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Sagebrush Steppe Vegetation Monitoring in Craters of the Moon National Monument and Preserve and City of Rocks National Reserve

2010 Annual Report

Natural Resource Technical Report NPS/UCBN/NRTR—2011/462

ON THE COVER
Sagebrush steppe vegetation in Brass Cap Kipuka, CRMO
Photograph courtesy of the Upper Columbia Basin Network

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Thomas J. Rodhouse

National Park Service
Upper Columbia Basin Network Inventory and Monitoring Program
20310 Empire Ave. Suite A-100
Bend, Oregon 97701

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Abstract

As part of the Upper Columbia Basin Network's (UCBN) effort to conduct vital signs monitoring in 2010, estimates of areal cover, in Daubenmire classes, of principal native and non-native sagebrush steppe plant species and exposed bare soil were obtained from 2000 1 m^2 plots in City of Rocks National Reserve (CIRO) and Craters of the Moon National Monument and Preserve (CRMO). Cover estimates are key indicators of sagebrush steppe vegetation biotic integrity, soil stability, and hydrologic function and provide a description of the status of these attributes in these parks. Cover estimates will inform park management about the trends in these attributes via sustained monitoring. Sagebrush steppe is one of the most threatened ecosystems in the intermountain west, and land use practices both within and adjacent to UCBN park steppe communities have resulted in fragmented and altered park ecosystems. Accelerated climate change may exacerbate these changes, particularly under predicted scenarios for the region that include reduced snowpack and drought. This annual report summarizes cover estimates from key species of particular interest, including big sagebrush (*Artemisia tridentata*), bluebunch wheatgrass (*Pseudoeregneria spicata*), and cheatgrass (*Bromus tectorum*). Methods followed a protocol that was peer-reviewed and approved following the 2009 pilot field season (Yeo et al. 2009). In 2010, data were collected across the two parks in multiple discrete sampling "frames", which in the case of CIRO overlap with different active grazing allotments, and in the case of CRMO capture a wide range of environmental conditions and site histories. Sample plot locations for each frame were drawn using a spatially-balanced random sampling design, a generalized random tessellation stratified (GRTS) design, which ensures a representative random sample with statistically-optimal spatial dispersion within each sampling frame.

This report presents the patterns in selected sagebrush steppe plant and bare ground cover indicators that were encountered during 2010 sampling in CIRO and CRMO. In general, the results from 2010 provide consistent and biologically interpretable descriptions of existing conditions (status) of park frames. Areas in good condition have higher amounts of native vegetation and fewer non-native species, in contrast to areas in poor condition that are dominated by non-native vegetation and native species like steppe bluegrass (*Poa secunda*) that are considered resistant to stressors such as sustained overgrazing. . However, a wide range of conditions were encountered among park frames. The proportion of plots containing cheatgrass, a ubiquitous invasive annual grass introduced from Eurasia during the 19th century, ranged from 0% in several CIRO and CRMO frames, to over 90% in several frames in CRMO. The proportion of plots with cheatgrass cover >25%, a useful threshold for distinguishing heavily infested areas, ranged among frames from 0%-9% in CIRO and from 0%-88% in CRMO. Bluebunch wheatgrass, a fundamental native perennial bunchgrass species included in potential natural vegetation descriptions for both parks, was encountered with >5% cover in 2%-36% of plots among different frames in CIRO and in 0%-72% of plots in CRMO. The 5% threshold is useful for this species because it distinguishes areas with little to no cover from those with moderate (>5%) to large (e.g., >25%) amounts of cover. Some CRMO frames with no bluebunch wheatgrass were dominated by another key native species Idaho fescue (*Festuca idahoensis*), such as in Brass Cap Kipuka (frame 25) which is in good condition with very few non-native species present. However, several frames in CRMO are dominated instead by the native perennial steppe bluegrass and cheatgrass, together taken as a sign of degradation. The proportion of plots containing >5% cover of big sagebrush ranged from 15% to 91% in CIRO,

and from 6% to 82% in CRMO. Noxious weeds were not encountered within CIRO plots. Only rush skeletonweed (*Chondrilla juncea*) was encountered in one CRMO plot, although several noxious weed species were encountered while traveling between plots in CRMO.

It is important to stress that while comparisons made among frames both within and between these two parks is instructive, each of these park frames occurs in very different environmental settings that ultimately need to be carefully considered within their own biophysical context. Elevations, soil types, and land use histories differ widely among the parks and these differences are reflected in status estimates. Accordingly, this report presents results by park and park frame in a graphical format.

The results presented here are far from comprehensive. Decisions for reporting, including the cover class thresholds chosen for summary (e.g., >5% cover), for example, will need to be revisited in conversation with park managers regarding what is meaningful to park management. Current thresholds (e.g., 5% for bluebunch wheatgrass) are arbitrary but useful to distinguish meaningfully among sites relative to the range of cover values observed. However, in the interim before park management thresholds and desired future conditions are established, these results describe some fundamental patterns in key indicators of park rangeland health that can be used to guide setting of future thresholds. Inspection of the tables and graphs presented here will provide the reader with a picture of the range of current ecological conditions in these steppe systems. In both parks, several areas jump out as being in exceptionally good condition: Brass Cap Kipuka and the Sunset Cone area on the north end of CRMO and much of the northern portion of CIRO and Castle Rocks State Park. Other areas clearly emerge as being severely degraded as indicated by the abundance of non-native invasive species.

In both parks, the impacts of recent wildfires on accelerated cheatgrass invasion are clear. Results reported here contain data from recent fires that describe much higher levels of cheatgrass infestation than in surrounding unburned areas, underscoring the significant risk that fires pose to many contemporary sagebrush steppe ecosystems. The results reported here are also of relevance to CIRO's active grazing management program. The park discontinued grazing in the Circle Creek area in 2006. Patterns observed in 2010 suggest that these areas are in good ecological condition, but yet bear some evidence of past overgrazing. This report represents an important early contribution to these parks' efforts to engage in science-based adaptive management. By identifying not only the overall condition of park rangelands but also *where* areas of good and poor condition exist, the parks will be better able to prioritize and target effective management strategies. These two parks will not be surveyed again by the UCBN until 2012, representing the 3rd survey to some park frame areas since 2008, at which time trend analyses will begin.

Acknowledgments

Special thanks to Jeff Yeo, consulting ecologist, who collected field data in 2010 and provided invaluable comments regarding the performance of the field methods. This work could not have been accomplished without the critical support from CIRO and CRMO park staff.

Introduction

Prior to European colonization, sagebrush steppe covered approximately 44 million ha of the Intermountain West, the vast areas of land between the Rocky Mountains and the Cascades and Sierra Nevada mountain ranges (West and Young 2000). Since then the sagebrush steppe ecosystem has experienced extensive changes (USDA Forest Service 1996, West and Young 2000, Bureau of Land Management 2002, Reid et al. 2002). Substantial portions of the region have been converted to agriculture and development (West and Young 2000, Bunting et al. 2002). Much of the remaining sagebrush steppe has been degraded through overgrazing by livestock, altered fire regimes, and invasion of introduced plants (Reid et al. 2002). These changes have had significant impacts on the ecological condition of the sagebrush steppe, including a decline in native flora and fauna, decreased soil stability, and reduced hydrologic function (Mack and D'Antonio 1998, Wisdom et al. 2000, Keane et al. 2002, Knick et al. 2003, Dobkin and Sauder 2004). Sagebrush steppe today is one of the most threatened ecosystems in the Intermountain West (Noss et al. 1995). Biological invasions, altered fire regimes, and other stressors continue to cause major, possibly irreversible, changes to steppe ecosystem structure and function, including a loss of foundational species and dominance by non-native weedy annual grasses (e.g., Knick et al. 2003, Brooks et al. 2004, Dobkin and Sauder 2004).

The degradation of sagebrush steppe that has occurred throughout the Intermountain West has also occurred within UCBN parks as well. Sagebrush steppe is the most extensive ecosystem type in the Upper Columbia Basin Network (UCBN), occupying over 50% of land cover in City of Rocks National Reserve (CIRO), Hagerman Fossil Beds National Monument (HAFO), and the John Day Fossil Beds National Monument (JODA). At Craters of the Moon National Monument and Preserve (CRMO), where bare lava rock comprises 81% of the total land cover, sagebrush steppe represents over 90% of the vegetation cover. At Lake Roosevelt National Recreation Area (LARO), sagebrush steppe is present and extensive in the southern half of the recreation area. Historic and current land use practices such as grazing and farming both within and adjacent to UCBN park units, continue to fragment and alter steppe ecosystems (e.g., Knick and Rotenberry 1997, Hanser and Huntly 2006). Predicted climate change scenarios for the region will likely exacerbate these changes with potential outcomes including increased frequency of drought and wildfire, increased ability of non-native species to invade sagebrush steppe, and altered plant phenology (Smith et al. 2000, Wagner et al. 2003, Karl et al. 2009). Long-term vegetation trends at the Idaho National Laboratory (INL) near CRMO provide substantial evidence of the importance of climate patterns on sagebrush steppe vegetation dynamics (Anderson and Inouye 2001). A half century of monitoring at INL has shown a multi-decadal plant community response to prolonged drought during the mid-20th century that has important implications for management within the context of varying and changing climate.

The UCBN has identified the ecological condition of sagebrush steppe vegetation as a high priority vital sign and monitoring of steppe condition will be a central element to the UCBN monitoring program (Garrett et al. 2007). Community response to fire and drought, vulnerability to invasion, and the potential for restoration and recovery can differ significantly among sagebrush steppe communities (Reid et al. 2002, Bureau of Land Management 2002). The heterogeneity of sagebrush community types (e.g., alliances and associations defined by *Artemisia* subtaxa) in the UCBN, the complexity of ecological threats to sagebrush steppe ecosystems, and the substantial variability of vegetation change that has been reported among years and decades emphasizes the uncertainty that managers face. Understanding the complexity of change at the park level is critical for effective management strategies to be developed. These challenges underscore the need for a long-term monitoring program that provides for routine evaluation of the status of UCBN steppe communities, and for identification of trends over time within parks and across the network. This information will provide the feedback required for effective adaptive management.

In this report I present the results of monitoring in CIRO and CRMO. In 2010 a final peer-reviewed and approved protocol (Yeo et al. 2009) was implemented in these two parks, following two years of pilot work (Rodhouse 2009, 2010). Following methods outlined by Yeo et al. (2009), information on the cover and frequency of occurrence of principal indicator species of rangeland health, including both native and non-native species, as well as the cover of exposed bare soil, were obtained. These data are some of the first available to quantify the composition and abundance of sagebrush steppe vegetation in these parks. This report describes fundamental baseline conditions for the following key indicators: cover of exposed bare soil, steppe bluegrass (*Poa secunda*), bluebunch wheatgrass (*Pseudoeregneria spicata*), cheatgrass (*Bromus tectorum*), big sagebrush (*Artemisia tridentata*), green rabbitbrush (*Chrysothamnus viscidiflorus*), and several forb species. Cover estimates of other principal species are also available upon request from the UCBN, and these will be described with in-depth trend reporting beginning in 2013. 2010 data for a total of 79 species that were included in target principal species lists for these two parks are stored in a project Access database and can be queried for summaries. The presentation of results in this report is primarily graphical, providing snapshots of condition in each park sampling frame, and facilitating referencing by park managers and visual comparisons among frames within parks.

Objectives

The monitoring objectives for this vital sign monitoring program are:

- Determine the status (current condition) and trends (change in condition over time) in the composition and abundance (cover) of principal native plant species in UCBN sagebrush steppe communities.
- Determine the status and trends in composition and abundance (cover) of principal invasive plant species, including annual grasses, in UCBN sagebrush steppe communities.
- Determine the status and trend in the amount of exposed soil (cover), a fundamental indicator of soil stability.

Methods

The UCBN used a generalized random tessellation stratified (GRTS) spatially-balanced sampling design (Stevens and Olsen 2004) within each of multiple park sampling frames in CIRO and CRMO in 2010 (Figures 1 and 2) following methods outlined by Yeo et al. (2009). The GRTS design ensures that each frame is sampled with statistical representativeness and optimal spatial dispersion (Stevens and Olsen 2004). The randomly located points provide the location for subsequent plot-based estimation of cover (described in the next paragraph). The total number of randomly located sampling points was 2000, distributed across frames following sample size determination described by Yeo et al. (2009). A minimum of 50 points were sampled in any one frame and adjusted upward proportional to the area of each frame. Table 1 summarizes the sample sizes obtained in each park frame. Sample frames in CRMO are labeled by an arbitrary frame number, from 1-35. More intuitive names for these frames will be appended in the future based on geographic location or nearby topographic features. Frames 1, 31, 32, and 35 were also sampled in 2009 and were named “Sunset Cone”, “Huff Lake Lava”, “Golden Chariot Fire”, and “Sand Kipuka” (Rodhouse 2010). Frames 19, 20, 25, 26, 27, 28, and 35 are in kipukas. Kipukas are areas of land within the CRMO lava fields that are completely surrounded by younger lava flows. Often kipukas have developed soils and late-successional vegetation. In CRMO, kipukas are ecologically important because they have been isolated from livestock grazing, and, in a few cases, still support quasi-pristine plant communities and are therefore of special interest to CRMO park staff. Table 2 shows the kipuka identification numbers for these 7 frames from the CRMO kipuka geodatabase and also the official or tentative descriptive names for these kipukas.

Sampling methods followed those detailed by Yeo et al. (2009). The approach utilized 1 m^2 PVC quadrats frames (plots), anchored at each GRTS sample point on the lower right-hand corner of the quadrat. Cover was visually estimated within each quadrat following Daubenmire’s (1959) 6-point cover class system (7 classes when “0” is included; Table 3). Cover was estimated separately for principal native and non-native plant species as well as for exposed bare soil. The lists of principal species for each park are listed by Yeo et al. (2009). For this report, bar graphs were utilized to present mean cover class estimates for each sampling frame, and include 90% confidence intervals obtained by calculating the more efficient “local” variance estimator developed for GRTS samples by Stevens and Olsen (2003). The height of each bar represents the proportion of plots within each sample frame that were estimated to contain the corresponding amount of cover for each of the cover classes. These estimates are also a population estimate of the proportion of sample frame area covered by a given species in each cover class. Ninety-percent confidence intervals provide a measure of uncertainty for each of these point estimates. In some figures graphs are color coded to facilitate readability but also to provide a qualitative measure of the level of concern associated with 2010 estimates. For example, cheatgrass cover is of concern to the integrity of park sagebrush steppe ecosystems. Accordingly, the colors of bars in graphs are graded from green to red for increasing cheatgrass cover. I have refrained from using strong colors where value judgments of good versus bad are less certain, or where judgments need to be made in a more nuanced manner within the context of other factors, such as ecological site or site history. The colors should not be interpreted rigidly, but rather are meant to draw attention quickly to differences among frames, and where additional management attention may wish to focus. Environmental attributes such as the age of lava and subsequent soil development in CRMO are unique to each frame. These unique frame attributes influence patterns of bare ground and other indicators, and relative change over time within frames will be more meaningful than comparisons among frames in many cases. This report focuses on only 6 key indicators: exposed bare soil cover, steppe bluegrass cover, bluebunch wheatgrass cover, cheatgrass cover, big sagebrush cover, and green rabbitbrush cover. Information on deep-rooted perennial native forbs is also presented. However, not all species for which data have been collected (see Yeo et al. 2009 for a list of species) are addressed in this report. Additional information on the larger suite of indicator species collected during 2010 sampling will be included in subsequent trend reports, and will be made available upon request from the UCBN during the interim. In order to focus attention on the most immediately apparent and meaningful patterns, only 1 cover class threshold (typically >5% cover) was used per indicator. Although arbitrary, these thresholds are useful to distinguish meaningfully among sites relative to the range of cover values observed. In many cases choosing another threshold would mask real differences among plots and frames because too few plots would be represented in one category. As more information is collected from the monitoring program and a greater understanding is achieved about the range of cover values expected in park steppe landscapes, these cover class reporting decisions can be revised. Importantly, these decisions should be made within the context of park management goals and desired future conditions.

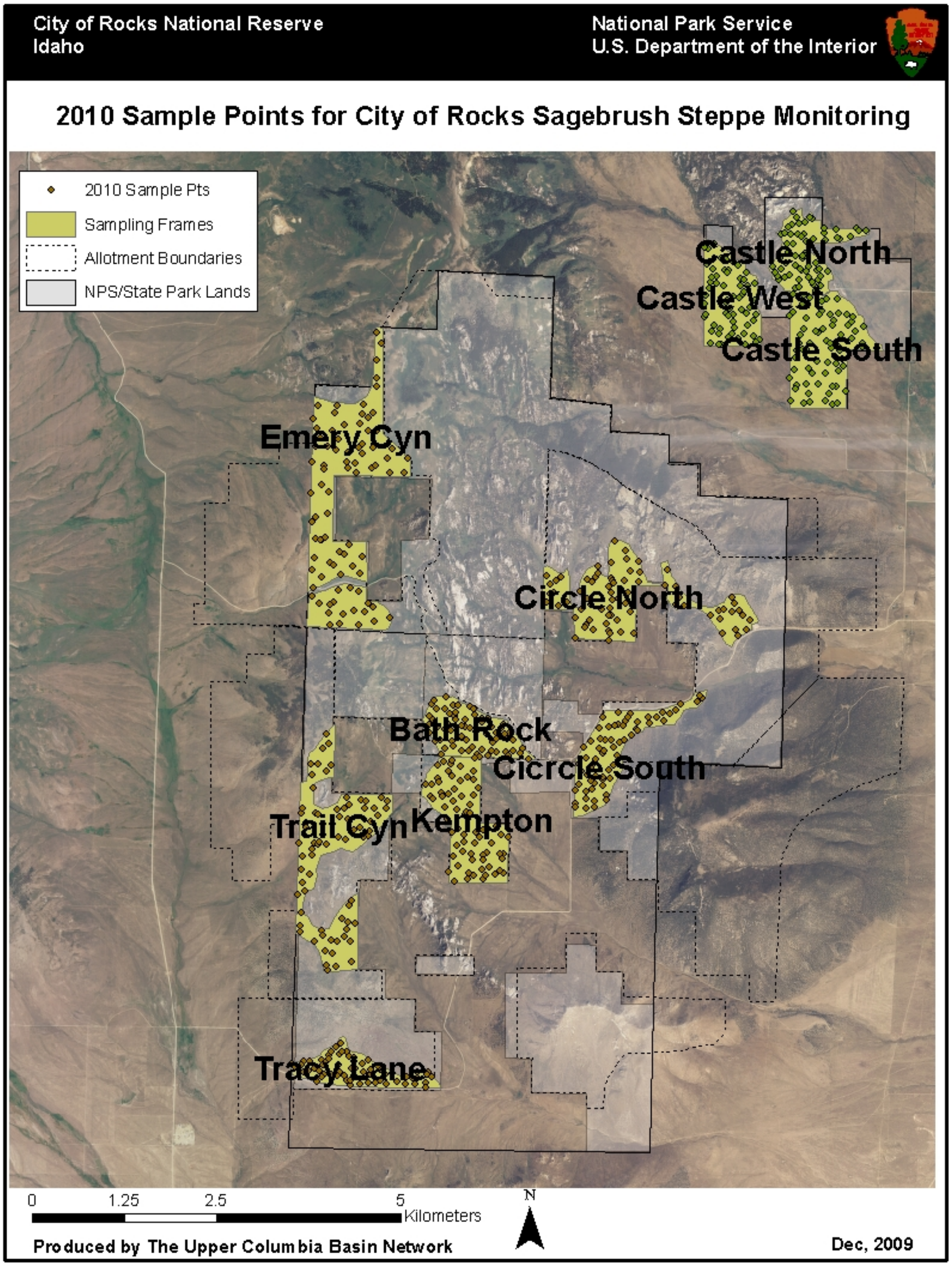

Figure 1. Sagebrush steppe vegetation monitoring sampling frames and spatially-balanced random sample points (GRTS sample points) for 2010 monitoring in City of Rocks National Reserve. Note that this map was produced prior to the expansion of the Castle Rocks State Park Boundary.

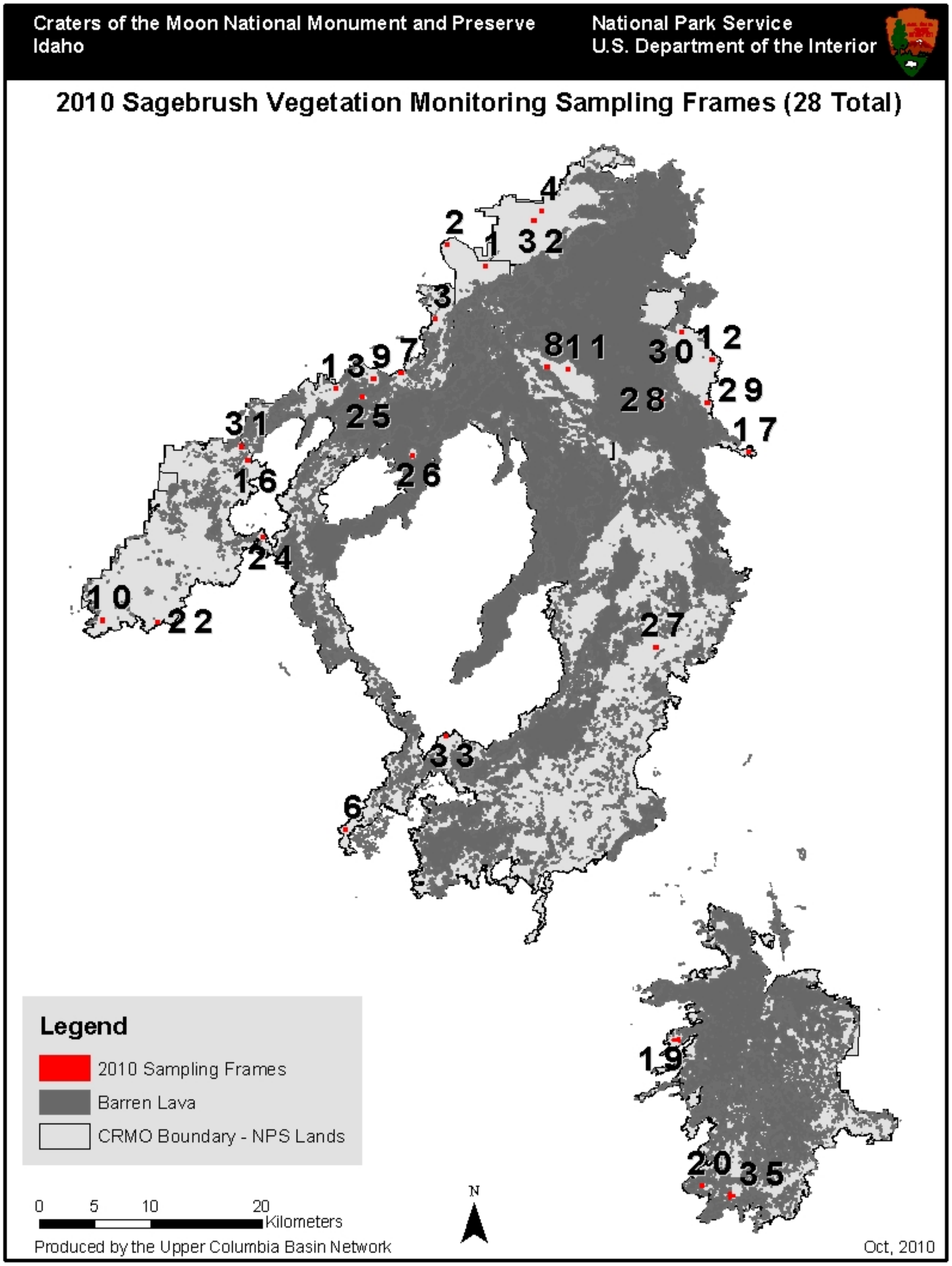

Figure 2. Sagebrush steppe vegetation monitoring sampling frames visited in 2010 in Craters of the Moon National Monument and Preserve. 50 spatially balanced random plots were measured in each frame.

Table 1. Sample sizes obtained for each park sampling frame in 2010 monitoring.

Park Unit	Sample Size
CIRO TOTAL	600
CIRO-Bath Rock	55
CIRO-Circle Cr. South	55
CIRO-Circle Cr. North	65
CIRO-Emery Cyn.	75
CIRO-Tracy Lane	55
CIRO-Kempton	60
CIRO-Trail Cyn.	65
CRSP-West	55
CRSP-North	60
CRSP-South	55
CRMO TOTAL	1400
Frames 1-35 (28 total)	50 ea.
Note: Frames 5, 14, 15, 18, 21, 23, 34 not sampled in 2010	
TOTAL	2000

Table 2. The names and identification numbers of seven CRMO sampling frames that encompass or fall within kipukas, which are unique areas of park management interest.

Kipuka name	Sample Frame ID	Kipuka Geodatabase ID
Schodde Well	19	469
Baker Cave	20	591
Brass Cap	25	89
Carey	26	410
Bear Park	27	382
County Line	28	55
Sand	35	536

Table 3. Daubenmire's cover classes used for visually estimating vegetation cover in 1 m^2 square plots (quadrats) placed at spatially-balanced locations in each sampling frame.

Cover Class	Range	Midpoint
0	0%	0%
1	1-5%	2.50%
2	>5-25%	15%
3	>25-50%	37.50%
4	>50-75%	62.50%
5	>75-95%	85%
6	>95%	97.50%

Results

City of Rocks National Reserve

Bare Ground

The proportion of plots where bare ground cover was estimated to be >5% ranged from 0% to 25% among frames (Figure A-1). Highest estimates were in the two Circle Creek sampling frames, in Tracy Lane, and in Castle Rocks State Park South. Bare ground cover >25% was estimated in 4% of plots in Circle Creek South and in 5% of plots in Circle Creek North, representing the highest estimates of bare ground cover made in 2010 in that park.

Principal Native Species

Table 4 presents summaries of the proportion of plots where selected native species cover was estimated to be >5%. Figure A-1 provides a graphical summary of the same information. Figure A-2 shows additional detail in the full distribution of plots across all cover classes for big sagebrush, providing an insight in to the spatial distribution as well as the overall abundance of sagebrush in the 10 CIRO sampling frames. For example, big sagebrush is absent from most of Tracy Lane and Castle Rocks West except for some small patches of moderate density (e.g., 5-25%) and cover, whereas Circle Creek North is dominated by large dense patches of sagebrush cover (Figure A-2). Figures B-1 and B-2 provide maps of the locations of plots, color coded by cover class estimates for bluebunch wheatgrass and big sagebrush, providing a spatial representation of these patterns. Arrowleaf balsamroot (*Balsamorhiza sagittata*), an important deep-rooted perennial forb, was particulary widespread in Bath Rock, Emery Canyon, and Trail Canyon, with the frequency of occurrence ranging from 17%-38%, and the proportion of plots with cover >25% ranging from 1 to 6% (Table 4). Lupines (*Lupinus spp.*), ecologically important nitrogen-fixing forbs, were also abundant in those areas, particularly in Bath Rock and Trail Canyon (Table 4).

Principal Non-Native Species

No noxious forbs were encountered in plots during 2010 sampling. The invasive annual grass cheatgrass is the most widespread and threatening non-native species in the park. Table 4 presents the summaries of the proportion of plots where cheatgrass cover was estimated to be >5%. Figure A-1 provides a graphical summary of the same information. Figure A-3 provides additional detail in the full distribution as well as in the overall abundance of cheatgrass in the 10 CIRO sampling frames. Figure B-3 provides a map of the locations of plots, color coded by cover class estimates for cheatgrass. The absence of any plots with cheatgrass > 5% cover in Circle Creek South, and nearly the same pattern in Castle Rocks West is striking and noteworthy, and stands out in contrast from the Tracy Lane frame. Other frames with low amounts of cheatgrass cover include Emery Canyon and Castle Rocks South, but these do have some small patches of more abundant cheatgrass too, as indicated by the 2-3 plots of high cover estimates. The other frames appear to have a more established population of cheatgrass, particularly Tracy Lane, which burned in 2000. Other non-native grasses that occur across the park in moderate abundance are crested wheatgrass (*Agropyron cristatum*) and bulbous bluegrass (*Poa bulbosa*). These species occur in all park frames and in some places are abundant. Cover estimates for at least one of these species were >25% (cover classes >3) in >5% of plots in almost every frame.

Table 4. The proportion of plots (%) in CIRO sampling frames estimated to have >5% cover for selected principal native species and for the non-native annual grass cheatgrass.

Frame	Steppe bluegrass	Bluebunch wheatgrass	Big sagebrush	Green rabbitbrush	Arrowleaf balsamroot	Lupine species	Cheatgrass
Bath Rock	9	2	55	24	13	15	4
Circle Cr. North	6	2	91	6	0	9	9
Circle Cr. South	35	7	76	15	0	7	0
Emery Canyon	11	9	45	16	7	9	1
Kempton	12	2	65	10	3	12	12
Tracy Lane	13	13	15	24	0	0	25
Trail Canyon	14	12	57	23	20	22	9
Castle Rocks North	9	16	71	16	2	4	5
Castle Rocks South	13	15	55	5	0	0	3
Castle Rocks West	4	36	15	2	0	2	0

Craters of the Moon National Monument and Preserve

Bare Ground

The proportion of plots where bare ground cover was estimated to be >5% ranged widely from 0% to 74% among frames (Figure C-1). Highest estimates were in frames 25 and 27, Brass Cap and Bear Park Kipukas, respectively. All other frames had much lower estimates ≤ 20%. However, no plots in frame 25 had cover estimates >25%. In contrast, 16% of plots in frame 27 had cover estimates >25%. The exceptionally high bare ground cover in frame 27 may have been caused by a local irruption of herbivorous voles (Jeff Yeo, personal communication).

Principal Native Species

Table 5 presents summaries of the proportion of plots where selected native species cover was estimated to be >5%. Figures C-2 – C-7 provide a graphical summary of the same information. Figures D-1 – D-3 provide maps of the locations of plots, color coded by cover class estimates for bluebunch wheatgrass and big sagebrush, providing a spatial representation of these patterns. There is tremendous variability among the frames for all species due to differences in site disturbance history (e.g., frame 32 is within the Golden Chariot Fire perimeter that burned in 2000) and other factors. Proportion of plots with >5% cover of bluebunch wheatgrass ranged from 0 to 72%. Frame 1, north of Sunset Cone, had the highest amount of this species, and 12% of plots in this frame also had bluebunch wheatgrass cover estimates >25%. Frame 25, Brass Cap Kipuka, is noteworthy because of the dominance of Idaho fescue (*Festuca idahoensis*), with 52% of plots having >5% cover of that species. Bluebunch wheatgrass was encountered in only 1 plot in that frame. Many frames with low amounts of bluebunch wheatgrass have high amounts of the other native perennial bunchgrass, steppe bluegrass. For example, frames on the Wapi Flow (19, 20, and 35) all follow this pattern. Frame 20 also had a substantial proportion of cover from another rhizomatous native perennial grass western wheatgrass (*Agropyron smithii*). Frame 27, Bear Park Kipuka, had exceptionally low cover of steppe bluegrass and other vegetation because of an apparent irruption of voles in the area (Jeff Yeo, personal communication). Big sagebrush also ranged widely among the frames. Frame 25, Brass Cap Kipuka, was dominated by another similar species, low sagebrush (*Artemisia arbuscula*). Seventy-four percent of the plots in that frame had cover >5% for that species. Frame 32, which burned in 2000, also had low cover of big sagebrush (Table 5 and Figure C-6). The big tap-rooted perennial forbs arrowleaf balsamroot and lupine species ranged widely among frames as well. In frame 28, the “county line” kipuka (Table 2), the proportion of plots with arrowleaf balsamroot cover >5% was 92%, which is a very striking pattern.

Principal Non-native Species

The noxious forb rush skeletonweed (*Chondrilla juncea*) was encountered in one plot in frame 22 on the west side of the Preserve during 2010 sampling. Three other rush skeletonweed plants were found while walking between plots. One leafy spurge (*Euphorbia esula*) plant was also found outside a plot while surveying in frame 22. Six Canada thistle (*Cirsium arvense*) plants were found outside sampling frame 26 on the edge of Carey Kipuka. Several dyer’s woad (*Isatis tinctoria*) plants were encountered along the trail in to frame 35, Sand Kipuka. No other noxious non-native forbs were encountered in plots. The invasive annual grass cheatgrass is the most widespread and threatening non-native species in the park. Table 5 presents the summaries of the proportion of plots where cheatgrass cover was estimated to be >5%. Figure C-8 provides a graphical summary of the same information. Figure D-2 provides maps of the locations of plots, color coded by cover class estimates for cheatgrass, providing a spatial representation of these patterns. The absence of any plots with cheatgrass >5% cover in frames 1 (Sunset Cone), 4, 8, 25 (Brass Cap Kipuka), and 33, and the low proportion in several other frames is noteworthy. However, none of these frames is completely free of cheatgrass. One plot was found with cheatgrass in frame 25 with 1-5% cover, for example (Figure D-2). Conversely, several frames are noteworthy for the high abundance of cheatgrass. Frames on the Wapi flow have upwards of 90% of the plots with cheatgrass >5% cover. An outlier in the general trend of decreasing cheatgrass cover from south to north along the park elevational gradient can be found in frame 32, on the north end of the Monument, which burned in 2000.

Table 5. The proportion of plots (%) in CRMO sampling frames estimated to have >5% cover for selected principal native species and for the non-native annual grass cheatgrass.

Frame	Steppe bluegrass	Bluebunch wheatgrass	Big sagebrush	Green rabbitbrush	Arrowleaf balsamroot	Lupine species	Cheatgrass
1	12	72	70	4	0	0	0
2	2	64	48	2	34	14	42
3	46	24	80	0	0	0	4
4	28	10	62	0	0	0	0
6	14	0	52	0	0	0	2
7	8	0	82	0	0	0	26
8	4	0	74	10	0	0	0
9	58	0	66	0	0	0	42
10	24	0	44	0	0	0	2
11	2	0	30	2	0	0	16
12	56	14	62	0	0	0	8
13	38	0	48	0	0	0	16
16	20	0	68	2	0	0	10
17	42	14	42	0	0	0	26
19	54	6	28	2	0	0	52
20	46	0	30	0	6	18	92
22	44	0	64	0	0	0	2
24	16	4	34	0	0	0	8
25	28	0	6	0	0	0	0
26	24	34	28	32	2	6	64
27	0	0	42	10	0	10	22
28	8	58	14	2	92	12	4
29	36	14	32	6	0	0	36
30	40	12	52	0	0	0	26
31	28	0	62	0	0	0	16
32	48	16	10	6	0	0	60

Table 5. The proportion of plots (%) in CRMO sampling frames estimated to have >5% cover for selected principal native species and for the non-native annual grass cheatgrass (continued).

Frame	Steppe bluegrass	Bluebunch wheatgrass	Big sagebrush	Green rabbitbrush	Arrowleaf balsamroot	Lupine species	Cheatgrass
33	4	0	40	0	0	0	0
35	52	0	20	0	20	2	78

Discussion

The UCBN sagebrush steppe monitoring program completed a second season of monitoring in CIRO and CRMO in 2010. The analyses provided in this report are some of the first quantitative descriptions of sagebrush steppe plant communities in these parks, particularly for CIRO. Sample sizes ranged from 50 to 75 per sampling frame, and were extensive enough to support strong inferences about indicators of ecological condition and resilience, including cover of bare ground, and native and non-native vegetation. These estimates provide descriptions of current conditions of park steppe ecosystems and will contribute to the foundation of science-based adaptive management in these parks. These ecosystems are highly variable both over space and time, however, and several years of subsequent sampling in each of these parks will be required before a good understanding can be acquired of how to interpret these indicators within the context of this variability. Of particular importance is a recognition that environmental conditions (e.g., elevation, soil types, and land use histories) in each of the frames are so varied and influential that comparison among parks, and even among frames within parks, must be done very cautiously, and primarily as a general way to provide context for interpreting current conditions, or to look at regional patterns. For example, it appears that a local vole irruption in CRMO frame 27 heavily influenced the cover estimates made there, and events such as these need to be taken in to account when interpreting monitoring data. Ultimately, relative change over time within frames will provide the best measure of ecological condition and changes in those conditions for park resource managers to consider in their decision making. An important case in point is the recent park decision to eliminate livestock grazing from both Circle Creek frames in 2006. Importantly these frames have low abundance of cheatgrass, yet bear some evidence of overgrazing, including elevated bare ground cover. Monitoring of these sites over time will provide the park with invaluable information about the efficacy of this decision to improve rangeland condition.

City of Rocks National Reserve

The overall patterns reflected in the data collected in 2010 suggest that much of CIRO and Castle Rocks State Park remains in good ecological condition. Particularly noteworthy is the overall low levels of cheatgrass infestation, and the rarity of other noxious non-native species. An exception to this pattern is the moderate amount of cheatgrass present in the Tracy Lane frame, which burned in 2000. In general it appears that low elevation portions of the park may be more vulnerable to cheatgrass, particularly if climate change predictions for the region, which include increased aridity, are realized (Chambers et al. 2007, Karl et al. 2009). However, there is variability in that relationship, and experience from CRMO suggests that even high elevation sagebrush steppe in good ecological condition can become infested following fire. The small, dense patches of cheatgrass that occur in several otherwise un-infested frames underscore the risk that these park landscapes face. Deep-rooted native perennial forbs were well represented in most sampling frames. Native perennial forb cover has been attributed to ecological resistance and resilience in western sagebrush rangelands, generally (Germino et al. 2004, Prevey et al. 2010). Maintaining this component of CIRO sagebrush steppe ecosystems should be a management goal for the park and monitoring of these species will provide a good indication of ecological condition. The active livestock grazing program that continues at CIRO presents a clear challenge to successful management and conservation of park sagebrush steppe. While most indicators presented in this report suggest park steppe areas are in good condition, particularly given the low levels of cheatgrass infestation in most sampling frames, there are some indications of adverse grazing pressure in some areas. In the Circle Creek area, the combination of very high sagebrush cover, high bare ground cover, low bluebunch wheatgrass cover, low forb cover, and high steppe bluegrass cover (in Circle Creek South) is a pattern that suggests overgrazing. Grazing was discontinued in Circle Creek in 2006. These indicators should be watched carefully over time and considered within the context of other information such as short-term utilization monitoring as outlined by the park grazing management plan. The low levels of cheatgrass in the Circle Creek area, particularly in the southern half, underscores that these areas are of high ecological value to the park and should be managed carefully, especially in light of the post-fire infestation apparent in Tracy Lane. In general, the Snake River Plain where CIRO is located has experienced high rates of cheatgrass invasion over the last 150 years and it is increasingly rare to find cheatgrass-free (or nearly so) areas that still exist in CIRO (Knick and Rotenberry 1997, Chambers et al. 2007).

Craters of the Moon National Monument and Preserve

Patterns of cover observed in CRMO frames in 2010 tended to co-occur in ways that suggest areas of high ecological condition (e.g., Brass Cap and Count Line Kipukas, Sunset Cone) and low ecological condition (e.g., Sand Kipuka on the Wapi Flow). The estimates of cover in Sunset Cone plots were particularly striking for their consistency, and describe an area of the park that appears to be resistant to cheatgrass invasion and other attributes of degradation. Native perennial forb cover was substantial there. Native perennial forb cover has been attributed to ecological resistance and resilience in western sagebrush rangelands, generally (Germino et al. 2004, Prevey et al. 2010). The high amount of cheatgrass observed in the Golden Chariot Fire frame, frame 32, was striking. The Golden Chariot Fire occurred very close to Sunset Cone and sampling frame 4, areas of similar elevation but that have no cheatgrass, and illustrates the changes that could occur in these areas in response to fire. Of particular interest for the Golden Chariot Fire frame is the large numbers of sage grouse that use the area for lekking and brood rearing (M. Munts, CRMO, personal communication). Monitoring data that provides a measure of change in that frame will be important for park management.

In general it appears that low elevation portions of the park are less likely to exhibit resilience, particularly if climate change predictions for the region, which include increased aridity, are realized (Chambers et al. 2007, Karl et al. 2009). The three frames on the Wapi Flow (frames 19, 20, and 35), all kipukas, in the lowest portion of CRMO, as well as Carey Kipuka located approximately in the middle of the elevational gradient, were observed with high amounts of cheatgrass cover. These observations underscore that even areas physically isolated from past grazing are vulnerable to degradation, particularly if burned. Finally, management attention should be given to the frame 2 (Little Cottonwood Creek frame), which presented somewhat incongruous results. The relatively high cheatgrass cover in that frame was surprising, given the elevation of the frame, and its relative isolation. The frame was estimated to have high cover of native vegetation, except steppe bluegrass. Site disturbance history may explain the localized cheatgrass invasion. Sheep grazing and mining activities have occurred in the drainage in the past (J. Apel, CRMO, personal communication). Trends in cheatgrass cover in this frame should be watched carefully. Little Cottonwood Creek frame is in an area proposed for National Natural Landmark designation, along with Brass Cap Kipuka, and is located near Sunset Cone.

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Appendix A. CIRO

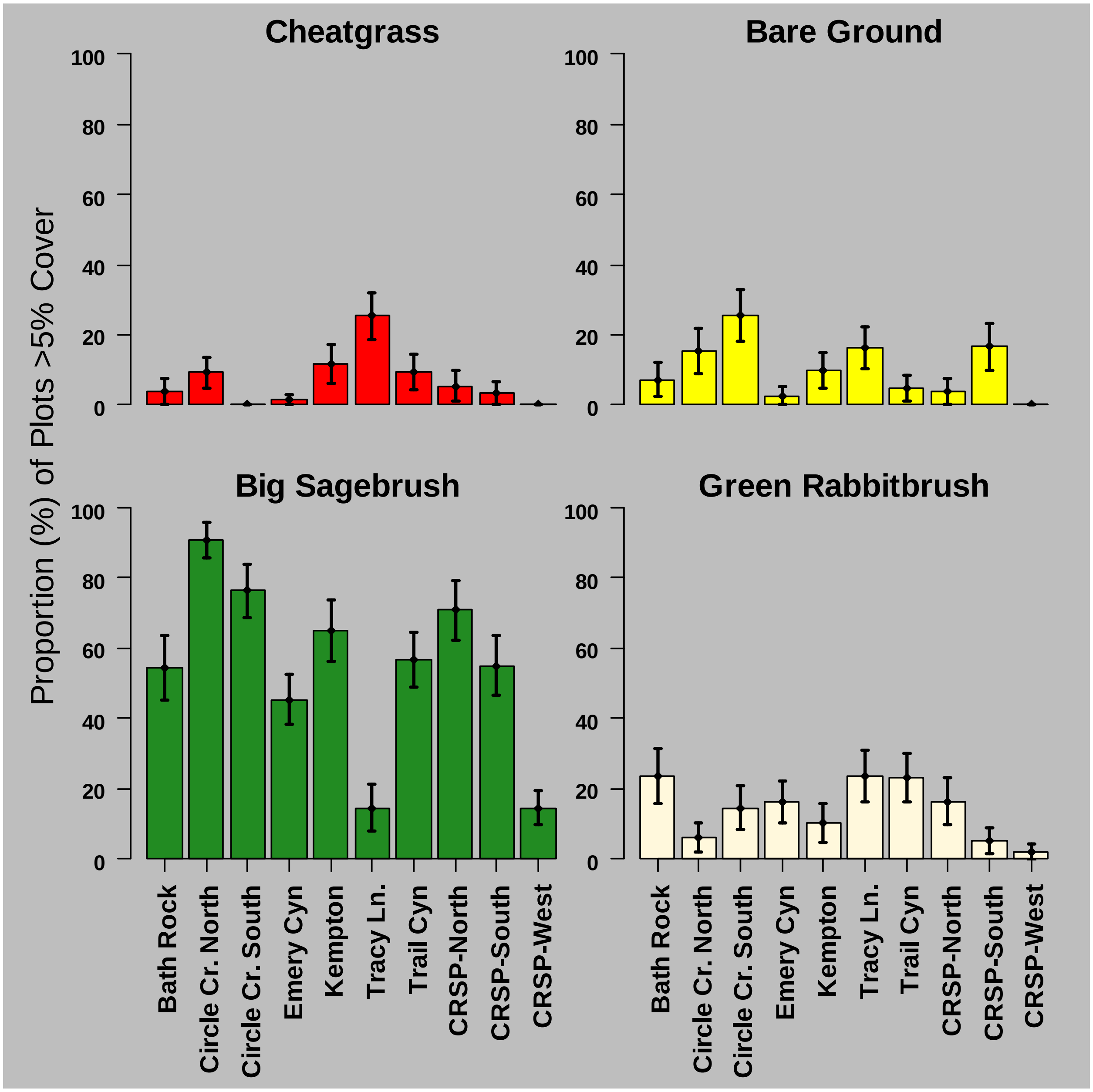

Figure A-1. Proportion of plots, expressed in percent, in which indicator species (labeled) were estimated to occur with >5% cover for each of 10 CIRO sampling frames sampled in 2010. 90% confidence intervals for point estimates are presented as black vertical bars.

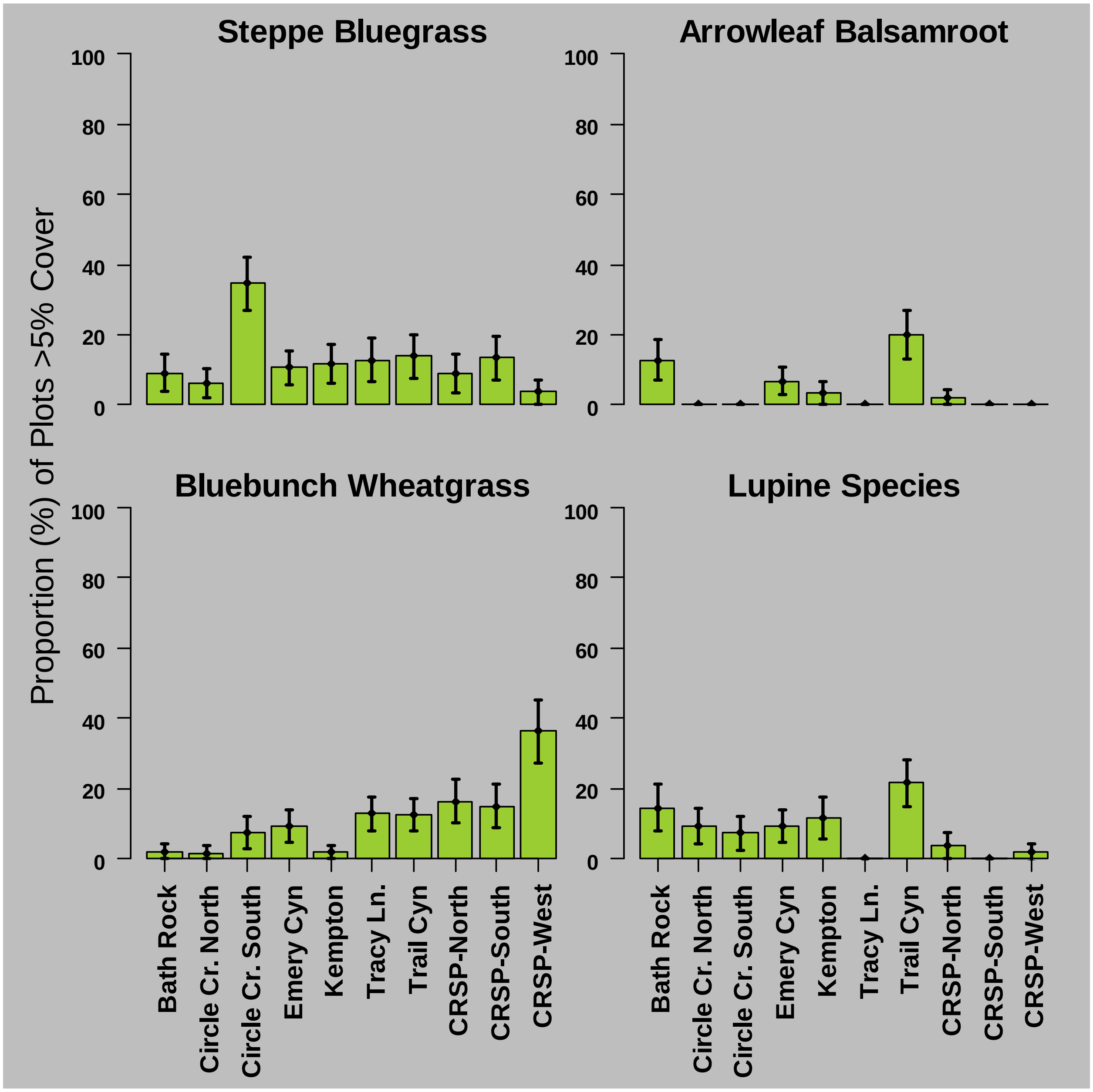

Figure A-1. Proportion of plots, expressed in percent, in which indicator species (labeled) were estimated to occur with >5% cover for each of 10 CIRO sampling frames sampled in 2010. 90% confidence intervals for point estimates are presented as black vertical bars (continued).

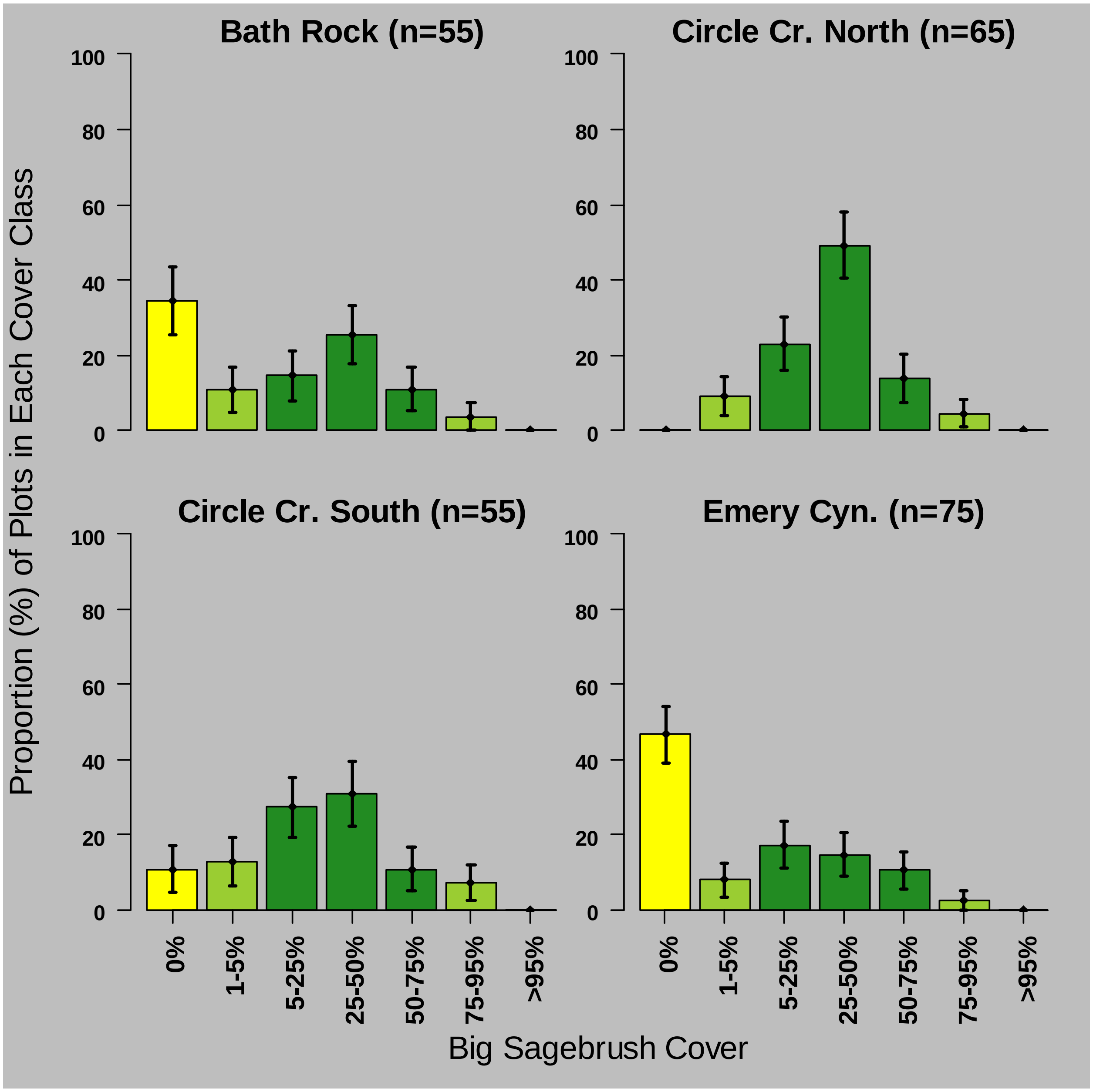

Figure A-2. The proportion of 2010 plots (and 90% confidence intervals) containing big sagebrush in each Daubenmire cover class, by CIRO sampling frame.

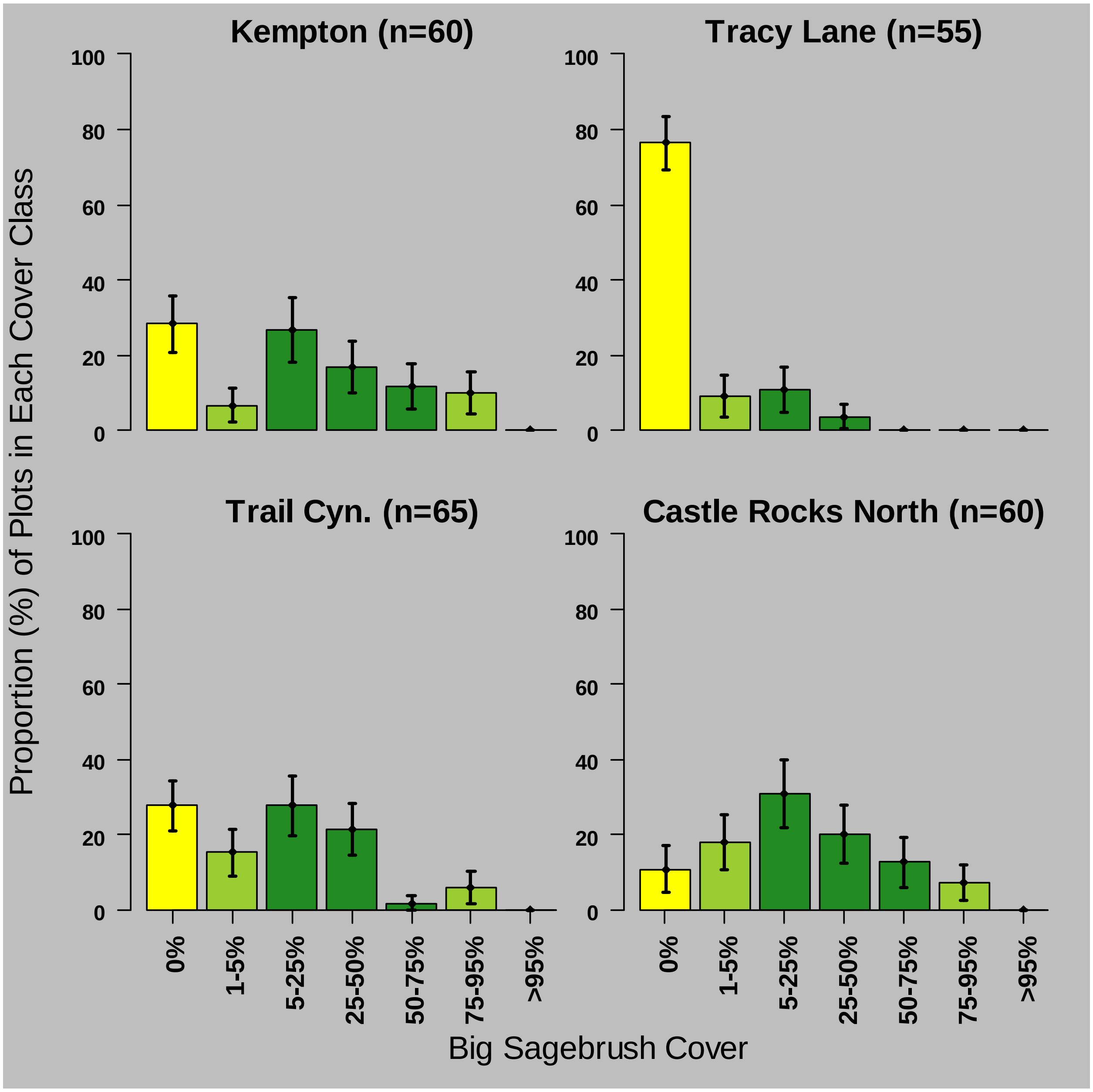

Figure A-2. The proportion of 2010 plots (and 90% confidence intervals) containing big sagebrush in each Daubenmire cover class, by CIRO sampling frame (continued).

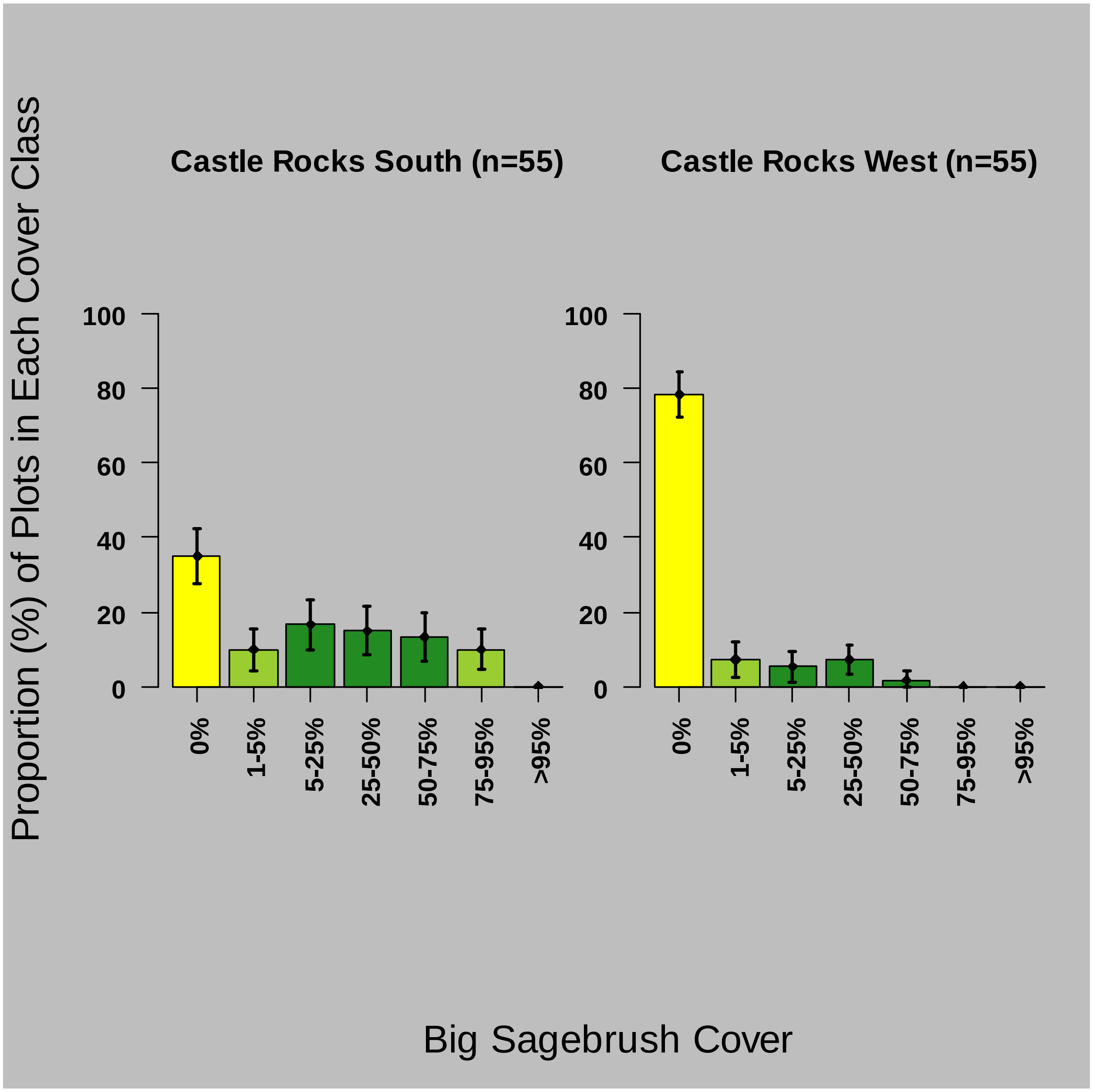

Figure A-2. The proportion of 2010 plots (and 90% confidence intervals) containing big sagebrush in each Daubenmire cover class, by CIRO sampling frame (continued).

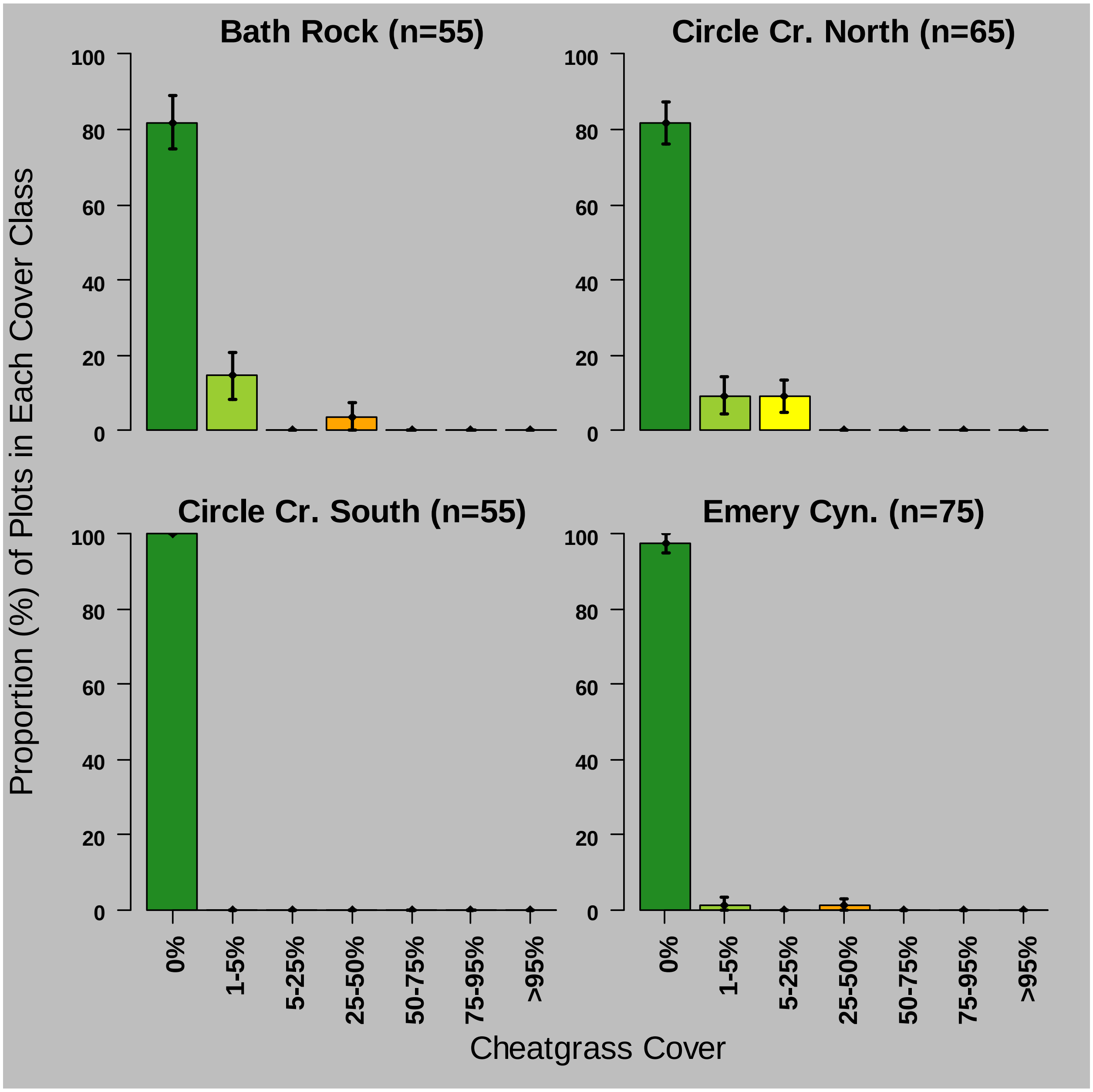

Figure A-3. The proportion of 2010 plots (and 90% confidence intervals) containing cheatgrass in each Daubenmire cover class, by CIRO sampling frame.

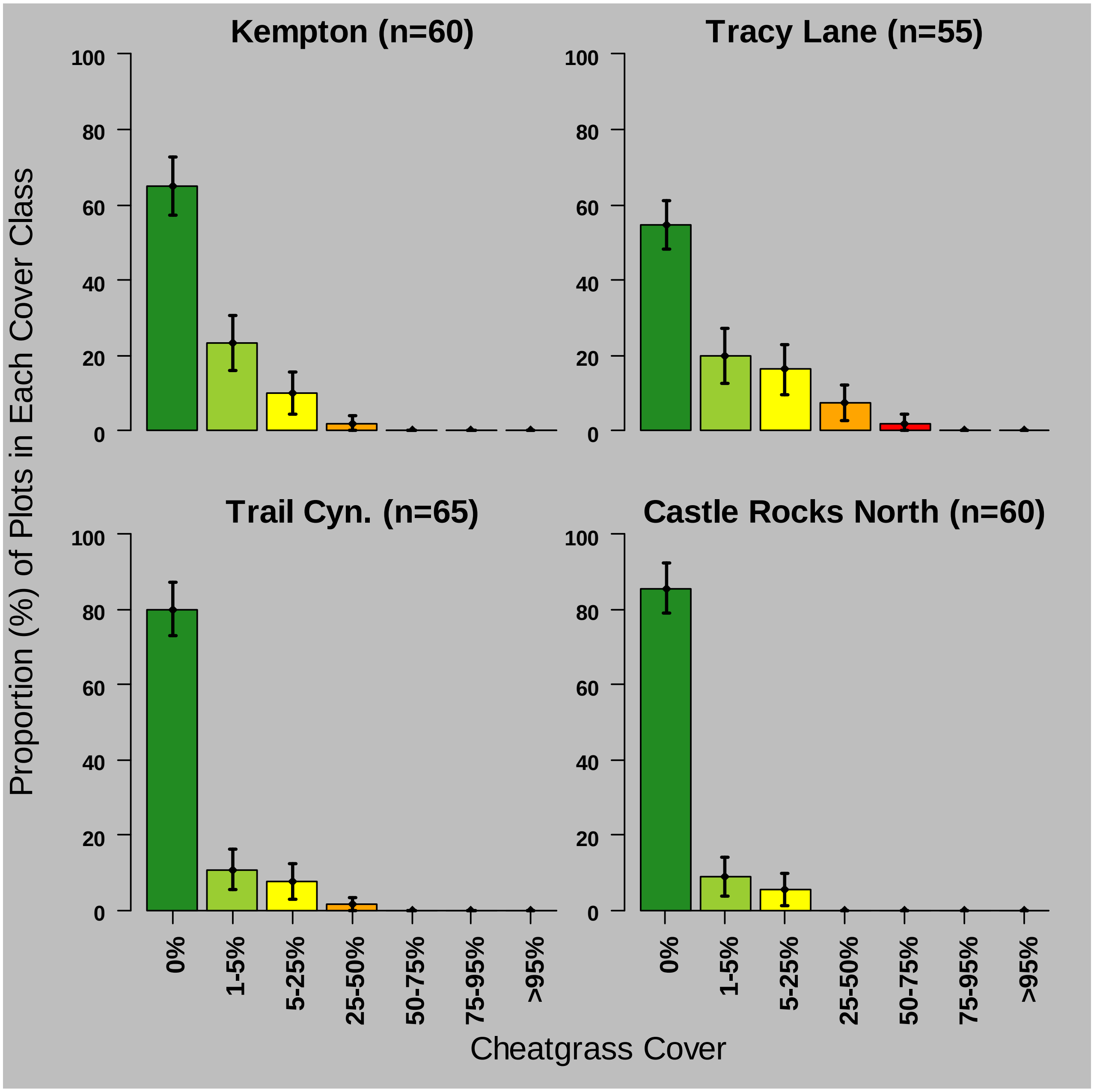

Figure A-3. The proportion of 2010 plots (and 90% confidence intervals) containing cheatgrass in each Daubenmire cover class, by CIRO sampling frame (continued).

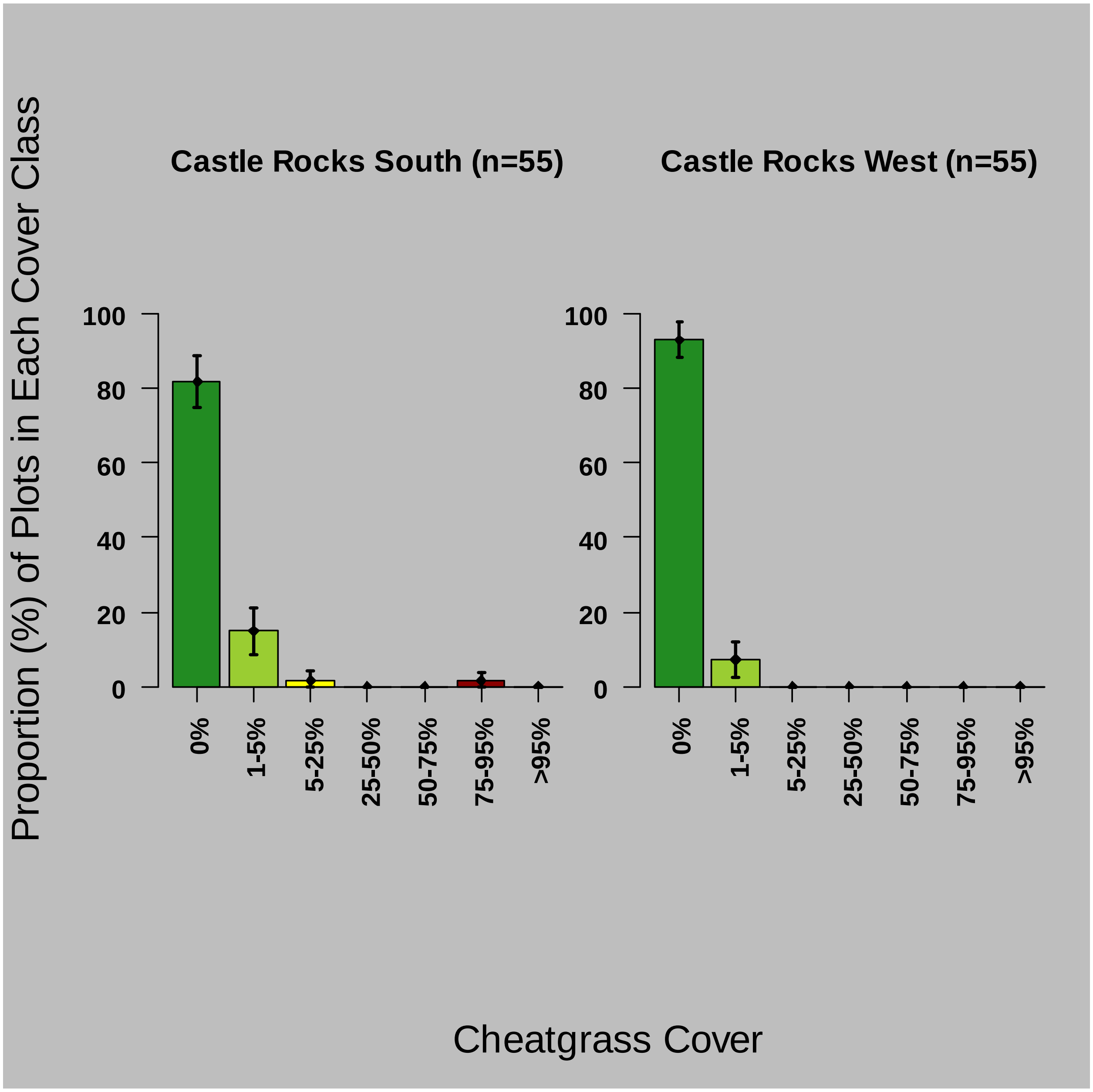

Figure A-3. The proportion of 2010 plots (and 90% confidence intervals) containing cheatgrass in each Daubenmire cover class, by CIRO sampling frame (continued).

Appendix B. CIRO

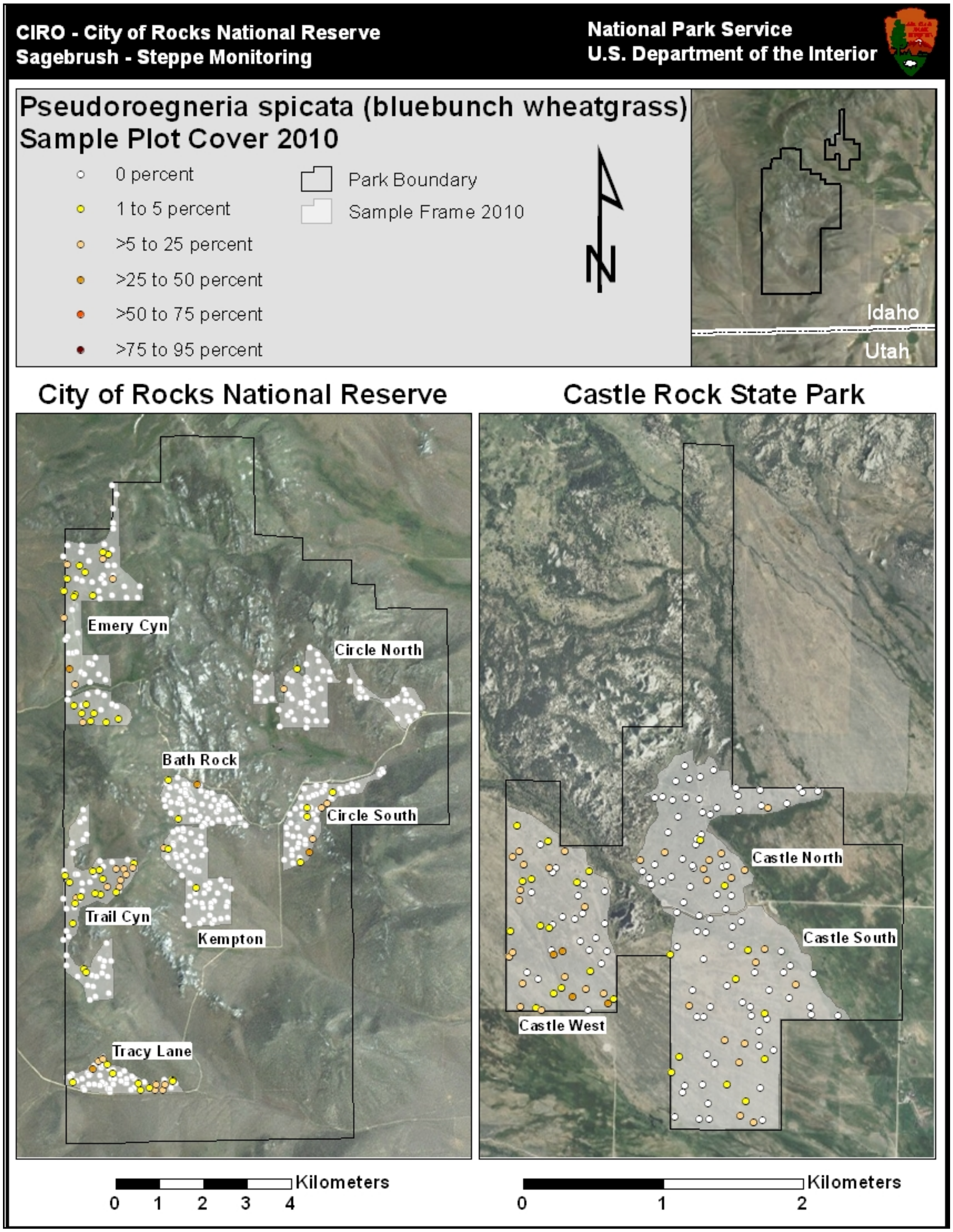

Figure B-1. The location of 2010 plots in CIRO containing bluebunch wheatgrass, color coded by Daubenmire cover class.

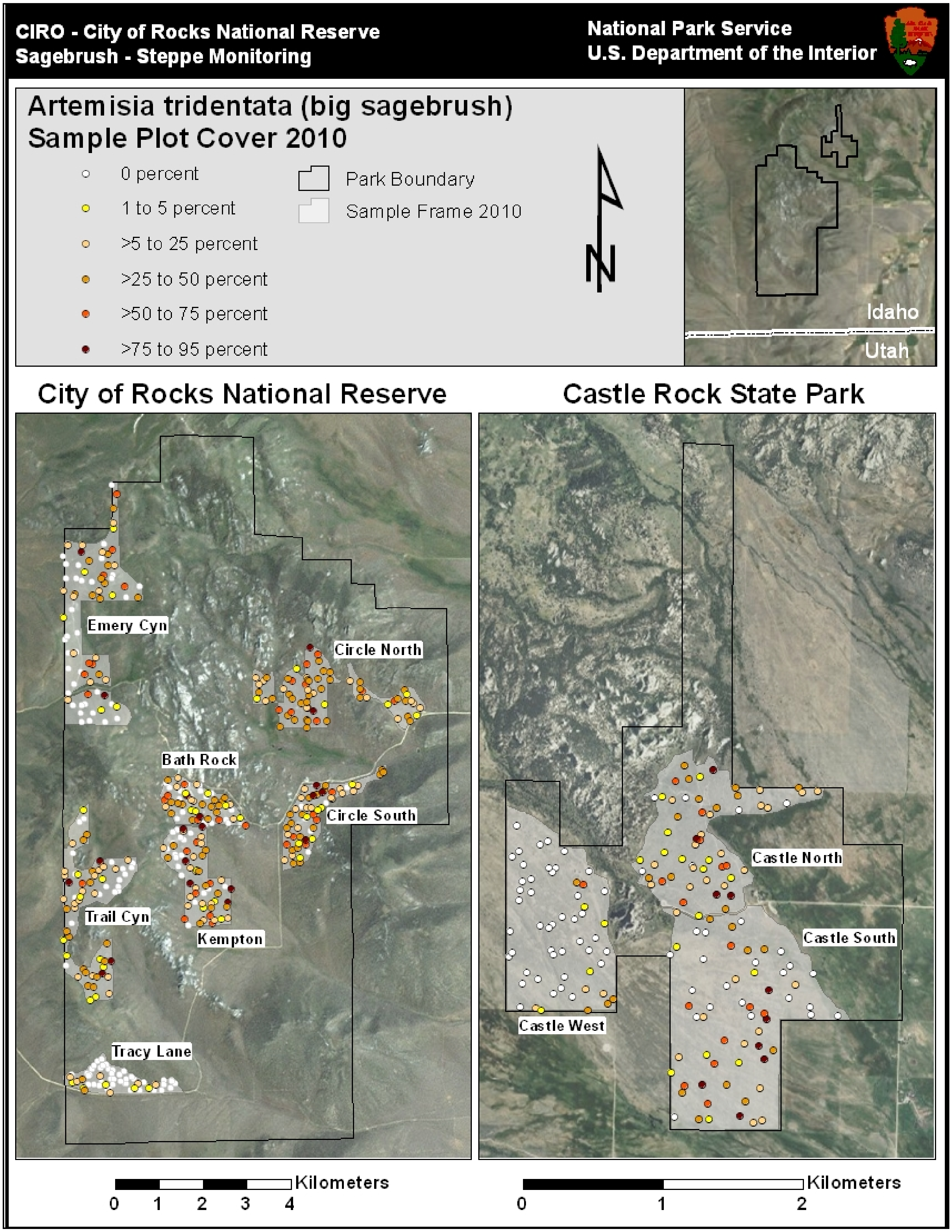

Figure B-2. The location of 2010 plots in CIRO containing big sagebrush, color coded by Daubenmire cover class.

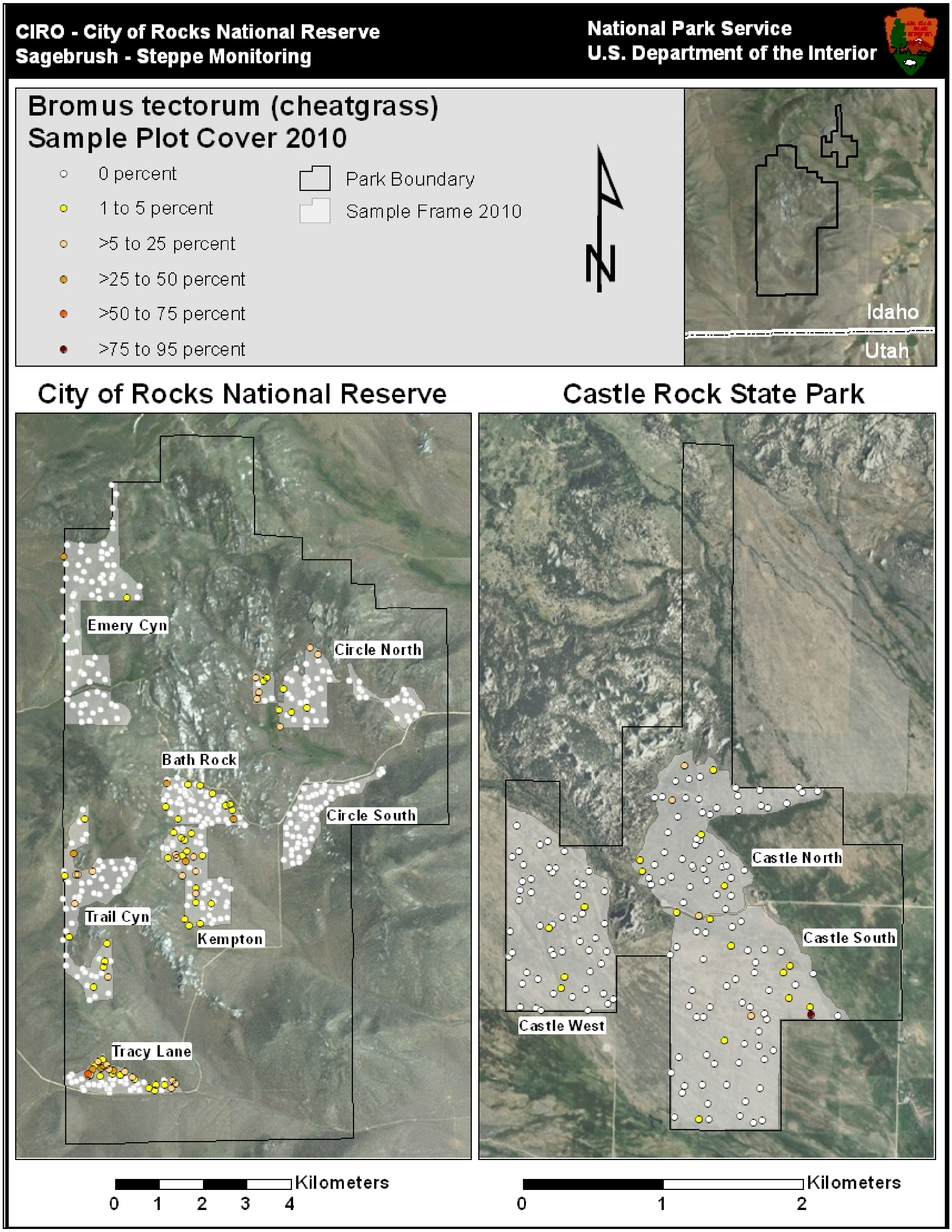

Figure B-3. The location of 2010 plots in CIRO containing cheatgrass, color coded by Daubenmire cover class.

Appendix C. CRMO

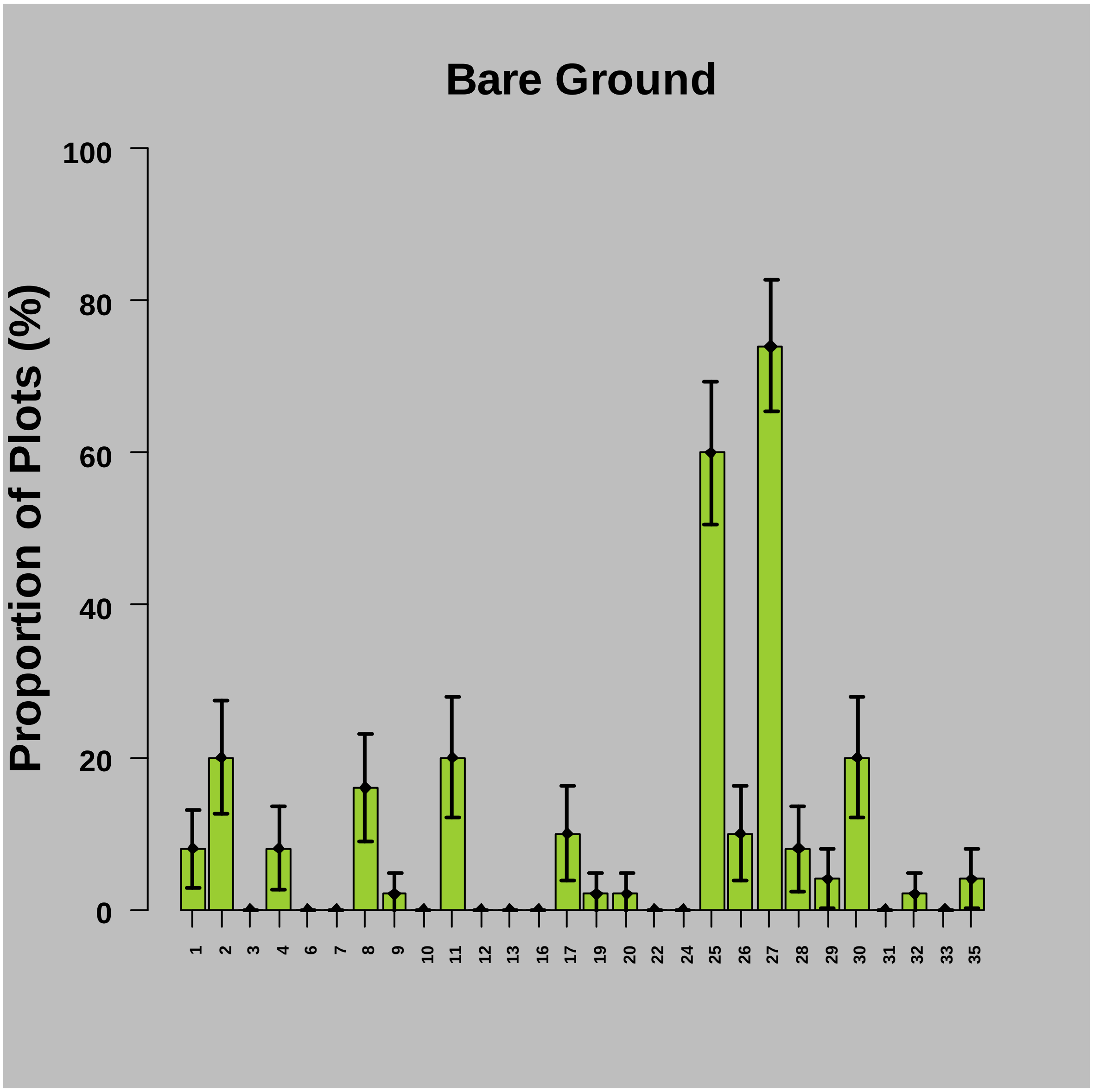

Figure C-1. Proportion of plots, expressed in percent, in which exposed bare ground was estimated to occur with >5% cover for each of 28 CRMO sampling frames sampled in 2010. 90% confidence intervals are presented as black vertical bars. Frames 19, 20, 25, 26, 27, 28, 35 are located in kipukas (see Table 2).

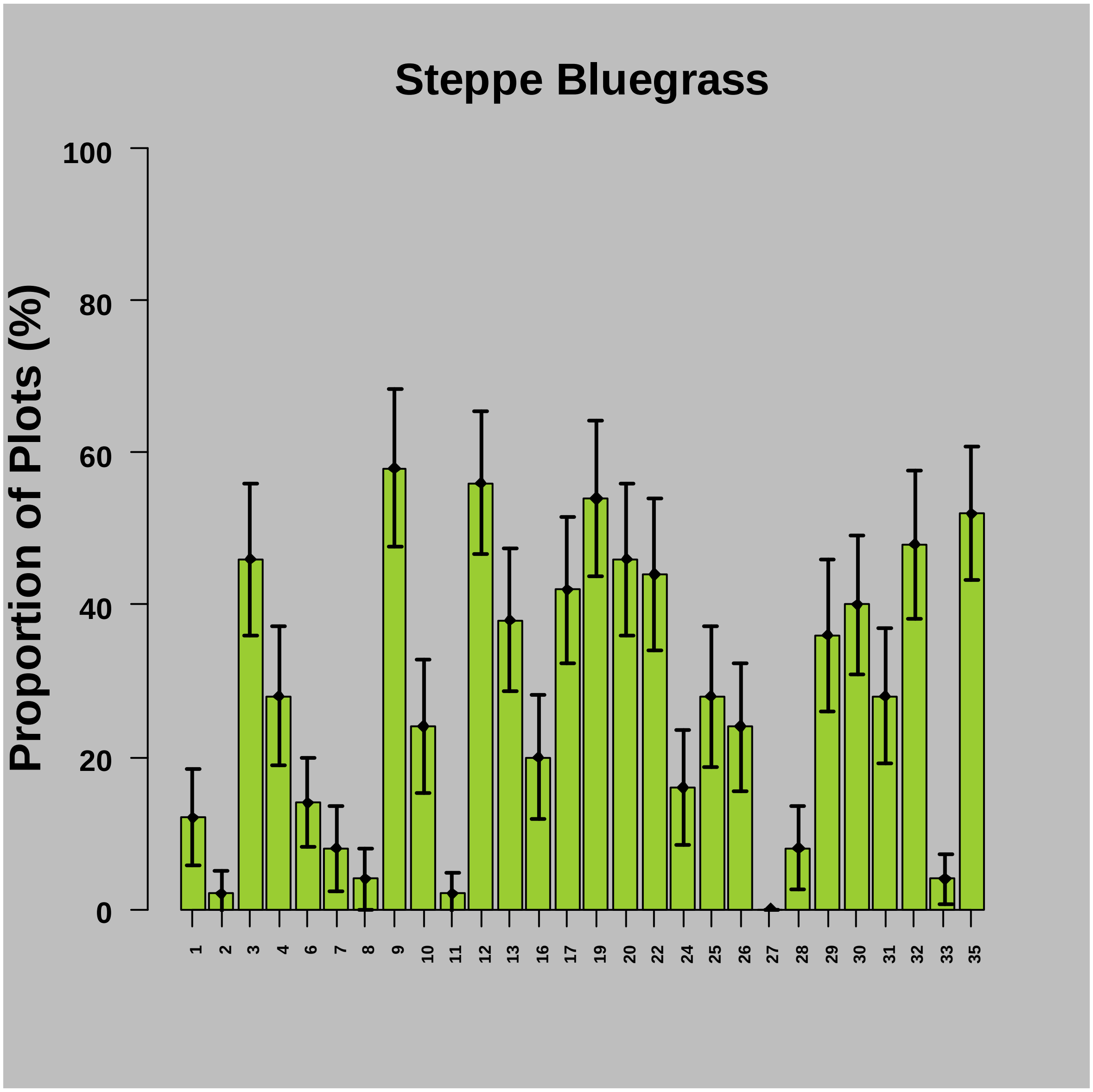

Figure C-2. Proportion of plots, expressed in percent, in which steppe bluegrass species was estimated to occur with >5% cover for each of 28 CRMO sampling frames sampled in 2010. 90% confidence intervals are presented as black vertical bars. Frames 19, 20, 25, 26, 27, 28, 35 are located in kipukas (see Table 2).

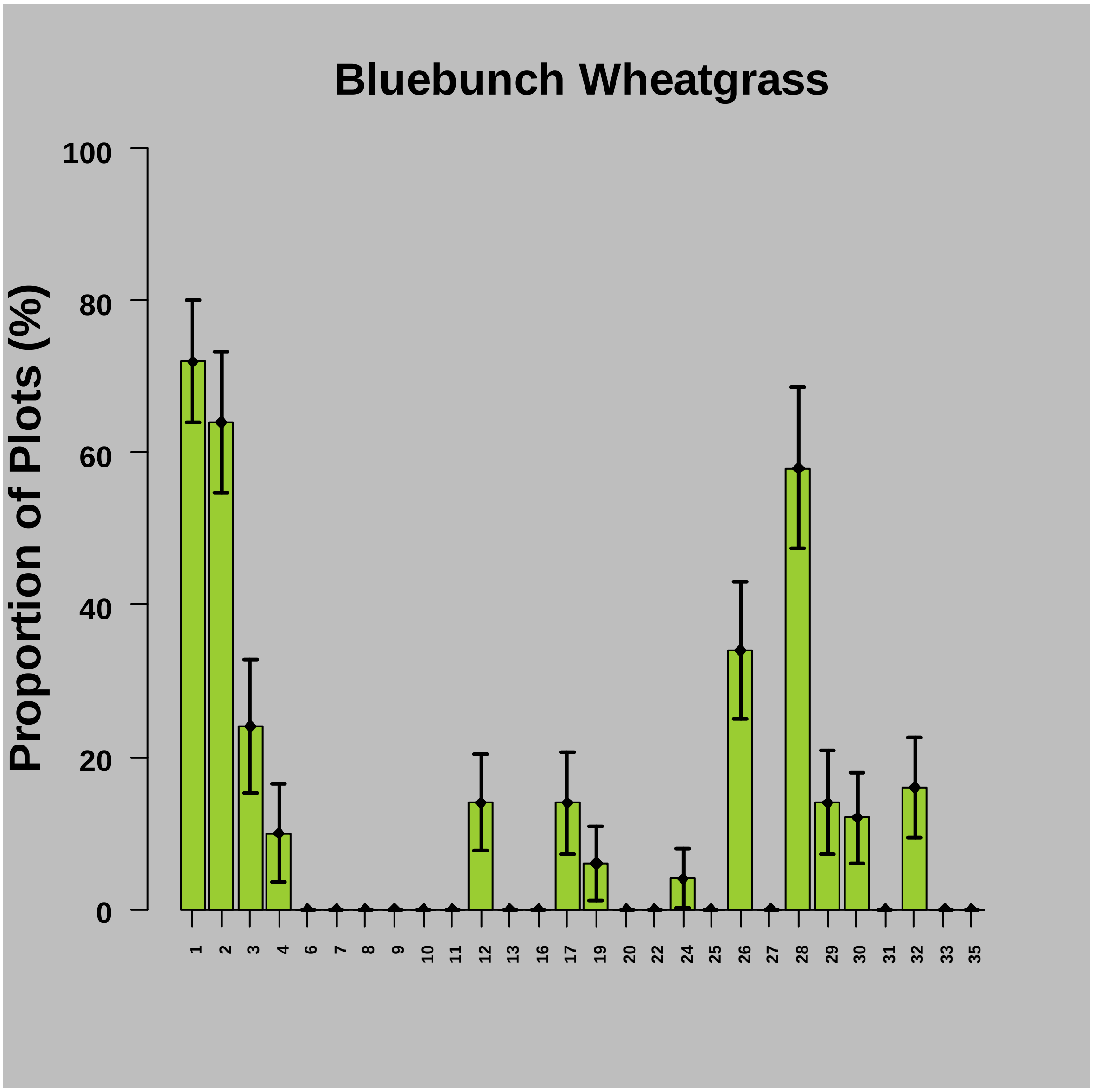

Figure C-3. Proportion of plots, expressed in percent, in which bluebunch wheatgrass was estimated to occur with >5% cover for each of 28 CRMO sampling frames sampled in 2010. 90% confidence intervals are presented as black vertical bars. Frames 19, 20, 25, 26, 27, 28, 35 are located in kipukas (see Table 2).

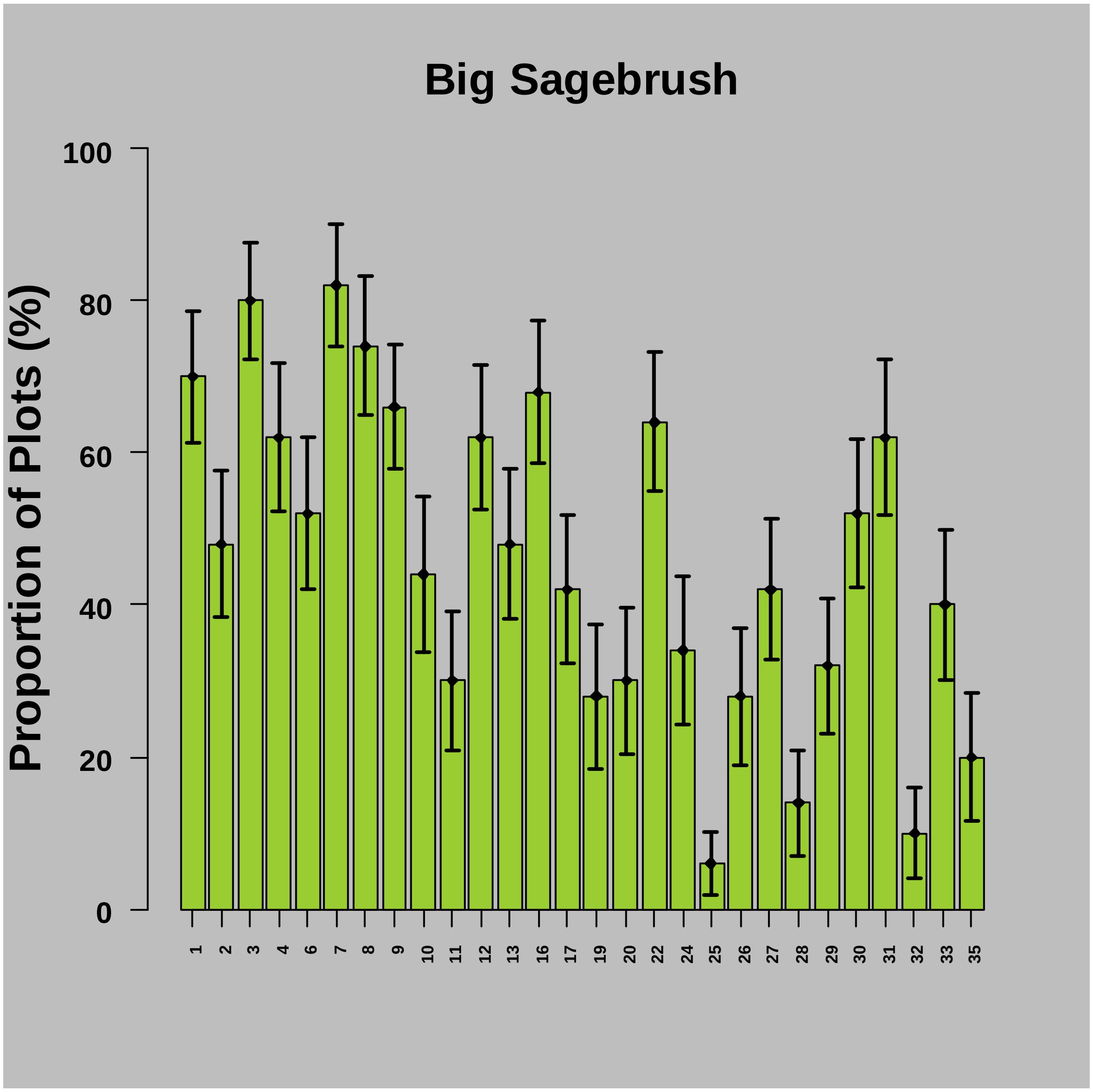

Figure C-4. Proportion of plots, expressed in percent, in which big sagebrush species was estimated to occur with >5% cover for each of 28 CRMO sampling frames sampled in 2010. 90% confidence intervals are presented as black vertical bars. Frames 19, 20, 25, 26, 27, 28, 35 are located in kipukas (see Table 2).

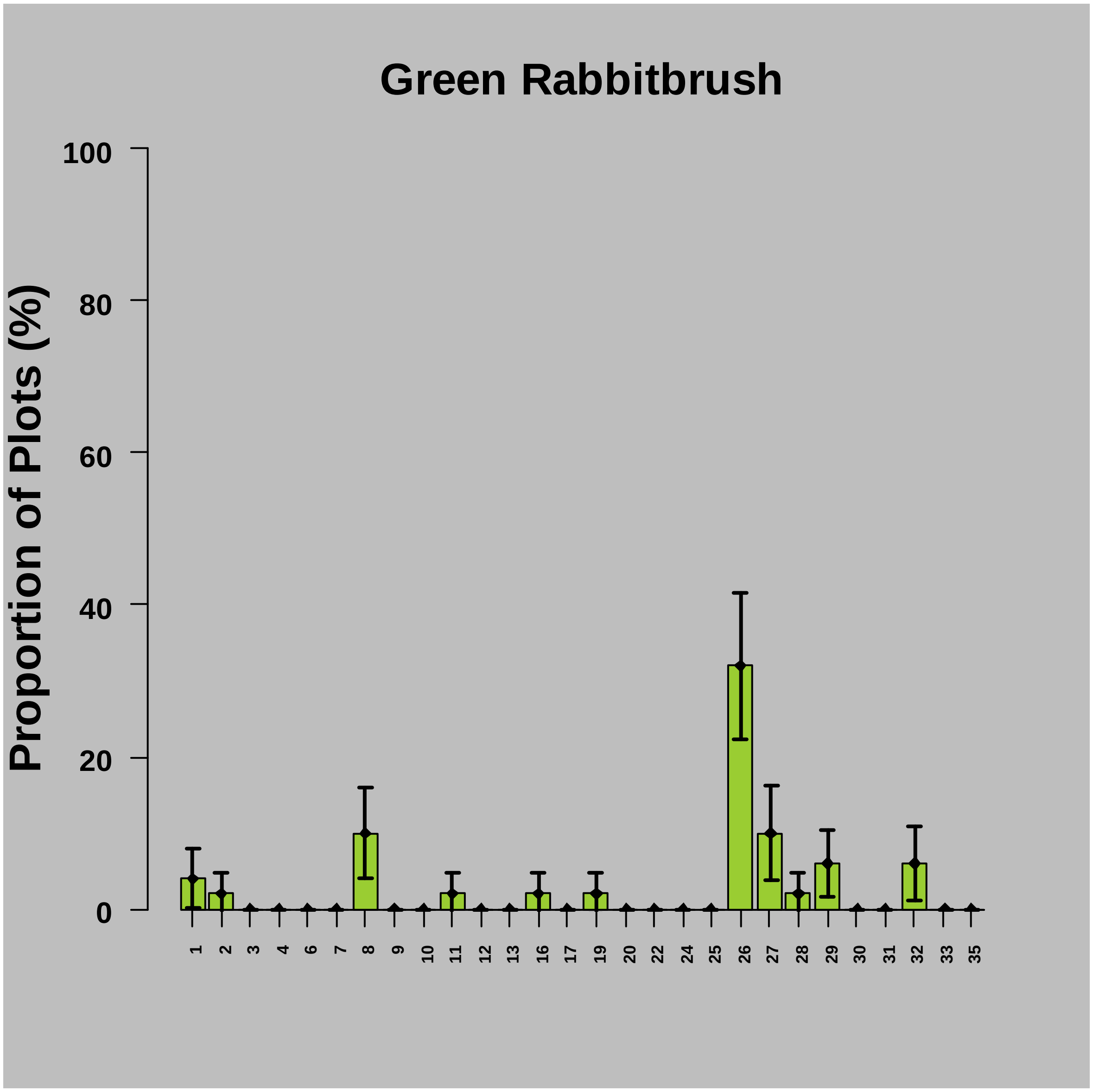

Figure C-5. Proportion of plots, expressed in percent, in which green rabbitbrush species was estimated to occur with >5% cover for each of 28 CRMO sampling frames sampled in 2010. 90% confidence intervals are presented as black vertical bars. Frames 19, 20, 25, 26, 27, 28, 35 are located in kipukas (see Table 2).

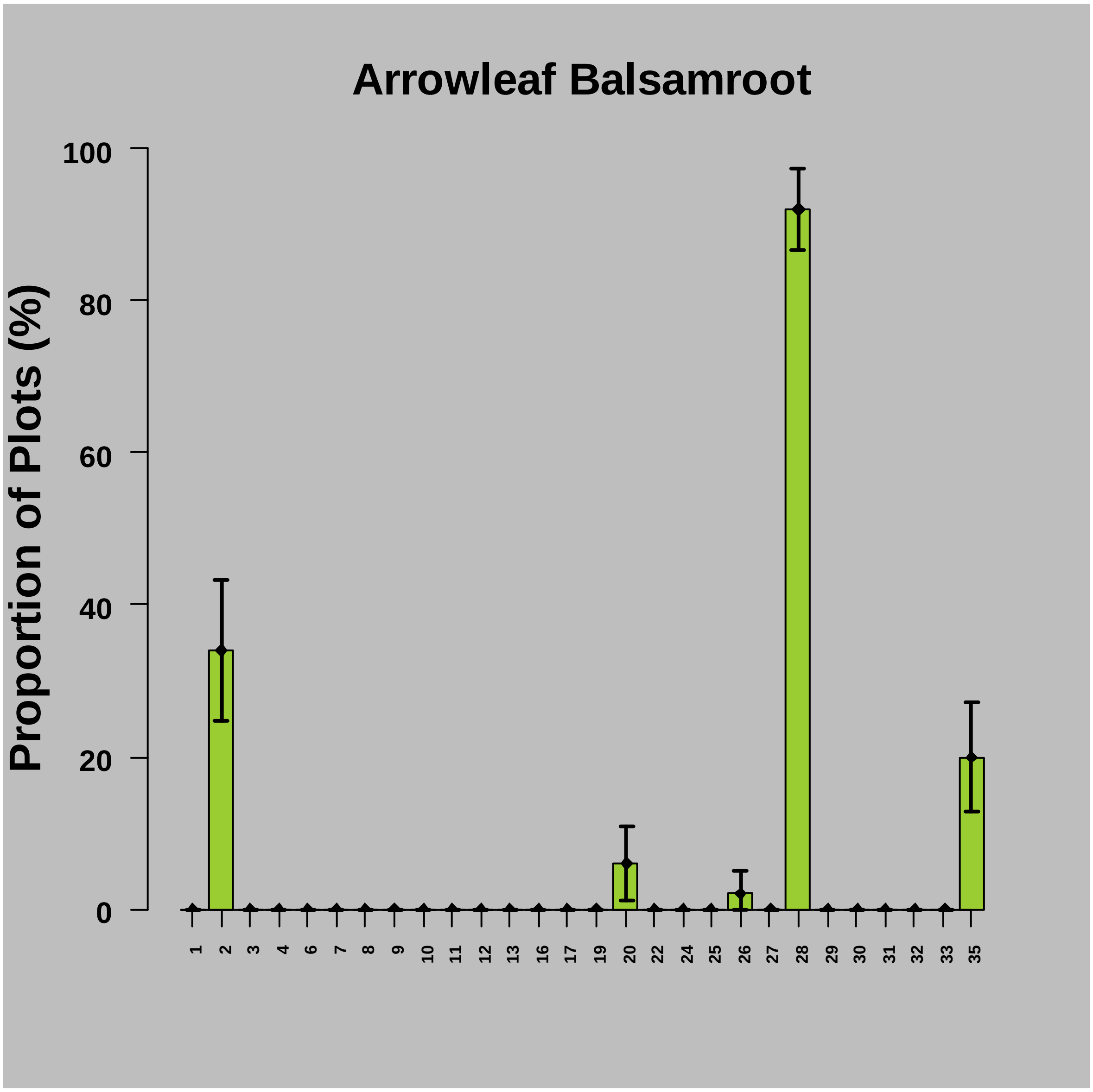

Figure C-6. Proportion of plots, expressed in percent, in which arrowleaf balsamroot was estimated to occur with >5% cover for each of 28 CRMO sampling frames sampled in 2010. 90% confidence intervals are presented as black vertical bars. Frames 19, 20, 25, 26, 27, 28, 35 are located in kipukas (see Table 2).

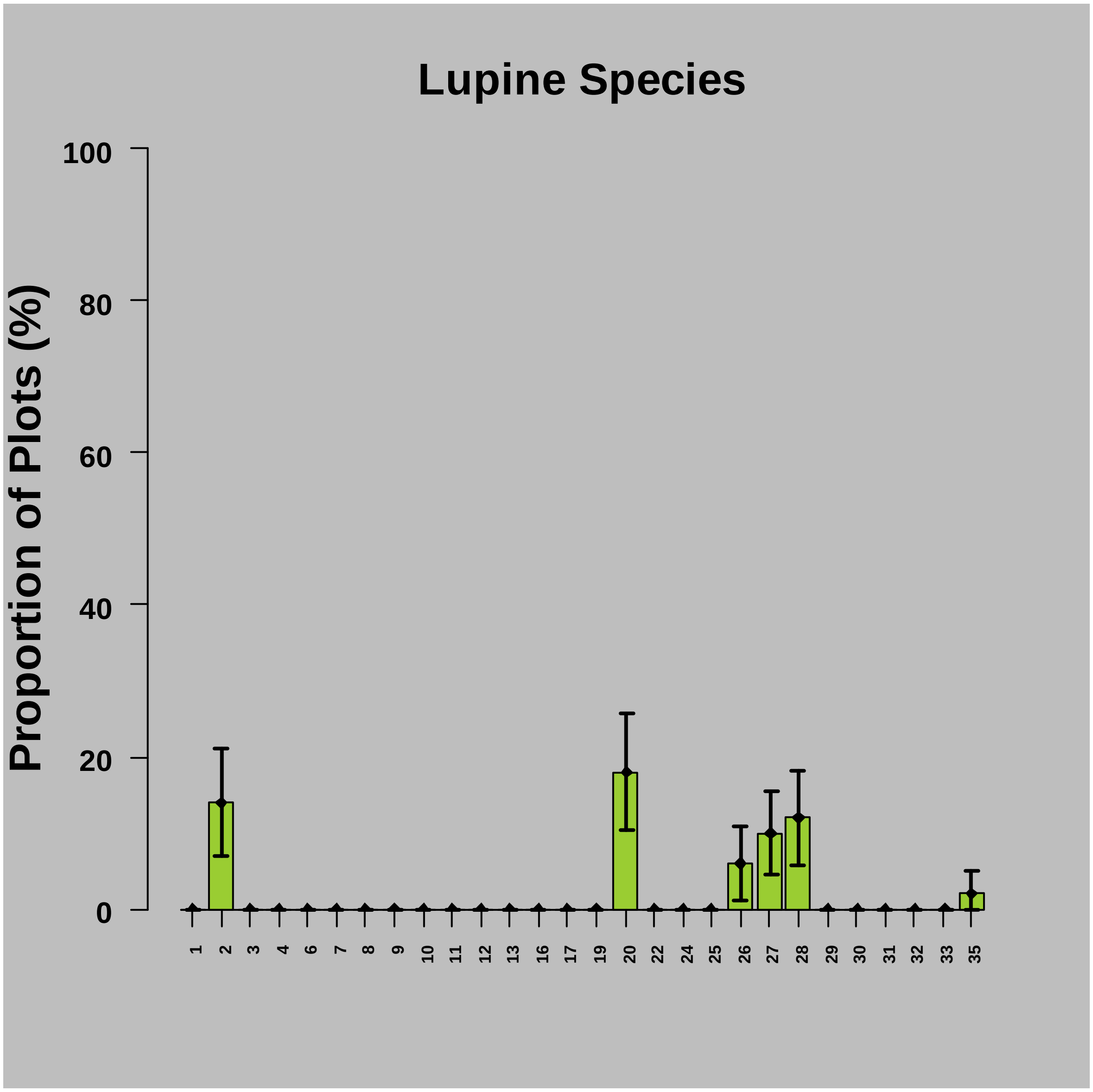

Figure C-7. Proportion of plots, expressed in percent, in which lupine species were estimated to occur with >5% cover for each of 28 CRMO sampling frames sampled in 2010. 90% confidence intervals are presented as black vertical bars. Frames 19, 20, 25, 26, 27, 28, 35 are located in kipukas (see Table 2).

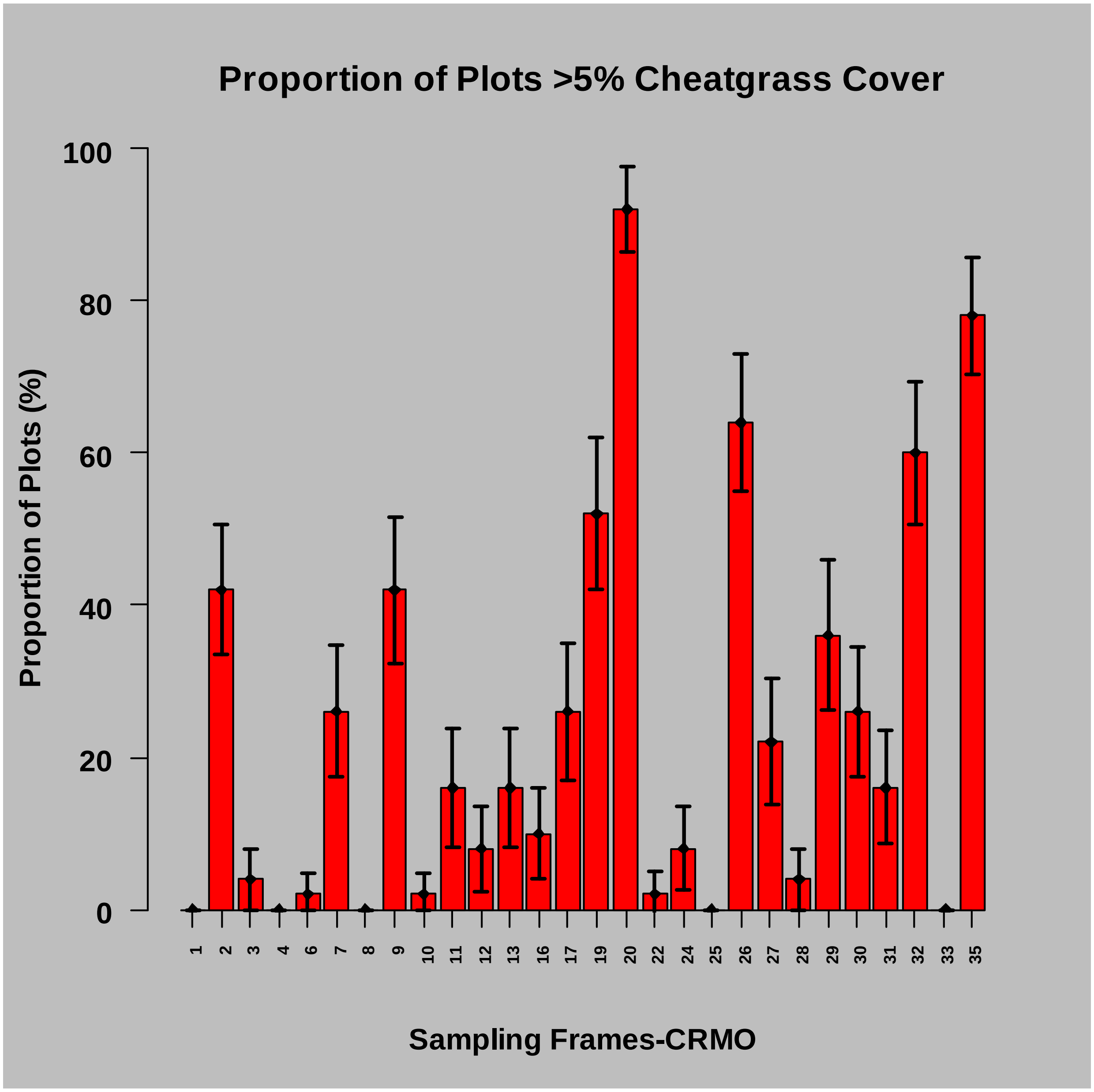

Figure C-8. Proportion of plots, expressed in percent, in which cheatgrass was estimated to occur with >5% cover for each of 28 CRMO sampling frames sampled in 2010. 90% confidence intervals are presented as black vertical bars. Frames 19, 20, 25, 26, 27, 28, 35 are located in kipukas (see Table 2).

Appendix D. CRMO

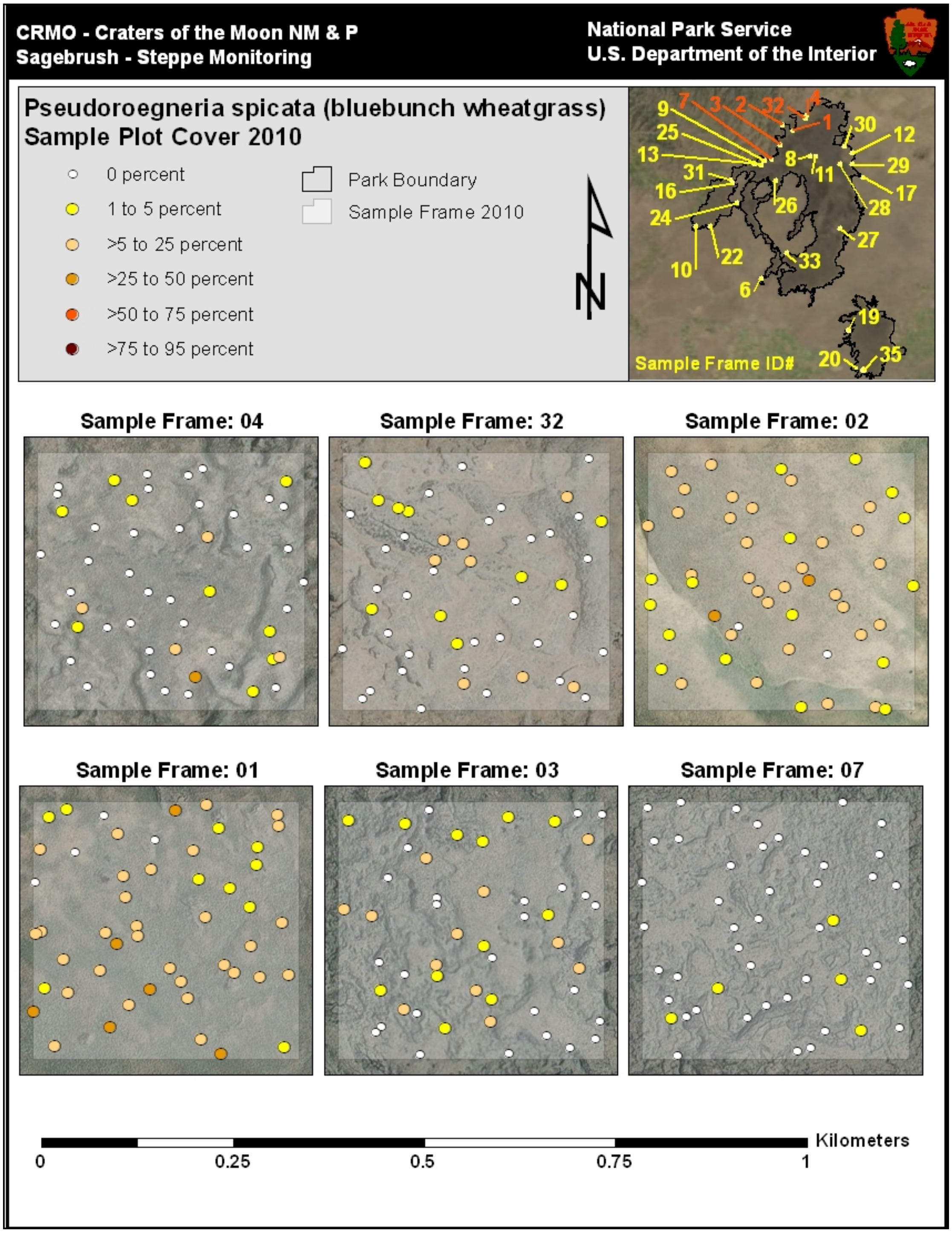

Figure D-1. The location of 2010 plots in CRMO containing bluebunch wheatgrass, color coded by Daubenmire cover class. Frame numbers correspond to the iterative order of identification and development during protocol development (Yeo et al. 2009), and are grouped for illustration here by geographic proximity.

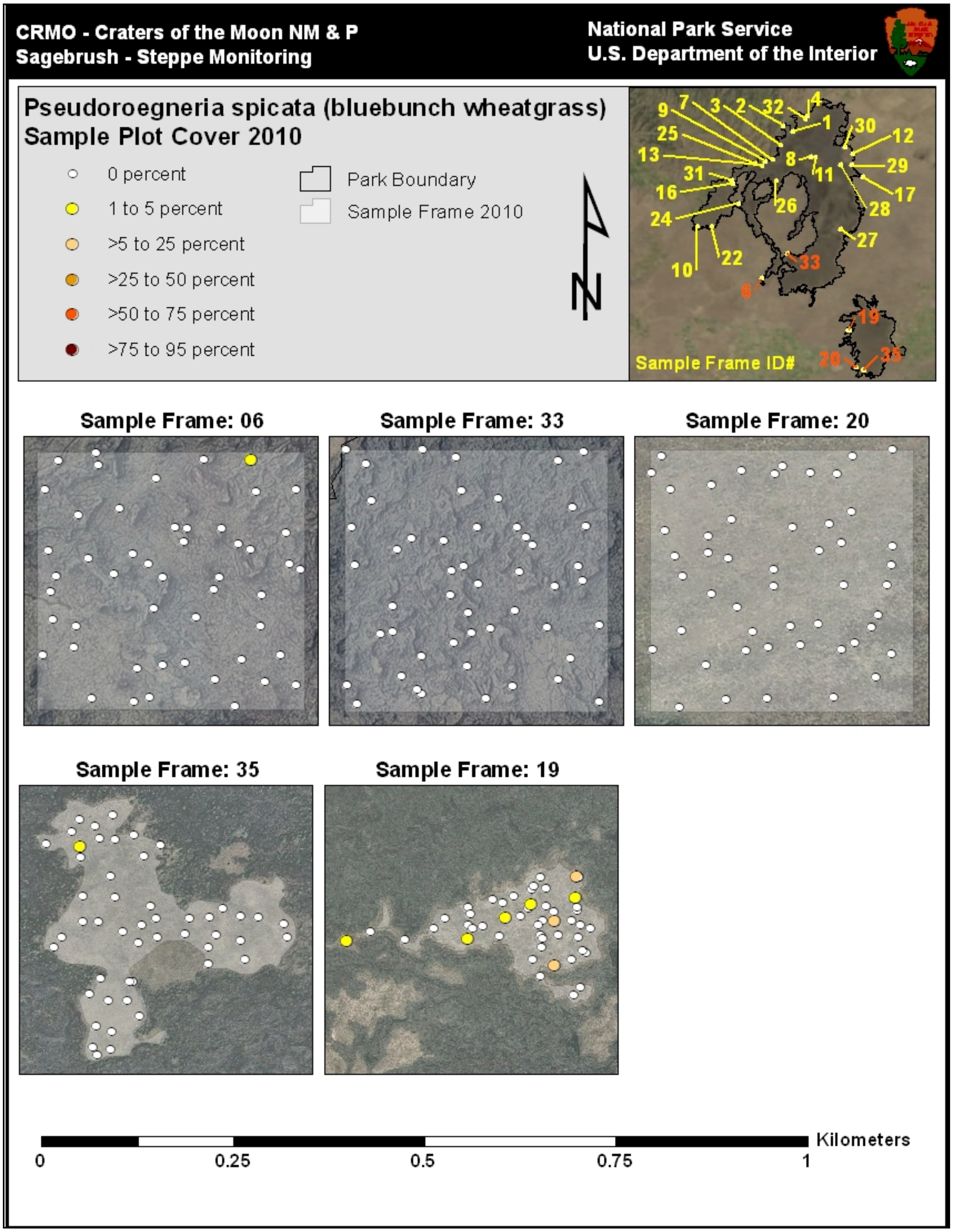

Figure D-1. The location of 2010 plots in CRMO containing bluebunch wheatgrass, color coded by Daubenmire cover class (continued).

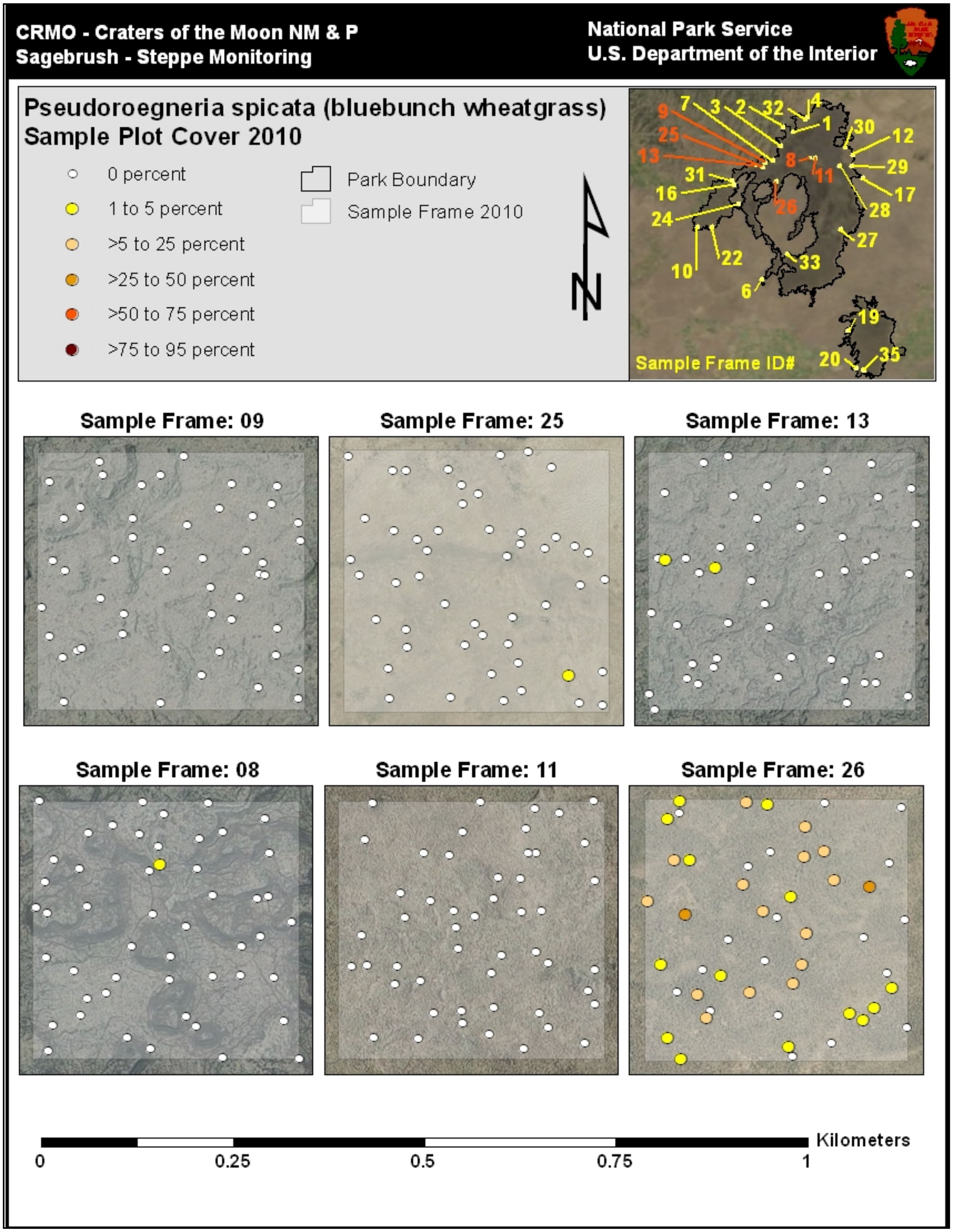

Figure D-1. The location of 2010 plots in CRMO containing bluebunch wheatgrass, color coded by Daubenmire cover class (continued).

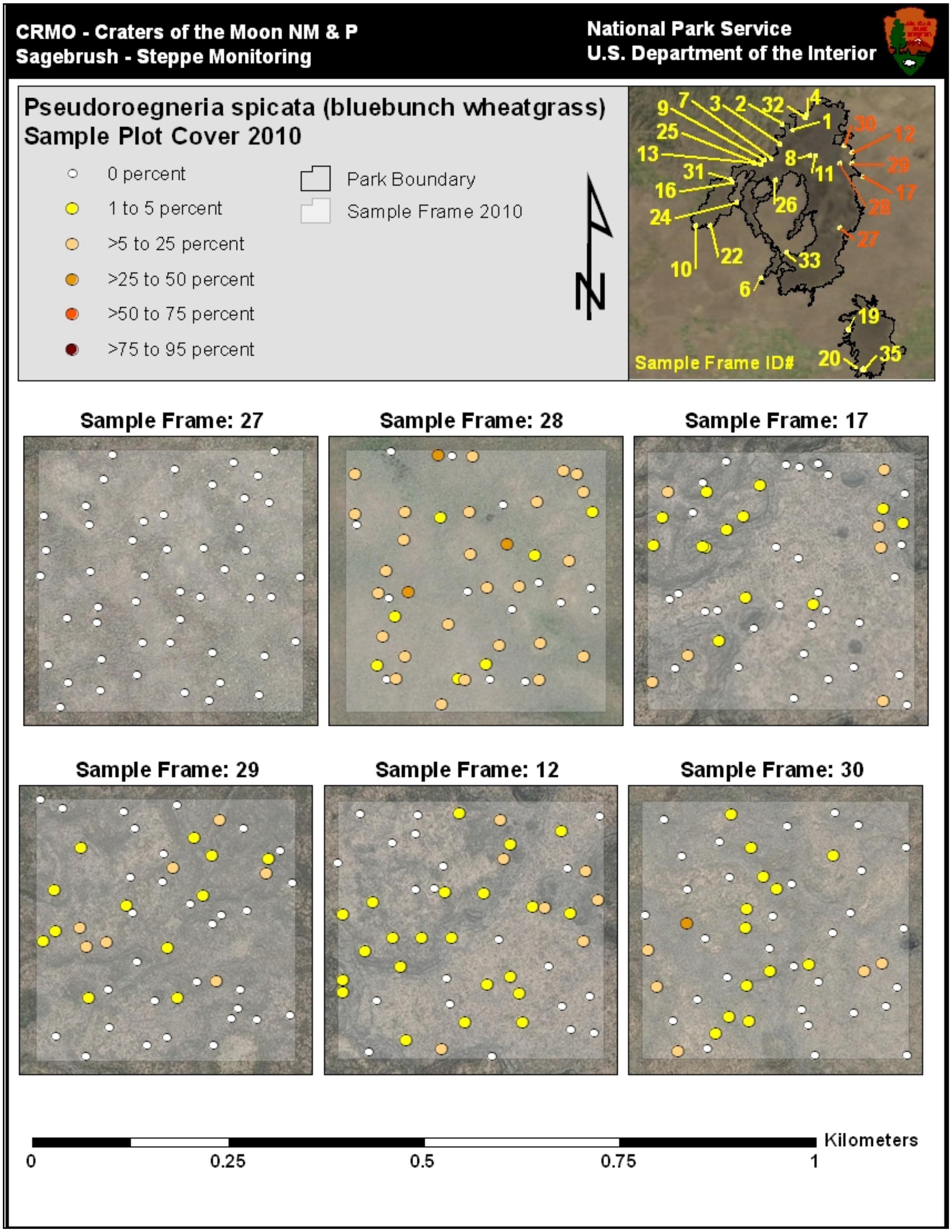

Figure D-1. The location of 2010 plots in CRMO containing bluebunch wheatgrass, color coded by Daubenmire cover class (continued).

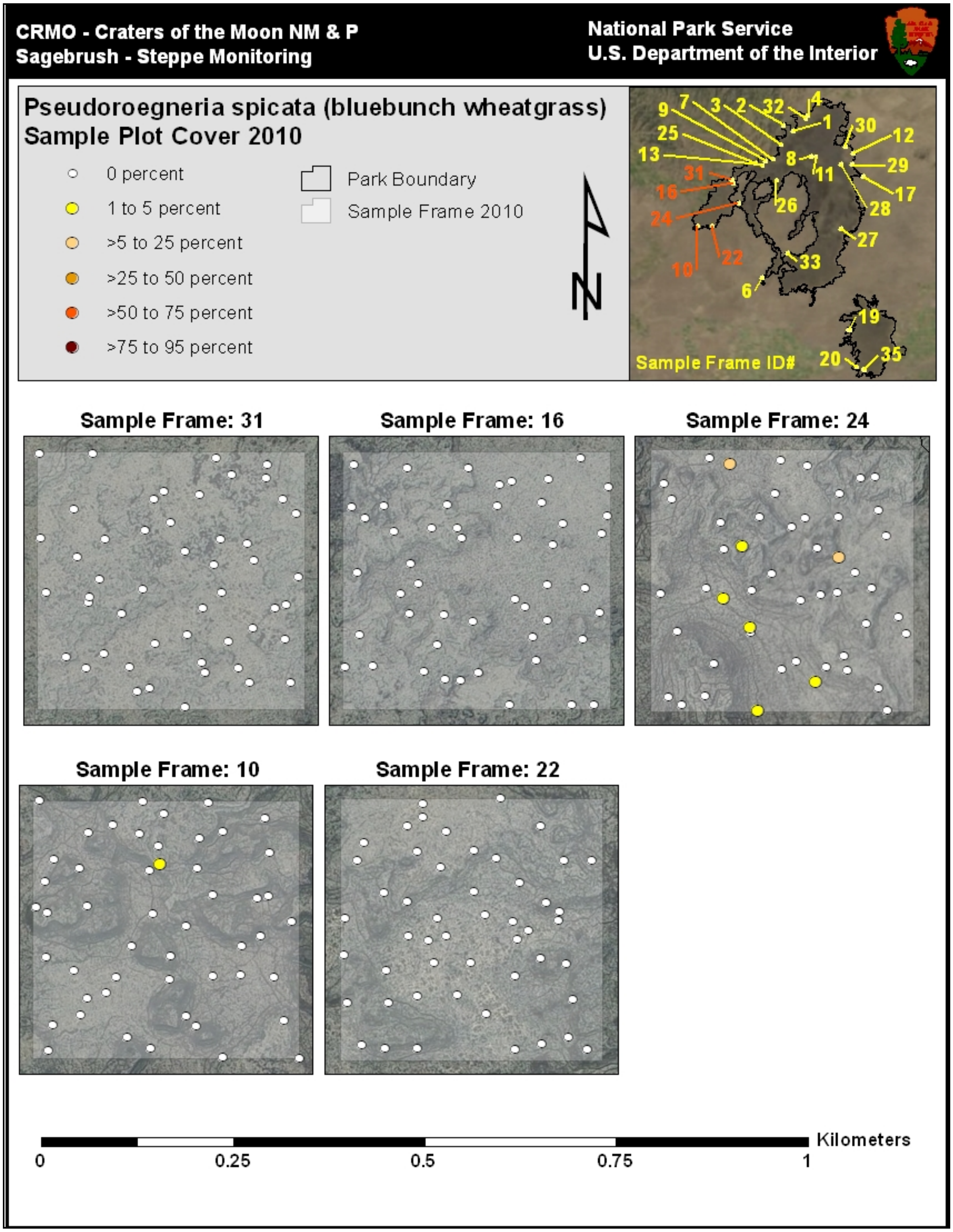

Figure D-1. The location of 2010 plots in CRMO containing bluebunch wheatgrass, color coded by Daubenmire cover class (continued).

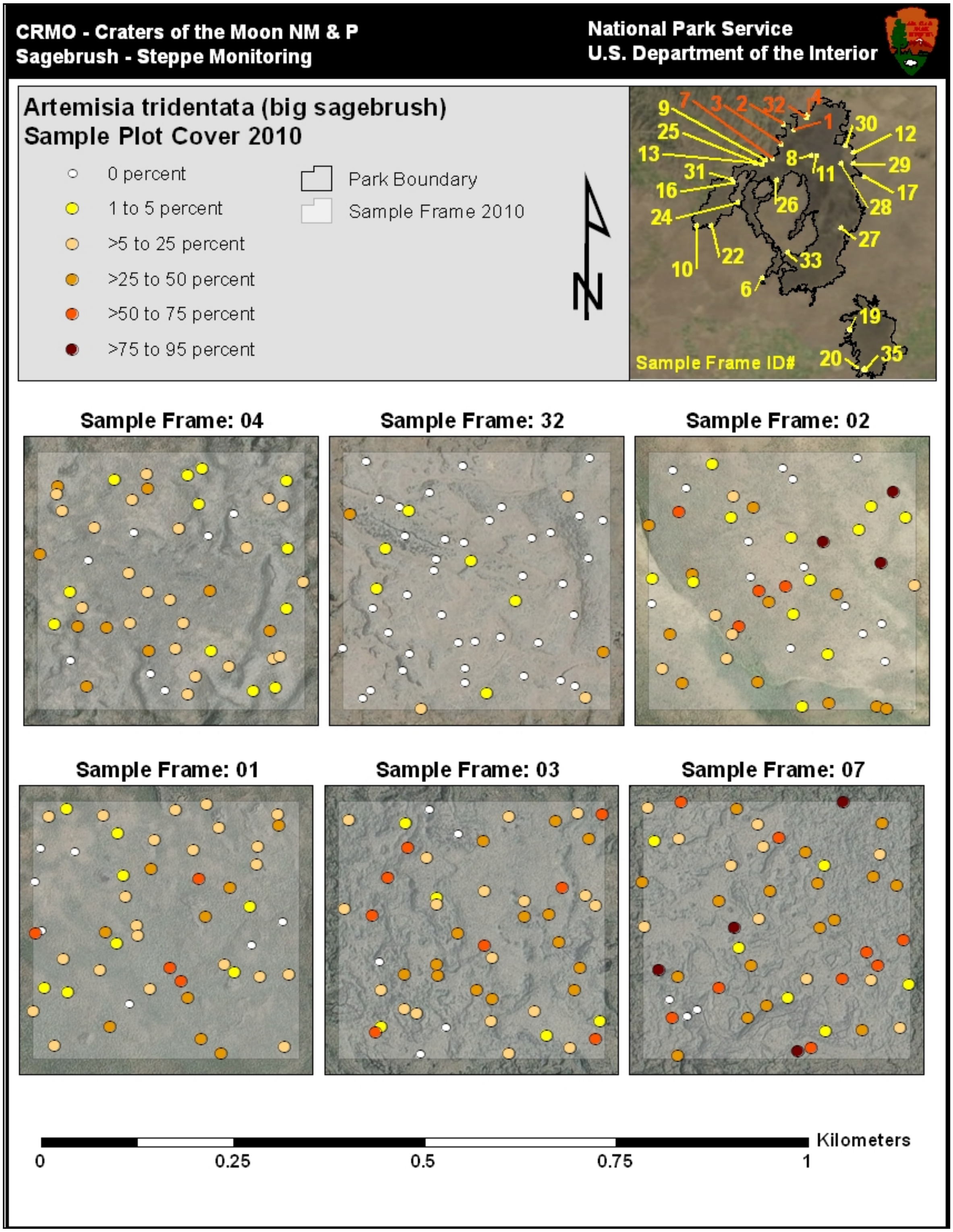

Figure D-2. The location of 2010 plots in CRMO containing big sagebrush, color coded by Daubenmire cover class.

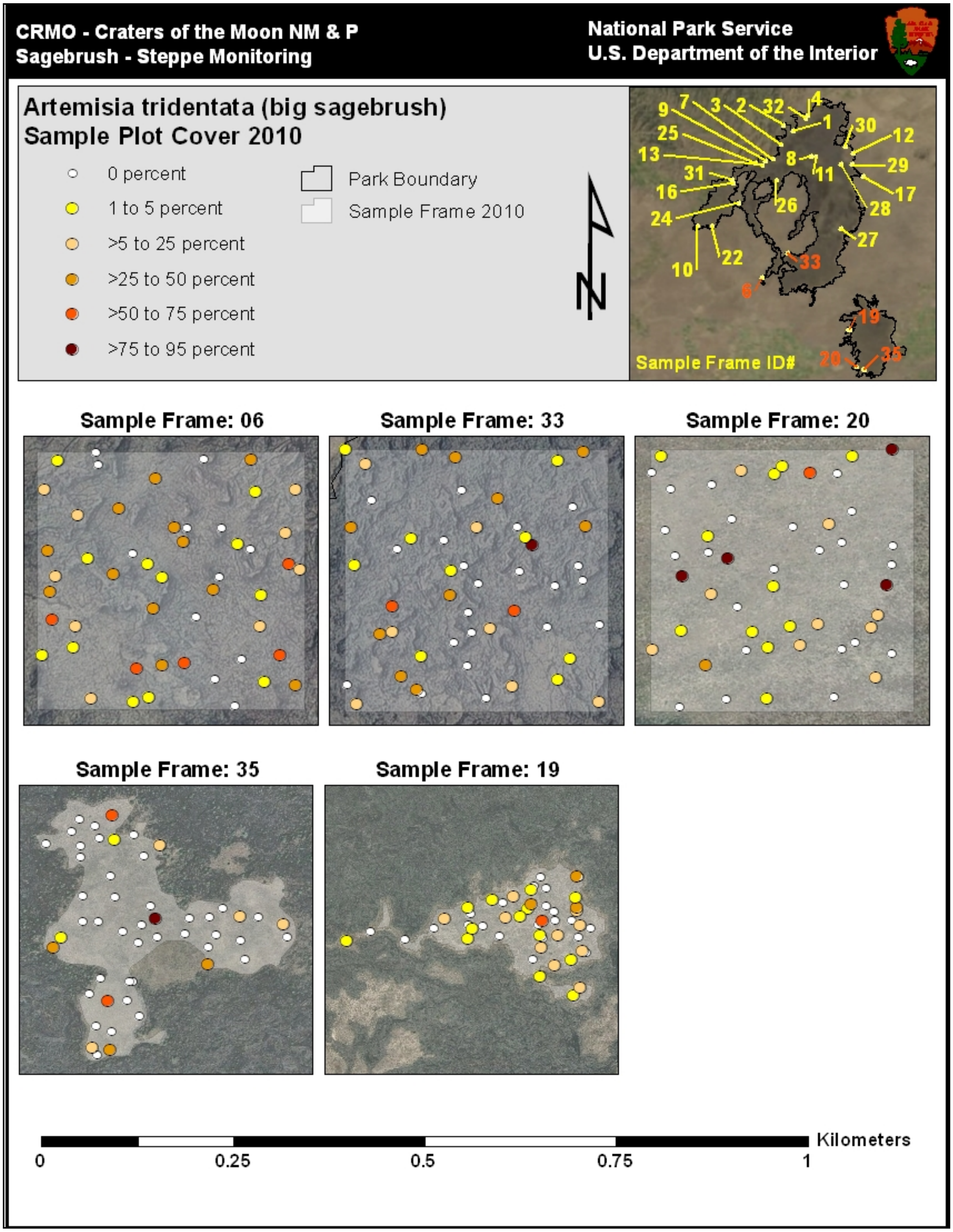

Figure D-2. The location of 2010 plots in CRMO containing big sagebrush, color coded by Daubenmire cover class (continued).

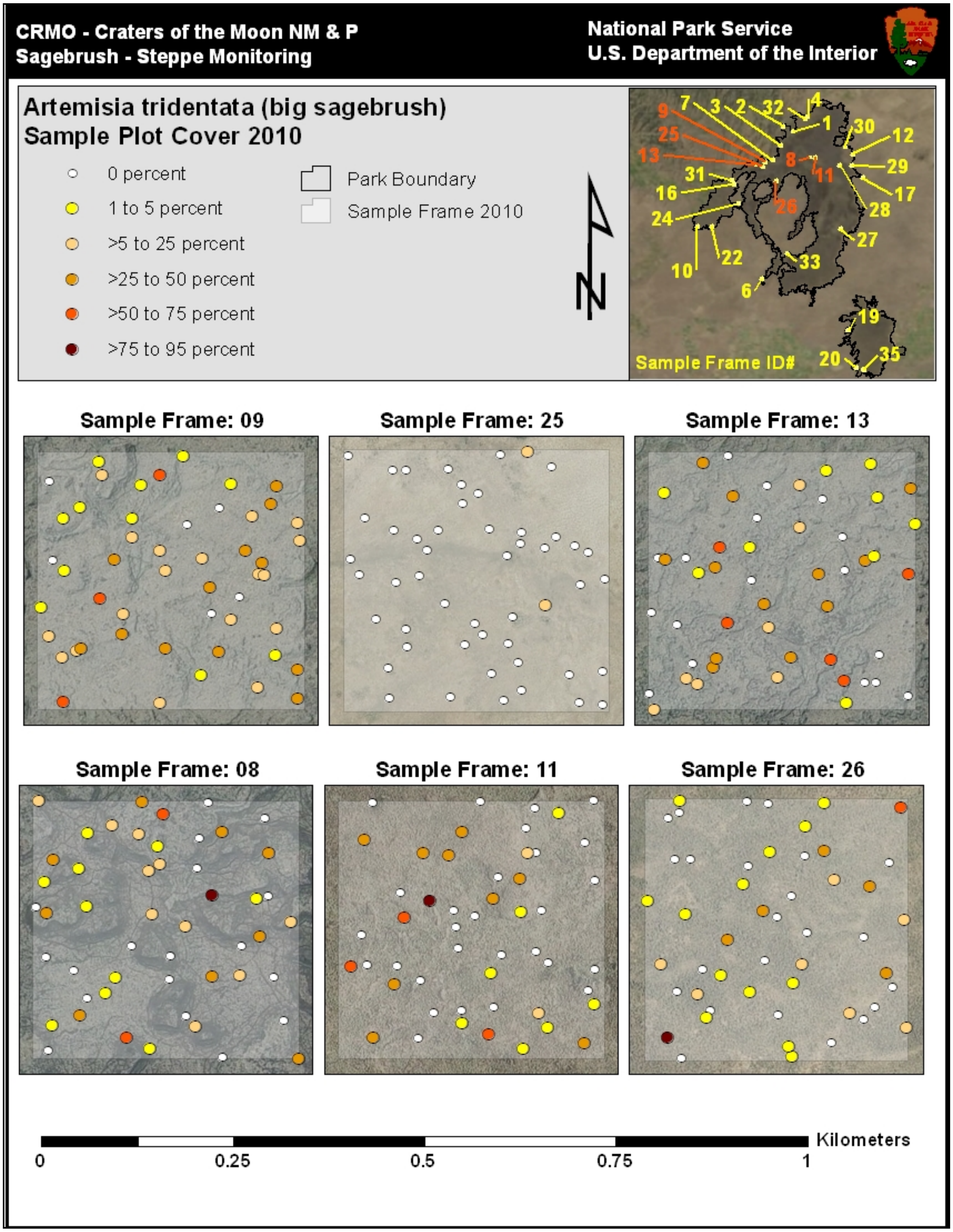

Figure D-2. The location of 2010 plots in CRMO containing big sagebrush, color coded by Daubenmire cover class (continued).

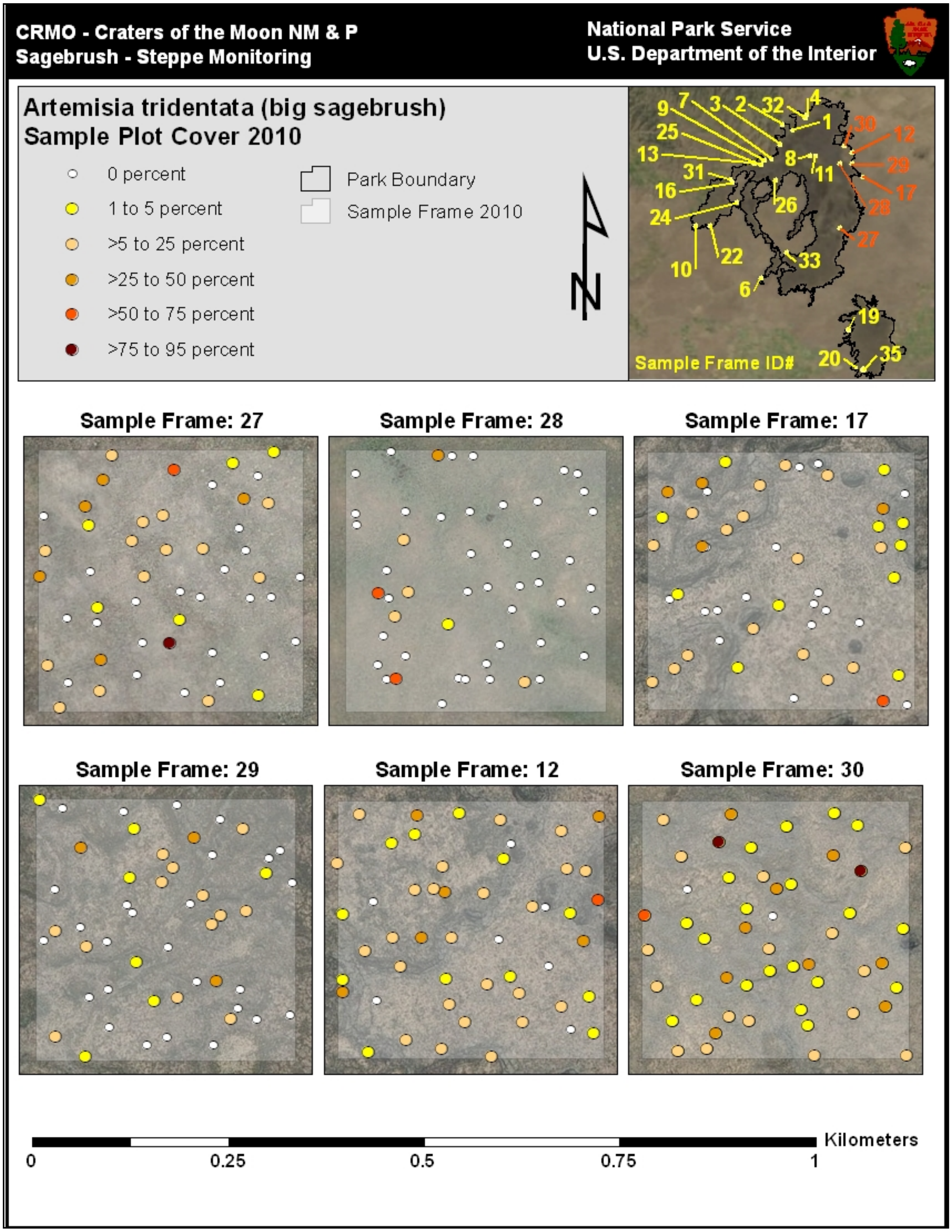

Figure D-2. The location of 2010 plots in CRMO containing big sagebrush, color coded by Daubenmire cover class (continued).

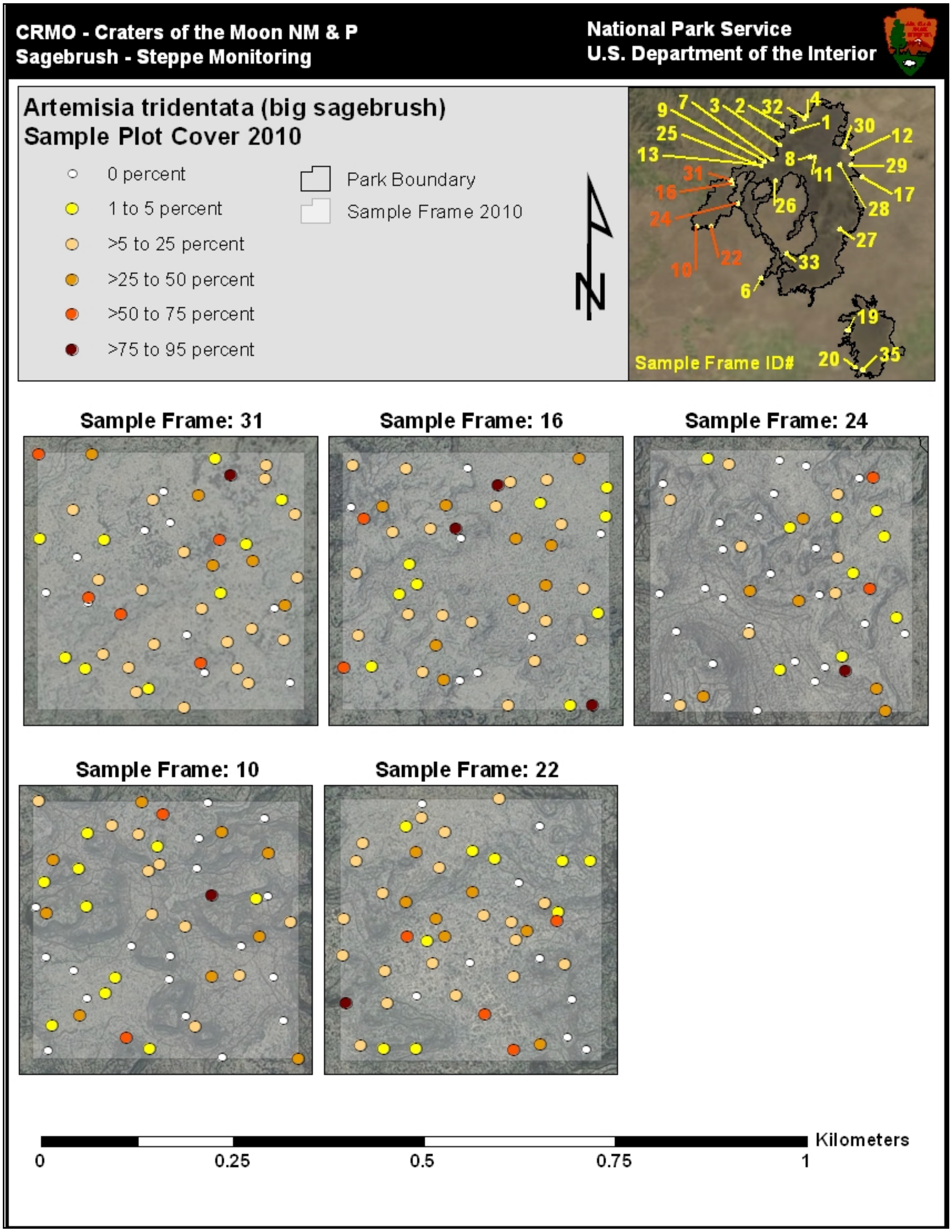

Figure D-2. The location of 2010 plots in CRMO containing big sagebrush, color coded by Daubenmire cover class (continued).

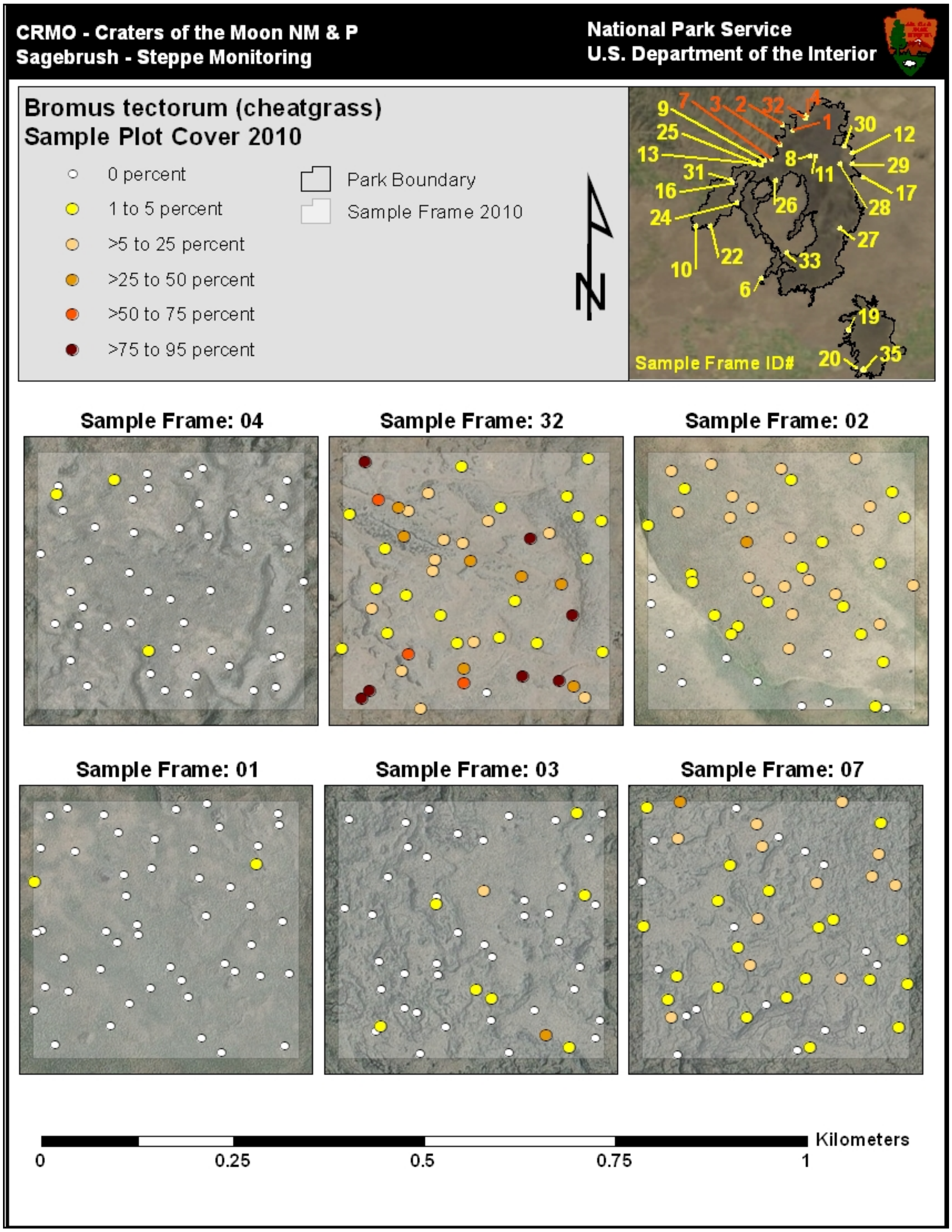

Figure D-3. The location of 2010 plots in CRMO containing cheatgrass, color coded by Daubenmire cover class.

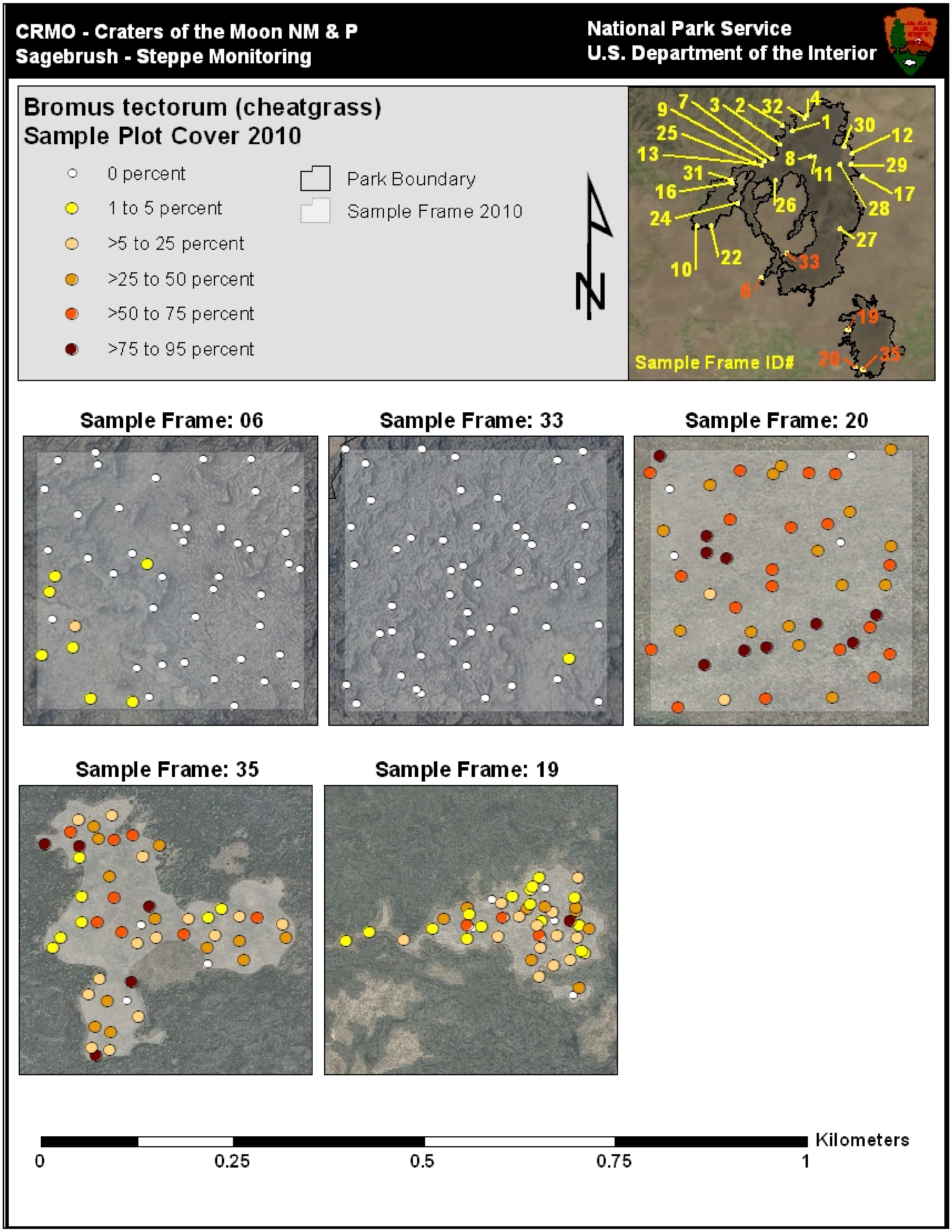

Figure D-3. The location of 2010 plots in CRMO containing cheatgrass, color coded by Daubenmire cover class (continued).

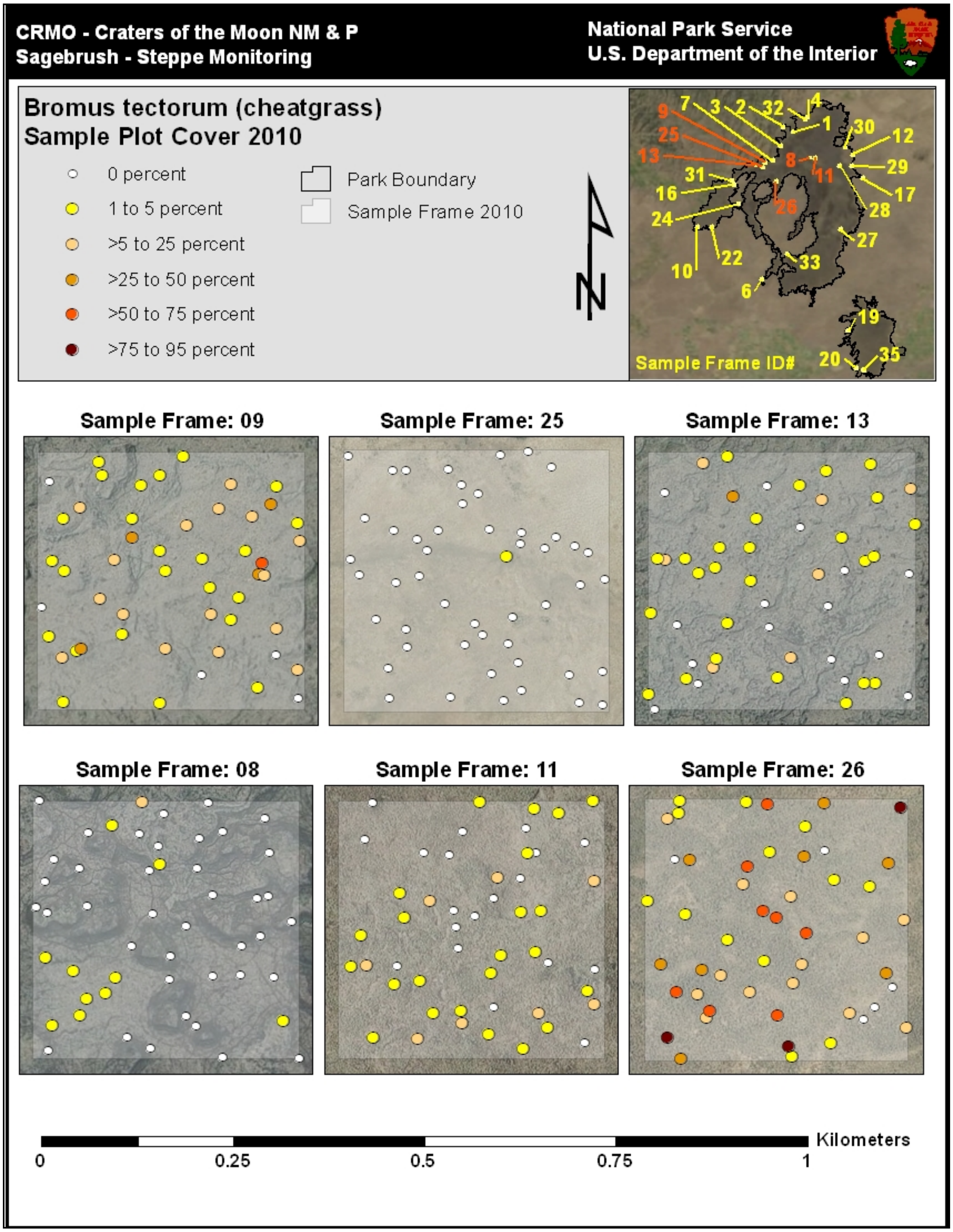

Figure D-3. The location of 2010 plots in CRMO containing cheatgrass, color coded by Daubenmire cover class (continued).

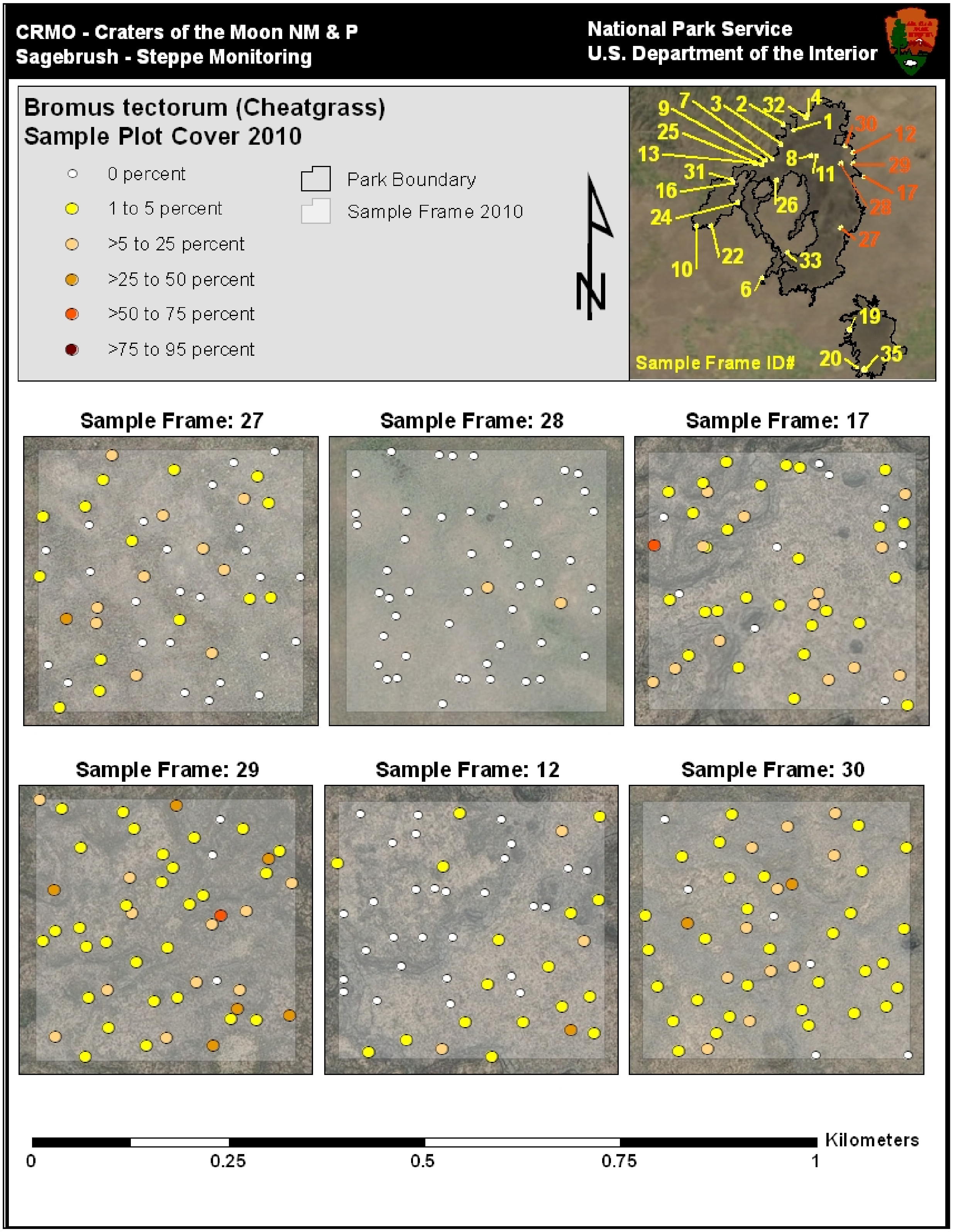

Figure D-3. The location of 2010 plots in CRMO containing cheatgrass, color coded by Daubenmire cover class (continued).

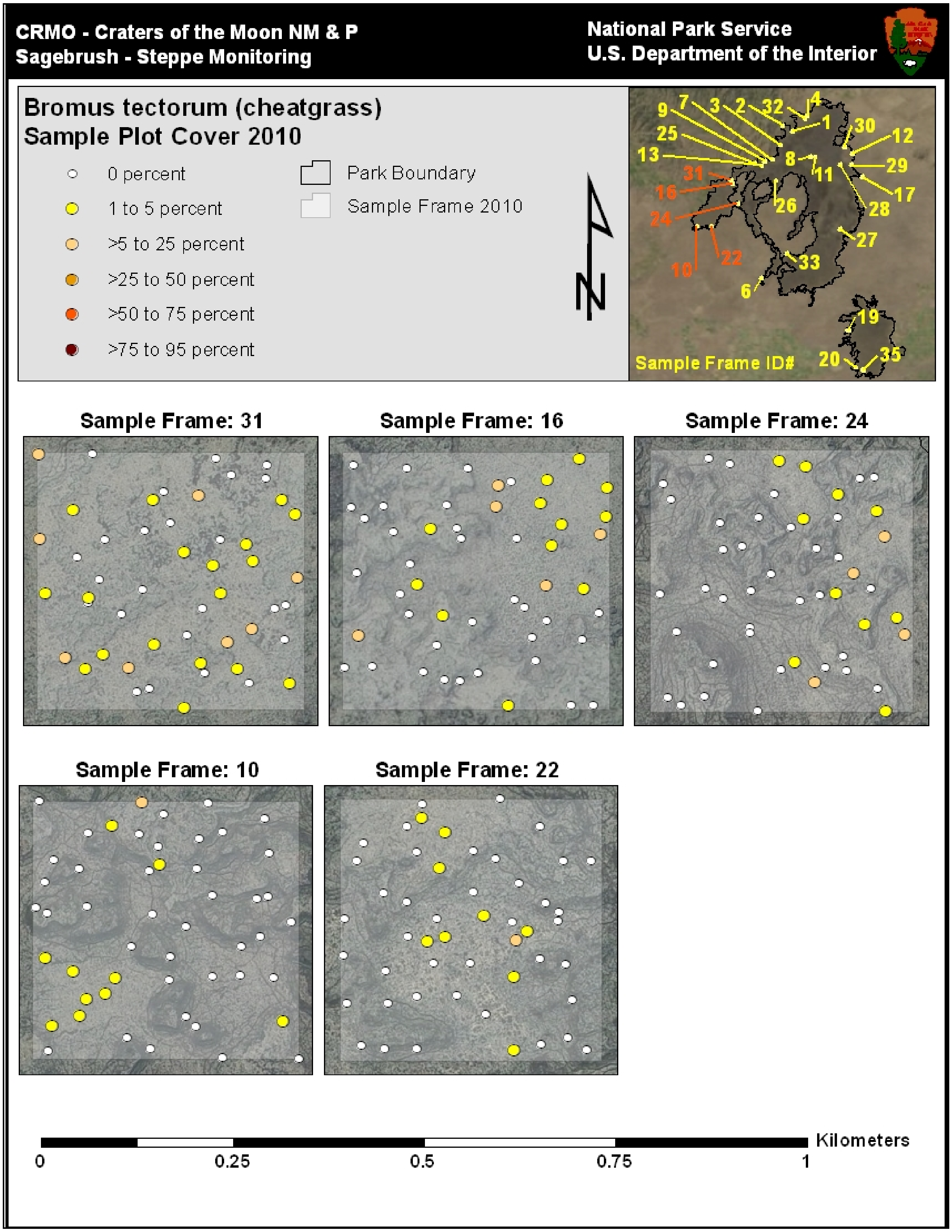

Figure D-3. The location of 2010 plots in CRMO containing cheatgrass, color coded by Daubenmire cover class (continued).

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National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

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