



Research Article

Additions to the “Martian Flora”: new botanical records from the Mars Desert Research Station, Utah

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Abstract

The Mars Desert Research Station (MDRS) is a Mars-simulation campus set in a Martian planetary analogue in southern Utah. Despite a long history of astrobiology research, collections-based taxonomic inventories of the macro-level biodiversity around the station are relatively new. This study serves to add to the initial vascular plant list published for the station in 2016, where 39 species were recorded for MDRS. Here we report 40 new species, two new taxa recorded only to genus and two species re-identified from our 2016 fieldwork, bringing the total number of taxa in the “Martian” flora to 79 species and two taxa recorded to genus.

Keywords

Floristics, Utah, Mars analogue, botany

Introduction

The Mars Desert Research Station (MDRS) in south-eastern Utah (Fig. 1) is a Mars mission simulation centre owned and operated by the Mars Society in the deserts outside of Hanksville (Persaud et al. 2003). Teams composed of scientists, engineers, medical practitioners, journalists, artists, etc. rotate through this station during one-to-two-week missions, where they work to understand and mitigate the technical and psychological challenges that will come with crewed Martian exploration (Rai and Kaur 2012, Sawyer et al. 2012) and conduct field research to better understand this site as an analogue of our planetary neighbour (Foing et al. 2011).

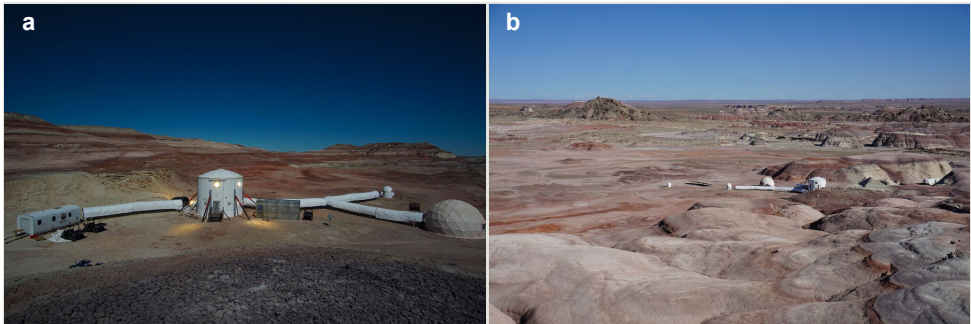


Figure 1.

The Mars Desert Research Station Near Hanksville, Utah. Photos by P.C. Sokoloff.

a: MDRS campus (L to R), the Repair and Maintenance Module (RAMM), the Hab, the GreenHab, the Robotic Observatory and the Science Dome. [doi](#)

b: The analogue environment surrounding MDRS. "Hab Ridge" rises immediately to the right of MDRS and "Phobos Peak" is the hill in the left background. [doi](#)

The deserts surrounding the station, south of the San Rafael Swell, are a true geologic analogue to Mars (Stoker et al. 2011). As such, there is a strong history of astrobiological field campaigns based out of the station, examining the microbial diversity of this unique area and techniques we might use in the search for such life on Mars (Direito et al. 2011, Martins et al. 2011, Thiel et al. 2011). Until recent years, nearly all biological fieldwork at MDRS focused on microbial life; however, in 2014, Crew 143, a Mars Society supported mission, began work to take inventory of the vascular plant, lichen and algal biodiversity of MDRS (Sokoloff et al. 2016).

Though there is a long tradition of floristic work across Utah and there are comprehensive plant lists for many areas near MDRS, like the San Rafael Swell (Harris 1983) and Capitol Reef National Park (Fertig 2009) - see Sokoloff et al. (2016) for a complete synopsis - the work started by Crew 143 was the beginning of a checklist specific to MDRS. In addition to 13 lichen and 6 algae/cyanobacterial taxa, this study recorded 39 vascular plant species for MDRS (reported erroneously as 38 in that paper).

While this initial study provided a baseline to work from, these collections were made primarily in November, when many species might not be conspicuously flowering or fruiting. At that point in the year, annuals or taxa which only spend part of their life cycle above ground (geophytes, for example) might also be overlooked. With 491 taxa recorded for the San Rafael Swell (Harris 1983) and 887 recorded for Capitol Reef National Park (Fertig 2009), it is highly likely that many species that do occur in the MDRS area were not apparent to Crew 143 or not in a phenological state where a collection would have led to a definitive identification.

Crew 143 also operated as a Mars-mission simulation, where trips outside of the main station campus (the Hab) were tightly controlled as simulated extra-vehicular activities (EVAs). On these excursions, crews were limited to exploring pre-approved sites, with a small team for a short amount of time (to simulate the constraints of working on Mars), reducing the amount of botanical exploration time available to the team. Additionally, the crew was required to wear simulated spacesuits while outside the hab, reducing visibility and dexterity while collecting. While all these conditions serve as a realistic learning opportunity about how to undertake field science on another world, it likely reduced the number of taxa recorded during the rotation.

The objective of our current study is to continue to develop the vascular plant checklist for MDRS by filling in collecting gaps caused by the above limitations. By re-collecting previously explored sites in the spring (rather than late autumn), we aim to fill in phenological gaps in our existing dataset. By botanising new locations and microhabitats across the MDRS exploration area in a non-simulation mission, with a crew made up predominantly of biologists, we hope to add new vascular plant taxa to the "Martian" flora.

Materials and Methods

Crew 210, our biodiversity survey group, worked out of MDRS between 13-20 April 2019. During this week, our team made 63 vascular plant collections from 13 sites across the MDRS exploration area (Fig. 2, Table 1). We also made two new lichen collections (*Sokoloff et al. 1264* and *Sokoloff et al. 1323*) which are not treated in this manuscript.

At each sampling site, we surveyed the vegetation by searching various microhabitats on foot, seeking out plant taxa not previously documented from the station in Sokoloff et al. (2016). These plants were photographed *in situ* (where possible), dug up by the roots and placed in a plastic bag for transport back to MDRS, where they were pressed in the station's lab. Field notes - including coordinates, locality and habitat descriptions and a list of associated taxa - were recorded for each site for eventual transcription into specimen labels.

These herbarium specimens were identified using various literature sources, including the Flora of North America (Flora of North America Editorial Committee, eds. 1993), A Utah Flora (Welsh et al. 1993), the Atlas of North American *Astragalus* (Barneby 1964) and other publications as referenced in the annotated checklist below. A complete set of these

voucher specimens have been deposited at the National Herbarium of Canada (CAN) at the Canadian Museum of Nature and duplicate specimens (as indicated in the specimen citations below) have been deposited at: the Intermountain Herbarium at the University of Utah (UTC), the Herbar Marie-Victorin at the Université de Montréal (MT) and the National Collection of Vascular Plants at Agriculture and Agri-Food Canada (DAO).

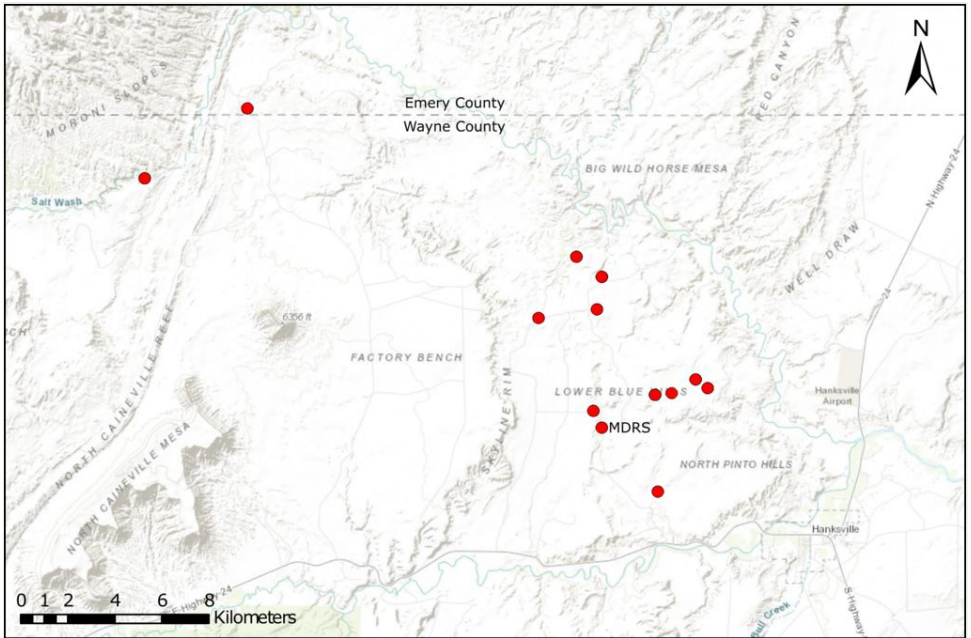


Figure 2. [doi](#)
Collecting sites for the 2019 fieldwork carried out by Crew 210. Map Data: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) Open Street Map contributors and the GIS User Community.

Table 1.
Collection Sites for Crew 210

Collection Numbers	Date	Locality	Coordinates	Habitat
1260-1264	14 April 2019	Emery County, "Valley of the Stars", 16 km from Highway 24 along Factory Bench Road.	38°30'6.48"N, 110°55'37.44"W	Sandstone bluffs with <i>Atriplex gardneri</i> , <i>Dasyochloa pulchella</i> , <i>Ephedra viridis</i> , <i>Artemisia tridentata</i> .

Collection Numbers	Date	Locality	Coordinates	Habitat
1265-1270	14 April 2019	Wayne County, Salt Wash at the end of Factory Bench Road, 20 km from Highway 24.	38°28'51.3"N, 110°57'58.62"W	Sandy shoreline of Salt Creek, dominated by <i>Tamarix ramosissima</i> and <i>Ericameria nauseosa</i> .
1271-1279	14 April 2019	Wayne County, area just south of Burpee Dinosaur Quarry at the end of Cow Dung Road, 5 km N of the Mars Desert Research Station.	38°27'5.42"N, 110°47'30.74"W	Sandy plains dominated by <i>Allium textile</i> , <i>Gutierrezia sarothrae</i> , <i>Ephedra viridis</i> .
1280-1291	16 April 2019	Wayne County, west side of Bureau of Land Management Road 1104, 2 km NE of the Mars Desert Research Station.	38°24'58.28"N, 110°46'17.4"W	Sandy plains dominated by <i>Artemisia filifolia</i> and <i>Scabrethia scabra</i> .
1292-1295, 1323	16 April 2019	Wayne County, south side of Bureau of Land Management Road 1104, 3.5 km NE of the Mars Desert Research Station.	38°25'14.84"N, 110°45'22.07"W	Rocky desert plain with basalt ejecta, with <i>Atriplex</i> sp. and <i>Sporobolus</i> sp.
1296-1300	16 April 2019	Wayne County, sandy wash south of Bureau of Land Management Road 1104, 3.75 km NE of the Mars Desert Research Station.	38°25'5.5"N, 110°45'5.5"W	Sheltered, sandy wash in rocky valley, with <i>Ericameria nauseosa</i> and <i>Artemisia tridentata</i> .
1301	16 April 2019	Wayne County, south side of Bureau of Land Management Road 1104, 3.5 km NE of the Mars Desert Research Station.	38°25'0.2"N, 110°45'54.4"W	Rocky desert plain with basalt ejecta, with <i>Atriplex</i> sp. and <i>Sporobolus</i> sp.
1302-1306	17 April 2019	Wayne County, east side of Cow Dung Road, on a ridge just east of turnoff onto Bureau of Land Management Road 1572, 4 km N of the Mars Desert Research Station	38°26'30.2"N, 110°47'37.3"W	Rocky ridge with <i>Atriplex</i> sp.
1307-1309	17 April 2019	Wayne County, crossroads of Bureau of Land Management Road 1572 and 1575, 4 km NW of the Mars Desert Research Station.	38°26'21.2"N, 110°48'57.6"W	Clay Mancos Shale ridge with <i>Atriplex corrugata</i> .
1310-1314	17 April 2019	Wayne County, "Copernicus Valley" along Bureau of Land Management Highway 0157, 5.7 km NW of the Mars Desert Research Station.	38°27'26.9"N, 110°48'5.5"W	Silty clay flats with <i>Sarcobatus vermiculatus</i> .

Collection Numbers	Date	Locality	Coordinates	Habitat
1315-1317	17 April 2019	Wayne County, "Hab Ridge", sandstone ridge at edge of Lower Blue Hills, immediately west of the Mars Desert Research Station.	38°24'40.9"N, 110°47'42.4"W	Dakota Sandstone/Mancos Shale substrate with <i>Aristida purpurea</i> and <i>Gutierrezia sarothrae</i> .
1317b-1319	17 April 2019	Wayne County, North Pinto Hills, desert flats immediately east of Cow Dung Road, 1.75 km N of Highway 24.	38°23'13.97"N, 110°46'13.51"W	Flat sandy plains dominated by <i>Allium textile</i> and <i>Sarcobatus vermiculatus</i> .
1320-1322	17 April 2019	Wayne County, area immediately surrounding the Mars Desert Research Station.	38°24'22.71"N, 110°47'30.79"W	Red clay flats.

Results

Of the 63 collections made by Crew 210, 12 were of taxa previously recorded from MDRS (Sokoloff et al. 2016), while the rest were vouchers for taxa newly recorded for the area (for our complete collection dataset, see Suppl. material 1). In addition to these specimens, we photo-documented one new species and two new genera for the study area, for a total of 42 newly-reported taxa for MDRS below the family level. Table 2 summarises these new records according to the linear sequence proposed by APG IV (The Angiosperm Phylogeny Group 2016); in the annotated checklist following, these taxa are listed alphabetically by family and species. Two Cactaceae specimens collected in 2016 have since been re-identified are also reported in the annotated checklist below.

The collecting sites visited during our rotation included a wider variety of habitats than our previous work in 2014, owing to the fact that Crew 210 was not working within the restraints of a Martian surface mission simulation and, therefore, had wider latitude to visit more sites each day and to go further afield. While complete habitat descriptions for all collecting sites can be found in Table 1, selected habitats are described below to illustrate a sample of the habitat diversity around the station.

In Emery county, north of MDRS, Factory Bench Road cuts through the "Valley of the Stars" (Fig. 3a), a gravelly scree slope with extensive gypsum deposits scattered across the eroded sandstone desert surface, where the minimal vegetative cover was dominated by *Artemisia tridentata*, *Ephedra viridis* and *Dasyochloa pulchella*. Further along the road, back in Wayne County, on the sandy shoreline of Salt Wash, a sheltered valley and water availability provide a sheltered microclimate where invasive *Tamarix ramosissima* and native *Ericameria nauseosa* thrive (Fig. 3b).

In Wayne County, east of the station, a sheltered, sandy wash provides adequate substrate and microclimate to host a unique local flora, including larger shrubs like *Rhus trilobata*

subsp. *trilobata* and *Populus fremontii* subsp. *fremontii* (Fig. 3c). North of the station "Copernicus Valley" is a dry river valley with silty soils that host annual species like *Cleomella palmeriana* and *Phacelia demissa* var. *demissa*, alongside shrubby *Sarcobatus vermiculatus* (Fig. 3d). Immediately west of the station, "Hab Ridge" rises above MDRS, where a compacted capstone layer of the Dakota Sandstone formation is dominated by grasses (*Aristida purpurea*, for example) and shrubby species like *Gutierrezia sarothrae* (Fig. 3e, f).

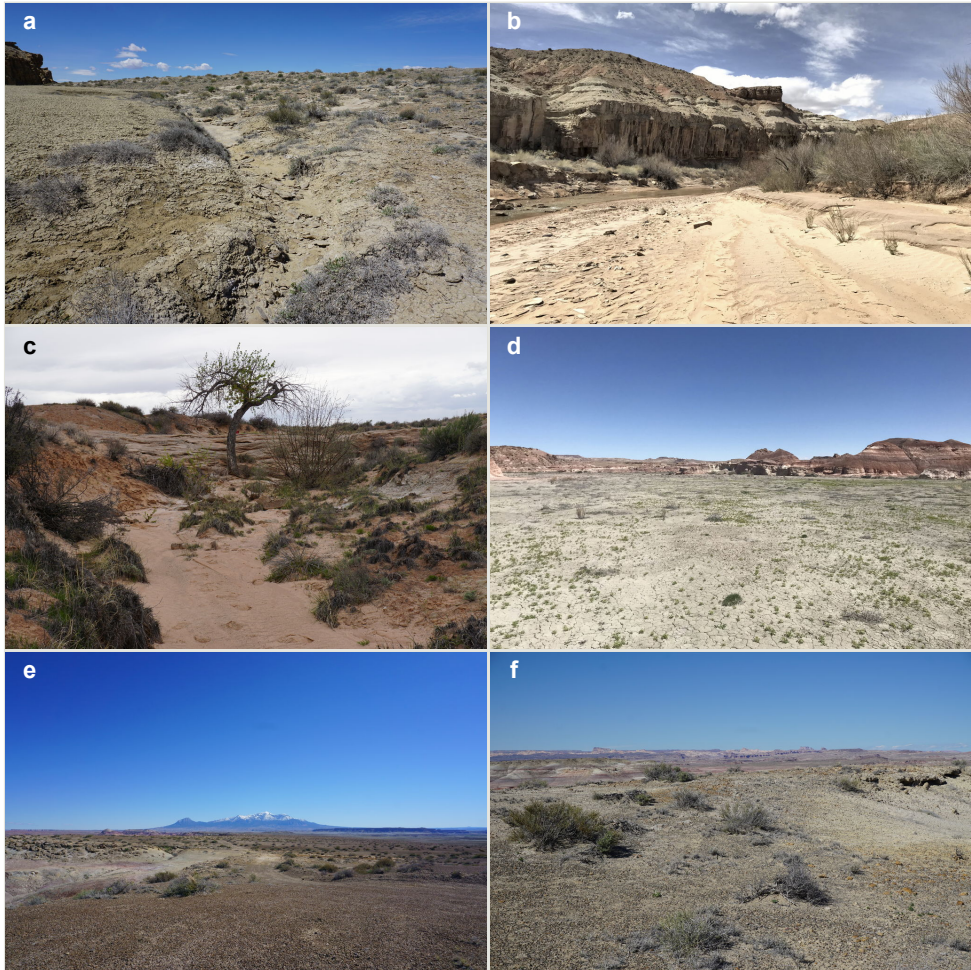


Figure 3.

Habitats sampled in the MDRS Area. Photos by P.C. Sokoloff.

- a: Valley of the Stars, Emery County (Sokoloff et al. 1260-1264). [doi](#)
- b: Salt Wash, Wayne County (Sokoloff et al. 1265-1270). [doi](#)
- c: Sandy wash, Wayne County (Sokoloff et al. 1296-1300). [doi](#)
- d: "Copernicus Valley", Wayne County (Sokoloff et al. 1310-1314). [doi](#)
- e: "Hab Ridge", Wayne County (Sokoloff et al. 1315-1317). [doi](#)
- f: "Hab Ridge", Wayne County (Sokoloff et al. 1315-1317). [doi](#)

Table 2. New plant taxa documented by Crew 210 for the Mars Desert Research Station area, arranged according to the APG IV linear sequence. Taxa with an asterisk* were photo-documented only.			
monocots	Asparagales	Amaryllidaceae	<i>Allium macropetalum</i> Rydb
		Asparagaceae	<i>Eremocrinum albomarginatum</i> (M.E.Jones) M.E.Jones
			<i>Yucca harrimaniae</i> Trel.
	Poales	Poaceae	<i>Eremopyrum triticeum</i> (Gaertn.) Nevski
			<i>Vulpia octoflora</i> (Walter) Rydb. var. <i>octoflora</i>
eudicots	Fabales	Fabaceae	<i>Astragalus mollissimus</i> var. <i>thompsoniae</i> (S. Watson) Barneby
			<i>Astragalus pardalinus</i> (Rydb.) Barneby
			<i>Astragalus praelongus</i> E. Sheld.
			<i>Astragalus woodruffii</i> M.E. Jones
			<i>Hoffmannseggia repens</i> (Eastw.) Cockerell
			<i>Lupinus pusillus</i> Pursh
	Malpighiales	Salicaceae	<i>Populus fremontii</i> S. Watson subsp. <i>fremontii</i>
	Myrtales	Onagraceae	<i>Camissonia eastwoodiae</i> (Munz) P.H. Raven
			<i>Oenothera pallida</i> Lindl.
	Sapindales	Anacardiaceae	<i>Rhus trilobata</i> Nutt. var. <i>trilobata</i>
	Brassicales	Cleomaceae	<i>Cleomella palmeriana</i> M.E. Jones
		Brassicaceae	<i>Chorispora tenella</i> (Pall.) DC.*
			<i>Descurainia pinnata</i> subsp. <i>brachycarpa</i> (Richardson) Detling
			<i>Stanleya pinnata</i> (Pursh) Britton var. <i>pinnata</i>
			<i>Streptanthella longirostris</i> (S.Watson) Rydb.
			<i>Strigosella africana</i> (L.) Botsch.
	Caryophyllales	Polygonaceae	<i>Eriogonum gordonii</i> Benth.
			<i>Eriogonum wetherillii</i> Eastw.
		Amaranthaceae	<i>Atriplex argentea</i> Nutt.
			<i>Atriplex canescens</i> (Pursh) Nutt. var. <i>canescens</i>
			<i>Blitum nuttallianum</i> Schult.
		Nyctaginaceae	<i>Abronia elliptica</i> A. Nelson
	Cactaceae	Cactaceae	<i>Pediocactus</i> Britton & Rose*
			<i>Sclerocactus</i> Britton & Rose*
	Cornales	Loasaceae	<i>Mentzelia pterosperma</i> Eastw.

Boraginales	Boraginaceae	<i>Cryptantha crassisejala</i> var. <i>elachantha</i> I.M. Johnst.
		<i>Oreocarya flava</i> A.Nelson
		<i>Oreocarya flavoculata</i> A. Nelson
		<i>Phacelia corrugata</i> A. Nelson
		<i>Phacelia demissa</i> A. Gray var. <i>demissa</i>
		<i>Tiquilia latior</i> (I.M. Johnston) A. Richards.
Asterales	Asteraceae	<i>Chaenactis stevioides</i> Hook. & Arn.
		<i>Malacothrix sonchoides</i> (Nutt.) Torr. & A. Gray
		<i>Prenanthes exigu</i> a (A. Gray) Rydb.
		<i>Tetradymia glabrata</i> Torr. & A. Gray
Dipsacales	Caprifoliaceae	<i>Symphoricarpos longiflorus</i> Gray.
Apiales	Apiaceae	<i>Cymopterus glomeratus</i> (Nutt.) Raf.

Annotated Checklist of New Vascular Plant Taxa

All vascular plant collections made by Crew 210 are included in the checklist below, which is arranged alphabetically by family and then species. Taxa previously collected at MDRS and recollected in 2019, are briefly listed under the family name. Taxa new to MDRS are listed under their own header, which includes the collection numbers corresponding to the species vouchers, any relevant notes about taxonomy, identification, and distribution, and if the taxon is present in one of four complete floristic inventories of locations close to MDRS: the San Rafael Swell (Harris 1983), Capitol Reef National Park (Fertig 2009), Glen Canyon National Recreation Area (Hill and Ayers 2009) and the Orange Cliffs region (Shultz et al. 1987).

Amaranthaceae

We documented three new species in one new genus and one previously-documented genus for the MDRS area. We also made collections of species previously known from the station, including: *Atriplex confertifolia* (Torr. & Frém.) S. Wats. (Sokoloff et al. 1317 [Fig. 4a], 1322), *Atriplex gardneri* var. *cuneata* (A. Nelson) S.L. Welsh (Sokoloff et al. 1281, 1302) and *Kali tragus* (L.) Scop. (Sokoloff et al. 1310).

Atriplex argentea Nutt.

Specimen Examined: Utah, Wayne County: Sokoloff et al. 1314 (CAN).

Found growing in silty sediment in Copernicus Valley, this species has been reported from Capitol Reef National Park (as var. *argentea*) (Fertig 2009), as uncommon in the San Rafael Swell (Harris 1983) and as uncommon in Glen Canyon National Recreation Area

(Hill and Ayers 2009). Based on leaf shape, this specimen may be var. *rydbergii* following Welsh (2003), but as this collection is immature, we have only identified it to species.



Figure 4.

Amaranthaceae, Amaryllidaceae, Anacardiaceae, and Apiaceae. Photos by P.C. Sokoloff.

a: *Atriplex confertifolia*, branches and infructescence (Sokoloff et al. 1317). [doi](#)

b: *Blitum nuttallianum*, habit (Sokoloff et al. 1320). [doi](#)

c: *Allium macropetalum* (Sokoloff et al. 1319). [doi](#)

d: *Rhus trilobata* var. *trilobata*, leaf detail (Sokoloff et al. 1297). [doi](#)

e: *Rhus trilobata* var. *trilobata*, inflorescences (Sokoloff et al. 1297). [doi](#)

f: *Cymopterus glomeratus*, inflorescence (Sokoloff et al. 1273). [doi](#)

Atriplex canescens* (Pursh) Nutt. var. *canescens

Specimen Examined: Utah, Wayne County: *Sokoloff et al.* 1318 (CAN).

This shrub is widespread throughout Utah's deserts (Welsh 2003) and is common in the San Rafael Swell (Harris 1983), present in Capitol Reef National Park (Fertig 2009) and present in the Orange Cliffs region (Shultz et al. 1987). The nominate variety, var. *canescens*, is widespread throughout the species range, following Welsh (2003). In southern Utah and around MDRS, this species is distinguished by its four-winged fruiting bracteoles (Andersen 1996).

***Blitum nuttallianum* Schult.**

Specimen Examined: Utah, Wayne County: *Sokoloff et al.* 1320 (CAN, UTC).

This native annual species is commonly found on wetter, sub-alkaline clay (Holmgren 2003). This species was only recorded from the MDRS area in the immediate vicinity of the Hab, in lower areas where precipitation might accumulate in wet months (Fig. 4b). This species was previously recorded as occasional in the San Rafael Swell (Harris 1983), present in Capitol Reef National Park (Fertig 2009) and occasional in Glen Canyon National Recreation Area (Hill and Ayers 2009) as *Monolepis nuttalliana* (Schult.) Greene; however, recent phylogenetic work places this species in *Blitum* L. (Fuentes-Bazan et al. 2012).

Amaryllidaceae

We documented one new species in one new genus for the MDRS area.

***Allium macropetalum* Rydb**

Specimens Examined: Utah, Wayne County: *Sokoloff et al.* 1271 (CAN); 1319 (CAN).

A common sight in the MDRS area (Fig. 4c), this species can be distinguished from the sympatric (and closely-related) *Allium textile* A.Nelson & J.F.Macbr. by its 3-5-veined spathe bracts (as opposed to 1-veined in *A. textile*) (McNeal and Jacobsen 2002). This species has been previously reported from Capitol Reef National Park (Fertig 2009), as uncommon in Glen Canyon National Recreational Area (Hill and Ayers 2009) and uncommon in the San Rafael Swell (Harris 1983).

Anacardiaceae

We documented one new species in one new genus for the MDRS area.

Rhus trilobata* Nutt. var. *trilobata

Specimen Examined: Utah, Wayne County: *Sokoloff et al.* 1297 (CAN, UTC).

This taxon was only encountered in the sheltered sandy wash south of BLM road 1104, with a unique local vegetation including *Populus fremontii* subsp. *fremontii* and *Symphoricarpos longiflorus* (Fig. 4d, e). Recorded as common in washes and roadsides in the San Rafael Swell (Harris 1983), the protected valley in the wash likely provides a warmer and less windy environment, providing an ideal microhabitat for multiple species not seen elsewhere near MDRS. This taxon has also been recorded from Capitol Reef National Park - as *Rhus aromatica* var. *trilobata* (Nutt.) A. Gray - (Fertig 2009) and as common in Glen Canyon National Recreation Area (Hill and Ayers 2009).

Apiaceae

We documented one new species in one new genus for the MDRS area.

Cymopterus glomeratus (Nutt.) Raf.

Specimen Examined: Utah, Wayne County: *Sokoloff et al.* 1273 (CAN, UTC).

This species was occasionally encountered throughout the MDRS area (Fig. 4f). This variable species has been reported from Capitol Reef National Park (Fertig 2009), as occasionally occurring in Glen Canyon National Recreation Area (Hill and Ayers 2009) (in both locations as *Cymopterus acaulis* var. *fendleri* (A. Gray) Goodrich), as present in the Orange Cliffs (Shultz et al. 1987) and common in the San Rafael Swell (Harris 1983) (in both locations as *Cymopterus fendleri* A. Gray). Current taxonomic concepts place both *C. acaulis* (including var. *fendleri*) and *C. fendleri* in *C. glomeratus* (Sun et al. 2005).

Asparagaceae

We documented two new species in two new genera for the MDRS area.

Eremocrinum albomarginatum (M.E.Jones) M.E.Jones

Specimen Examined: Utah, Wayne County: *Sokoloff et al.* 1289 (CAN, UTC).

This monotypic species was encountered sporadically on sandy soils east of MDRS (Fig. 5a). Endemic to the Colorado Plateau in southeast Utah and northern Arizona (Reveal and Utech 2002), this species has been reported from the San Rafael Swell, where it is common (Harris 1983), as present in Capitol Reef National Park (Fertig 2009) and from Glen Canyon National Recreation Area (Hill and Ayers 2009), where it is uncommon.

Yucca harrimaniae Trel.

Specimen Examined: Utah, Wayne County: *Sokoloff et al.* 1298 (CAN).

This species was encountered infrequently, only on the top of "Hab Ridge" and in the sandy wash south of BLM road 1104 (Fig. 5b, c, d). Following Neese and Welsh (1985), these plants would be considered var. *harrimaniae*; however, recent treatments do not

recognise varieties within this species (Hess and Robbins 2002). This species has been reported as common in the San Rafael Swell (Harris 1983), uncommon in Glen Canyon National Recreation Area (Hill and Ayers 2009) and present in Capitol Reef National Park (as var. *harrimaniae*) (Fertig 2009).

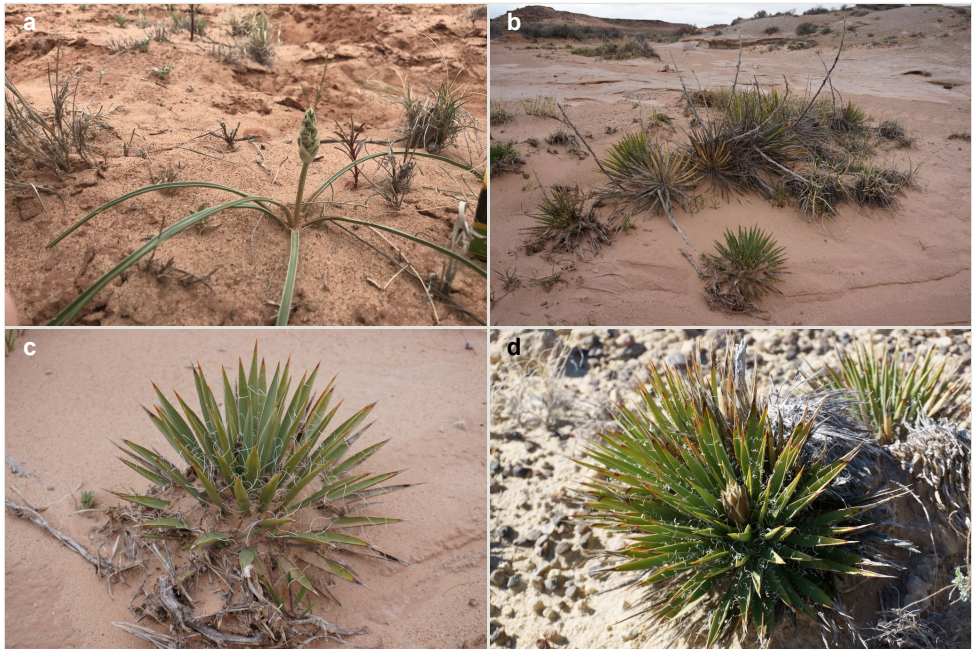


Figure 5.

Asparagaceae. Photos by P.C. Sokoloff.

a: *Eremocrinum albomarginatum*, habit (Sokoloff et al. 1289). [doi](#)

b: *Yucca harrimaniae*, habitat (Sokoloff et al. 1298). [doi](#)

c: *Yucca harrimaniae*, habit (Sokoloff et al. 1298). [doi](#)

d: *Yucca harrimaniae*, developing inflorescence ("Hab Ridge" west of MDRS). [doi](#)

Asteraceae

We documented four new species from four new genera for the MDRS area. We also made collections of species previously documented at the station, including: *Gaillardia spathulata* A. Gray (Sokoloff et al. 1267) and *Thelesperma subnudum* A. Gray (Sokoloff et al. 1283).

Chaenactis stevioides Hook. & Arn.

Specimen Examined: Utah, Wayne County: Sokoloff et al. 1293 (CAN, UTC).

This species was not yet flowering when collected during our field season, but the characteristically hairy, dissected leaves made identification relatively straightforward

(Morefield 2006). Found across the southwest United States (Andersen 1996), it is common in the San Rafael Swell (Harris 1983), present in Capitol Reef National Park (Fertig 2009), present in the Orange Cliffs area (Shultz et al. 1987) and widespread in Glen Canyon National Recreation Area (Hill and Ayers 2009). This species, along with its congener *Chaenactis fremontii* Gray, is believed to have arisen from independent aneuploid reduction events in *C. gabriuscula* DC. (Kyhos 1965).

***Malacothrix sonchoides* (Nutt.) Torr. & A. Gray**

Specimen Examined: Utah, Wayne County: Sokoloff et al. 1277 (CAN, UTC).

While our specimen was not flowering at the time of collection (Fig. 6a), we were able to identify this annual species on the basis of the species' distinctive leaf morphology (David 2006). It is common in the San Rafael Swell (Harris 1983), present in Capitol Reef National Park (Fertig 2009) and occasional in Glen Canyon National Recreation Area (Hill and Ayers 2009).



Figure 6.

Asteraceae. Photos by P.C. Sokoloff.

a: *Malacothrix sonchoides*, basal rosette (Sokoloff et al. 1277). [doi](#)

b: *Prenanthes exigua*, habit (Sokoloff et al. 1306). [doi](#)

c: *Tetradymia glabrata*, habit (Sokoloff et al. 1316). [doi](#)

d: *Tetradymia glabrata*, leaf detail (Sokoloff et al. 1316). [doi](#)

***Prenanthes exigua* (A. Gray) Rydb.**

Specimens Examined: Utah, Emery County: *Sokoloff et al.* 1263 (CAN). Wayne County: *Sokoloff et al.* 1306 (CAN).

These young specimens possess toothed, black-spotted basal leaves which appear to be uncommon in the species (Fig. 6b); neither species accounts in the Flora of North America (Chambers 2006) nor A Utah Flora (Welsh et al. 1993) mention this trait and a search online ([SEINet](#)) only found two specimens with similar colouration (*Lehto* 23527 [ASU 0103025] and *Williams* 83-56-14 [NESH 81108]). It is reported as common in the San Rafael Swell (Harris 1983), present in Capitol Reef National Park (Fertig 2009), occasional in the Glen Canyon National Recreation Area (Hill and Ayers 2009) and present in the Orange Cliffs region (Shultz et al. 1987). Previously treated as *Lygodesmia exigua* A. Gray, Spencer Tomb (1972) re-established the species in *Prenanthes* (following Rydberg), based on chromosome number and pollen morphology. Molecular work by Lee et al. (2002) found this species to form a clade with *Pleiocanthus spinosus* (Nutt.) Rydb., another species formerly placed in *Lygodesmia*.

***Tetradymia glabrata* Torr. & A. Gray**

Specimen Examined: Utah, Wayne County: *Sokoloff et al.* 1316 (CAN, UTC).

Common in the San Rafael Swell (Harris 1983) and present in Capitol Reef National Park (Fertig 2009), this taxon is readily distinguished from other *Tetradymia* species in southern Utah by its spreading, club-shaped, glabrous secondary leaves (Fig. 6c, d) (Strother 1974, Strother 2006). This species is known to cause liver toxicity in livestock (Jennings et al. 1978).

Boraginaceae

We documented six new species in three new genera and one previously-documented genus for the MDRS area.

***Cryptantha crassisejala* var. *elachantha* I.M. Johnst.**

Specimen Examined: Utah, Wayne County: *Sokoloff et al.* 1276 (CAN, UTC).

Variety *elachantha* is the more common infraspecific taxon of this annual species (Johnston 1959) and is the only variety present in Utah (Welsh et al. 1993). This taxon is common in the San Rafael Swell (Harris 1983), widespread in Glen Canyon National Recreation Area (Hill and Ayers 2009), present in Capitol Reef National Park (Fertig 2009) and present in the Orange Cliffs region as *Cryptantha crassisejala* s.l. (Shultz et al. 1987). This taxon is common throughout the MDRS operational area (Fig. 7a, b).



Figure 7.

Boraginaceae. Photos by P.C. Sokoloff.

a: *Cryptantha crassisejala* var. *elachantha*, habit (Sokoloff et al. 1276). [doi](#)

b: *Cryptantha crassisejala* var. *elachantha*, inflorescence (Sokoloff et al. 1276). [doi](#)

c: *Oreocarya flava*, habit (Sokoloff et al. 1275). [doi](#)

d: *Oreocarya flava*, inflorescence (Sokoloff et al. 1291). [doi](#)

e: *Oreocarya flavoculata*, habit (Sokoloff et al. 1268). [doi](#)

f: *Oreocarya flavoculata*, inflorescence (Sokoloff et al. 1268). [doi](#)

Oreocarya flava A.Nelson

Specimens Examined: Utah, Wayne County: Sokoloff et al. 1275 (CAN, UTC); 1291 (CAN, UTC).

Common throughout southeast Utah (Higgins 1971, Payson 1927), this yellow-flowered species is distinctive in the MDRS area (Fig. 7c, d). Previously placed in *Cryptantha*, recent phylogenetic work has shown that genus to be polyphyletic and resurrected several genera previously submerged into *Cryptantha* as sections or subgenera (Hasenstab-Lehman and Simpson 2012, Mabry and Simpson 2018).

As *Cryptantha flava* (A. Nelson) Payson, this species has been reported as common in the San Rafael Swell (Harris 1983) and Glen Canyon National Recreation Area (Hill and Ayers 2009), as present in Capitol Reef National Park (Fertig 2009) and present in the Orange Cliffs region (Shultz et al. 1987).

***Oreocarya flavoculata* A. Nelson**

Specimen Examined: Utah, Wayne County: *Sokoloff et al. 1268* (CAN, UTC).

Only encountered once in the MDRS area near Salt Wash (Fig. 7e, f), this species is common in the southwest United States (Higgins 1971). This species was also formerly placed in *Cryptantha*, until recent phylogenetic work confirmed the monophyly of *Oreocarya* (Hasenstab-Lehman and Simpson 2012, Mabry and Simpson 2018). This species is present in the Orange Cliffs Region (Shultz et al. 1987), occasional in Glen Canyon National Recreation Area (Hill and Ayers 2009), present in Capitol Reef National Park (Fertig 2009) and common in the San Rafael Swell (Harris 1983).

***Phacelia corrugata* A. Nelson**

Specimens Examined: Utah, Emery County: *Sokoloff et al. 1260* (CAN, UTC). Wayne County: *Sokoloff et al. 1309* (CAN, UTC).

This species was encountered occasionally on rocky hilltops and raised clay swells in the MDRS area (Fig. 8a, b, c). Previously treated as *Phacelia crenulata* var. *corrugata* (A. Nelson) Brand (Welsh et al. 1993), molecular evidence supports the recognition of this taxon at the species level (Walden et al. 2014, Walden et al. 2016). This species is common in the San Rafael Swell (Harris 1983) and common in Glen Canyon National Recreation Area (Hill and Ayers 2009). *Phacelia crenulata* Torr. ex S. Watson is reported as present in the Orange Cliffs region (Shultz et al. 1987), though their taxonomic concept may have included *P. corrugata*.

Phacelia demissa* A. Gray var. *demissa

Specimens Examined: Utah, Wayne County: *Sokoloff et al. 1308* (CAN); *1312* (CAN, UTC).

Common on the silty flats of Copernicus Valley and on clay formations around the MDRS area (Fig. 8d, e), this species is endemic to the Four Corners States and Wyoming (Soreng et al. 1984). This taxon is present in Capitol Reef National Park (Fertig 2009), common in Glen Canyon National Recreation Area (Hill and Ayers 2009) and occasional in the San

Rafael Swell (Harris 1983). Harris (1983) also reported *Phacelia demissa* var. *heterotricha* J.T. Howell from the San Rafael Swell; however, that variety is now considered a synonym of var. *demissa* (Welsh et al. 1993). *Phacelia demissa* var. *minor* N.D. Atwood is found outside the MDRS area in the Uintah Basin (Welsh et al. 1993).

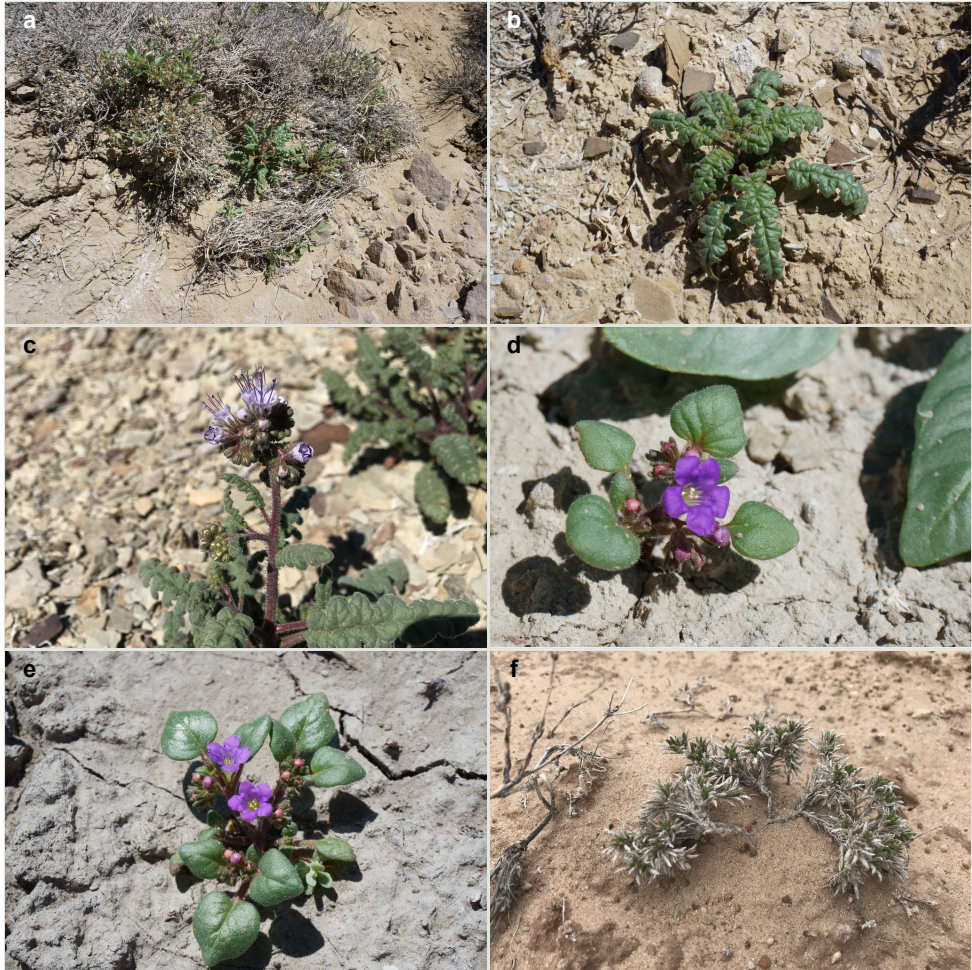


Figure 8.

Boraginaceae. Photos by P.C. Sokoloff.

a: *Phacelia crenulata* var. *corrugata*, habitat (Sokoloff et al. 1260). [doi](#)

b: *Phacelia crenulata* var. *corrugata*, habit (Sokoloff et al. 1260). [doi](#)

c: *Phacelia crenulata* var. *corrugata*, inflorescence (Sokoloff et al. 1309). [doi](#)

d: *Phacelia demissa* var. *demissa*, inflorescence (Sokoloff et al. 1308). [doi](#)

e: *Phacelia demissa* var. *demissa*, habit (Sokoloff et al. 1312). [doi](#)

f: *Tiquilia latior*, habit (Sokoloff et al. 1290). [doi](#)

***Tiquilia latior* (I.M. Johnston) A. Richards.**

Specimen Examined: Utah, Wayne County: *Sokoloff et al.* 1290 (CAN).

Only encountered once in the MDRS area on sandy plains (Fig. 8f), this species is endemic to the south-western United States and is found in Utah, Arizona and Nevada (Higgins 1979, Moore and Jansen 2007). This species is present in Capitol Reef National Park (Fertig 2009), common in Glen Canyon National Recreation Area (Hill and Ayers 2009) and occasional in the San Rafael Swell (Harris 1983).

Brassicaceae

We documented four new species from four new genera for the MDRS area. We also made a collection of a species previously known from the station: *Lepidium montanum* Nutt. (*Sokoloff et al.* 1304).

***Chorispora tenella* (Pall.) DC.**

This invasive weed was photographed (Fig. 9) in the vicinity of the Burpee Dinosaur Quarry north of MDRS, but was not collected at that time. It is common across the western United States (Rollins 1980) where it readily grows in disturbed areas, fields and along roadsides (Al-Shehbaz 2010d). This species has been reported from Capitol Reef National Park (Fertig 2009) and as uncommon in the San Rafael Swell (Harris 1983).

***Descurainia pinnata* subsp. *brachycarpa* (Richardson) Detling**

Specimens Examined: Utah, Emery County: *Sokoloff et al.* 1262 (CAN, UTC). Wayne County: *Sokoloff et al.* 1303 (CAN).

Widespread throughout much of North America (Goodson and Al-Shehbaz 2010), this species was encountered sporadically on rocky ridges and hilltops (Fig. 9). *Descurainia pinnata* (not determined to subspecies) is reported as common in Glen Canyon National Recreation Area (Hill and Ayers 2009) and present in the Orange Cliffs Region (Shultz et al. 1987), while this taxon is reported as uncommon in the San Rafael Swell (Harris 1983) and present in Capitol Reef National Park (Fertig 2009) as *Descurainia pinnata* var. *intermedia* (Rydberg) C. L. Hitchcock - a synonym of subsp. *brachycarpa* (Goodson and Al-Shehbaz 2010).

Stanleya pinnata* (Pursh) Britton var. *pinnata

Specimen Examined: Utah, Wayne County: *Sokoloff et al.* 1266 (CAN).

This well-known selenophyte (Feist and Parker 2001) was only encountered once in the MDRS area, near Salt Wash. Delimitation of varieties in this species has changed through time (Rollins 1939, Lichvar 1983, Turner 2004); here we follow Al-Shehbaz (2010a). This taxon is reported as widespread in Glen Canyon National Recreation Area (Hill and Ayers

2009). *Stanleya pinnata* is reported from the Orange Cliffs region (Shultz et al. 1987) and Capitol Reef National Park (Fertig 2009) and as common in the San Rafael Swell (Harris 1983).



Figure 9.

Brassicaceae. Photos by P.C. Sokoloff.

- a:** *Chorispora tenella*, habit (vicinity of Burpee Dinosaur Quarry). [doi](#)
- b:** *Descurainia pinnata* subsp. *brachycarpa*, inflorescence (Sokoloff et al. 1262). [doi](#)
- c:** *Descurainia pinnata* subsp. *brachycarpa*, habit (Sokoloff et al. 1262). [doi](#)
- d:** *Streptanthella longirostris*, inflorescence (Sokoloff et al. 1261). [doi](#)
- e:** *Streptanthella longirostris*, habit (Sokoloff et al. 1261). [doi](#)
- f:** *Strigosella africana*, habit (Sokoloff et al. 1278). [doi](#)

***Streptanthella longirostris* (S.Watson) Rydb.**

Specimen Examined: Utah, Emery County: *Sokoloff et al.* 1261 (CAN).

This specimen is common in the MDRS area (Fig. 9d, e) and across the south-western United States (Al-Shehbaz 2010c). Phylogenetic work that includes this currently monotypic genus has shown that it is not monophyletic and that future taxonomic revision may be required (Ivalú Cacho et al. 2014). This species is present in the Orange Cliffs region (Shultz et al. 1987), widespread in Glen Canyon National Recreation Area (Hill and Ayers 2009), present in Capitol Reef National Park (Fertig 2009) and common in the San Rafael Swell (Harris 1983).

***Strigosella africana* (L.) Botsch.**

Specimens Examined: Utah, Wayne County: *Sokoloff et al.* 1269 (CAN, UTC); 1278 (CAN, UTC).

Commonly seen across the MDRS area (Fig. 9f), this invasive weed proliferates in disturbed areas across the western United States (Al-Shehbaz 2010b, Rollins 1980). This species has been reported as common in the San Rafael Swell (Harris 1983), present in Capitol Reef National Park (Fertig 2009) and as occasional in Glen Canyon Recreation Area (Hill and Ayers 2009). This species was recorded in these inventories as *Malcolmia africana* (L.) W.T. Aiton; however, it is now placed in *Strigosella* (Al-Shehbaz et al. 2014, Botschantzev 1972).

Cactaceae

While conducting fieldwork at MDRS, Crew 210 occasionally encountered populations of small barrel cacti, consistent with members of the Cactaceae subfamily Cactoidae (Parfitt and Gibson 2003). Several species within this subfamily are known to occur within the San Rafael Swell and nearby Capitol Reef National Park (Fertig 2009, Harris 1983), at least two of which are listed as endangered species by the U.S. Federal Government (Fertig 2009). Therefore, we did not collect these species, but rather photo-documented these populations and examined them *in situ*. Though these populations were not yet flowering when examined, visible morphological characters were sufficient to conclude that these are likely populations of *Pediocactus* Britton & Rose and *Sclerocactus* Britton & Rose (Parfitt and Gibson 2003). Without specimens, we are hesitant to guess at species, but crews visiting the area should take care to avoid disrupting any cacti populations regardless of species identity or conservation status. To aid in conservation efforts, we are withholding the photos and exact localities of these populations.

In 2014, Crew 143 collected two cacti specimens (Sokoloff et al. 2016). Originally, they were identified as *Opuntia basilaris* var. *basilaris* Engelm. & J.M. Bigelow and *Opuntia polyacantha* var. *polyacantha* Haw.; however, these taxa have since been re-identified to *Opuntia basilaris* var. *heilii* S.L. Welsh & Neese and *Opuntia nicholii* L.D. Benson,

respectively by *Opuntia* experts (Tony Frates and Dean Stock, personal communications, 2019).

Caprifoliaceae

We documented one new species in one new genus for the MDRS area.

Symphoricarpos longiflorus Gray.

Specimens Examined: Utah, Wayne County: *Sokoloff et al.* 1284 (CAN); 1296 (CAN, UTC).

This species was only encountered twice in the MDRS area (Fig. 10a), including several large plants in a sheltered shady wash with other locally-unique species, such as *Populus fremontii* var. *fremontii* and *Rhus trilobata* var. *trilobata*. This species is present in the Orange Cliffs region (Shultz et al. 1987), present in Capitol Reef National Park (Fertig 2009), occasional in the Glen Canyon National Recreation Area (Hill and Ayers 2009) and occasional in the San Rafael Swell (Harris 1983).

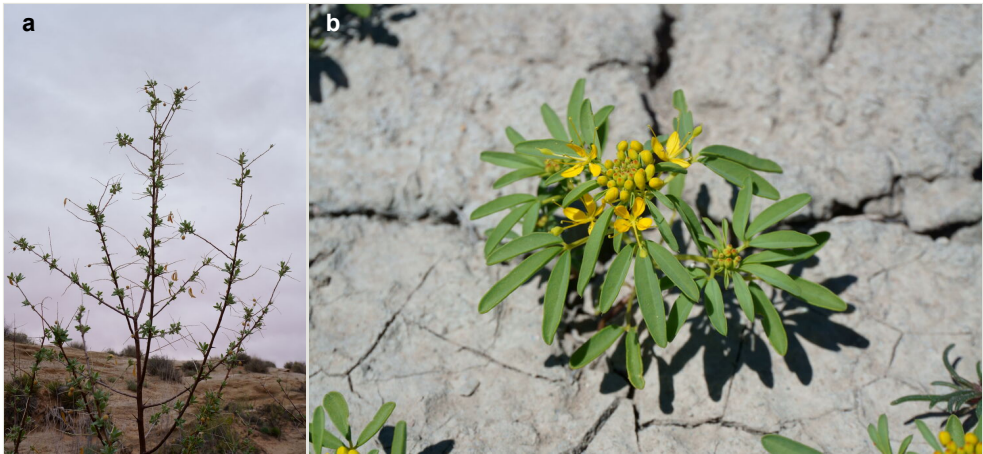


Figure 10.

Caprifoliaceae, Cleomaceae. Photos by P.C. Sokoloff.

a: *Symphoricarpos longiflorus*, habit (*Sokoloff et al.* 1296). [doi](#)

b: *Cleomella palmeriana*, habit (*Sokoloff et al.* 1311). [doi](#)

Cleomaceae

We documented one new species in one new genus for the MDRS area.

***Cleomella palmeriana* M.E. Jones**

Specimen Examined: Utah, Wayne County: *Sokoloff et al. 1311* (CAN, DAO, UTC).

Abundantly common on the silty floor of Copernicus Valley north of MDRS (Fig. 10b), where it was found growing with *Phacelia demissa* var. *demissa*, this annual plant is endemic to the Four Corners states (Vanderpool 2010). Intraspecific taxa are no longer recognised in this species following the transfer of *C. palmeriana* var. *goodrichii* Welsh to *C. hillmanii* var. *goodrichii* (S. L. Welsh) P.K. Holmgren (Holmgren 2004, Roalson et al. 2015), a move supported by genetic sequence data (Riser II et al. 2013). This species is common in Glen Canyon National Research Area (Hill and Ayers 2009), present in Capitol Reef National Park (as *C. palmeriana* var. *palmeriana*) (Fertig 2009) and occasional in the San Rafael Swell (Harris 1983).

Fabaceae

We documented six new species in two new genera and one previously-documented genus for the MDRS area. We also made a collection of a species previously known from the station: *Astragalus desperatus* M.E. Jones (*Sokoloff et al. 1317b* [Fig. 11a, b]).

***Astragalus mollissimus* var. *thompsoniae* (S. Watson) Barneby**

Specimens Examined: Utah, Wayne County: *Sokoloff et al. 1265* (CAN, UTC); *1299* (CAN, UTC).

Occasionally encountered in the MDRS area, this spring-flowering species was conspicuous in sandy washes (Fig. 11c, d). This variety is the only member of this widespread compound species present in Utah, where it is relatively common (Barneby 1964, Welsh et al. 1993, Welsh 2006). This taxon is present in the Orange Cliffs region (Shultz et al. 1987), present in Capitol Reef National Park (Fertig 2009), common in Glen Canyon National Recreation Area (Hill and Ayers 2009) and common in the San Rafael Swell (Harris 1983).

***Astragalus pardalinus* (Rydb.) Barneby**

Specimen Examined: Utah, Wayne County: *Sokoloff et al. 1286* (CAN, UTC).

Given the non-flowering nature of this specimen, our identification here is tentatively made, based on vegetative morphology. This species was only encountered once in the MDRS area. This species is endemic to this region (Barneby 1964, Welsh et al. 1993, Welsh 2006) and, though not listed at the state or federal level, it is listed as a "Category C3 Non-Candidate" species in the "Watch" category of an inventory of Utah's sensitive plant life (Utah Division of Wildlife Resources 1998). This species is present in Capitol Reef National Park (Fertig 2009), occasional in Glen Canyon National Recreation Area (Hill and Ayers 2009) and occasional in the San Rafael Swell (Harris 1983).



Figure 11.

Fabaceae. Photos by P.C. Sokoloff.

a: *Astragalus desperatus*, habit (Sokoloff et al. 1317b). [doi](#)

b: *Astragalus desperatus*, inflorescence (Sokoloff et al. 1317b). [doi](#)

c: *Astragalus mollissimus* var. *thompsoniae*, habit (Sokoloff et al. 1265). [doi](#)

d: *Astragalus mollissimus* var. *thompsoniae*, inflorescence (Sokoloff et al. 1265). [doi](#)

e: *Astragalus praelongus*, habit (Sokoloff et al. 1301). [doi](#)

f: *Hoffmannseggia repens*, habit (Sokoloff et al. 1285) [doi](#)

***Astragalus praelongus* E. Sheld.**

Specimen Examined: Utah, Wayne County: Sokoloff et al. 1301 (CAN, UTC).

Only seen once along the side of a road northeast of MDRS, this large, showy milkvetch is apparently uncommon in the operational area (Fig. 11e). Barneby (1964) and Welsh (2006)

largely agree on the infraspecific taxonomy of this species - Welsh describes a fourth variety from northwest Utah in addition to the three varieties present in both treatments. As our specimen was flowering, we have only identified it to species. This species is present in the Orange Cliffs region (Shultz et al. 1987), occasional in Glen Canyon National Recreation Area (Hill and Ayers 2009), present in Capitol Reef National Park (as var. *praelongus*) (Fertig 2009) and uncommon in the San Rafael Swell (as var. *praelongus*) (Harris 1983).

***Astragalus woodruffii* M.E. Jones**

Specimen Examined: Utah, Wayne County: *Sokoloff et al. 1280* (CAN, DAO, UTC).

Occasional on sandy soils northeast of MDRS, this species is endemic to the San Rafael Swell and surrounding deserts (Barneby 1964, Welsh et al. 1993, Welsh 2006). As with *Astragalus pardalinus*, *A. woodruffii* is not state- or federally-listed, but is listed as category C3 Non-Candidate" species in the "Watch" category in Utah's sensitive plant life survey (Utah Division of Wildlife Resources 1998). This species is present in Capitol Reef National Park (Fertig 2009) and uncommon in the San Rafael Swell (Harris 1983).

***Hoffmannseggia repens* (Eastw.) Cockerell**

Specimen Examined: Utah, Wayne County: *Sokoloff et al. 1280* (CAN, MT, UTC).

This species was occasionally encountered on sandy plains northeast of MDRS (Fig. 11f). Endemic to south-eastern Utah and adjacent Colorado (Simpson and Ulibarri 2006), this species is the northernmost member of a predominantly Central and South American genus (Simpson et al. 2004). This species is common in the San Rafael Swell (Harris 1983) and there are unconfirmed reports for Capitol Reef National Park (Fertig 2009).

***Lupinus pusillus* Pursh**

Specimen Examined: Utah, Wayne County: *Sokoloff et al. 1287* (CAN, UTC).

This species was occasionally encountered on sandy plains northeast of MDRS (Fig. 12a). Welsh et al. (1993) describes three varieties present in Utah, but notes that, in his opinion, there was insufficient evidence to recognise them within the state. As our specimen is vegetative, we were unable to ascribe it to any variety. This species is present in the Orange Cliffs (Shultz et al. 1987), common in the San Rafael Swell (as *L. pusillus* var. *pusillus* and *L. pusillus* var. *rubens* (Rydb.) Welsh) (Harris 1983), present in Capitol Reef National Park (as *L. pusillus* var. *pusillus* and *L. pusillus* var. *intermountanus* (Heller) C.P. Sm.) (Fertig 2009) and present in Glen Canyon National Recreation Area (as *L. pusillus* subsp. *pusillus* and *L. pusillus* subsp. *rubens* (Rydb.) D.B. Dunn) (Hill and Ayers 2009).



Figure 12.

Fabaceae, Nyctaginaceae, Onagraceae, Poaceae, Polygonaceae. Photos by P.C. Sokoloff.

a: *Lupinus pusillus*, habit (Sokoloff et al. 1287). [doi](#)

b: *Abronia elliptica*, habit (Sokoloff et al. 1292). [doi](#)

c: *Camissonia eastwoodiae*, habit (Sokoloff et al. 1307). [doi](#)

d: *Eremopyrum triticeum*, habit (Sokoloff et al. 1321). [doi](#)

e: *Eremopyrum triticeum*, inflorescences (Sokoloff et al. 1321). [doi](#)

f: *Eriogonum wetherillii*, habit (Sokoloff et al. 1272). [doi](#)

Loasaceae

We documented one new species in one new genus for the MDRS area.

***Mentzelia pterosperma* Eastw.**

Specimen Examined: Utah, Wayne County: *Sokoloff et al.* 1315 (CAN, UTC).

Only encountered once as a vegetative specimen on "Hab Ridge", on gravelly clay soil characteristic of its range in Utah (Schenk and Hufford 2016), this species may be more commonly encountered during flowering, when the plants are more conspicuous. This species is reported as occasional in Glen Canyon National Recreation Area (Hill and Ayers 2009), uncommon in the San Rafael Swell (Harris 1983) and present in Capitol Reef National Park (Fertig 2009).

Nyctaginaceae

We documented one new species in one new genus for the MDRS area.

***Abronia elliptica* A. Nelson**

Specimen Examined: Utah, Wayne County: *Sokoloff et al.* 1292 (CAN, UTC).

The taxonomy of *A. fragrans* and *A. elliptica* A. Nelson has a complicated history in Utah, with Welsh et al. (1993) lumping both species in the state together, despite earlier (Galloway 1975) and later (Galloway 2003) treatments separating them based on fruiting characters. Here we follow Galloway (2003); however, the specimens we collected were vegetative (Fig. 12b). Pending collection of material with mature fruits, we tentatively assign this specimen to *A. elliptica*, as continuing work by Eric LoPresti indicates that the majority of specimens from this complex in central Utah properly belong in this species, particularly around the San Rafael Swell (Mike Moore, personal communication, 2020). *Abronia elliptica* is reported as common in the San Rafael Swell (Harris 1983) and present in the Orange Cliffs Region (Shultz et al. 1987), while *A. fragrans* is not recorded at all. Conversely, *A. fragrans* (with *A. elliptica* in synonymy) is reported as present in Capitol Reef National Park (Fertig 2009) and widespread in Glen Canyon National Recreation Area (Hill and Ayers 2009). Further work will be needed to verify the true range of this species in the regions surrounding MDRS.

Onagraceae

We documented two new species in one new genus and one previously-documented genus for the MDRS area. We also made a collection of a species previously known from the station: *Oenothera cespitosa* subsp. *navajoensis* W.L. Wagner, Stockhouse & Klein M.E. Jones (*Sokoloff et al.* 1279).

***Camissonia eastwoodiae* (Munz) P.H. Raven**

Specimens Examined: Utah, Wayne County: *Sokoloff et al.* 1307 (CAN); 1313 (CAN, UTC).

A Colorado Plateau endemic (Welsh et al. 1993), this species was encountered occasionally around MDRS on the clay sediments in Copernicus Valley and on grey Mancos Shale layers (Fig. 12c), consistent with published habitat descriptions for this species (Raven 1969). Reported as common in the San Rafael Swell (Harris 1983), present in Capitol Reef National Park (Fertig 2009) and common in Glen Canyon National Recreation Area (Hill and Ayers 2009).

***Oenothera pallida* Lindl.**

Specimen Examined: Utah, Wayne County: *Sokoloff et al. 1288* (CAN).

This species was only encountered once in the MDRS area as an inconspicuous vegetative specimen; fieldwork during this species' flowering time may reveal it to be common in the area. The taxonomy of this group has fluctuated, with Welsh et al. (1993) recognising two varieties in Utah and Evans et al. (2005) recognising five subspecies across this species range. As the specimen cited here is immature, we have only determined it to the species level. This species has been reported from the Orange Cliffs (Shultz et al. 1987), as widespread in the Glen Canyon National Recreation Area (Hill and Ayers 2009), present in Capitol Reef National Park (Fertig 2009) and as common in the San Rafael Swell (Harris 1983).

Poaceae

We documented two new species in two new genera the MDRS area. We also made collections of species previously known from the station, including: *Achnatherum hymenoides* (Roem. & Schult.) Barkworth (*Sokoloff et al. 1282*) and *Sporobolus airoides* (Torr.) Torr. (*Sokoloff et al. 1294*).

***Eremopyrum triticeum* (Gaertn.) Nevski**

Specimen Examined: Utah, Wayne County: *Sokoloff et al. 1321* (CAN, UTC).

Though not reported from the San Rafael Swell (Harris 1983), Capitol Reef National Park (Fertig 2009) or Glen Canyon National Recreation Area (Hill and Ayers 2009), Frederiksen (2007) reports this annual weed as occurring across western North America, scattered across disturbed sites and Barkworth et al. (1983) reports this species as occurring across the Intermountain Region. At MDRS, this species was only found in areas immediately adjacent to the station (Fig. 12d, e), in disturbed, saline clay sediment matching the habitat description in Banner et al. (2011).

Vulpia octoflora* (Walter) Rydb. var. *octoflora

Specimens Examined: Utah, Wayne County: *Sokoloff et al. 1274* (CAN, UTC); *1295* (CAN, UTC).

Widespread across North America (Lonard 2007), this annual taxon was commonly encountered across the MDRS area during our study (Fig. 13). This genus is sometimes placed in *Festuca* (Lonard and Gould 1974). As *Festuca octoflora* Walter, this species is reported from Capitol Reef National Park (Fertig 2009). As *Vulpia octoflora*, this species is reported as widespread in Glen Canyon National Recreation Area (Hill and Ayers 2009), present in the Orange Cliffs region (Shultz et al. 1987) and occasional in the San Rafael Swell (Harris 1983).



Figure 13. [doi](#)

Vulpia octoflora var. *octoflora*, habit (Sokoloff et al. 1274). Photo by P.C. Sokoloff.

Polygonaceae

We documented two new species in one known genus for the MDRS area.

Eriogonum gordonii Benth.

Specimen Examined: Utah, Wayne County: Sokoloff et al. 1305 (CAN, UTC).

Common in the Four Corners states, Wyoming, South Dakota and Nebraska (Reveal 2005), this species was only encountered once in the MDRS area. This species is present in Capitol Reef National Park (Fertig 2009) and uncommon in the San Rafael Swell (Harris 1983).

***Eriogonum wetherillii* Eastw.**

Specimens Examined: Utah, Wayen County: *Sokoloff et al.* 1270 (CAN); 1272 (CAN, UTC).

Encountered occasionally in the MDRS area on sandy washes and clay soils (Fig. 12f), this species is endemic to the Four Corners states and common in southeast Utah (Reveal 2005). This species is present in the Orange Cliffs Region (Shultz et al. 1987), common in Glen Canyon National Recreation Area (Hill and Ayers 2009), present in Capitol Reef National Park (Fertig 2009) and occasional in the San Rafael Swell (Harris 1983).

Salicaceae

We documented one new species in one new genus for the MDRS area.

Populus fremontii* S. Watson subsp. *fremontii

Specimen Examined: Utah, Wayne County: *Sokoloff et al.* 1300 (CAN, UTC).

This species is common along the banks of the Fremont River south of the MDRS area, just south of Utah State Route 24 (P. Sokoloff, pers. obs.). This particular collection is the nearest-known population to MDRS and the only one encountered in the operational area in many years of fieldwork (S. Rupert, pers. obs). Consisting of one large tree and two smaller saplings (Fig. 14), this population was found in a protected sandy wash with other unique species in the MDRS area, including *Rhus trilobata* var. *trilobata* and *Symphoricarpos longiflorus*. This taxon, recorded as *Populus fremontii*, has been reported as common in the San Rafael Swell (Harris 1983), occasional in the Glen Canyon National Recreation Area (Hill and Ayers 2009) and present in the Orange Cliffs region (Shultz et al. 1987). This taxon has also been reported as present in Capitol Reef National Park as *Populus fremontii* var. *fremontii* (Fertig 2009). Following Eckenwalder (2010), these plants are all part of the more widely distributed nominate subspecies; the other subspecies: *P. fremontii* subsp. *mesetae* Eckenwalder, is only found in Texas.

Discussion

Adding our current inventory to the vascular plant list in our earlier work (Sokoloff et al. 2016) brings the total number of vascular plant taxa at MDRS to 81 (79 species and two taxa recorded to genus) in 24 families; our current study represents a ~110% increase in species diversity from our initial survey. As we expected, work in the spring greatly increased the number of taxa encountered, and working outside of Mars simulation conditions with a crew of dedicated biologists resulted in Crew 210 doubling the species list for MDRS in half the time that Crew 143 spent at the station.

Nine new families are documented for the MDRS area (Amaryllidaceae, Anacardiaceae, Apiaceae, Asparagaceae, Caprifoliaceae, Cleomaceae, Loasaceae, Nyctinaginaceae and Salicaceae). The remaining nine families that contain new species for the MDRS area

(Amaranthaceae, Asteraceae, Boraginaceae, Brassicaceae, Cactaceae, Fabaceae, Onagraceae, Poaceae and Polygonaceae) are relatively species-rich in the deserts of southeast Utah (Fertig 2009, Harris 1983) and were previously documented in the area (Sokoloff et al. 2016). Six families from our initial inventory are not represented in the new collections reported here (Ephedraceae, Euphorbiaceae, Juncaceae, Malvaceae, Sarcobataceae and Tamaricaceae). Of these families, Ephedraceae, Sarcobataceae and Tamaricaceae are large, conspicuous shrubby families with 1-2 species in the area (Fertig 2009, Harris 1983), all of which were observed, but not collected in 2019. New species in the Euphorbiaceae, Juncaceae and Malvaceae were not encountered in 2019.



Figure 14. [doi](#)

Populus fremontii subsp. *fremontii*, habit and habitat (Sokoloff et al. 1300). Photo by P.C. Sokoloff.

Species were scored as annual or perennial based on the USDA PLANTS Database (USDA, NRCS 2020) - any species that may occur annually were scored as such. Overall, 43% of our new vascular plant records are annuals: *Phacelia demissa* var. *demissa*, *Cleomella palmeriana*, *Eremopyrum triticeum*, *Cryptantha crassisepala* var. *elachantha*, *Vulpia octoflora* var. *octoflora*, *Lupinus pusillus*, *Camissonia eastwoodiae*, *Chorispora tenella*, *Descurainia pinnata* subsp. *brachycarpa*, *Streptanthella longirostris*, *Strigosella africana*, *Eriogonum gordonii*, *Eriogonum wetherillii*, *Atriplex argentea*, *Blitum nuttallianum*, *Phacelia corrugata*, *Chaenactis stevioides* and *Malacothrix sonchoides*. This is much higher than the 29% of annual species from our 2014 inventory. Two of the taxa recorded here are geophytes: *Allium macropetalum* and *Eremocrinum albomarginatum* (as recorded in Flora of North America Editorial Committee, eds. (1993)), which would likewise not have

been conspicuous during our earlier fall fieldwork. Additionally, *Pediocactus* is known to retract below ground when conditions are unfavourable (Shryock et al. 2014), reducing the likelihood that this species would be encountered in autumn or in drought years. Our 2019 fieldwork took place during a high-productivity year in the Utah desert (pers. obs.).

The San Rafael Swell and its surrounding deserts are habitat to numerous endemic vascular plant species (Harris 1983, Welsh et al. 1993, Flora of North America Editorial Committee, eds. 1993); our crew documented several occurrences of these species around MDRS, including *Hoffmannseggia repens*, *Astragalus pardalinus*, *Astragalus woodruffii* and populations of *Sclerocactus* and *Pediocactus*. We also documented populations of species endemic to the wider Colorado Plateau, like *Eremocrinum albomarginatum*, *Camissonia eastwoodiae* and *Phacelia demissa* var. *demissa*. These new records not only document the occurrence of these species at MDRS for future crews and biodiversity researchers, but provide important spatial and temporal records of these unique species to protected area managers and conservation planners.

Three of the species newly recorded for MDRS are invasive weeds in the southwest United States: *Eremopyrum triticeum*, *Strigosella africana* and *Chorispora tenella* (we also made one collection of the previously-documented weed *Kali tragus*). Documenting the occurrence of these taxa through vouchers and herbarium specimens will provide important information to land managers working to control these invasive species.

While we have greatly increased the number of vascular plant species known at MDRS, the high diversity documented for the nearby San Rafael Swell and Capitol Reef National Park indicate that there are many species not yet documented for the station. Filling in the gaps in this checklist will require additional field seasons in spring, summer and early autumn and continued botanical exploration of both previously-inventoried and newly-documented sites within the MDRS area. Consulting specimens from local herbaria (and those served in online databases) may provide species occurrence data from the regions around MDRS helpful in the search for new station taxa. Additionally, crews rotating through MDRS may add to the inventory effort through photo-documenting vascular plant species encountered and uploading these images to online databases like iNaturalist.

Continuing to collect and add to the ongoing floristic inventory of MDRS will greatly aid future missions at the station where crews need a local taxonomic checklist (for environmental DNA studies, for example), but also highlights the importance of an expanded mission profile at MDRS. As our knowledge of the local biota at the station increases, this unique place can become a hub for earthbound biodiversity monitoring, in addition to its important role in Martian analogue research.

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Supplementary material

Suppl. material 1: Crew 210 Collections [doi](#)

Authors: P.C. Sokoloff; S.R. McBeth, D.A. Murray, S.M. Rupert, M.G. Irvine

Data type: occurrences

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