Devils Tower Plant Inventory and Vegetation Assessment

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by the

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Abstract

The first description of the vegetation on the summit of Devils Tower came from rock climbers, in 1937. They reported that grass, sagebrush, cactus and ferns were "sparse but sufficient to protect the surprising amount of top soil." The first known plant collections from the summit were made by Marriott on occasional visits from 1977 through 1982, producing a known flora of 30 species. In 1992, Driese and Roth characterized summit vegetation using Daubenmire sampling. Cover averaged 51%, with grasses dominant. On the eastern aspect, they found more grass and Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*). They reported 21 species, including three not found earlier by Marriott. They also mapped human disturbances, identifying one area of severe disturbance—the trail between the Meadows route and the summit cairn. Moderate disturbance was found on two other trails and on the summit margins. Most of the summit showed little or no evidence of human impact.

In 2016, the National Park Service entered into a task agreement with the Wyoming Natural Diversity Database to conduct a floristic inventory of the summit and Meadows of Devils Tower; to characterize the vegetation of the summit; to assess human disturbance of summit vegetation; and to compile educational material for general park visitors and for rock climbers. Three visits were made through the field season to collect voucher specimens in identifiable condition. Specimens were deposited on permanent loan in the Rocky Mountain Herbarium at the University of Wyoming. Specimens and images can be accessed online at the herbarium website. The known flora of the summit comprises 53 species; 26 species were found in the Meadows area (66 species in all). None are rare. One was a new report for the Monument. Thirteen are non-native species; of these, only cheatgrass is common. We found small populations of two designated noxious weeds. Devils Tower National Monument (DETO) staff should revisit these sites in 2017 to remove any remaining plants and underground structures.

To characterize vegetation and provide a baseline for monitoring, we followed the Plant Community Composition and Structure Monitoring Protocol of the Northern Great Plains Inventory and Monitoring Network. Point intercept sampling was used to estimate vegetative cover by lifeform. Stands were classified according to the US National Vegetation Classification. Skunkbush Sumac / Bluebunch Wheatgrass Shrub Herbaceous Vegetation is found across much of the summit. The northeast part, where soils are better developed, supports Wyoming Big Sagebrush / Mixed Grasses Shrub Herbaceous Vegetation.

Human disturbances were visually mapped in aerial imagery and verified in the field. Severity was classified following the system used by Driese and Roth. Our findings were similar to theirs, with no obvious increase in disturbance. In October 2016, DETO staff mapped trails with a TrimbleGeoXT GPS receiver, running TerraSync. Data were recorded in UTM NAD 83, and the Newcastle, Wyoming base station was used for differential correction. Mapped features were added to the DETO Geographic Information System.

“What’s on top?” is one of the most common questions asked by visitors at DETO. To address this, we compiled information about plants of the summit for use in webpages, brochures, exhibits and other interpretive materials. We also compiled educational material aimed at rock climbers, with the goal of minimizing impact to summit vegetation. We recommend that summit trails be stabilized and made obvious. This would prevent additional disturbance, and make educational outreach more effective.

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Table of Contents

Introduction **3**

Previous Studies *5*

Current Project *7*

Methods **7**

Flora *7*

Vegetation *8*

Human disturbance *9*

Educational material *10*

Results **10**

Flora *10*

Vegetation *12*

Human disturbance *15*

Educational material *15*

Discussion **20**

Literature Cited **22**

Appendix A. Vascular plants of the summit and Meadows of Devils Tower **26**

Appendix B. Educational material for the general public **30**

Frequently-asked questions *30*

Plants of interest on the summit *31*

Appendix C. Educational material for rock climbers **32**

Caution … Plants Ahead! *32*

List of Figures

Figure 1. The first report on Black Hills geology featured Devils Tower as the frontispiece (Newton 1880). 3

Figure 2. George Hopkins on Devils Tower, 1941 (National Park Service, Photo Gallery). 5

Figure 3. Map of human disturbance on Devils Tower summit (Driese & Roth 1992). 6

Figure 4. Vegetation stands sampled on the summit. Google Earth (3D view); 4/18/2014. 8

Figure 5. Ponderosa pine on the edge of the summit. 10

Figure 6. Skunkbush Sumac / Bluebunch Wheatgrass Shrub Herbaceous Vegetation on Devils Tower summit.13

Figure 7. Skunkbush Sumac / Bluebunch Wheatgrass Shrub Herbaceous Vegetation on Devils Tower summit; percent cover by lifeform. 13

Figure 8. Wyoming Big Sagebrush / Mixed Grasses Shrub Herbaceous Vegetation on Devils Tower summit. 14

Figure 9. Wyoming Big Sagebrush / Mixed Grasses Shrub Herbaceous Vegetation on Devils Tower summit; percent cover by lifeform. 14

Figure 10. Human disturbances on the summit, mapped using visual interpretation with field verification; Google Earth imagery 3D view, 4/18/2014. 16

Figure 11. Summit and Meadows trails mapped by DETO staff, October 18, 2016; 2002 USGS digital orthoimagery. 17

Figure 12. Middle section of trail from Meadows route to summit cairn. 18

Figure 13. Bare area on trail from summit cairn to Meadows rappel. 18

Figure 14. Bare area at north edge of summit on trail from cairn. Most of the trail was moderately disturbed. 19

Figure 15. Area around summit cairn is a mix of bare rock, vegetation, and bare soil. 19

List of Tables

Table 1. Registered climbers from 1994 through October 2016 (not all reached the summit); from DETO park database. 4

Table 2. Plants observed in 2016 as vegetative or dead material. 11

Table 3. Plant species previously collected from the summit of Devils Tower but not relocated in 2016. Marriott specimens reside in the DETO herbarium (Rocky Mountain Region Digital Herbarium in Literature Cited). Driese and Roth (1992) reports were not vouchered. 11

Introduction

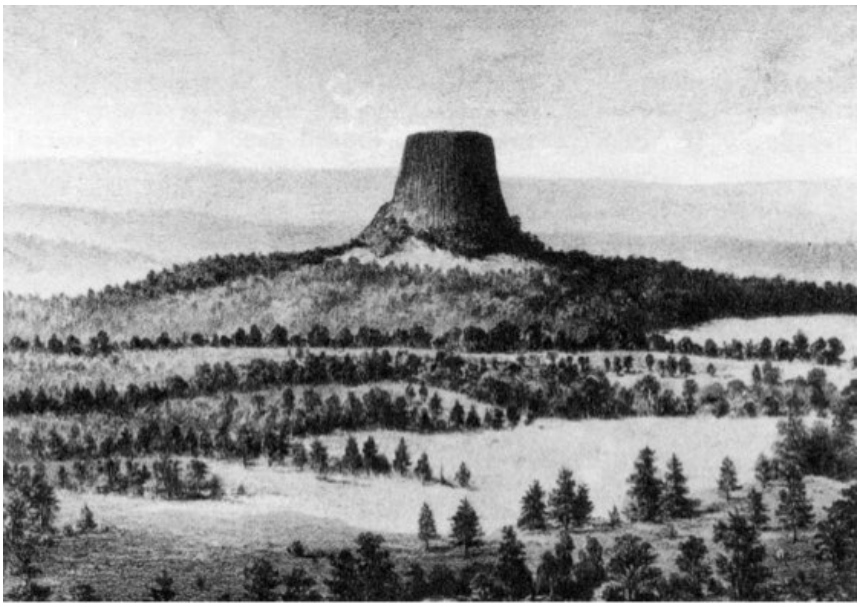
Devils Tower is a sheer rock monolith rising 1200 feet above the Belle Fourche River in northeast Wyoming. From its base, roughly 1.6 km (1 mi) in circumference, it tapers to an area of 0.6 ha (1.5 ac) at the top, about the size of a football field. The broad summit is gently-sloping, forming a low hill.

The Tower lies near the western end of a zone of igneous intrusions that crosses the northern Black Hills. These were emplaced about 50-60 million years ago, during uplift of the Black Hills (Lisenbee and DeWitt 1995). The Tower's distinctive "striations" are long vertical cracks separating massive polygonal columns 1-2.5 m across. The large columns and coarsely-crystalline rock (phonolite porphyry) indicate the Tower formed from magma that cooled slowly at depth. It was later exposed by erosion of surrounding sedimentary rocks. None of the other Tertiary intrusive features in the northern Hills (e.g. the Little Missouri Buttes and Sundance Mountain) are as steep and spectacular as Devils Tower.

The Tower's size, improbable location and striking form have long fascinated humans. Diverse Indian stories address its origins (National Park Service, First Stories), and early travelers expressed awe and wonder. Even geologist Henry Newton (1880) verged on poetic:

> "Its remarkable structure, its symmetry, and its prominence made it an unfailing object of wonder. It is a great rectangular obelisk of trachyte, with a columnar structure, giving it a vertically striated appearance, and it rises 625 feet, almost perpendicular, from its base. … in its shape and structure, [it] appears not to have been repeated elsewhere by Nature, but stands alone, unique and mysterious."

Figure 1. The first report on Black Hills geology featured Devils Tower as the frontispiece (Newton 1880).



Newton also noted that the "summit is so entirely inaccessible that the energetic explorer, to whom the ascent of an ordinarily difficult crag is but a pleasant pastime, standing at its base could only look upward in despair of ever planting his feet on the top." But he was wrong.

William Rogers and Willard Ripley made the first recorded ascent of Devils Tower in 1893, using a ladder of wooden pegs driven into a crack (Mattison 1955). In 1937, rock climbers Fritz Wiessner, Lawrence Coveney and William House reached the summit in a bold free ascent (ropes and pitons used only in case of a fall). By 1955, Devils Tower National Monument (DETO) staff had recorded 173 "individual ascents of the formation by skilled climbers" (Mattison 1955). Starting in the 1970s, popularity with climbers grew rapidly. By 1994, four to five thousand were registering each year. Though levels have plateaued (Table 1), there is concern that continued use could have negative impacts on the summit ecosystem.

Table 1. Registered climbers from 1994 through October 2016 (not all reached the summit); from DETO park database.

Year	Climbers			Annual Visitation	% Climbers vs. Annual Visitation
	June	Annual	% climbers in June		
1994	1225	5697	21.50%	454,776	1.25%
1995	167	4815	3.47%	420,528	1.14%
1996	181	4585	3.95%	436,591	1.05%
1997	236	4191	5.63%	389,137	1.08%
1998	190	3956	4.80%	399,064	0.99%
1999	163	4140	3.94%	395,892	1.05%
2000	222	3939	5.64%	393,468	1.00%
2001	225	4833	4.66%	375,596	1.29%
2002	271	4796	5.65%	404,934	1.18%
2003	276	4245	6.50%	396,266	1.07%
2004	342	4350	7.86%	386,558	1.13%
2005	277	4058	6.83%	369,575	1.10%
2006	295	4007	7.36%	335,764	1.19%
2007	265	3481	7.61%	322,272	1.08%
2008	272	3913	6.95%	336,303	1.16%
2009	280	3897	7.19%	397,023	0.98%
2010	244	4269	5.72%	436,200	0.98%
2011	391	3728	10.49%	395,203	0.94%
2012	341	4229	8.06%	416,994	1.01%
2013	434	3519	12.33%	417,326	0.84%
2014	335	5452	6.14%	440,875	1.24%
2015	383	4209	9.10%	478,833	0.88%
2016	374				

Previous Studies

The first known description of summit vegetation was provided by climbers. In 1939, at the request of Superintendent Newell Joyner, Wiessner and his party made observations of summit vegetation, and collected samples of plants and rocks:

> "Indigenous vegetation such as sage brush and cactus was sparse but sufficient to protect the surprising amount of top soil. As a forester, Bill [House] was interested in possible examples of isolated plant life. He arrived at the conclusion that strong winds would be capable of carrying to the summit seeds of most of the species found. Satisfactory identification could not be made in all cases, and specimens of plant and rock were collected for further study below" (Coveney 1937).
>
> "They remained on the top long enough to gather specimens from the summit which consisted of tufts of grass, sagebrush, cactus in full bloom, ferns, small samples of rock taken from the peak" (Joyner 1937; location of samples is unknown).

In 1941, stuntman George Hopkins parachuted from a plane onto Devils Tower, where he stayed for six days before being rescued by rock climbers (Mattison 1955). Aerial photos of the stranded Hopkins show the summit to be rocky but well-vegetated, with grass and shrubs (Figure 2).

Figure 2. George Hopkins on Devils Tower, 1941 (National Park Service, Photo Gallery).

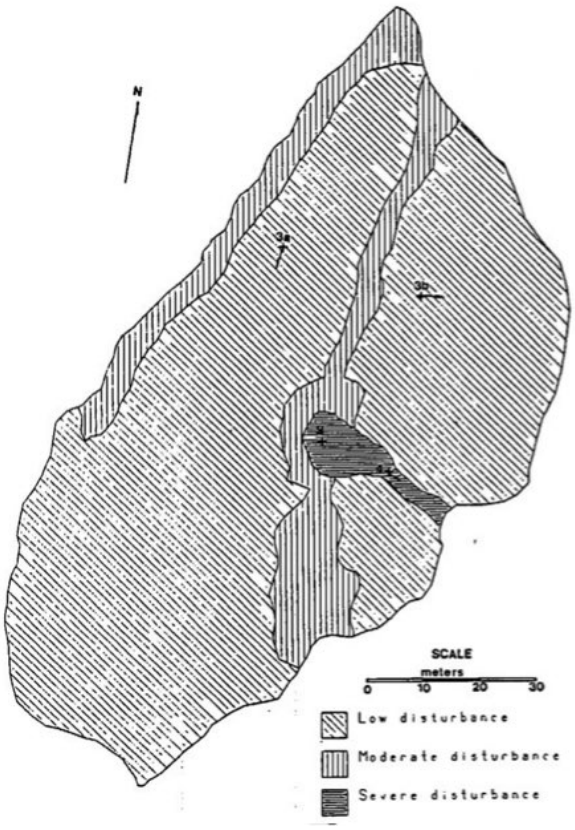
The first known plant collections from the summit of Devils Tower were made by Marriott[1] on occasional visits from 1977 through 1982. These are housed in the DETO Herbarium (Rocky Mountain Region Digital Herbaria in **Literature Cited**). By 1982, the known flora of the summit had reached 30 species, even without comprehensive survey.

[1] "Marriott" and "Mayer" refer to report authors.

In 1992, Driese and Roth characterized summit vegetation through Daubenmire canopy cover sampling. Average vegetative cover was estimated at 51%, with grasses dominant. On the eastern aspect, they found deeper soils and greater plant cover, with more grass and Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*).[2] They reported 21 species, including three not found earlier by Marriott. Vouchers were collected for unknowns, but disposed of after identification. Project data, maps, and photographs could not be found in 2016 (R. Ohms, personal communication, April 2016; K. Driese, personal communication, May 2016).

Driese and Roth also mapped severity of human disturbance, assigning areas to one of three categories: severe, vegetation destroyed and erosion visible; moderate, vegetation reduced in area and stature, little or no erosion; and low, vegetation undamaged, no erosion (Figure 3). They found a single area of severe impact—the trail between the Meadows route[3] and the summit cairn. Moderate impact was mapped around the cairn, along two trails from the cairn to the summit edge, and along the summit edge above the west face. The remainder of the summit was classified as low disturbance.

Figure 3. Map of human disturbance on Devils Tower summit (Driese & Roth 1992).



[2] Common names are used throughout the text, with scientific name included on first occurrence. The checklist in Appendix A includes both.

[3] The "Meadows" is a sloping vegetated area on the southeast side of Devils Tower. The "Meadows route" refers to the easy climb leading from the Meadows to the summit.

The summit was included in a vegetation mapping project at DETO in 1996 (The Nature Conservancy 1998). In this project, large plots and cover class categories were used to consistently describe vegetation. On the summit, a plot was placed in the more extensive of the two vegetation types reported by Driese and Roth, with less vegetative cover and more bare rock. Shrub and herbaceous cover were estimated at 5-25% each. The type was classified as Skunkbush Sumac / Bluebunch Wheatgrass (*Rhus aromatica* / *Pseudoroegneria spicata*) Shrub Herbaceous Vegetation (NatureServe Explorer 1996; Marriott and Faber-Langendoen 2000).

Current Project

In 2016, the National Park Service (NPS) entered into a task agreement with the Wyoming Natural Diversity Database to conduct a floristic inventory of the summit and Meadows of Devils Tower; to characterize the vegetation of the summit; to document human impact on summit vegetation; and to compile educational material for park visitors and for rock climbers.

Methods

Flora

Three collecting trips were made through the field season to collect voucher specimens in identifiable condition: May 8, July 1 and August 22, with a total of 27.5 person hours (ca. 20 specifically on the summit). NPS policy discourages rock climbing in June due to American Indian religious and cultural concerns (National Park Service 1995), so we did not visit during that part of the growing season.

Voucher specimens were collected for all species unless rare, in which case photos were taken. Collection data included date, collector(s), Global Positioning System (GPS) coordinates, aspect, associated species, other habitat information, and abundance. Specimens were identified at the Rocky Mountain Herbarium, University of Wyoming. Nomenclature followed the Integrated Taxonomic Information System (ITIS; 2016). Common names and nativity are based on NPSpecies records for DETO (National Park Service, NPSpecies database).

The NPS requested that specimens be deposited on permanent loan in the Rocky Mountain Herbarium (RM). Specimens were mounted, imaged, and added to the RM database. Records and images can be accessed online at the herbarium website.

A checklist of the flora was submitted separately (Marriott and Mayer 2016; see Appendix A).

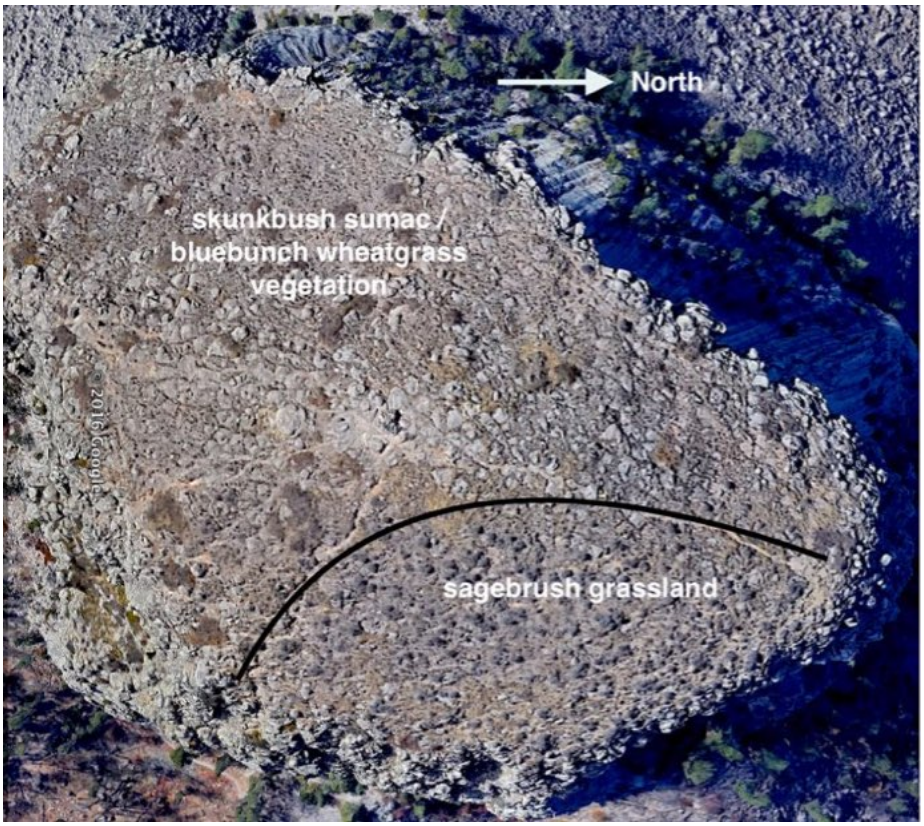
Vegetation

We did not replicate the Daubenmire sampling of Driese and Roth (1992) as there was no suitable baseline. As mentioned earlier, project data, maps and photographs could not be found, and without voucher specimens, we could not verify identifications (several were unclear). Equally important, Daubenmire sampling and quadrats in general are not recommended for monitoring cover, due to sensitivity to climate variation (Coulloudon et al. 1999).

In consultation with DETO staff, we chose the Plant Community Composition and Structure Monitoring Protocol of the Northern Great Plains Inventory and Monitoring Network (NGPN), which uses point intercept sampling, supplemented with quadrats, to track vegetative cover and species richness (Symstad et al. 2016). The NGPN has been monitoring vegetation at DETO for over 18 years; results were recently summarized by Ashton and Davis (2016). The summit of the Tower had not been included in earlier sampling, as technical climbing is required for access. But given concerns about recreational use, DETO staff decided extra effort was justified.

We recognized and sampled two stands of vegetation; both were clearly visible in aerial imagery and in the field (Figure 4). They corresponded to the Skunkbush Sumac / Bluebunch Wheatgrass Shrub Herbaceous Vegetation of Marriott and Faber-Langendoen (2000), and the grassland with sagebrush on the northeast part of the summit described by Driese and Roth (1992).

Figure 4. Vegetation stands sampled on the summit. Google Earth (3D view); 4/18/2014.



Following NGPN standard operating procedures (Symstad et al. 2016), we established a 50 m transect in each stand, in an area considered representative. Small stand size limited choices, but for the same reason, we were able to sample a large portion of each stand. Transect locations were documented with GPS points, azimuths and photos. At 50 evenly-spaced points along each transected, we collected intercept data for live plants and ground cover (bare soil, litter, etc.) (see Ashton and Davis 2016 for full details).

A great disadvantage of point intercept sampling is low rate of species capture, even for common species, resulting in underestimates of species richness (Coulloudon et al. 1999). To compensate, the NGPN uses 10 nested quadrats (10 m^2 total) to supplement point intercept sampling (Symstad et al. 2012). However, our comprehensive floristic inventory made quadrats unnecessary (more in **Discussion**).

Sampling intensity of the NGPN point-intercept protocol is insufficient to track individual species in most cases. Rather it is "designed to describe the status and trends of cover of ecologically meaningful functional groups, the cover of which can be calculated from the cover of their individual species" (Symstad et al. 2012). In the case of the summit, functional groups included four lifeforms—forb/herb, graminoid, shrub and subshrub—and native and non-native species within each lifeform. Lifeforms were assigned based on the USDA Plants Database (USDA-NRCS 2015).

Scanned field forms and digital photographs were sent to DETO and the NGPN office in Rapid City, South Dakota. Data were analyzed by the NGPN in FFI (FEAT/FIREMON Integrated; http://frames.gov/ffi/). After data were entered, records were verified to the original data sheets; 10% of records were reviewed a second time. Automated queries were then used to check for errors in the data. Summaries were produced using FFI reporting and query tools and statistical summaries, and graphics were generated using R software (version 3.2.2).

Human disturbance

Apparent human disturbances were marked in aerial photos prior to fieldwork, and verified in the field. Areas were classified in the field using the severity categories of Driese and Roth (1992). Trails and larger bare areas were clearly visible in imagery, but smaller areas did not stand out sufficiently from bare rock. Severity also was difficult to assess in imagery. We used an aerial photo taken in April; disturbance features and severity would be even more difficult to assess with imagery taken later in the season, when vegetative cover is greater.

In October 2016, DETO staff mapped trails with a TrimbleGeoXT GPS receiver, running TerraSync. Data were recorded in UTM NAD 83, and the Newcastle, Wyoming base station was used for differential correction. Mapped features were added to the DETO Geographic Information System.

Educational material

"What's on top?" is one of the most common questions asked by visitors (Marriott, personal observations; R. Ohms, personal communication, 2016). To address this, we compiled information about plants of the summit, which can be used by Monument staff to develop programs, brochures, exhibits and webpages.

We also compiled educational material aimed at rock climbers, with the goal of minimizing impact to summit vegetation. Both Marriott and Mayer climb, and are familiar with climbers' concerns. Many are interested in the natural history of areas where they climb, and most are eager to minimize impacts. Educational literature does not need to be heavy handed. To find suitable examples, we reviewed guidelines developed by the Access Fund, one of the largest climbing advocacy organizations in the United States (Access Fund, Educate yourself …).

Results

Flora

The known flora of the summit now consists of 53 species, with 26 species known from the Meadows (Appendix A). Vouchers were collected for all but one—a small ponderosa pine (*Pinus ponderosa* var. *scopulorum*; Figure 5). Six unknown plants observed as vegetative or dead material (Table 2) were not included in the checklist.

Figure 5. Ponderosa pine on the edge of the summit.

Table 2. Plants observed in 2016 as vegetative or dead material.

Scientific Name	Common Name	Location (datum: WGS 84)	Notes
Arnica sp. ?	looks like arnica	summit SE aspect, midway between edge and cairn; 522618E 4937492N	basal leaves in May; not relocated in later visits
Galium sp.	a bedstraw	central Meadows in dense stand of skunkbush sumac, SSE-facing; 522635E 4937448N	leafy stem in May; not relocated in later visits
unknown	maybe *Triodanis* (venus's looking glass)	lower Meadows on approach to Bon Homme rappel	small vegetative plants in May; not relocated in later visits
Drymocallis sp.	a cinquefoil	crack in rock in upper Meadows; 522643E 4937461N	dried fruit in August; too old for identification to species

Of the 53 species listed for the summit, eight were collected earlier by Marriott but not relocated in 2016 (Table 3). Some may have bloomed and senesced during the gap between early collecting on May 8, and the first summer visit on July 1.[4] For example, on May 8 Mayer saw leaves of either a wild onion or a sego lily (or both). On July 1, she found only dead individuals of a wild onion, not identifiable to species.

Five of the species not relocated are annuals. Abnormally warm and dry climatic conditions may have prevented germination and growth. In June 2016, Wyoming temperatures were "much above average" and precipitation "much below average" (NOAA 2016a). The northern part of the state experienced extreme drought (NOAA 2016b).

Table 3. Plant species previously collected from the summit of Devils Tower but not relocated in 2016. Marriott specimens reside in the DETO herbarium (Rocky Mountain Region Digital Herbarium in **Literature Cited**). Driese and Roth (1992) reports were not vouchered.

Scientific Name	Common Name	Notes
Carex praegracilis	clustered field sedge	not relocated 2016; Marriott 1211
Danthonia unispicata	onespike danthonia	not relocated 2016; Marriott 1240; Driese and Roth
Descurainia pinnata	western tansymustard	not relocated 2016; Marriott 1241; Driese and Roth
Calochortus nuttallii	sego lily	not relocated 2016; Marriott 1274
Cryptantha ambigua	basin cryptantha	not relocated 2016; Marriott 1275
Draba nemorosa	woodland draba	not relocated 2016; Marriott 1276
Vulpia octoflora	eight-flower six-weeks grass	not relocated 2016; Marriott 1280
Lappula occidentalis var. *occidentalis*	desert stickseed	not relocated 2016; Marriott 640; Driese and Roth

[4] Woodland draba was collected by Marriott on April 1, 1981; our early season visit may have been too late to catch this species.

One species "new" to DETO was collected from the summit and Meadows, a mountain tansy-mustard (*Descurainia incisa* ssp. *incisa*). It was listed for the Monument in NPSpecies under an older synonym, *D. incana* var. *viscosa*, but its status was Not In Park (False Report). We updated the Scientific Name and Occurrence fields in the NPSpecies record for DETO.

None of the plants on the summit are Federally-listed (Threatened, Endangered, Sensitive), nor tracked as rare in Wyoming (Wyoming Natural Diversity Database 2012).

Of the 66 species documented for the summit and Meadows, 13 are non-native. Of these, only cheatgrass (*Bromus tectorum*) is common. Though not designated noxious in Wyoming, it can be highly invasive and is of management concern. Marriott collected cheatgrass from the summit in 1982, noting it was common. It was a significant component in the analysis of Driese and Roth (1992), and was frequently recorded in our sampling as well (red bars in Figures 7 and 9 below). Cheatgrass is addressed further in **Discussion**.

We collected two species designated noxious in Wyoming (Wyoming Department of Agriculture n.d.). Creeping jenny (or field bindweed, *Convolvulus arvensis*) was found at the summit edge below five-foot high rocks (522582E 4937524N). Canada thistle (*Cirsium arvense*) was growing near the lower edge of the central Meadows, in shade under a boulder (522645E 4937441N). Both are perennials that can regenerate from rhizomes or roots. These sites should be revisited in 2017 to remove any remaining plants and underground structures.

Common mullein (*Verbascum thapsis*), a declared weed in Crook County (Wyoming Department of Agriculture 2016), was found on the summit and Meadows. It is not an aggressive invader, increasing mainly in response to disturbance (Gucker 2008).

Vegetation

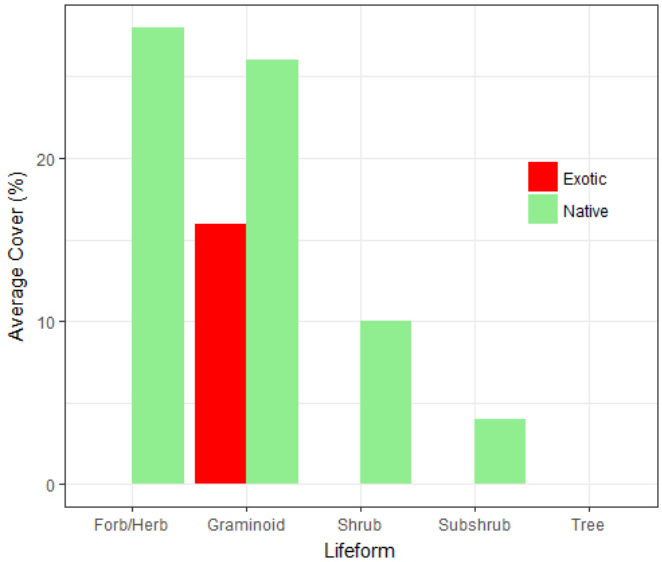
Results of data analysis were consistent with our recognition of two kinds of vegetation on the summit. We assigned these to corresponding types in the US National Vegetation Classification: Skunkbush Sumac / Bluebunch Wheatgrass Shrub Herbaceous Vegetation, and Wyoming Big Sagebrush / Mixed Grasses Shrub Herbaceous Vegetation.

Skunkbush Sumac / Bluebunch Wheatgrass Shrub Herbaceous Vegetation was the more extensive of the two types, occupying the rockier southern and western parts of the summit (Figure 6). Cover was provided mainly by forbs (specifically spikemoss, *Selaginella densa*) and graminoids (predominantly needle and thread, *Hesperostipa comata*, and bluebunch wheatgrass). Shrubs and subshrubs contributed ca. 14% cover, with skunkbush sumac and fringed sagebrush most common (Figure 7). Overall vegetative cover was roughly 50%—plants were recorded at 27 of 50 points (of the remainder, 22 were rock or bedrock).

Skunkbush Sumac / Bluebunch Wheatgrass Shrub Herbaceous Vegetation occurs elsewhere in eastern Wyoming and Montana, on rocky shallow soils on upper slopes and ridge tops (NatureServe Explorer 1996).

Figure 6. Skunkbush Sumac / Bluebunch Wheatgrass Shrub Herbaceous Vegetation on Devils Tower summit.

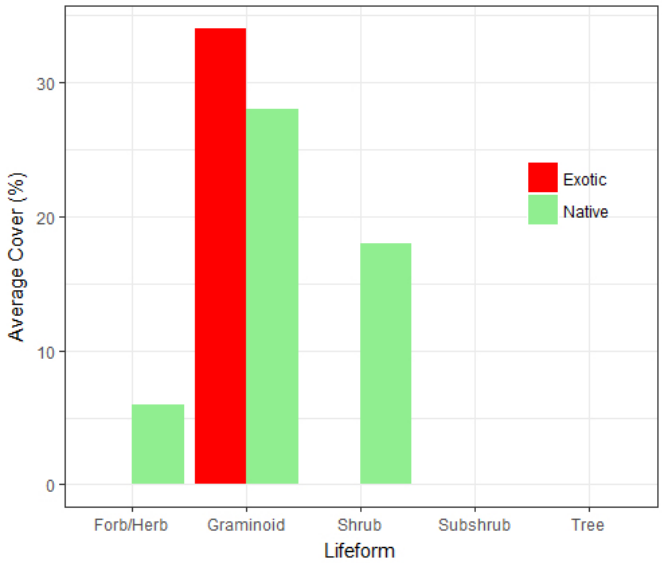
Figure 7. Skunkbush Sumac / Bluebunch Wheatgrass Shrub Herbaceous Vegetation on Devils Tower summit; percent cover by lifeform.



Wyoming Big Sagebrush / Mixed Grasses Shrub Herbaceous Vegetation (NatureServe Explorer 1997) occurred on the northeast part of the summit, on better-developed soil (Figure 8). Cover was greater, with graminoids dominant. Cheatgrass was common. Important native species were prairie Junegrass (*Koeleria macrantha*) and needle and thread. Wyoming big sagebrush dominated the shrub layer, with ca. 18% cover (Figure 9). Overall vegetative cover was roughly 60%—plants were recorded at 31 of 50 points (the remainder were litter, rock or bedrock).

Figure 8. Wyoming Big Sagebrush / Mixed Grasses Shrub Herbaceous Vegetation on Devils Tower summit.

Figure 9. Wyoming Big Sagebrush / Mixed Grasses Shrub Herbaceous Vegetation on Devils Tower summit; percent cover by lifeform.



Wyoming Big Sagebrush / Mixed Grasses Shrub Herbaceous Vegetation is widespread in Wyoming in basins and on lower foothills (Jones 1992). Common graminoids include seven species, six of which grow on the Tower summit. Jones considered this a "transitional community … named to include stands that would be difficult to place …"

Compared with DETO vegetation as a whole, the summit has much greater shrub cover, and overall vegetative cover is less (I. Ashton, personal communication, December 2016; Ashton and Davis 2016). This can be explained by the uniqueness of the summit *within DETO*. NGPN monitoring calculates average values based on plots located randomly across the Monument, and DETO is largely grassland and pine woodland. Soils are better developed, and conducive to greater plant cover. Outside the Monument, vegetation similar to that of the summit occurs on rocky sites with shallow soils and in xeric basins, as described above.

Human disturbance

We found human impacts to be similar in distribution and severity to what was described and mapped by Driese and Roth in 1992. Disturbances included three trails, the area of the summit cairn, and small areas (ca. 1-3 m^2 each) scattered along the summit edge (Figures 10 and 11). Most of the summit vegetation showed little evidence of human impact.

The only severely-disturbed area was the heavily-used trail between the summit cairn and the Meadows route. Some sections were devoid of vegetation (Figure 12). Of note, Driese and Roth reported in 1992 that "all vegetation within the bounds of this trail has been destroyed, and some soil erosion has occurred," whereas in 2016, plants were growing in some sections.

The area along the trail from the summit cairn southeast to the top of the Meadows rappel was moderately disturbed, with some small areas bare of vegetation (Figure 13). This trail is not as well-defined as the others, with traffic more dispersed. The trail north from the cairn also was classified as moderately disturbed, with one small bare area near the summit edge (Figure 14).

Driese and Roth classified the immediate area of the summit cairn as severely disturbed, surrounded by a larger area of moderate disturbance. In 2016, there were obvious human impacts, but much of the area was bare rock that can't support vegetation (Figure 15).

Educational material

Appendix B contains information that can be incorporated into programs, brochures, exhibits, webpages and other interpretive materials for the general public. Information directed at climbers is included in Appendix C. Content is similar to that for the general public, but with discussion of human impacts and conservation.

Figure 10. Human disturbances on the summit, mapped using visual interpretation with field verification; Google Earth imagery 3D view, 4/18/2014.

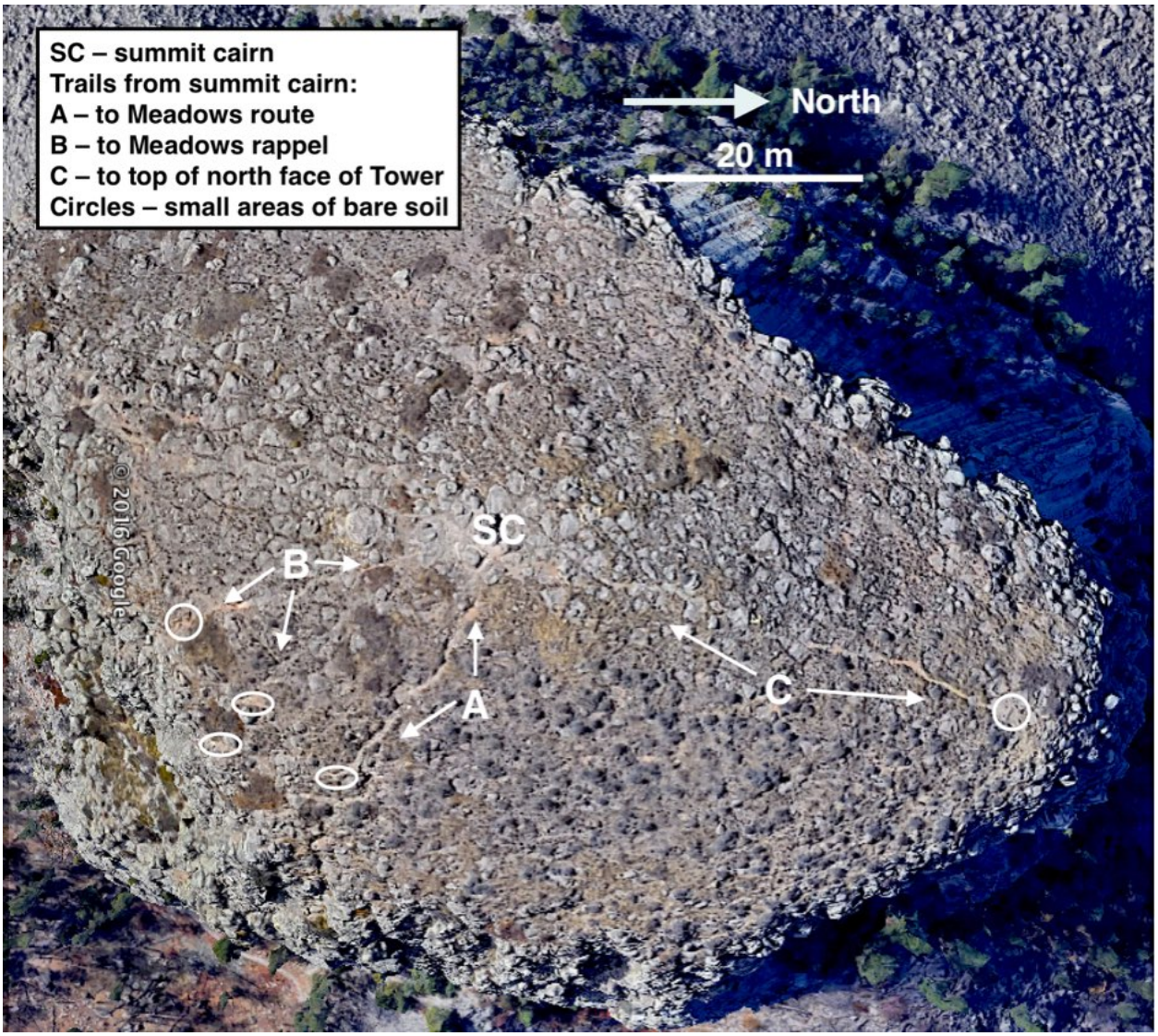


Figure 11. Summit and Meadows trails mapped by DETO staff, October 18, 2016; 2002 USGS digital orthoimagery.

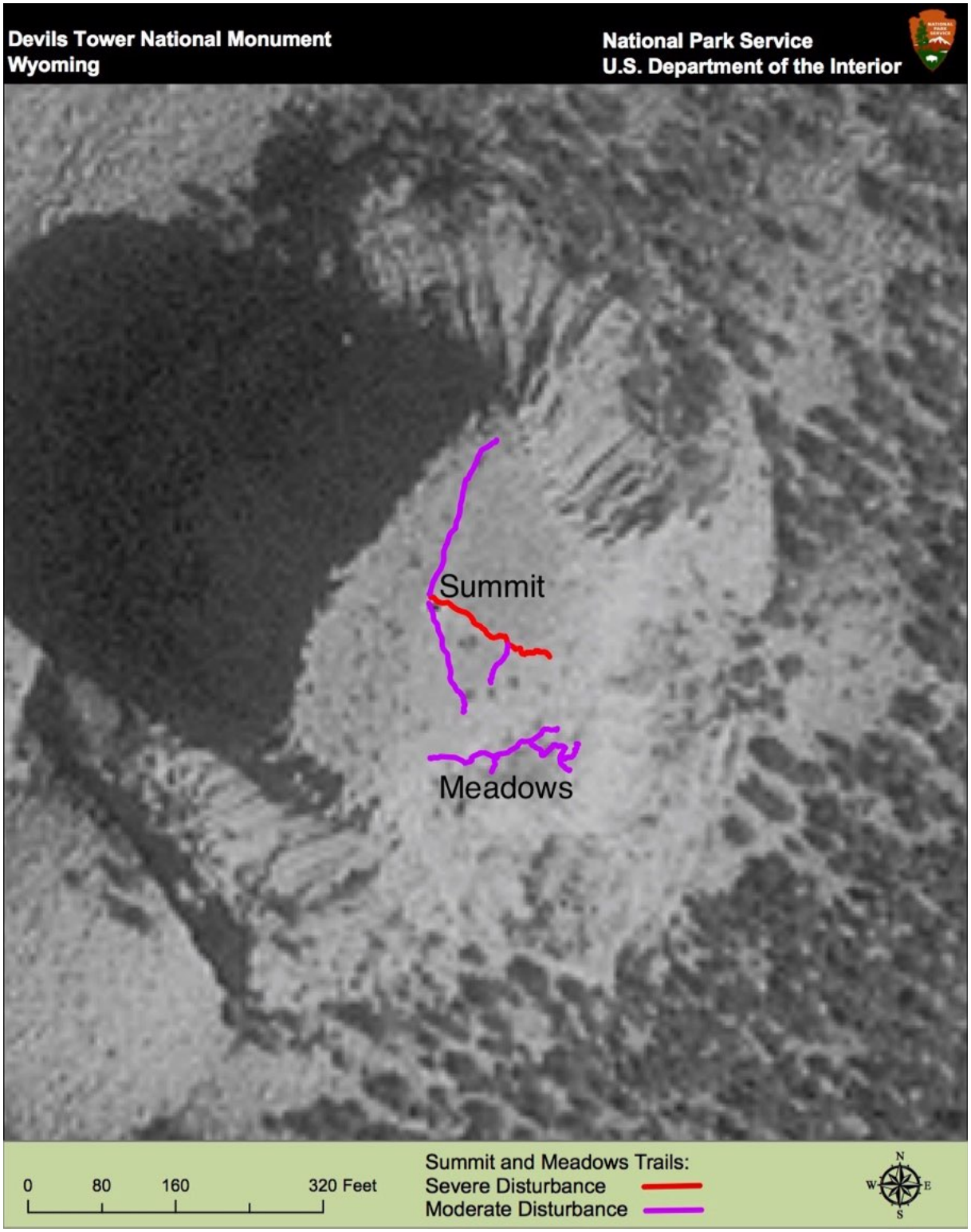


Figure 12. Middle section of trail from Meadows route to summit cairn.

Figure 13. Bare area on trail from summit cairn to Meadows rappel.

Figure 14. Bare area at north edge of summit on trail from cairn. Most of the trail was moderately disturbed.

Figure 15. Area around summit cairn is a mix of bare rock, vegetation, and bare soil.

Discussion

DETO now has a baseline and protocol for monitoring vegetation and disturbance on the Tower summit. Parameters include: cover by lifeform for each of the two vegetation types; species richness of the summit and Meadows; number of non-native species on the summit and Meadows; and distribution and severity of human impacts.

Standard NGPN monitoring evaluates DETO as a whole, generating park-wide values by averaging data from randomly located plots. In contrast, we characterized each of the two summit stands in order to track finer scale changes specific to the summit. However, because we followed NGPN methodology, these data can be added to the data set for DETO.

Results from 2016 cannot be compared directly with Driese and Roth (1992). They calculated average coverage values based on quadrats distributed across the summit, including areas with little vegetation, whereas we located transects in vegetated areas.

Because monitoring targets are lifeforms rather than species, and because summit vegetation is relatively-sparse and dominated by grasses and low shrubs, aerial imagery interpretation may provide an effective and efficient alternative. If so, vegetation of the entire summit could be characterized and mapped, thereby avoiding the issue of sample adequacy.

In addition to cover by lifeform, NGPN monitoring tracks species richness—number of species present, independent of abundance. However, point-intercept sampling does not pick up minor species unless the number of points is very large (Coulloudon et al. 1999; Symstad et al. 2012). Given the small area of the summit and Meadows, comprehensive floristic inventory would be an efficient and effective way to track species richness.

Point-intercept sampling will miss most of the non-native species on the summit, as populations are too small. This is another reason to repeat floristic inventory. Most of the non-natives pose little threat, but some (e.g. bindweed and Canada thistle) need to be found and eradicated before they become established.

Cheatgrass is the only common non-native species on the summit. Cover was estimated at 16-34% in areas sampled (red bars in Figures 7 and 9). This is well above the average for DETO as a whole (Ashton and Davis 2016), possibly because there is more open habitat on the summit, i.e. naturally bare soil. Across DETO, Ashton and Davis concluded that cover of annual bromes[5] had increased since 1998, and described annual bromes as an "emerging threat."

[5]Ashton and Davis combined cheatgrass and Japanese brome (*Bromus japonicus*) in discussions of non-native bromes. On the summit, we found hairy brome (*B. commutatus*) instead of Japanese brome. They are similar in appearance, and both occur elsewhere in the Monument (Heidel and Marriott 2014).

Cheatgrass is very persistent once established, making eradication unrealistic, especially where vegetation is naturally somewhat sparse, as on the summit and Meadows. Even if cheatgrass were removed, it would quickly reestablish on bare soil from long-lived seed banks and wind-transported seeds. Where cheatgrass occurs in the understory at relatively low densities, with perennials well-established (such as on the summit), community type conversion usually does not occur (Davison 2005; USDA Forest Service 2014; Zouhar 2003).

Given the presence of cheatgrass, creation of new habitat (bare soil) should be minimized. Human disturbance of summit vegetation remains limited, with little if any change since the work of Driese and Roth (1992), but there are areas of bare soil from foot traffic. To prevent increase, trails should be stabilized and made obvious. Better trails also would make educational outreach more effective. Elsewhere, trail projects have been done in cooperation with climbing organizations, with good results (Access Fund, For land managers …).

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Appendix A. Vascular plants of the summit and Meadows of Devils Tower

From: Marriott, H, and Mayer, C. 2016 (October 28). Checklist of vascular plants for the summit and Meadows of Devils Tower. Wyoming Natural Diversity Database, University of Wyoming. TA P16AC00387/UWY-216

Nomenclature follows the Integrated Taxonomic Information System (ITIS; https://www.itis.gov) (all websites listed here were accessed in October 2016). Common names and nativity are based on NPSpecies records for Devils Tower National Monument (DETO; https://irma.nps.gov/NPSpecies/Search/SpeciesList/DETO).

Marriott specimens date from 1978-1982, and are part of the DETO Herbarium (University of Wyoming Digital Collections, https://www-lib.uwyo.edu/digitalherbaria/public). Driese and Roth reports were not vouchered (Driese, KL, and Roth, DA. 1992. A description of the vascular flora and mammal fauna and the effects of human disturbance on the summit of Devils Tower. CA1268-1-9099; WO# UWY-21).

Scientific Name	Common Name	Nativity	Summit	Meadows	Notes
Achillea millefolium	western yarrow	Native	x	x	
Agrostis scabra	rough bentgrass	Native	x	x	
Alyssum desertorum	desert alyssum	Non-native	x		
Artemisia frigida	fringed sagebrush	Native	x		
Artemisia tridentata ssp. *wyomingensis*	Wyoming big sagebrush	Native	x		
Boechera collinsii	Collin's rockcress	Native	x		
Bouteloua gracilis	blue grama	Native	x		
Bromus commutatus	hairy brome	Non-native	x		
Bromus tectorum	cheat grass	Non-native	x	x	
Calochortus nuttallii	sego lily	Native	x		not relocated 2016; Marriott 1274
Campanula rotundifolia	harebell	Native	x	x	
Carex brevior	brevior sedge	Native	x	x	
Carex duriuscula	needleleaf sedge	Native	x		
Carex filifolia var. *filifolia*	sedge (threadleaf sedge in ITIS)	Native	x		

Scientific Name	Common Name	Nativity	Summit	Meadows	Notes
Carex praegracilis	clustered field sedge	Native	x		not relocated 2016; Marriott 1211
Chenopodium pratericola	desert goosefoot	Native		x	
Cirsium arvense	Canada thistle	Non-native		x	
Cirsium undulatum	wavyleaf thistle	Native	x		
Collinsia parviflora	blue-eyed Mary	Native	x	x	
Convolvulus arvensis	creeping jenny	Non-native	x		
Conyza canadensis	canada horseweed	Native	x		
Corydalis aurea ssp. *aurea*	golden corydalis	Native		x	
Cryptantha ambigua	basin cryptantha	Native	x		not relocated 2016; Marriott 1275
Cryptantha torreyana	Torrey's cat's-eye	Native		x	
Cystopteris fragilis	fragile fern	Native		x	
Danthonia unispicata	onespike danthonia	Native	x		not relocated 2016; Marriott 1240; reported by Driese & Roth
Descurainia incisa ssp. *incisa*	mountain tansy-mustard in ITIS	Native	x	x	
Descurainia pinnata	western tansymustard	Native	x		not relocated 2016; Marriott 1241; reported by Driese & Roth
Draba nemorosa	woodland draba	Native	x		not relocated 2016; Marriott 1276
Elymus trachycaulus ssp. *trachycaulus*	slender wheatgrass	Native	x	x	
Fallopia convolvulus	black bindweed	Non-native		x	
Hesperostipa comata ssp. *comata*	needle and thread	Native	x		
Koeleria macrantha	prairie Junegrass	Native	x		
Lappula occidentalis var. *occidentalis*	desert stickseed	Native	x		not relocated 2016; Marriott 640; reported by Driese & Roth
Leucocrinum montanum	sand lily	Native	x		

Scientific Name	Common Name	Nativity	Summit	Meadows	Notes
Lithophragma parviflorum	woodland-star	Native	x		
Logfia arvensis	field cottonrose	Non-native	x		
Mirabilis linearis	four o'clock	Native	x		
Muhlenbergia cuspidata	plain muhly	Native	x		
Muhlenbergia racemosa	green muhly	Native		x	
Opuntia polyacantha var. *polyacantha*	plains pricklypear	Native	x		
Orobanche fasciculata	clustered broomrape	Native	x		
Oxalis dillenii	Dillen's oxalis	Native		x	
Parietaria pensylvanica	Pennsylvania pellitory	Native		x	
Pascopyrum smithii	western wheatgrass	Native	x		
Pinus ponderosa var. *scopulorum*	ponderosa pine	Native	x		photo instead of voucher (single small tree)
Piptatherum micranthum	little-seed mountain-ricegrass	Native		x	
Poa bulbosa ssp. *vivipara*	bulbous bluegrass	Non-native	x		
Poa compressa	Canada bluegrass	Non-native	x		
Poa fendleriana	mutton grass	Native	x		
Poa interior	inland bluegrass	Native		x	
Poa secunda	big bluegrass	Native	x	x	
Potentilla pensylvanica	prairie cinquefoil	Native	x		
Pseudoroegneria spicata	bluebunch wheatgrass	Native	x		
Rhus aromatica var. *aromatica*	skunkbush	Native	x	x	
Ribes cereum var. *cereum*	western red current	Native	x	x	
Ribes oxyacanthoides var. *setosum*	inland gooseberry	Native	x		
Selaginella densa	rock spike moss	Native	x		

Scientific Name	Common Name	Nativity	Summit	Meadows	Notes
Setaria viridis	bottle grass	Non-native		x	
Solidago missouriensis	Missouri goldenrod	Native		x	
Taraxacum officinale ssp. *officinale*	dandelion	Non-native	x		
Tragopogon dubius	meadow salsify	Non-native	x		
Verbascum thapsus	mullein	Non-native	x	x	
Viola vallicola	sagebrush violet	Native	x		
Vulpia octoflora	eight-flower six-weeks grass	Native	x		not relocated 2016; Marriott 1280
Woodsia scopulina	Rocky Mountain cliff fern	Native	x	x	

Appendix B. Educational material for the general public

Information about summit plants is presented here as responses to frequently-asked questions. Staff may wish to use different formats for interpretive materials. We also include brief information about plants of interest, ideally to accompany photographs or illustrations. We recommend including scientific names, if not in the text then perhaps as endnotes. A small but significant portion of visitors are interested in knowing them, and scientific names resolve the confusion surrounding common names (e.g. our horseweed is "fleabane" in Great Britain).

Frequently-asked questions

What's on top? Is it all bare rock?

The summit of Devils Tower is a rounded rocky hilltop, with scattered bunch grasses and low shrubs. In the northeast part, where the soil is deeper, there's a small but vigorous stand of sagebrush and grass.

At first glance the summit looks dry and harsh—hospitable only to hardy drought-tolerant grasses, shrubs and cacti. But other plants grow on favorable microsites, for example in the shade of rocks and shrubs, and in crevices where soil and moisture accumulate. In all, 53 plant species have been found on the summit, which is only about the size of a football field.

How can plants grow on rock?

Rocks are not as permanent as they look. They fracture and weather. Dirt and debris slowly accumulate in cracks and pockets, where seeds sometimes land. A few germinate; a few of these grow into plants. Their roots help break up the rock—one tiny bit at a time.

What kinds of plants grow on the summit?

The most common grasses are bluebunch wheatgrass, needle-and-thread, and blue grama. These are species typical of grasslands and prairies in the surrounding area. Shrubs include skunkbush sumac and Wyoming big sagebrush. Starting in late spring, wildflowers add splashes of color: yellow violets and cinquefoils, white sand lilies and wild onions, pink four-o'clocks and wavy-leaf thistles, and blue harebells.

Are any plants unique to the summit?

All of the plants on the summit also grow in the surrounding area. However, Wyoming big sagebrush is much more common on the top of Devils Tower than anywhere else in the Monument (it's extremely common further west in the arid basins of Wyoming).

How do plants get up there?

Wind is the most likely means of seed transport, followed by birds. But small mammals climb Devils Tower too—chipmunks, packrats, and deermice have been seen on the sides and summit. Maybe they haul a few seeds up there on occasion. Rock climbers probably contribute few if any seeds, for they carry their painfully-tight smooth-soled climbing shoes up to the base of the rock, waiting as long as possible before they have to put them on.

Plants of interest on the summit

Sagebrush is the most common shrub of the American West—it covers one third of Wyoming[6]! Two kinds grow on the summit of the Tower: Wyoming big sagebrush and fringed sagebrush. Sagebrush is not related to the sage we use in cooking, but was so named because the aromatic gray-green leaves smell strongly of sage when crushed, or after a rain.

Another common shrub on the summit is skunkbush sumac. Its 3-parted leaves suggest poison ivy, and indeed, the two are close relatives. But this sumac is not at all poisonous. In fact, its twigs have long been used to make a citrus-flavored tea. The appealing fragrance explains the scientific name—*Rhus aromatica*.

Prickly pear cacti grow in dry prairies—like the one on top of Devils Tower. When prickly pear blooms, everyone notices the big beautiful yellow flowers. Otherwise it's drab and easily overlooked—and painful when accidentally bumped, as climbers will attest!

Harebells may look delicate but they're tough, surviving even where there's very little soil. They grow in cracks on the sides of the Tower, and among rocks on top.

One of the most common plants on the summit is rock spikemoss, but it's rarely noticed because it's so small—less than an inch tall (2 cm). This is not a true moss but rather a relative of ferns. Rock spikemoss grows and produces spores during favorable conditions in late spring and summer. Then it lies dry and dormant, looking quite dead as it awaits next spring's moisture.

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[6] Knight, DH, et al. 2014. Mountains and plains; the ecology of Wyoming landscapes, 2nd ed. Yale University Press (p. 109).

Appendix C. Educational material for rock climbers

In the following example, a description of summit vegetation is followed by discussion of vulnerability and conservation.

Caution … Plants Ahead!

What's on top of Devils Tower? A lot more than rock! First-time visitors are surprised to find a dry rocky prairie. Drought-tolerant grasses and shrubs dominate, but there's much more—53 species in all, including wildflowers, cacti and ferns.

Skunkbush sumac and Wyoming big sagebrush are the most common shrubs on the summit.
[photos or illustrations]

Summit grasses include species typical of the Great Plains to the east and the dry steppes to the west—for example needle-and-thread, bluebunch wheatgrass and blue grama.
[illustrations of blue grama and needle-and-thread, with their distinctive seed heads]

In season, wildflowers add flashes of color—yellow violets and cinquefoils, white sand lilies and wild onions, pink four-o'clocks and wavy-leaf thistles, and blue harebells.
[photos of several common wildflowers, perhaps cinquefoils and harebells]

Watch out for cacti! Plains prickly pear is common in dry prairies, and the Tower summit is no exception. In bloom, everyone notices the big beautiful yellow flowers. Otherwise it's drab and easily overlooked—and painful when accidentally bumped.
[photo of prickly pear in bloom]

Plants on the summit are tough, surviving in shallow soil with little shade and minimal water. But they're not immune to disturbance, and recovery is slow in these harsh conditions. Human impact is obvious on the summit trails, especially the one between the top of the Meadows route and the summit cairn and register. No one constructed this trail. Traffic alone removed vegetation and soil.

Fortunately the impact of climber traffic on the summit remains limited, with most areas showing little sign of human use. To keep it this way, the Park Service is stabilizing existing trails,* and asking climbers stay on trails and bare rock whenever possible.

* include if DETO decides to take this step