sites supporting Wyoming big sagebrush, mountain big sagebrush, and pinyon-juniper communities in Dinosaur National Monument. Estimates of spatial extent include inaccessible areas.

Community type	Ecological site #	Ecological site name	Estimated area (ha)	% of total land area	Potential sagebrush productio n (%)	Associated soil map units (>10% area)
Wyoming big sagebrush	R034XY298CO	Rolling Loam	4384.5	5.3	20	16, 27, 28, 30, 31, 32, 45, 72, 73
	R034XY310CO	Sandy Foothills	113.0	0.1	15	29
	R034XY330CO	Sandyland	524.5	0.6	20	16, 60
	R034XB328CO	Semidesert Clay Loam	167.8	0.2	20	8
	R034XY206UT	Semidesert Gravelly Sandy Loam (Wyoming Big Sagebrush)	648.0	0.8	30	39, 58
	R034XY327CO	Semidesert Loam	36.2	0.0	15	17
	R034XY212UT	Semidesert Loam (Wyoming Big Sagebrush)	1041.1	1.3	20	1, 12, 36, 41
	R034XY214UT	Semidesert Sand (Four-wing Saltbush)	613.2	0.7	0* ~	7
	R034XB326CO	Semidesert Sandy Loam	493.9	0.6	5-15* +	35, 38, 71
	R034XY216UT	Semidesert Sandy Loam (Fourwing Saltbush)	1780.2	2.1	5*	6, 7, 37, 39, 44, 74
	R034XY225UT	Semidesert Shallow Loam (Wyoming Big Sagebrush)	233.0	0.3	20	71
Mountain big sagebrush	R047XC430UT	Mountain Loam (Mountain Big Sagebrush)	3661.9	4.4	15	13, 15, 19, 21, 25, 29, 32
	R047XC446UT	Mountain Shallow Loam (Mountain Big Sagebrush)	862.5	1.0	20	13, 53
	R047XY378CO	Mountain Stony Loam	240.3	0.3	5*	26
	R047XC460UT	Mountain Stony Loam (Bitterbrush)	473.6	0.6	10-15	76
Pinyon-Juniper	R034XY909CO	Pinyon-Juniper	21690.2	22.0	na	2, 3, 9, 12, 14, 27, 28, 30, 38, 40, 42, 43, 44, 47, 49, 50, 52, 54, 55, 57, 58, 59, 60, 61, 62, 63, 65, 70, 71, 73
Total DINO area =			83015.5			

*These ecological sites may not have enough big sagebrush to be considered a “sagebrush” ecological site.

~This ecological site was evaluated for the sagebrush sampling frame as a result of our field observations. We found Wyoming big sagebrush growing on sandy soils in areas predicted as this ecological site and believe a similar sagebrush ecological site may be added in the future.

+This range encompasses values listed for the range site description and associated soil map units.

Assessing Potential Target Ecological Sites

Field scouting was performed to determine which soil map units should be included in the sampling frame for each vegetation type. Areas of all potential soil map units for sagebrush and PJ (Table 2) were combined, clipped to the accessible area of the DINO, and rasterized to10 m to form the reconnaissance (recon) sampling frame (Figure 3). Reversed Randomized Quadrant Recursive Raster (RRQRR - Theobold et al. 2007) was used to randomly select 1000 points within this area. These points were then further characterized by soil and vegetation map unit and grazing allotment. Using RRQRR order, up to 3 points were selected for each unique vegetation/soil/grazing allotment combination (489 points total). This included six points that were added to represent soil map units with small areas inside DINO that did not receive any points in the initial RRQRR run. All points were checked to make sure that each vegetation/soil/grazing allotment combination had at least one point that was fully inside the polygon and not too close to a boundary. This resulted in 10 points being shifted towards the center of a polygon. Since it was not possible to visit all recon points in the available time frame (2 pay periods for a 2-person crew), points were further prioritized to maximize visits to unique soil map units, especially those under consideration for the sagebrush sampling frame.

At each point, ecological site was recorded in addition to other biophysical site characteristics. A total of 165 points were visited in October 2008. Data from these points were used to assess the suitability of each ecological site and soil map unit for inclusion in the sampling frame.

Target Ecological Sites

Due to the current condition of ecological site descriptions for DINO, all potential sagebrush ecological sites were used in upland monitoring. This includes the eleven Wyoming big sagebrush ecological sites and 3 mountain big sagebrush ecological sites described in Table 3. Mountain Stony Loam (378CO) was dropped after field visits confirmed that this was not a mountain big sagebrush site.

For PJ, ecological sites were not used for monitoring since none existed in June 2009 when the sampling design was being developed. Any site dominated by PJ community or dominated by PJ before fire was used for monitoring. The only PJ sites that were excluded were ones that could be recognized as sagebrush ecological sites with PJ invasion. Ecological site descriptions for PJ are not included in Table 3 since these have not yet been determined for DINO.

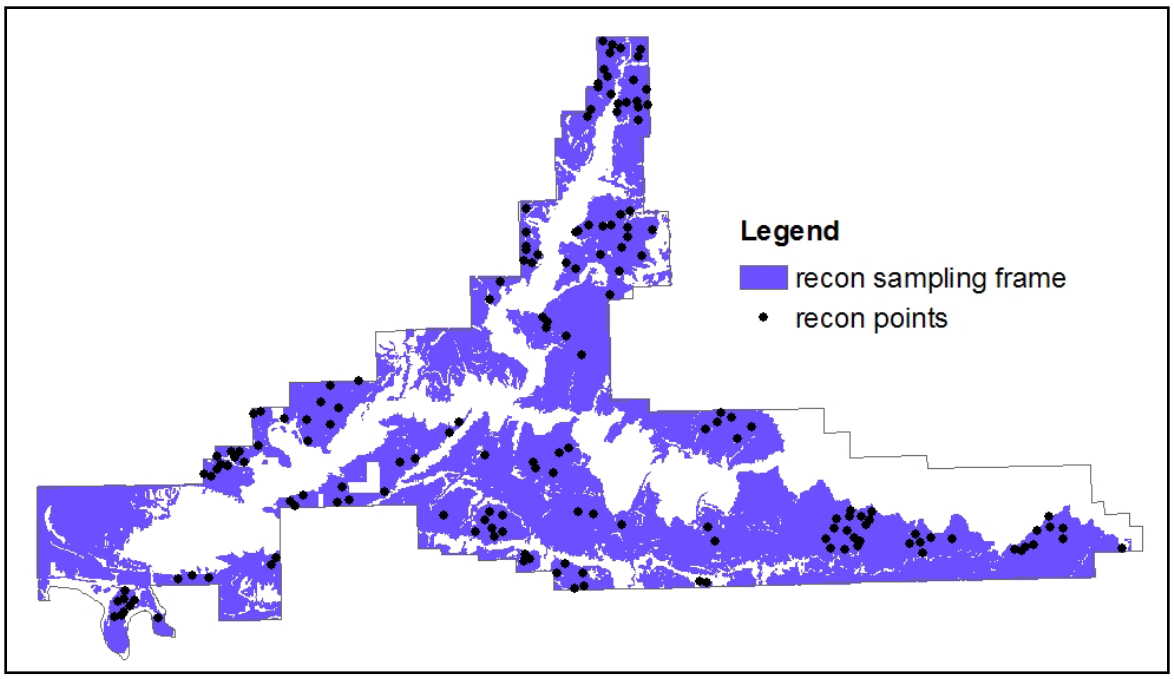

Figure 3. Sampling frame for Dinosaur National Monument recon including locations of 165 points visited throughout the park unit. The sampling frame was created from the accessible area of all soil map units dominated by sagebrush and/or PJ ecological sites.

Table 3. Description of Wyoming and mountain big sagebrush ecological sites selected for upland monitoring in Dinosaur National Monument.

Ecological Site Name	Ecological Site Number	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
Rolling Loam	R034XY298CO	deep sandy loams, loams, & gravelly loams	eolian deposits, alluvium, residuum, and/or colluvium	dominated by Wyoming big sagebrush, western wheatgrass, & needle and thread	Decreased bunchgrasses from overgrazing. PJ, cheatgrass, and exotic annuals may invade.
Sandy Foothills	R034XY310CO	shallow to moderately deep loamy sands	Eolian deposits over residuum weathered from shale or just residuum	dominated by Wyoming big sagebrush and needle and thread	Decreased bunchgrass and increased sagebrush from overgrazing. Decreased antelope bitterbrush from excessive browsing. Cheatgrass, Russian thistle, annual mustards, and juniper may invade.
Sandyland	R034XY330CO	deep loamy sands	alluvium and/or residuum	dominated by Wyoming big sagebrush, Indian ricegrass, & needle and thread	Decreased bunchgrass and increased sagebrush from overgrazing. Cheatgrass, Russian thistle, annual mustards, and juniper may invade.
Semidesert Clay Loam	R034XB328CO	deep clay loams on footslopes and toeslopes	alluvium and/or colluvium over residuum weather from shale	dominated by Wyoming big sagebrush, western wheatgrass, bluebunch wheatgrass, & Sandberg bluegrass	Decreased palatable grasses & shrubs and increased big sagebrush from overgrazing. Cheatgrass, Russian thistle, annual mustards, and juniper may invade.
Semidesert Gravelly Sandy Loam (Wyoming Big Sagebrush)	R034XY206UT	Deep gravelly loams	Alluvium, colluvium, and/or reworked eolian from sandstone or limestone	dominated by Wyoming big sagebrush & galleta	Decreased bunchgrasses and increased shrubs from overgrazing. Increased rabbitbrush and decreased sagebrush from fire. Cheatgrass and juniper may invade.
Semidesert Loam	R034XY327CO	deep loams on footslopes and toeslopes	alluvium derived from sandstone and shale	dominated by Wyoming big sagebrush & galleta	Decreased bunchgrasses and palatable shrubs from overgrazing. Bulbous bluegrass, greasewood, cheatgrass, & Russian thistle may invade.
Semidesert Loam (Wyoming Big Sagebrush)	R034XY212UT	deep sandy loams	alluvium & eolian deposits	dominated by Wyoming big sagebrush & Indian ricegrass	Decreased bunchgrasses and increased sagebrush from overgrazing. Decreased sagebrush from fire or fall/winter grazing by sheep. Increased grasses and forbs after fire. Cheatgrass, annual weeds, & juniper may invade.

Ecological Site Name	Ecological Site Number	Soil properties	Geological properties	Vegetative properties	Disturbance-mediated alternative states
Semidesert Sand (Four-wing Saltbush)	R034XY214UT	deep sand on footslopes and toeslopes	eolian deposits	dominated by Indian ricegrass, sand sagebrush, four-wing saltbush, & needle and thread	Decreased Indian ricegrass, needle and thread, and four-wing saltbush and increased snakeweed, rabbitbrush, sandhill muhly, and threeawn from overgrazing. Cheatgrass and annual weeds may invade.
Semidesert Sandy Loam	R034XB326CO	deep sandy loams	eolian deposits, alluvium, residuum, and/or colluvium	dominated by Indian ricegrass, needle and thread, & Wyoming big sagebrush	Decreased bunchgrasses and winterfat from overgrazing. Cheatgrass, Russian thistle, annual mustards, and juniper may invade.
Semidesert Sandy Loam (Fourwing Saltbush)	R034XY216UT	deep sandy loams	eolian & alluvial deposits	dominated by Indian ricegrass & needle and thread	Decreased Indian ricegrass, winterfat, and four-wing saltbush from overgrazing. Decreased sagebrush & four-wing saltbush from fire. Increased snakeweed, rabbitbrush, and galleta from overgrazing and fire.
Semidesert Shallow Loam (Wyoming Big Sagebrush)	R034XY225UT	shallow cobbly sandy loams	Slope alluvium and/or colluvium over residuum from sandstone and limestone	dominated by Wyoming big sagebrush & needle and thread	Decreased bunchgrasses and increased sagebrush, galleta, and snakeweed from overgrazing. Cheatgrass may invade.
Mountain Loam (Mountain Big Sagebrush)	R047XC430UT	deep loams	alluvium, eolian deposits, and/or colluvium	dominated by mountain big sagebrush & western wheatgrass	Decreased bunchgrasses and antelope bitterbrush and increased sagebrush, rabbitbrush, and western wheatgrass from overgrazing. Decreased sagebrush and increased rabbitbrush and western wheatgrass from fire.
Mountain Shallow Loam (Mountain Big Sagebrush)	R047XC446UT	Shallow, extremely flaggy, sandy loams on shoulders and summits	slope alluvium and/or colluvium derived from sandstone	dominated by mountain big sagebrush & bluebunch wheatgrass	Decreased bunchgrasses and increased sagebrush and western wheatgrass from overgrazing. Decreased sagebrush and increased rabbitbrush and western wheatgrass from fire.
Mountain Stony Loam (Bitterbrush)	R047XC460UT	deep loams & channery loam on backslopes	colluvium	dominated by mountain big sagebrush, snowberry, & wheatgrasses	Decreased bunchgrasses and increased sagebrush and snowberry from overgrazing. Decreased sagebrush from fire.

Predictive Mapping of Ecological Sites on the Landscape

A predictive map of sagebrush and PJ was developed based on soil map units associated with target ecological sites (Figure 4). Points visited in the field recon effort were used to confirm whether or not each soil map unit (Table 2) was dominated by sagebrush ecological sites and/or PJ. In cases where inadequate field data were collected for a soil map unit (either no points were visited or points were only visited in some areas of DINO but the soil map unit occurred in other areas of DINO), soil map units were further evaluated using the NCPN vegetation map (Coles et al. 2008). In most cases, soil map units were accepted as the predicted vegetation type. In a few cases, soil map units were further refined using the vegetation map. For example, vegetation map units 16, 20, 31, 32, 47, 68, and 73 (Table 1) were considered potential indicators of sagebrush ecological sites. If soil map units in the sagebrush sampling frame contained large areas of non-target vegetation map units, these areas could be removed from the sampling frame. Soil map units could also be accepted as "PJ and sagebrush". This meant that the soil map unit could be dominated by either PJ or sagebrush and would be included in both sampling frames. Additional details on the development of the sagebrush and PJ sampling frames are given below.

The predictive map is a conservative estimate of sagebrush and PJ across the landscape. When questions arose about the dominant vegetation type of a soil map unit, only those areas definitely not associated with the target ecological sites were excluded. For example, outside of the target PJ sampling area, soil map units dominated by both sagebrush and PJ often had large areas of grassland that could be associated with either sagebrush ecological sites or PJ depending on landform, soil depth, etc. These grassland areas were kept in the sagebrush sampling frame knowing that many points in the area would be rejected as burned shallow PJ sites.

Sagebrush sampling frame

In general, soil map units accurately predicted the presence of sagebrush ecological sites. All soil map unit associated with sagebrush ecological sites (Table 2) were included in the sagebrush sampling frame with the following exceptions and modifications listed in Table 4. Soil map units 12, 26, and 73 were not dominated by sagebrush and were therefore not included in the sampling frame. Only specific polygons of soil map unit 38 that were dominated by sagebrush were included in the sampling frame. Soil map unit 53 was included in the sampling frame, but modified to exclude significant areas of non-target black sagebrush/cushion plant communities. For soil map unit 58, the vegetation map was used to delineate areas of potential sagebrush ecological sites, and only these areas were included in the sampling frame. Soil map units 27, 28, 44, 58, and 71 were included in both the sagebrush and PJ sampling frames.

The sagebrush sampling frame was further stratified by elevation and grazing to look at management issues of concern. Elevation was divided into high and low based on the approximate ranges of Wyoming and mountain big sagebrush (Figure 5). Uinta Basin Flora (Goodrich and Neese 1986) listed the boundary of the ranges as 6500 to 7000 feet. We used 2000 m (6562 ft) to distinguish between the two subspecies of big sagebrush in the sampling frame. A cutoff was necessary because the subspecies are known to hybridize where their ranges overlap. This meant that Wyoming big sagebrush ecological sites could occur in the high elevation sampling frame and mountain big sagebrush ecological sites could occur in the low elevation

sampling frame. This was not common, however, and should be rectified when the ecological sites are updated in the future.

Areas of the sagebrush sampling frame were further classified as grazed or ungrazed according to the current map of grazing allotments (Figure 2). This created four types of sagebrush (high grazed, high ungrazed, low grazed, and low ungrazed) that could be used to look more closely at management issues (Figure 5).

Table 4. Edits to the sagebrush sampling frame by soil map unit**.**

Soil map unit #	Edits to sagebrush sampling frame	Reasoning	Validated by
12	Not included in sampling frame	Soil map unit dominated by PJ not sagebrush	Vegetation map
26	Not included in sampling frame	378CO-Mountain Stony Loam is a mixed montane shrubland not a sagebrush site.	Field recon
38	Polygons in the Disappointment Draw area included in sampling frame; all other polygons of the soil map unit excluded from the sampling frame.	Field recon on the Yampa Bench and near Lodore indicated that this soil map unit was mostly PJ. Polygons in the Disappointment Draw area were not visited during field recon but vegetation map units indicated that this area was predominately sagebrush ecological site.	Field recon & Vegetation map
53	Excluded area of vegetation map unit 40 from this soil map unit	Vegetation map unit 40 delineated non-target ecological site dominated by black sagebrush and herbaceous subalpine plants.	Field recon
58	Included only areas within this soil map units designated by vegetation map unit 16 or 31	Soil map unit dominated primarily by PJ, but vegetation map unit 16 and 31 were included as potential sagebrush ecological site area.	Vegetation map
73	Not included in sampling frame	Soil map unit dominated PJ not sagebrush	Vegetation map

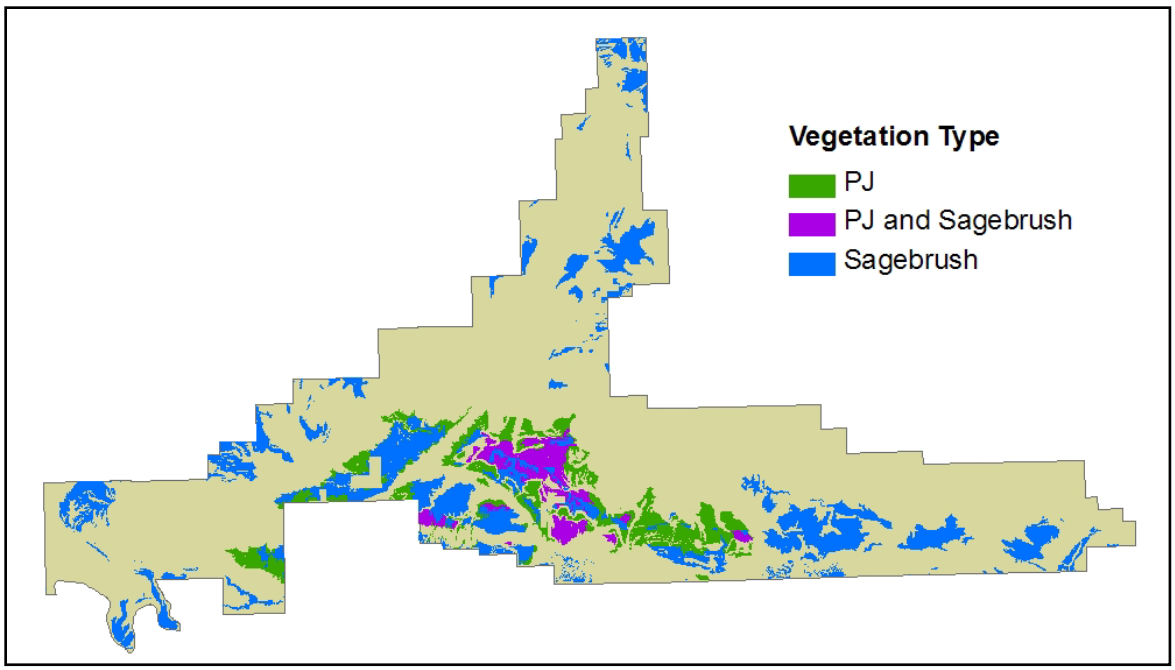

Figure 4. Sampling frame for upland monitoring in Dinosaur National Monument. This map predicts accessible areas of sagebrush through the entire monument and accessible areas of PJ within a limited section of the park. The area labeled as "PJ and Sagebrush" has significant areas of both vegetation types, and monitoring plots may be established if they fit the selection criteria for sagebrush or PJ ecological sites.

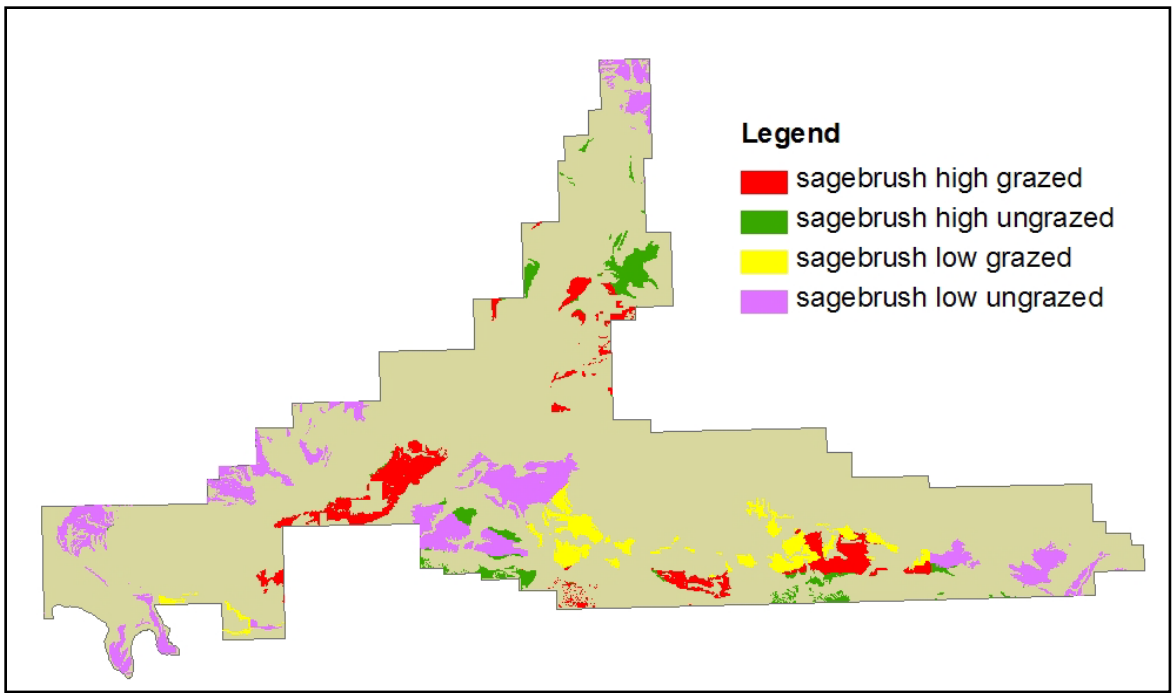

Figure 5. Sampling frame for accessible area of sagebrush in Dinosaur National Monument illustrating stratification by elevation (high and low) and grazing. The boundary between low and high elevation is 2000 m (6562 ft).

PJ sampling frame

Since PJ communities are the second priority for upland monitoring but cover the greatest area in DINO, there was a need to limit the PJ sampling frame. Originally, we thought that soil map units could be grouped to form meaningful aggregates of PJ according to landform or soil characteristics. Evaluation of the PJ points visited during site recon confirmed large variability between landforms and soil types where PJ communities occurred. From this data, we concluded that there was no easy way to stratify PJ using soil map units. As an alternative, we consulted with resource management staff for ideas on how to stratify PJ based on management concerns. None were identified so we decided to limit sampling by geographic area of the park unit. DINO was divided into 5 areas and DINO resource management was given the choice to monitor one of these areas. They choose the area in Figure 4 (PJ, PJ and sagebrush), mainly because it represented a wide range of elevation.

Soil map units within this area were then evaluated for their ability to predict PJ communities. Many soil map units from the recon effort were eliminated from the sampling frame because they did not occur in the area selected for sampling. Soil map units included in the sampling frame are listed in Table 5. This included soil map units that were predominantly PJ communities as well as a few soil map units that were dominated by both sagebrush and PJ. The five soil map units dominated by both vegetation types were included in the sampling frame for sagebrush as well as PJ.

Sampling Frame Area
The sampling frame area was restricted to a 6 km hiking distance due to the difficulty of the terrain in some sections of DINO. The total area of the sampling frame is approximately 20.8% of the total park area (see Table 6 for area of each stratum). Notice that the elevation and grazing stratifications of sagebrush create unequal sampling areas ranging from 1680 to 5917 ha.

Table 5. Soil map units included in the pinyon-juniper sampling frame for Dinosaur National Monument.

Vegetation type	Soil Map Units
PJ	2, 38, 42, 43, 47, 52, 54, 55, 59, 61
PJ and sagebrush	27, 28, 44, 58, 71

Table 6. Area (ha) of each vegetation type included in the sampling frame for upland monitoring at Dinosaur National Monument.

Vegetation type	elevation	grazing	Area (ha)*
Mountain big sagebrush	high	grazed	3328
		ungrazed	1680
Wyoming big sagebrush	low	grazed	2111
		ungrazed	5917
Total big sagebrush			13035
PJ/sagebrush			1812
PJ	na	na	6082
Total sampling frame			17306

* Based on the accessible area within a 6 km hiking distance.

Monitoring Site Selection

Using the sampling frame created from field scouting and vegetation map assessments, monitoring sites were selected using RRQRR and a 10-m grain size. The use of a 10-m grid was to ensure complete coverage of the landscape while balancing the amount of time necessary for RRQRR to select points. We found that at a 1-m grid, RRQRR took most of a day to select points that had no better spatial balance than at a 10-m grid. Sites were selected with equal probability for the entire sampling frame including any potential sagebrush or PJ area (Figure 4). The sampling frame was not buffered prior to RRQRR site selection due to the complexity of ecological sites across the landscape and the large sampling frame area.

Points were then assigned a predicted vegetation type based on the Figure 4. Points predicted as sagebrush could only be accepted if they were one of the 14 sagebrush ecological sites. Points

predicted as PJ could only be accepted if they were PJ communities. Points predicted as PJ-sagebrush could be accepted as either as one of the sagebrush ecological sites or as PJ.

Sagebrush points were further categorized by elevation (low or high) and grazing (grazed or ungrazed) creating 4 stratifications of sagebrush (Figure 5). For the pilot monitoring phase, 8 plots were visited in each stratum.

Monitoring Site Selection Shape Files

To provide simple PlotID numbers, the sequential order of plots was determined by the ascending order of the "order_" attribute. All locations listed in these shape files have a selection probability of 1. The following shape files werer produced:

DINO_smp_pts- ordered list of all possible monitoring points selected through RRQRR.
DINO_sample_pts- ordered list of 500 initial monitoring points selected through RRQRR.

Tracking Monitoring Sites

DINO_upland_master.shp, derived from DINO_sample_pts.shp, contains the first 500 potential monitoring plots and any relevant tracking information (Table 7). The attributes include acceptance or rejections of plots, reasons for rejection, and date of plot establishment. It is used to schedule pre-monitoring evaluation of sites and for the eventual derivation of selection probabilities. In this file, the "order_" attribute was renamed "RQorder" for consistency among parks.

Response Design

The response design for DINO is based on NCPN upland monitoring protocols and varies by vegetation type. In DINO, sagebrush is monitored using the grassland/shrubland response design, and PJ is monitored using the woodland response design. Table 8 outlines specific methods used for each response design.

Table 7. Attributes of DINO_upland_master.shp for tracking upland monitoring locations in Dinosaur National Monument.

Field	Description
Veg_Type	Vegetation type for upland sampling methods (grassland/shrubland or woodland)
PredEcoType	Predicted vegetation type based on sampling frame (PJ, Sagebrush, or PJ-sagebrush)
EcoType	Actual vegetation type of the monitoring plot (PJ, Sagebrush, non-target)
Grazing	Indicates whether grazed or ungrazed; not applicable to PJ
sage_type	High or low elevation
MasterStrat	Indicates groups for analyzing data (low ungrazed sage, low grazed sage, high ungrazed sage, high grazed sage, PJ)
PlotID	The plot number, based on ascending order of the RQorder field, renumbered to give unique plot numbers for each point on the list.
panel	Panel that plot is associated with in the revisit design
PanelYear	Year(s) that panel is sampled
EvalStatus	Ultimate status of a plot (estab = established; NotEval = not visited; accept = visited and deemed to be acceptable as a monitoring site; reject = rejected)
S_Action	Status of plot determined in the field and recorded on GPS (accept or reject)
EvalReason	Describes why a site was accepted or rejected
Estab_Date	Month, day, and year of plot establishment
Soil_MU	Soil map unit from UT692 associated with the monitoring plot
X	UTM E (NAD83, Zone 12)
Y	UTM N (NAD83, Zone 12)
Hike_km	Hiking distance to plot in kilometers
AreaDescr	General area of the park where the plot is located
Comments	Miscellaneous
RQorder	Sequence number produced by RRQRR that doesn't start at 1 or increment by 1 (=order_ in sample_pts shape files and =GRID_CODE in smpts shape files)
inc_prob	inclusion probability; 1 indicates equal probability of selection for all points from the sample_pts shape file
Gridcode	Used to distinguish between stratifications in the sampling (=1 for all points in DINO)
FrameType	Used to distinguish the different combinations of PredEcoType, Grazing, and sage_type (1-7)

Table 8. Response design for vegetation types monitored in Dinosaur National Monument.

Method	Grassland/Shrubland	Woodland
Transects	3 – 50 m transects	3 – 50 m transects
Plot establishment	Rebar at transect ends	Rebar at transect ends, plot side slopes, optional witness trees
Photos	Transect origin, BSCs	Transect origin and end, BSCs
Point-intercept	X	X
Gap intercept	X	
Soil stability	X	X
1-m belt transect (shrub and seedling density, exotic frequency)	X	X
5-m belt transect (sapling density)	When trees are present	X
Tree census	When trees are present	X
Fuels		X
Site Impact	X	X

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