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Aspen Forest Condition Assessment and Restoration Guidance

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Overview: This preliminary report is the first installment of an ongoing aspen assessment at Bryce Canyon National Park (BCNP). Over a 1.5-year period beginning in 2021, I assembled available BCNP and conducted a preliminary field survey to gain a better understanding of the quaking aspen (*Populus tremuloides*) resource within the Park. Findings suggest a long history of vegetation mapping with mixed results in terms of highlighting aspen presence—a notable species of overall low coverage—as well as aspen importance, at BCNP. In brief, though this species has limited presence, it is of high biodiversity conservation value. According to a 2002 vegetation map, aspen total approximately 0.13% of the total area of BCNP. Monitoring plots installed in the fall of 2021 broadly confirm an earlier survey that primarily wild ungulate browsing (with notable exceptions of cattle browse along the west boundary) is having a significant impact on successful aspen recruitment. Exceptions include areas on the east side of BCNP ("below the rim") and recently burned areas where ample regeneration seems to be overwhelming browse levels. I recommend a thorough survey of aspen throughout BCNP to gain a more credible assessment of conditions, as well as to develop a park-wide management plan for this important habitat forest type.

Statement of Need: Bryce Canyon National Park has undergone numerous vegetation surveys and at least one prior aspen assessment. These efforts have not indicated comprehensive understanding, nor resilience prognosis, for aspen at-large within the Park. Given the recognized contribution of aspen communities to landscape biodiversity, this project provides a preliminary aspen assessment, as well as a roadmap for future aspen monitoring, management, and restoration across the entire Park.

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Background & Objectives: Quaking aspen (*Populus tremuloides*) communities host a biodiverse suite of plants and animals, garnering the title "keystone species" throughout the Rocky Mountain West (Stohlgren et al. 1997). BRNP contains numerous aspen communities, mostly in the southern region of the park where elevations approach 2700 meters (9000 feet), or below the rim of the breaks at sites typically associated with perennial springs. While the majority of these stands are less than a few acres, their relatively small size actually elevates their importance from a landscape biodiversity perspective (Griffis-Kyle & Beier 2003). They provide important habitat for wildlife, create islands of diversity for many plant species, are sought after by people for their aesthetic value, and often contain cultural resources indicative of historic land use (e.g., dendroglyphs). Regular disturbances—primarily wildfire, but also insects, diseases, land- and snow- slides, and moderate browsing—enhance aspen health over time, as these communities require disruptions to reproduce from vegetative root suckering (Jones & Schier 1985; Rogers et al., 2014). However, the small and scattered state of BRCA's aspen communities make them more vulnerable to rapid die-off from a range of causal factors, including climate change, anthropogenic development, disruptions in natural disturbance cycles, overbrowsing, and other land use practices (Rehfeldt et al. 2009; Rogers & McAvoy 2018; Worrall et al. 2013).

The purpose of this report is to investigate previous reports and combine them with a preliminary field sample in order to develop a strategy for comprehensive and ongoing aspen assessment at BCNP. The following element comprise the written objectives:

1. Compile and synthesize existing data and information on aspen stand-scale conditions within the park's public viewsheds (i.e. near road and trails, Fig. 1) and associated stressors.
2. Design and conduct a rapid assessment protocol using established methods to collect limited field data on current conditions in a subset of representative aspen stands and that can be used for long-term monitoring by park staff.
3. Identify suitable treatment and protection options using established methods based on stand conditions, management objectives, and other criteria developed in collaboration with park staff.
4. Provide a summary of findings and recommendations to guide subsequent implementation of the FLREA-funded project in a brief written report.
5. Provide subject-matter expertise on an as needed basis during FLREA-funded project planning and implementation.

Previous Vegetation and Aspen Surveys

Historic Vegetation Mapping: An Aspen Perspective

Since the found of BCNP in 1928 a series of vegetation surveys have taken place, mostly following the lead of Hayle Buchanan after his doctoral work after 1960 (Buchanan 1980). During this 20-year period, the authors established a series of grand transects to systematically document BCNP's floral community, as well as change in plants over time. According to Buchanan & Harper (1980, p.3), "In summary, fifty years of management in Bryce Canyon's biotic communities has resulted in the loss or reduced abundance of many of the biotic resources that Bryce Canyon National Park was established to preserve." In terms of aspen, there are several references in these reports about the increased density of forests through the mid-20th century contributing to the decline in aspen coverage and concomitant loss of understory plant diversity that these forests facilitate. A trend that was becoming evident national appears in the writings of Buchanan and colleagues; they question the efficacy of continued fire suppression in the face of increasing forest stand density and myriad affects on Park floristics resulting from this activity. They also suggest that increasing tree density during the 1970s, "…reduced carrying capacities for big game and many smaller animals" (1980, p.3). This latter conclusion would be questioned by most ecologists familiar with wild ungulate browsing pressure across the Colorado Plateau today.

A team lead by Kirsten Ironside remeasured the transects established by the Buchanan group during 2007 and 2018, thus completing a 60-year series of plant inventories at BCNP (Ironside 2020). In total, six sampling regimes were applied to the same transect framework, one per decade, over this period. Ironside also found increasing forest densities, particularly in the mid- and upper- montane zones, but chronicled reduced densities where recent prescribed and wild fires had thinned forests commensurate with vary fire intensities. In general, these fires allowed greater penetration of sunlight to the forest floor increasing plant diversity and giving aspen forests opportunities to rejuvenate via root suckering. The Ironside (2020) work also began documenting wildlife visitations using motion sensing cameras at select transect points. Among other conclusions, wildlife photos showed the increasing impact of deer, elk, and cattle browsing on BCNP vegetation, most notably aspen juveniles which are both nutritious and susceptible at this stage (Rogers & McAvoy 2018).

Roberts et al. (1992) developed a different method from previous plant mapping efforts within BCNP. They took a habitat type, remote sensing, and modeling approach to understanding and mapping current conditions and disturbance history. In relation to aspen, these authors suggest that as much as 750 ha (1,853 acres) could support aspen, while only ~250 ha (618 acres) actually do. Of this coverage, they found that aspen was dominant on only 14 percent (35 ha; 86 acres) of that those sites where it was then present. Over the 30+ years since this report, intervening prescribed and wildfires likely have changed this situation considerably – we don't have accurate contemporary coverage data to compare to these figures. Roberts et al. (1992, p. 79) confirm this positive role of fire for aspen thusly: "…to maintain or expand quaking aspen in the Park fire in the most mesic types will be required."

A related factor affecting aspen community health is fire occurrence and history at a given locale. Within BCNP, Jenkins (1995) examined an ~400-year record of tree-rings to produce a fire history specifically within the "mixed-conifer/aspen" forest types. Overall, Jenkins found that reduction in fire frequency from an average of 16-years presettlement to 87-years during the 20th Century was the main cause for increased density, a shift in tree composition from Ponderosa pine to white fire/Douglas-fir, and an overall loss in aspen cover. What is less clear is the cause of that shift. While Jenkins (1995) clearly supports a fire suppression theory, other authors subscribe to climate being the prime driver of such changes (Elliot & Baker 2004; Millar et al. 2004; Schoennagel et al. 2004). Regardless of causal agent, a clear pattern of advancing succession with reduced disturbance leading to decreasing aspen cover was supported by all of the vegetation/fire surveys cited for BCNP. More recently, prescribed burning and wildfires have created new opportunities for aspen renewal and decreasing conifer cover, though overall fire extent in the mixed-conifer/aspen zone has been limited.

Between 2001-2011 the National Park Service undertook a detailed vegetation mapping project as part of a nationwide effort to map all NPS holdings (Tendrick et al. 2011). Of course, implementation at BCNP was not explicitly centered on aspen coverage within the park or the total map extent (a larger area capturing surrounding environs; Fig. 1). However, we derived coverages for the "Aspen Forest Complex" specifically to gain understanding of a point-in-time measure of the species' status.

Figure 1: Map of vegetation types within and around Bryce Canyon National Park (Tendrick et al. 2011) with preliminary aspen survey plots shown (see Aspen Condition Assessment below). A detail description of all vegetation types is found in Tendrick et al. (2011, p.74).

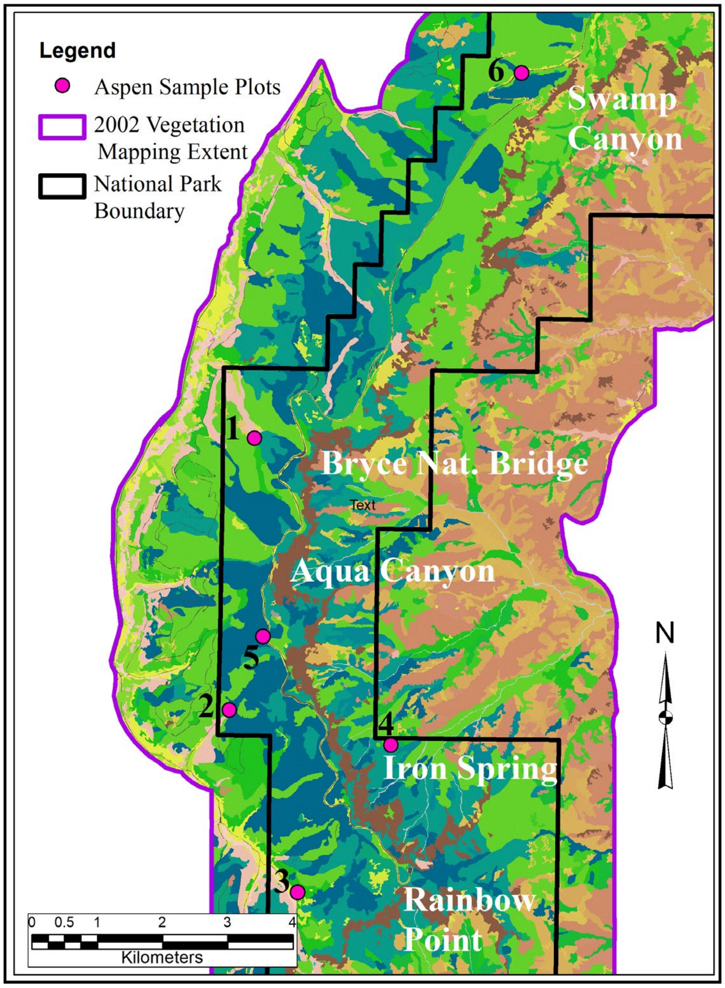


Table 1 describes those basic figures here. Differences between the aspen cover found by Roberts et al. (1992) and the Tendrick et al. (2011) report may be attributed to one or more of the following factors: varying definitions of aspen cover, different methods employed remote sensing, and advancing succession between surveys. For the present work, we are adopting the most recent Tendrick et al. vegetation survey as the most accurate available source of aspen cover, while still being fully aware of shortcomings and now an additional decade that has passed with all accompanying vegetation changes related to aspen cover.

Table 1: Total BCNP and Aspen Forest Complex cover area based on the 2002 Vegetation Map (Tendrick et al. 2011)

Total BCNP acres	Total BCNP ha	Aspen acres within park boundary	Aspen total ha within BCNP boundary	Aspen % of total BCNP area	Aspen acres 2002 veg map extent	Aspen ha in 2002 veg map extent
35968.00	14555.75	46.90	18.98	0.13	95.90	38.81

Previous Aspen Survey at BCNP

In Charles Kay (2013) submitted a report to BCNP explicitly addressing aspen status and trends within the Park. Due to the nature of this study, we can make only limited interpolations. In short, there are too few sample locations and they are only in a small area of BCNP. Furthermore, reliance on exclosures has its own limitations: while the area outside the enclosure is subject to unfettered ambient browse levels, the area inside the fence is exposed to no browsing. This results in the enclosure really being an experiment of maximum regeneration-to-recruitment growth potential and not any sort of understanding of "natural conditions" or sustainable levels of browsing. Bearing these caveats in mind, there are some useful lessons to be gained from Dr. Kay's survey. First, survey transects and exclosures were both located within a recently burned (Puma Fire, 2006) area that straddles NPS and USFS lands, allowing for comparisons between land management designations. Second, browse levels were very high (60-100%) both inside and outside the Park at nearly every site over five consecutive years of remeasurement. For reference, annual aspen regeneration browsing levels exceeding 30% are thought to be unsustainable (Olmstead 1979). Third, while regeneration following fire was more than ample, heights of suckers overall were not progressing due to chronic browse. For all research plots after five years, the average height of the *tallest* aspen regeneration within BCNP was 58 cm (22.7 in.), while it 32 cm (12.6 in.) on adjacent Dixie National Forest plots. For reference, the standard target is to move regeneration to the recruitment height class, commonly established as >200 cm (Rogers & McAvoy 2018). Average height of aspen suckers within Kay's exclosures following wildfire was 312 cm (123 in.) and outside the Park, where the enclosure was not established until after a season of heavy browsing, was 142 cm (56 in.). Fourth, elk were the predominant browsing ungulate having twice as many pellet groups as cattle and three times more than deer. Note that cattle pellets may have been higher during this period due to easy access to BCNP after the Puma fire damaged the boundary fence.

Aspen Condition Assessment, New Data Acquisition in 2021

Summary of Field Methods

To augment historic vegetation mapping and aspen surveys, we developed a limited field-based aspen survey to gain a preliminary understanding of current conditions at BCNP. To be clear, with only six randomly located aspen plots at BCNP, we cannot make definitive conclusions about the overall status of this important forest community. However, development of this survey allowed us to test the methods in the BCNP setting, as well as gain a sense of conditions under varying ecological circumstances (e.g., west side, post-fire, below the canyon rim). Field plots are designed to take from 2-4 hours to complete. Each field plot has a fixed layout and orientation consisting of two perpendicular 30 x 2 m transects within which most data are collected (Fig. 2). Data is collected at the plot-level to describe broad conditions in the area and the transect-level to gather fine data on all mature trees, plus aspen status/damage, regeneration and browse level, and recruitment. Additionally, we collect information on presence of browsing species by scat counts within the fixed-area transects. Plots were not permanently marked, though we did record geographic position system (GPS) coordinates so that they could be relocated with modest accuracy. Other plot-level descriptors collected at each site include elevation, number aspen layers, and a qualitative stand condition rating (Rogers & Mittanck 2014). A complete list of sample indicators is shown in Table 2.

Figure 2: Field survey plot configuration.

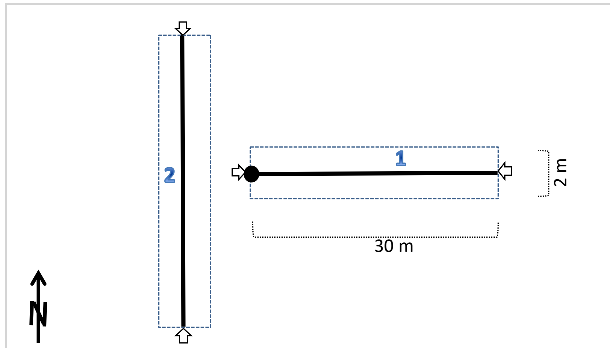


Table 2: Sample indicators for aspen assessment field plots at Bryce Canyon National Park

Indicator	Description
Plot number	A unique number given to each aspen plot
GPS Easting	Plot easting value based on GPS reading, Universal Transverse Mercator (UTM)
GPS Northing	Plot northing value based on GPS reading, Universal Transverse Mercator (UTM)
Elevation	GPS reading of elevation at sample collection site
Number of layers	Visual estimation of the predominant number of aspen vertical layers
Stand condition	A visual rating system based on a three-point scale of overall conditions (Rogers & Mittanck 2014)
Aspen functional type	Assess whether aspen stands are seral or stable at the sample location (Rogers et al. 2014)
Fecal counts (by cattle, deer, elk, sheep)	A count of fecal piles, by species, within both fixed-area transects
Mature tree count by diameter size class	Trees are tallied by species, live/dead, size class that are >8 cm diameter at breast height (dbh)
Regeneration count by size class	Aspen regeneration (aspen stems < 2 m height) are tallied in three classes (0-0.5 m, 0.6-1 m, 1.1-2 m)
Recruitment count	Live aspen stems > 2 m height and < 8 cm dbh are tallied
Browse level	Each regeneration stem tallied is examined for missing terminal buds; a percentage of browsed stems based on all regeneration stems is calculated

Current Conditions

There are a number of ways to assess aspen stand conditions and project those outcomes to small and large landscapes (Rogers 2017). With only six sample locations (plots) in this preliminary field assessment were, it would be inappropriate to conduct formal statistical analysis; interpolation to the entire BCNP would be considered scientific malpractice due to the small sample size. Here, we summarize data from our preliminary aspen survey using descriptive statistics and graphics only. Further sampling and analysis would be required to evaluate the complete aspen resource at BCNP in a defensible manner. Moreover, our quick survey and summation focuses on variables known to be most telling of sustainable aspen communities based on previous works (Rogers & McAvoy 2018; Rogers & Mittanck 2014). A more exhaustive analysis would incorporate all field indicators measured and additional variables derived from the original data set. With this in mind, the following figures (Fig. 3a-3c) directly examine aspen regeneration, browse percent, and recruitment. Additionally, we will take a brief look at fecal counts to assess which browsing animals are limiting recruitment and how that varies at differing locales within BCNP.

Figure 3a: Aspen regeneration (raw count) by height class and location (see Fig. 1) within BCNP. Regeneration are live aspen stems < 2 m in height. Locations BC01-BC06 correspond to locations 1-6 on all maps within this report. Plots BC01-BC03 are found along the west boundary of the Park. BC04 is at Iron Spring on the east boundary and below the rim. Location BC05 is found within the 2006 Puma Fire (Figure 4). BC06 is located in a deep ravine near the Park's highway.

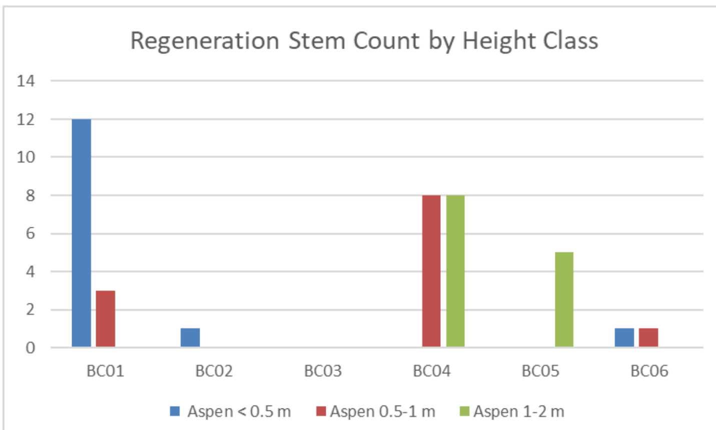


Figure 3b: Aspen regeneration per hectare and browse levels by location (see Figure 1) within BCNP. Browsed stems are live aspen < 2 m in height where the terminal bud (apical meristem) is removed.

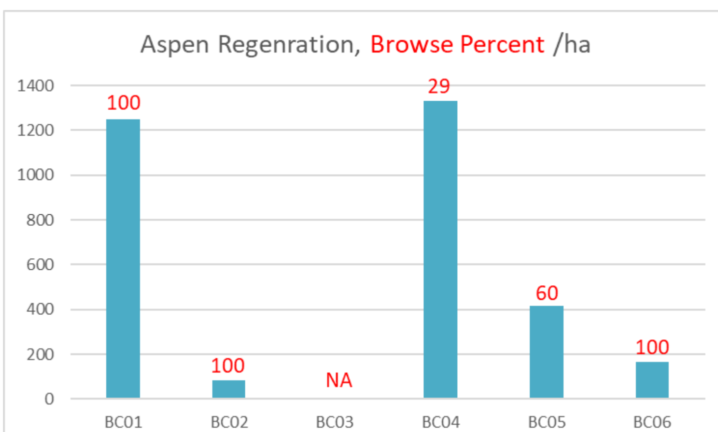


Figure 3c: Aspen recruitment per hectare by location (see Fig. 1) within BCNP. Recruitment are live aspen stems > 2 m in height and < 8 cm diameter at breast height (dbh).

Overall, regeneration of aspen is generally low with the exception of location BC01. Even this plot is considered marginal in terms of being able to sustain aspen communities long-term (Kitchen et al. 2019; Mueggler 1987). Plots along the western margin of BCNP (BC01-BC03) all have poor representation in the tallest regeneration class of 1-2 m. This is a common sign of persistent reproduction, but without progression beyond convenient browse heights. Notably, plots located at Iron Spring and within the relatively recent burn scar have few shorter and more taller aspen regeneration. Plot BC06, near the Park highway, is devoid of any significant regeneration; we also not that this plot was densely populated with various conifer species and the remaining mature aspen were in poor health or already dead. Figure 3b describes browse beyond sustainable levels at all sites except for Iron Spring (BC04), though even this amount of terminal leader removal, if sustained annually, would also not support long-term aspen according to work conducted by Olmsted (1979) at Rocky Mountain National Park.

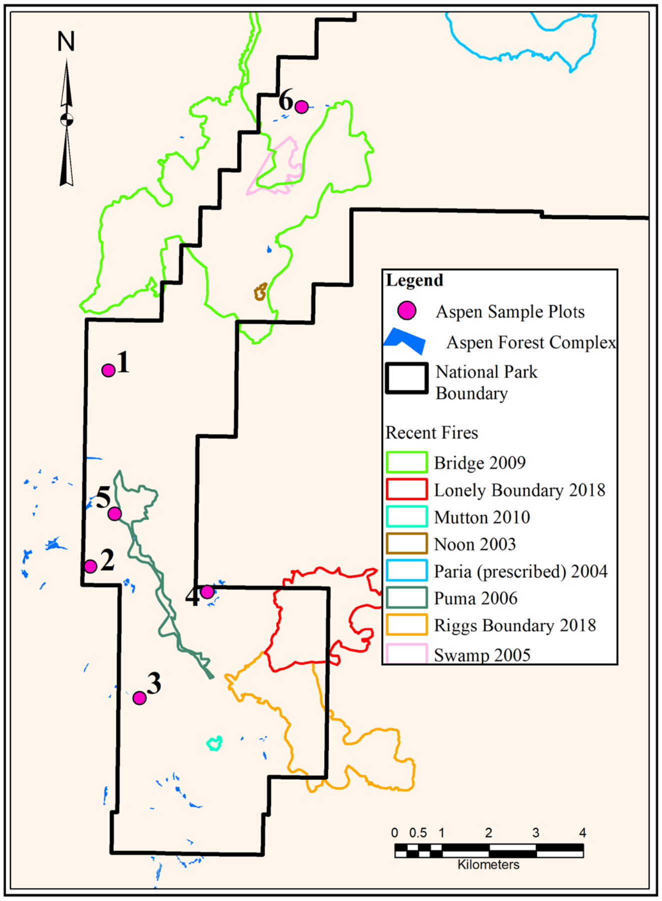
Recruitment, meaning stems successfully growing above the common reach of all browsers, is thought to be the most important indicator of aspen health (Rogers 2017). It is not uncommon to have relatively high presence of aspen regeneration and still have few stems progressing to the recruitment stage due to browsing. Thus, Figure 3c is most telling: only two sampled locations within BCNP appear to have adequate aspen recruitment, while the others have none at all. The Iron Spring and recent burn sites show promising signs of resilience to future disturbance, including chronic browsing. Unfortunately, the remaining sites should be considered a threatened resource in their present condition. A compounding factor is a very new, a very concerning, invading pest (Oystershell Scale; *Lepidosaphes ulmi*) which was found on aspen recruitment stems at Iron Spring (Fig. 4). This invasive species seems most adept at attacking and killing sapling-size aspen (Crouch et al. 2021) and appears to be spreading rapidly based on a 2022 revisit to this site by U.S. Forest Service, Forest Health Protection entomologist Darren Blackford (personal comm.).

Figure 4: Oystershell Scale (*Lepidosaphes ulmi*) on aspen sapling near Iron Spring, Bryce Canyon National Park. (Photo: Paul C. Rogers)

Causes of Aspen Conditions

Data presented here generally confirms earlier vegetation and mapping efforts within BCNP regarding long-term aspen trends. The main causal agents affecting aspen in the Park appear to be advancing succession (i.e., forests generally moving from aspen to conifer cover) and chronic browsing. Each of these factors is supported by broader trends in western forest and wildlife management. Forest management, generally speaking, has been subjected to a very wet 20th century and, secondarily, fire suppression. In the past few decades, however, a more drought-prone turn in climate has spawned a number of wildfires regionally and locally that provide opportunity for renewal within declining aspen communities. In the current preliminary survey of BCNP, plot BC05 fell within the 2006 Puma fire and showed promising levels of surviving recruitment approximately 15 years post-disturbance (Fig. 3c & 5). Wildlife browsing, in many areas, has increased with elimination of predators, as well as incentivization of increasing deer and elk populations by state-managed wildlife agencies. Livestock management, having some peripheral effect at BCNP where boundary fences are often in disrepair, is also impacting juvenile aspen growth at lower elevations where the Park borders other federal, state, and private lands.

Figure 5: Map depicting recent fire boundaries within Bryce Canyon National Park with preliminary aspen monitoring plots from this study shown.



Caution should be used in interpreting the current report due to the preliminary nature of data collection, the relatively small size of the overall BCNP aspen community, and the dynamic nature of disturbance events which may potentially have significant impacts, both positive and negative, on aspen forests. For instance, a warming and drying climate should be expected to spawn more and larger fires which should be expected to favor aspen cover. Moreover, recent studies in Colorado have demonstrated that aspen will benefit, not only from fire, but from short-rotation instances of multiple forest disturbances (Kulakowski et al. 2013; Andrus et al. 2021). Disturbance events generally promoting aspen may not be successful if moderate-to-heavy browsing by large ungulates persists. Thus, having a plan for protecting prescribed or natural disturbance events from browsing is required if post-disturbance aspen persistence is the intended objective (Rogers 2017; Kitchen et al. 2019). Burgeoning threats, such as the recently discovered Oystershell Scale, will need to be closely tracked and active mitigation may be required before such damaging invasive agents become epidemic.

Recommended Actions for Aspen Resilience at BCNP

Management Strategy for the Landscape-level

The following actions are recommended to fully assess conditions and strategically plan for sustainable aspen communities at BRNP:

1. Develop and implement a scientifically defensible survey to assess overall aspen status and trends at BCNP. To date, this has not been done. Since there are a relatively small number of Aspen Forest Complex polygons (~35) mapped within BCNP (Tendrick et al. 2011; Fig. 5), a baseline survey of all aspen stands greater than 0.1 ha (2.47 acres) should be considered.
2. Closely coordinate plans for fuels and fire management with aspen proliferation in mind. A fire management strategy incorporating both prescribed and wild fires should prioritize areas of advanced succession where aspen is present and areas where aspen regeneration is not progressing to the recruitment stage.
3. Coordinate forest and wildlife management disciplinary areas within and adjacent to the Park to alleviate excess browsing pressure on current and post-fire aspen regeneration. It cannot be overstated that in many instances chronic herbivory is the base causal agent of aspen decline and, thus, should be addressed directly. Just as active forest management may be used effectively to promote "front country" (near road) aspen communities, active large ungulate manipulation, culling, or restriction of movement should be employed to protect post-disturbance aspen growth. In some instances, managers may take advantage of natural refugia (e.g., talus, steep slopes, heavy tree fall) or purposely use on-site materials, such as felled trees or large boulders, to restrict browser access to juvenile aspen. Figure 6 depicts a ravine near the park boundary adjacent to plot BC02 (Figure 6).
4. Follow-up all actions with site specific aspen monitoring. Even the most thoroughly prescribed actions sometimes respond in unpredictable ways. Post-action monitoring allows managers, a.) to change course before aspen stand failure occurs and, b.) learn from successes and mistakes to better plan future actions.

Figure 6: Large deadfall lay in a ravine creating natural protection against browsing animals and allowing aspen stems to reach recruitment height (> 2 m).

Near-Road Aspen Demonstration Projects

Small aspen stands in BCNP's front country, near roads, are more visible to Park visitors and provide an opportunity not only for restoration within the public eye, but also opportunities for science communication. This does not diminish the need for broader ecosystem stewardship centered on aspen resilience at-large within the Park. Such near-road aspen, however, require special handling with the dual purposes of preservation and education. With this in mind, and as part of a broader strategic plan encompassing the previous section's actions, we recommend these high visibility aspen stands consider the following points:

1. Regardless of treatment selection (even no treatment), allocate adequate resources for post-treatment protection from browsers. Oversight on this important consideration may result in stimulation and potential death of mature aspen, a regeneration response, and complete denudation of that response by browsers attracted to this new growth. Since planned treatments near roads are assumed to be relatively small, a brief period of heavy browse could decimate any new growth.
2. Closely related to the first point, some level of monitoring will be essential to gaging success, as well as altering practices (e.g., increasing browse protection or burning following cutting) should measures of inadequate response occur. Monitoring is sound practice, as well, for maintaining long-term data sets of prescribed actions for future Park staff to refer to.
3. Select from treatment options that best emulate "functional types" (Rogers et al. 2014) and present stand conditions. For instance, it is most appropriate for seral aspen stands to select from burning or silvicultural practices that remove at least 50% of overstory conifers, but less than 20% of mature aspen (some aspen removal will further stimulate suckering, but is not essential). Hotter fires will generally have more favorable aspen regeneration responses, but prescribing

such burns (as opposed to letting wildfires burn through near-road aspen) is admittedly challenging. Stable aspen stands, or which BCNP appears to have few if any, are difficult to burn and should not be subjected to clearfell-coppice cutting as this is a departure from process-based restoration practices (i.e., these forests do not commonly experience stand-replacing events). Rather, stable aspen may be treated with low percentage selective cuts emulating small patch or gap-phase openings.

4. Post-treatment fencing: Success of small, visible, aspen stands slated for restoration should consider barriers to large ungulate browsers (see #1). While metal fencing may be the best option in some situations, there are a few "natural" options to select from. Metal fencing may seem out of place in a National Park and/or some visitors may take offense to such intrusions. Thus, if enough conifers are felled, they may be mechanically stacked around the edges of the target aspen stand to form pyramid shaped barriers at least 2 m tall and 3 m across the base. BCNP may also elect to experiment with "lopping and scattering" cut trees throughout the site, though post-treatment monitoring is highly recommended as this technique has born widely varying results in different locales. A variation on this practice is "hinging" (cutting trees with a high stump [1-1.5 m] partially through, which allows the tree to remain connected by a thin strip, and perched on the stump, effectively creating small fences throughout the stand) which at least partially deterred elk browsing in South Dakota (Kota & Bartos 2010).
5. Education & interpretation: Where treatments near roads occur, BCNP should take advantage of these unique opportunities to inform visitors about the value of aspen forests, as well as the intention and duration of the treatments/fencing. At minimum, succinct information signs could be place along fences or log barriers describing values and practices. Lager restoration efforts may consider interpretive staff programs which point out these values, intentions, and (presumably) signs of success as treated areas progress.

What Does Success Look Like?

Thriving aspen ecosystems are consistent with National Park directives to, "…conserve the scenery and...leave them unimpaired for the enjoyment of future generations." (NPS Organic Act, 1916). Moreover, aspen communities worldwide, as well as around the Colorado Plateau, act as biodiversity oases within conifer-dominated montane forests (Chong et al. 2001; Rogers et al. 2020). The goal for sustainable aspen communities within BCNP should focus on three elements: diverse stand conditions, adequate recruitment, and success in visible locations. Progress toward each of these goals should be documented by consistent monitoring. First, diversity in aspen stands means that it is desirable to that these forests be scattered across the BCNP landscape in various stages of succession (early, middle, and late successional conditions). We do not want to create uniform aspen conditions. Advancing succession (i.e., dense conifer cover with intermingled aspen) is to be expected, just as post-disturbance rejuvenation, even temporary aspen dominance, should be present at other sites. Second, post-disturbance aspen, whether active management or passive "natural" disturbances, must display ample levels of recruitment. We should be cautious of the common occurrence of moderate- to high- regeneration that is accompanied by heavy browsing that ultimately results in insufficient recruitment levels. Third, at BCNP, we will pointedly focus additional attention to near-road aspen communities that require restoration. Because of the public nature of these (often) small aspen stands, intensified protection and monitoring may be warranted to ensure their success and, we anticipate, opportunity for interpretive outreach. If we focus these three key elements, we should anticipate landscape-level aspen in resilient form, such that found currently at Iron Spring and in some post-fire situations (Figure 7).

Figure 7: Looking west through the Puma Fire (2006) scar, summer 2021, at ample recruitment (> 2 m height) of aspen alongside nearly total clearing of the mature conifer layer.

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Appendix 1: Plot-level data file for preliminary aspen monitoring plots, Oct. 2021 (See Append. 3 for detailed procedures and variable descriptions).

Plot#	date	UTM_E	UTM_N	Elev	#layers	Stand cond	Functional Type
BC01	10/19/2021	387937	4154911	2501	2	3	seral
BC02	10/19/2021	387547	4150747	2538	1	3	seral
BC03	10/19/2021	388593	4147954	2538	1	3	seral
BC04	10/20/2021	390027	4150213	2382	3	1	seral
BC05	10/20/2021	388063	4151873	2696	1	2	seral
BC06	10/21/2021	392031	4160508	2494	1	3	seral

Appendix 2: Rapid Assessment Plot Data Sheet (See Append. 3 for detailed procedures and variable descriptions).

Data Sheet: Bryce Canyon prelim monitoring 2021

plot#: _____ date ________ GPS X __________ GPS Y ____________ Elev. __________

Stand (aspen) layers ________ Stand condition_______

Aspen cover est: Tr #1 A___ A___ A___ A___ A___ A___ A___ Treatment_______________

Aspen cover est: Tr #2 A___ A___ A___ A___ A___ A___ A___ Common Juniper Cover____

Plot-level comments:

Fecal Count (transect)	1	2
Cattle		
Sheep		
Elk		
Deer		

Tree Tally (classes = 1-3 Regeneration; 4 Recruitment; 5-7 Mature):

Line	transect #	class	species	count	brow se	dead	comments
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
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21							
22							
23							
24							
25							
26							

	Photo Point ID
E	
W	
N	
S	

Appendix 3: Field Procedures for Bryce Canyon Aspen Monitoring

Field Procedures
Bryce Canyon National Park
Paul C. Rogers
October 2021

At Each Field Location (plot):

- Plots are not permanently marked
- Leave no trace, remove all materials, makers, flagging upon completion

Data collection:

I. Percent of aspen tree crown cover and stems/ha:
   - Establish two 30 x 2 meter belt transects perpendicular (E-W; N-S) to each other (with 5 m gap) between belt transect edges (see tally sheet diagram). Ensure transects will not intersect edge of stand (this should be accomplished in the pre-field/study design phase) by further adjusting along cardinal directions by 5 m intervals. *This survey always uses a compass declination of 0° (check your compass before beginning).*.
   - **Canopy/mature tree tally:** Count all mature (**Class 5-7**) stems by dbh classes (5=8-15, 6=15-25, 7= >25), dead/live (0,1), species codes (below)
   - Species codes: aspen (as); subalpine fir (sf); white fir (wf); Douglas-fir (df); ponderosa pine (pp); limber pine (lp); Rocky Mtn. juniper (rmj); Utah juniper (up); Gambel oak (go)

II. Regeneration and recruitment count (**Tree Tally)**:
   - Within each belt transect, count all live regeneration (**Class 1** = 0 - .5 m; **Class 2** = >.5 - 1 m; **Class 3** = >1 - 2 m ht.) and all recruitment (**Class 4** > 2 m ht. < 8 cm dbh) of aspen and conifer stems.
     - For regeneration (**Class 1-3**), note presence of any browse in upper/outer 15 cm (i.e., terminal leader and twigs) for each distinct aspen stem/clump. Record total stems browsed.
     - For recruitment (**Class 4**), count live stems by species. Note species.
   - **Note:** Multiple stems arising from the same point near the base should be counted as a single stem. In cases where either regeneration or recruitment arise from the base of a mature tree (Class 3) count the smaller stem classes as a separate stem. Do not count separate classes when unified clumps contain regeneration and recruitment; defer to the tallest stem for the class code.

III. Location/stand description:

- **GPS:** Record X & Y GPS coordinates at the west end of transect 1 (Plot Center) and take a digital photo facing east.
- **Plot Notes:** Note any unusual items that may affect the entire sample area which may not be picked up by other data items (e.g., trees < 8 cm are forming the upper canopy; aspen mostly competing with oak, juniper, tall shrubs, or other uncommon species; fresh dead elk carrion found near transects).
- **Stand (aspen) layers**: Visually look through the 1 ha stand and describe the number of distinct vertical layers of aspen (record 1,2,3, or 4). The canopy is one layer, the short regeneration

another, and the medium recruitment a third. On some stands there are no obvious layers, as they become continuously blended in a complex vertical profile. Stands with more than 3 distinct layers should be recorded as "4".

IV. Estimate overall visual **Stand condition** using the following scale. Key indicators include: aspen mortality, condition/amount of regeneration and recruitment, level of browsing. Guidelines for estimation include:

1. Good (all 3 requirements met): Minimal overstory mortality and stem disease present (< 5%); several aspen layers (≥ 3) visually identifiable; browsing impacts on regeneration uncommon (< 25%).
2. Moderate: stands not fitting into categories 1 or 3.
3. Poor (any 2 of 3 requirements met): Overstory mortality and/or stem cankers common (> 25%); visual aspen layering absent or minimal (1-2 layers only); browsing impacts clearly evident (> 50%) on regeneration.

I. **Fecal counts** (deer, elk, cattle)

- For each species count pies or pellet groups within 30 x 2 m belt transects
- Pellet groups are defined as those consisting of > 3 pellets (Bunnefeld, et al. 2006). After counting group disperse pellets/pies by kicking them apart and/or removing them from the sample transect area