

**Scratching the Surface at Joshua Tree National Park:
Introducing Non-vascular Plants to the Public - Bryophyte Component**

Final report

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Summary

The primary focus of this project was to improve our understanding of bryophyte diversity within Joshua Tree National Park. The project included three parts: 1) a scientific survey of bryophyte biodiversity; 2) development of long term monitoring protocols that could be useful for citizen scientists; 3) production of bryophyte images suitable for use in educational displays about the bryophyte flora of the park.

John Brinda visited the park several times between March 2011 and May 2012. As a result of these visits and the study of older herbarium specimens, a total of 62 bryophyte taxa have been identified as occurring within the park. The identified taxa are listed in appendix A of this report. This list of 62 taxa represents a dramatic improvement of our understanding of the bryophyte diversity within the park. The park lacks any published bryophyte flora and has not seen much interest because of its assumed lack of diversity. However, our list shows that it possesses an interesting flora containing many desert-adapted species that are rare or absent in other areas. Careful taxonomic work in the park will continue to yield range extensions for well-known species and probably also species new to science.

A citizen science methodology was developed that uses phenology to monitor the effects of climate change on the park's bryophyte species. This protocol mirrors other efforts such as Project BudBurst that monitor similar changes in vascular plants. The protocol appears in appendix B of this report. In addition, 32 photographic images depicting 17 different bryophyte species were taken during visits to the park. These images are suitable for website development and should allow for the production of a more engaging online educational experience.

Introduction

Bryophytes are plants that belong to three major phyla: Bryophyta (Mosses), Marchantiophyta (Liverworts), and Anthocerotophyta (Hornworts). The group contains the very first lineages of plants that evolved from algae and colonized land over 400 million years ago. They are generally small plants that reproduce via spores rather than seeds. They are also often called "non-vascular" plants since they typically lack the highly specialized water transport tissues of ferns and seed plants. While vascular plants are often larger and more conspicuous on the landscape, bryophytes continue to thrive in the same habitats that they first colonized millions of years ago. This is especially true of substrates that vascular plants find it difficult to survive on, such as bare rock.

The bryophyte diversity contained in the deserts of the American Southwest has remained relatively poorly understood. Most experts have avoided the region because of the perception that it was too dry to support much bryophyte biodiversity. However, bryophytes as a group are experts at exploiting small sheltered microhabitats of the type that abound in the mountainous terrain of the area. Shaded, north-facing rock outcrops often host many species huddled together to avoid the harsh desert sun.

Because they live at the limits of their tolerance to heat and drought, desert bryophytes are potentially valuable indicators of changes to climate. However to fully exploit this potential we need to learn much more about their ecology and distribution. This effort will have to involve the collection of baseline biodiversity data as well long term monitoring of change over time. This project was designed to make progress in both these areas as well as engage the public and introduce them to desert bryophytes (perhaps in many cases for the first time).

Methods

John Brinda visited the park several times between March 2011 and May 2012. Sites were selected based on their potential to harbor a high number of bryophyte species. In arid regions like Joshua Tree NP the best sites are typically on steep north-facing slopes and deeply shaded canyons. These sites see lower levels of solar radiation allowing the bryophytes to stay hydrated longer during the cool winter months. Some water-loving species are also found in the vicinity of permanent springs and seasonal seeps so these were examined as well.

The sites were spread throughout the park in order to incorporate differences in vegetation and geology. Because so much of the park is wilderness, the majority of the sites with the best potential diversity occur far from roads. In order to visit many of these, travelling long distances through the backcountry was necessary. The list of sites in the order visited is given below:

Location	Habitat
Wash east of Aqua Peak, Coxcomb Mountains	Azonal Cliff, Canyon
West Fork Fortynine Palms Canyon	Azonal Cliff, Canyon
Fortynine Palms Oasis, Fortynine Palms Canyon	Riparian, Spring Outflow
Small draw along Fortynine Palms Oasis Trail	Desert Scrub, Creosote Bush
Southwest of National Park Loop Road, Hidden Valley	Woodland, Pinyon Pine-Oak
Draw east of Inspiration Point, Little San Bernardino Mountains	Woodland, Pinyon Pine-Oak
Wash at mouth of Buzzard Spring Canyon, Eagle Mountains	Riparian, Creosote Bush-Palo Verde
Buzzard Spring Canyon, Eagle Mountains	Azonal Cliff, Canyon
Buzzard Spring, Eagle Mountains	Riparian, Springhead
Little San Bernardino Mountains, hills southwest of Boundary Trail West	Woodland, Pinyon-Yucca
Little San Bernardino Mountains, Upper Long Canyon	Woodland, Pinyon-Yucca
Little San Bernardino Mountains, draw northeast of Eureka Peak	Woodland, Pinyon-Yucca-Scrub Oak
Little San Bernardino Mountains, draw north of Eureka Peak	Woodland, Pinyon-Yucca-Scrub Oak
Covington Flats, Upper Covington Spring Canyon	Woodland, Pinyon-Juniper
Covington Flats, Covington Spring Canyon	Woodland, Pinyon-Yucca-Scrub Oak
Little San Bernardino Mountains, Smith Water Canyon	Riparian, Seep/Spring
Little San Bernardino Mountains, Black Rock Canyon	Woodland, Pinyon-Yucca-Scrub Oak
Little San Bernardino Mountains, canyon above Pinyon Well	Woodland, Pinyon-Yucca-Scrub Oak
Little San Bernardino Mountains, Pinyon Well	Riparian, Seep/Spring
Hexie Mountains, Squaw Tank	Rocky Outcrop, Granite

West of Wonderland of Rocks, North Canyon Trail	Desert Scrub, Creosote Bush-Yucca
Wonderland of Rocks, south of Indian Cove, Rattlesnake Canyon	Azonal Cliff, Canyon with occasional pine
North-facing slopes near Victory Palms, Eagle Mountains	Desert Scrub, Sonoran
Lost Palms Oasis, Eagle Mountains	Riparian, Palm Oasis
North-facing slopes of Pinkham Canyon, Cottonwood Mountains	Desert Scrub, Creosote Bush-Yucca
Canyon on northeast slope of Pinto Mountain, Pinto Mountains	Desert Scrub, Creosote Bush-Acacia
Wash west of Golden Bell Mine, Hexie Mountains	Desert Scrub, Creosote Bush
Black Eagle Mine Road, east of Smoke Tree Wash, Eagle Mountains	Desert Scrub, Creosote Bush-Encelia
Conejo Well area, Eagle Mountains	Woodland, Juniper-Yucca
Canyon east of Keys Ranch, Wonderland of Rocks Area	Rocky Outcrops, in Pinyon-Oak Woodland
Draw just north of Summit of Ryan Mountain	Desert Scrub, Blackbrush
South of Sheep Pass Group Campground	Rocky Outcrop, Granite
Indian Cave, base of Ryan Mountain Trail	Woodland, Pinyon Pine
Berdoo Canyon, Little San Bernardino Mountains	Desert Scrub, Creosote Bush-Encelia
North-facing slopes of Fried Liver Wash, Hexie Mountains	Desert Scrub, Creosote Bush-Encelia
Draw above Quail Springs, Quail Mountain	Disturbed, Recovering Burn in Pinyon-Juniper Woodland
Stubbe Spring Loop Trail, Little San Bernardino Mountains	Woodland, Pinyon-Juniper
Stubbe Spring, Little San Bernardino Mountains	Woodland, Pinyon-Juniper
Canyon northeast of Pine City	Rocky Outcrops, in Pinyon-Oak Woodland
Pinto Mountains, west of Clarks Pass	Desert Scrub, Creosote Bush-Acacia
Northeast slopes of Aqua Peak, Coxcomb Mountains	Desert Scrub, Creosote Bush-Ambrosia

In addition, herbarium specimens of older collections were examined from the following locations:

Location	Habitat
Barker Dam Trail	Woodland, Pinyon Pine-Oak
Between Keys Ranch and Barker Dam	Desert Scrub
Jumbo Rocks Campground	Rocky Outcrop, Granite
Vicinity of Barker Dam and Reservoir	Azonal Cliff, Canyon with occasional pine
Desert Queen Mine	Desert Scrub
0.5 miles north of Barker Dam at southern end of "Wonderland of Rocks"	Azonal Cliff, Canyon with occasional pine

A map of all these locations is shown below (Fig. 1).

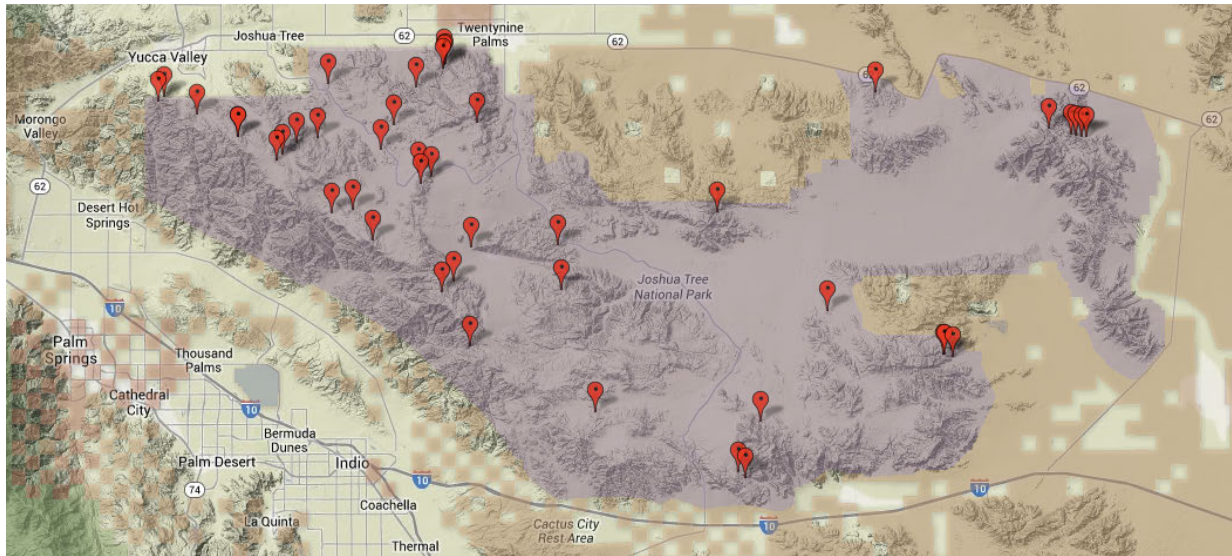


Figure 1. Map showing locations of site visits and localities of older herbarium specimens.

During the site visits digital photographs of bryophytes as they appear in the field were taken when possible. The best of these photographs were selected for inclusion in this report. Since many bryophyte species cannot be reliably identified without examination under a microscope, samples were removed from the sites for identification to species in the laboratory. Because the bryophyte flora of the southwestern deserts is poorly known, identification to species is sometimes difficult. In a few cases samples were sent to an expert in the taxonomic group for verification.

In consultation with Joshua Hoines and Mitzi Harding at the park, a citizen science methodology was developed that uses phenology to monitor the effects of climate change on the park's bryophyte species. This protocol mirrors other efforts such as Project BudBurst that monitor similar changes in vascular plants. The protocol appears in appendix B of this report.

Results

As a result of the site visits and study of older herbarium specimens, a total of 62 bryophyte taxa (58 mosses and 4 liverworts) have been identified as occurring within the park. The checklist of identified taxa with a summary of where they are found appears in appendix A of this report. A summary of the bryophyte taxonomic diversity by family is given in figure 2.

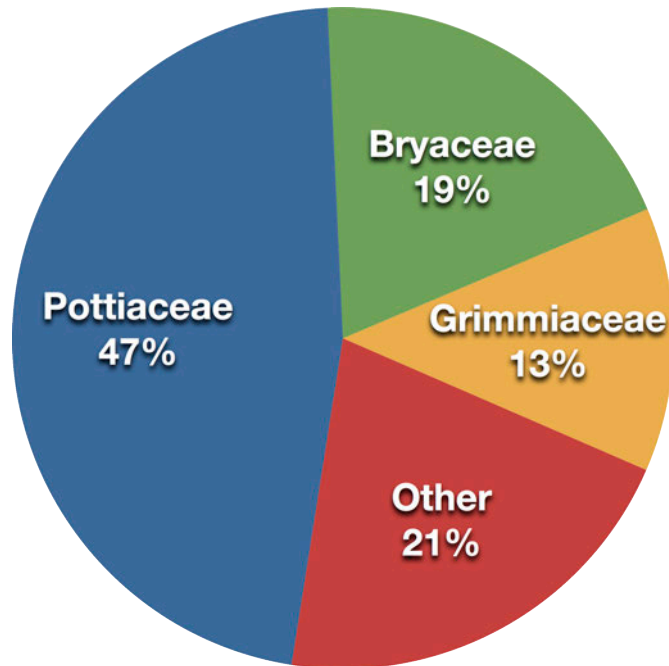


Figure 2. Breakdown of bryophyte diversity in Joshua Tree NP by taxonomic family.

The arid landscape of Joshua Tree National Park supports a high diversity of mosses in the family Pottiaceae. The species in this family are usually highly desiccation tolerant, making them well-adapted to the desert environment. They can be found throughout the world in similar habitats. Of the 12 bryophyte families found in the park (see appendix A), only two others are represented by more than three species. The Bryaceae family is especially diverse in California but its members are not as desiccation tolerant and consequently become less common in desert regions. The park also provides abundant habitat for species of the family Grimmiaceae which are the common cushion mosses of bare rock faces.

Thirty-two photographic images depicting 17 different bryophyte species were taken by John Brinda while visiting the park. The images are given below with a short discussion of the species depicted in each. High resolution versions of these images will be delivered to the park digitally for their use in print and/or online media.

Anacolia menziesii (1 image)



Anacolia menziesii is one of the larger mosses found in the park. The leaves are long and the branches curl up near the tips giving the whole plant a soft appearance. It is a common species of coastal California that is usually found on shaded rock ledges. Its occurrence in drier inland habitats is sporadic and restricted to the more mesic, protected sites. In the park it is usually found at higher elevations such as near Eureka Peak where this photograph was taken.

Didymodon tophaceus (2 images)



Didymodon tophaceus is a common moss that is almost always associated with springs and seepy rock faces. It is a widespread species that occurs in Europe and Africa as well as North and South America. The plants have a brownish color and prefer to colonize the thick tufa deposits that often develop along the margins of desert springs.

Didymodon vinealis (1 image)



Didymodon vinealis occurs throughout western North America and is one of the most common mosses in southern California. Shady rock crevices in the southwestern deserts almost always host a population of this ubiquitous species. The above picture shows a partially hydrated patch of this moss—the dark green plants on the right are dry while the bright green plants are wet. Unlike most vascular plants, bryophytes can dry down completely during times of drought and resume growing right where they left off once the next rains arrive. This phenomenon is called desiccation tolerance and makes bryophytes well suited to surviving the harsh desert environment.

Fabronia pusilla (1 image)



Fabronia pusilla is one of only two pleurocarpous mosses found in the park. Pleurocarpous mosses usually grow in creeping mats rather than as upright stems. *Fabronia* can be recognized by the silvery sheen that plants have. This is caused by the long, ciliate hairs that can be found on the margins of the leaves. In the park this moss is restricted to deeply shaded rock crevices at higher elevations.

Funaria hygrometrica (1 image)



Funaria hygrometrica is one of the most common and recognizable mosses. It is a weedy species with a global distribution. The plants are not very tolerant of desiccation so in the park it is restricted to wet soil in the vicinity of springs and seeps. In these habitats it often forms large pure mats with a thick tangle of sporophytes.

Gemmabryum dichotomum (2 images)



Gemmabryum dichotomum is a common species that is found worldwide. The plants form tiny propagules called bulbils that fall from the stem and allow them to reproduce asexually. In desert habitats the species is less common and seems to be restricted to wet soil around springs and seeps.

Gemmabryum valparaisense (3 images)



Gemmabryum valparaisense can be found at virtually every spring in the park. The bright green plants grow on wet soil and form cushions on seepy rock faces. They produce numerous minute tubers on their rhizoids (root-like structures that grow from the base of the stem) that serve as asexual propagules.

Grimmia alpestris (2 images)



Grimmia alpestris is one of several *Grimmia* species that form compact blackish cushions on bare rock faces. The species normally occurs at more mesic sites and is consequently restricted to the northwest quarter of the park. The plants often have a somewhat bluish-green cast but are best identified using microscopic characters.

Grimmia anodon (3 images)



Grimmia anodon is one of the easier *Grimmia* species to identify thanks to the large, immersed capsules that are nearly always present. It forms shaggy, unkempt cushions on bare rock faces and can be found throughout the park.

Grimmia laevigata (2 images)



Grimmia laevigata is a widespread moss that is especially common in California chaparral habitats. It is not favored in extremely arid environments and therefore is restricted to the northwest quarter of the park. Its robust appearance usually serves to distinguish it since it is somewhat larger than the other *Grimmia* species that occur within the park.

Grimmia montana (1 image)



Grimmia montana forms compact blackish cushions on bare rock and is restricted to the more mesic northwest quarter of the park. It is found in similar habitats as *G. alpestris* but usually at slightly lower elevations. Where their ranges overlap, these two species can be exceedingly difficult to separate.

Grimmia moxleyi (3 images)



Grimmia moxleyi was first described from a collection made in Los Angeles County in 1926. It is probably the most common *Grimmia* species within the park. Like *G. anodon* it often produces capsules but in this species they are exserted above the leaves.

Grimmia poecilostoma (2 images)



Grimmia poecilostoma is a fairly common species usually found on bare granite rock. It is best distinguished from other similar species by the dark blackish-green leaves that strongly contrast with the bright white, flat, papery hairpoints. When the hairpoints are poorly developed the plants are much more difficult to identify.

Hymenostylium recurvirostrum (2 images)



Hymenostylium recurvirostrum is a common species found worldwide at springs, seeps and waterfalls. Like *Didymodon tophaceus* it often colonizes the tufa deposits produced by desert springs in the park. The plants are greener than *D. tophaceus* and the leaves are strongly recurved from the stem.

Syntrichia ruralis (2 images)



Syntrichia ruralis is one of the most common and abundant mosses within the park. This combined with its relatively large size make it the most conspicuous member of the park's bryophyte flora. The species has a rusty red-brown color and its leaves are usually twisted around the stem when dry. The species is a model organism for genetic studies of desiccation tolerance in plants and can be found throughout the park on well-shaded soil.

Targionia [undescribed species] (3 images)



The only commonly occurring liverwort in the park is an undescribed species in the genus *Targionia*. Its thalloid growth form is so unique that it is hard to mistake for any other bryophyte found in the park. When wet, the plants form lush, deep green carpets on rock ledges and at the bases of boulders and cliffs. However they curl up tightly when dry, exposing only their purplish-black undersides. At this stage they are very hard to detect unless one knows what to look for.

Tortula inermis (1 image)



Tortula inermis is perhaps the most common moss in the park and is found in a variety of habitats. The plants are short and the leaves normally coil tightly around the stem when dry. They prefer shaded soil and rock crevices and usually produce a rich crop of tall sporophytes as shown in the photograph above.

Discussion

While the park mostly lacks the wet and humid environments usually associated with bryophytes, it offers a diverse array of microhabitats set in a varied topography. These habitats promote a high diversity of desert-adapted species especially in the family Pottiaceae. The park's location also allows a mixing of Mojave and Sonoran influences, enhancing its diversity. As this study demonstrates, even the driest parts of the California deserts host a complex bryophyte flora worthy of further attention and close study.

Many species occurring on the monument have a broad distribution that includes arid regions throughout the globe. These species are usually well understood and present few taxonomical problems even if their exact distributions are not yet clearly defined. However, since the bryophyte flora of the southwestern deserts is relatively poorly known, interesting discoveries continue to be made and these are discussed below.

According to Doyle & Stotler (2006) the known California distribution of *Reboulia hemisphaerica* consists of only three populations. The population in Rattlesnake Canyon therefore represents an important range extension and is the first to be documented in the California deserts. Alan Whittemore, an expert on the thalloid liverworts of California, has verified the determination of a sample collected in the park. In addition, all of the examined populations of *Targionia* within the park belong to an undescribed species that is related to *Targionia hypophylla* (see Doyle & Stotler 2006 for a discussion).

Gemmabryum demaretianum is reported here as new to California. It is a somewhat weedy species that was previously known only from Quebec in North America (Spence 2011). John Spence, an expert in the Bryaceae, has examined plants from the park and confirmed their determination. The plants are not rare and are likely to be found throughout southern California. The species was described from Belgium in 1992 so the plants have either been recently introduced or overlooked for some time. It was found in the park several times during this study and also occurs in herbarium specimens dating from 1977 and 1994. *Entosthodon tucsonii* is rare in California (Norris & Shevock 2004) the report here represents the first for the California deserts. *Fissidens exiguus* is not recognized as occurring in California by Norris & Shevock (2004) and its taxonomic status is unclear. However, the plants are not difficult to distinguish from *F. sublimbatus* due to their large, clear cells and the complete absence of a limbidium.

Tortula brevissima has only recently been recognized as occurring in North America (Kellman 2012) however it was found at several sites in the park and these stations represent the first reports for the California deserts. *Anoetangium handelii* has only recently been reported as occurring in California (Zander & Eckel 2007) and although uncommon it can be found in suitable habitat throughout the park. *Pottiopsis sweetii* was first reported for California by Norris & Shevock in 2004 (as *Trichostomum sweetii*) consequently its status in the state is still poorly understood. However, during this study *P. sweetii* was found at several sites in the park. The discovery of *Didymodon norrisii* at Jumbo Rocks in 1994 represents the first report from the California deserts. This collection is small and the plants immature but they are still referable to *D. norrisii*. Mishler (2007) dismisses all reports of *Syntrichia cainii* from other than the type locality in Ontario, Canada. However the plants found in the park do not intergrade with the

other species present at the site and the characters they present in the field are maintained under common garden conditions. Further study is needed, but in the meantime the most appropriate name that can be applied to these plants is *S. cainii*. *Syntrichia virescens* is generally not recognized as occurring in North America (Mishler 2007) however many (if not most) reports of *S. bartramii* outside of Arizona and New Mexico probably represent this species.

References

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Appendix A:
Bryophyte Checklist

Bryophyte Checklist for Joshua Tree National Park

62 taxa (58 mosses, 4 liverworts)

LIVERWORTS

Aytoniaceae

Mannia californica (Gottsche) L.C. Wheeler

- uncommon, found in Fortynine Palms Canyon and the Wonderland of Rocks area

Reboulia hemisphaerica (L.) Raddi

- apparently rare within the park, only found in Rattlesnake Canyon

Ricciaceae

Riccia cf. *cavernosa* Hoffm.

- a single poor specimen was found in Buzzard Spring Canyon

Targioniaceae

Targionia aff. *hypophylla* L.

- common and often abundant throughout the park

MOSESSES

Amblystegiaceae

Amblystegium serpens var. *juratzkanum* (Schimp.) Rau & Herv.

- apparently rare within the park, found only once at Fortynine Palms Oasis

Bartramiaceae

Anacolia menziesii cf. var. *baueri* (Hampe) Paris

- uncommon at higher elevations in the northwest quarter of the park

Bryaceae

Bryum argenteum Hedw. var. *argenteum*

- common in the northwest quarter of the park

Bryum argenteum var. *lanatum* (P. Beauv.) Hampe

- less common but with a similar distribution as the typical variety

Gemmabryum demaretianum (Arts) J.R. Spence

- uncommon in the western half of the park

Gemmabryum dichotomum (Hedw.) J.R. Spence & H.P. Ramsay

- a weedy species but found only in Smith Water Canyon

Gemmabryum gemmilucens (R. Wilczek & Demaret) J.R. Spence

- a weedy species but found only once in 1994 in the vicinity of Barker Dam

- cf. *Gemmabryum kunzei* (Hornsch.) J.R. Spence
 - common and found throughout the park
Gemmabryum valparaisense (Thér.) J.R. Spence
 - common and found throughout the park in the vicinity of springs and seeps
Gemmabryum violaceum (Crundw. & Nyholm) J.R. Spence
 - uncommon but widespread within the park
Imbribryum muehlenbeckii (Bruch & Schimp.) N. Pedersen
 - apparently rare within the park, found only once at Lost Palms Oasis
Plagiobryoides vinosula (Cardot) J.R. Spence
 - uncommon in the northwest quarter of the park
Rosulabryum canariense (Brid.) Ochyra
 - uncommon but widespread within the park
Rosulabryum torquescens (Bruch ex De Not.) J.R. Spence
 - uncommon but widespread within the park

Fabroniaceae

- Fabronia pusilla* Raddi
 - uncommon in the northwest quarter of the park

Fissidentaceae

- Fissidens exiguus* Sull.
 - widespread within the park but less common than *F. sublimbatus*
Fissidens sublimbatus Grout
 - uncommon but widespread within the park

Funariaceae

- Entosthodon tucsonii* (E.B. Bartram) Grout
 - apparently rare, Coxcomb & Hexie Mountains
Funaria hygrometrica Hedw.
 - uncommon but widespread, always associated with springs and seeps
Funaria muhlenbergii var. *lineata* Grout
 - common and often abundant throughout the park

Grimmiaceae

- Grimmia alpestris* (F. Weber & D. Mohr) Schleich.
 - uncommon at higher elevations in the northwest quarter of the park
Grimmia anodon Bruch & Schimp.
 - common throughout the park
Grimmia laevigata (Brid.) Brid.
 - uncommon at higher elevations in the northwest quarter of the park
Grimmia montana Bruch & Schimp.
 - uncommon at higher elevations in the northwest quarter of the park

Grimmia moxleyi R.S. Williams

- common and often abundant throughout the park

Grimmia orbicularis Bruch

- uncommon in the eastern half of the park

Grimmia poecilostoma Cardot & Sebille

- uncommon in the western half of the park

Grimmia pulvinata (Hedw.) Sm.

- uncommon, Rattlesnake Canyon & Coxcomb Mountains

Pottiaceae

Anoetangium handelii Schiffner

- uncommon, usually associated with seepy rock crevices

Crossidium aberrans Holz. & E.B. Bartram

- common and widespread throughout the park

Crossidium crassinerve (De Not.) Jur.

- uncommon but widespread within the park

Crossidium seriatum H.A. Crum & Steere

- uncommon, Coxcomb & Pinto Mountains

Crossidium squamiferum var. *pottioideum* (De Not.) Mönk.

- common and widespread throughout the park

Desmatodon guepinii Bruch & Schimp.

- uncommon but widespread within the park

Didymodon australasiae (Hook. & Grev.) R.H. Zander

- common and often abundant throughout the park

Didymodon brachyphyllus (Sull.) R.H. Zander

- apparently rare within the park, found only once in the canyon above Pinyon Well

Didymodon nicholsonii Culm.

- apparently rare within the park, found only once in Covington Spring Canyon

Didymodon norrisii R.H. Zander

- apparently rare within the park, only found once in 1994 at Jumbo Rocks

Didymodon tophaceus (Brid.) Lisa

- uncommon but widespread, always associated with springs and seeps

Didymodon vinealis (Brid.) R.H. Zander

- common and widespread throughout the park

Eucladium verticillatum (Brid.) Bruch & Schimp.

- uncommon, Rattlesnake Canyon & Lost Palms Oasis

Gymnostomum calcareum Nees & Hornsch.

- uncommon, Rattlesnake Canyon & Fortynine Palms Canyon

Hymenostylium recurvirostrum (Hedw.) Dixon

- uncommon but widespread, always associated with springs and seeps

Microbryum starckeanum var. *brachyodus* (Bruch & Schimp.) R.H. Zander

- uncommon in the eastern half of the park

Pottiopsis sweetii (E.B. Bartram) Ros & O. Werner

- uncommon but widespread within the park

Pseudocrossidium crinitum (Schultz) R.H. Zander

- uncommon, Rattlesnake Canyon & Coxcomb Mountains

Syntrichia caninervis Mitt.

- uncommon in the northern portion of the park

Syntrichia ruralis (Hedw.) F. Weber & D. Mohr

- common and often abundant throughout the park

Syntrichia cf. *cainii* (H.A. Crum & L.E. Anderson) R.H. Zander

- apparently rare, found only once in the Eagle Mountains

Syntrichia virescens (De Not.) Ochyra

- common at higher elevations in the northwest quarter of the park

Tortula atrovirens (Sm.) Lindb.

- common and widespread throughout the park

Tortula brevipes (Lesq.) Broth.

- uncommon but widespread within the park

Tortula brevissima Schiffner

- uncommon but widespread within the park

Tortula inermis (Brid.) Mont.

- common and often abundant throughout the park

Weissia andrewsii E.B. Bartram

- common and widespread throughout the park

Weissia controversa Hedw.

- a weedy species but found only once near Pine City

Weissia ligulifolia (E.B. Bartram) Grout

- uncommon but widespread within the park

Ptychomitriaceae

Jaffueliobryum wrightii (Sull.) Thér.

- uncommon but widespread within the park

*Voucher specimens collected for this project will be deposited at the Herbarium of the University of Nevada, Las Vegas (UNLV). When enough material for duplicates exists these will be sent to the park for their reference collection as well as other major North American herbaria.

Appendix B:
Long-term Monitoring and Citizen Science Protocol for
Bryophytes in Joshua Tree National Park

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Bryophytes, Phenology, and Climate Change

Bryophytes (both mosses and liverworts) are a small but important component of the vegetation in the deserts of southern California. A little more than 50 different species of bryophytes live within the boundaries of Joshua Tree National Park. They are inconspicuous or sometimes absent on sunny south-facing slopes but on shady, north-facing slopes and in canyons they often thrive and become dominant members of the plant community. Where they are common, bryophytes can significantly influence the ecosystem. For example, in areas with sandy soils such as the park, bryophytes have been shown to influence soil formation as well as its mineral and elemental content.

Phenology is the study of periodically recurring plant and animal life cycle stages. Among the types of things included in phenological studies are bud break, leaf out, and flowering in plants as well as bird migrations and insect emergence in animals. These phenomena are often sensitive to variations in climate and are therefore increasingly being used to study climate history and modern-day global warming. There is a long tradition among natural historians and others of making phenological observations of the organisms they were interested in. The most widely cited example of this is the timing of cherry blossoming in Japan with a record that goes back over 1300 years. Data sets like these can be used to reconstruct climate for years before systematic measurements of temperature were made. In addition, they can be used to predict some of the biological consequences of global warming.

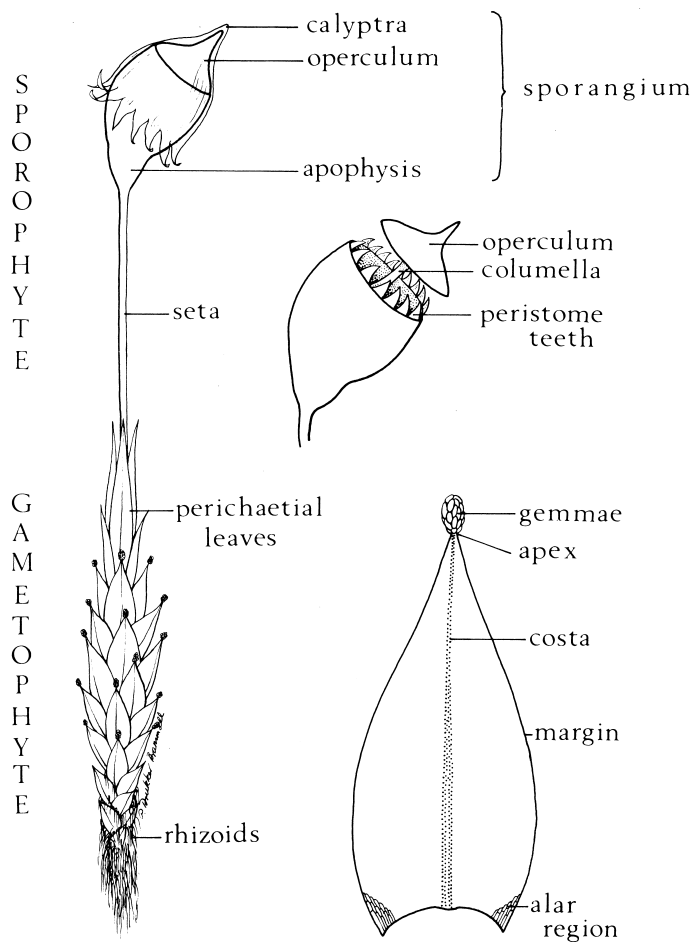
Just like all other plants, the growth and reproduction of bryophytes is affected by changes in their environment. However, relatively little is known about bryophyte phenology and how it might respond to climate change. It is reasonable to predict that desert bryophytes in particular should respond strongly to both changes in temperature and precipitation brought on by climate change, but both the strength of their response and its direction are still unknown. The data you collect will begin to answer these questions.

Sampling Protocol

In the Mojave Desert, bryophytes are physiologically active mainly in the cooler months, when much of the annual precipitation falls. Sporophyte maturation also occurs during this time and therefore phenological observations during winter and early spring are the most useful. We will target the species *Tortula inermis* because it is common in the area and frequently bears sporophytes. The reproductive biology of *Tortula inermis* is fairly well understood (Stark 1997) and there is also some evidence that it is sensitive to changes in climate (Stark 2002a). However including as many other species as possible will better improve our understanding. Not all species will respond in the same manner and documenting this may allow us to predict future changes in species composition, etc.

- 1) Locate a patch of moss and try to determine the species (or take a good close-up photograph). Georeference the location and/or collect a voucher if necessary.
- 2) Examine the plants and look for sporophytes (get on your hands and knees and look closely).
- 3) Count the sporophytes and place them into one of the 5 developmental stages. If more than one stage exists then give a count for each.

Basic Bryophyte Anatomy



Above is a diagram of an idealized moss (taken from Schofield 1992). Note in the diagram that the mature sporophyte sits on top of the gametophyte (the green leafy part of the moss). The spores are contained in a somewhat cylindrical capsule (or sporangium) that is elevated on a narrow stalk called the seta. At the apex of the capsule is the opening from which the spores are eventually dispersed. This opening is covered by three layers of tissue, each with a different purpose. The calyptra is actually gametophytic tissue that splits from the gametophyte as the sporophyte grows and is carried up by the elongating seta. The calyptra serves to protect the growing sporophyte as it matures. Below the calyptra lies the operculum which is the lid to the capsule. When the sporophyte is fully mature the capsule dehisces along the line demarcating the operculum which then falls away. Inside the operculum lies the peristome which regulates spore release from the deoperculate capsule. The peristome usually consists of toothlike structures that are hygroscopic and articulated. They often move in response to changes in relative humidity and thereby bring about a slow, regulated spore release. Details of peristome anatomy are often useful in moss taxonomy in the same way the flower characteristics are useful for vascular plant systematics.

Common bryophyte species found in or near Black Rock Canyon:

Anacolia menziesii (Hampe) Paris
Bryum argenteum Hedw.
**Crossidium aberrans* Holz. & E.B. Bartram
**Crossidium squamiferum* (Viv.) Jur.
**Desmatodon guepinii* Bruch & Schimp.
Didymodon australasiae (Hook. & Grev.) R.H. Zander
Didymodon tophaceus (Brid.) Lisa
Didymodon vinealis (Brid.) R.H. Zander
Fabronia pusilla Raddi
**Fissidens sublimbatus* Grout
**Funaria hygrometrica* Hedw.
**Funaria muhlenbergii* var. *lineata* Grout
Gemmabryum demaretianum (Arts) J.R. Spence
Gemmabryum valparaisense (Thér.) J.R. Spence
**Grimmia anodon* Bruch & Schimp.
Grimmia laevigata (Brid.) Brid.
Grimmia montana Bruch & Schimp.
**Grimmia moxleyi* R.S. Williams
Grimmia poecilostoma Cardot & Sebille
**Grimmia pulvinata* (Hedw.) Sm.
**Jaffueliobryum wrightii* (Sull.) Thér.
**Pottiopsis sweetii* (E.B. Bartram) Ros & O. Werner
**Rosulabryum torquescens* (Bruch ex De Not.) J.R. Spence
Syntrichia caninervis Mitt.
Syntrichia ruralis (Hedw.) F. Weber & D. Mohr
Syntrichia virescens (De Not.) Ochyra
**Targionia* aff. *hypophylla* L.
**Tortula atrovirens* (Sm.) Lindb.
**Tortula brevipes* (Lesq.) Broth.
**Tortula inermis* (Brid.) Mont.
**Weissia controversa* Hedw.
Weissia andrewsii E.B. Bartram
Weissia ligulifolia (E.B. Bartram) Grout

* = species commonly found with sporophytes

References:

- Schofield, W. B. 1992. Some common mosses of British Columbia, second edition. Royal British Columbia Museum, Victoria.
- Stark, L. R. 1997. Phenology and reproductive biology of *Syntrichia inermis* (Bryopsida, Pottiaceae) in the Mojave Desert. *Bryologist* 100: 13–27.
- Stark, L. R. 2002a. Skipped reproductive cycles and extensive sporophyte abortion in the desert moss *Tortula inermis* correspond to unusual rainfall patterns. *Canadian Journal of Botany* 80: 533–542.
- Stark, L. R. 2002b. Phenology and its repercussions on the reproductive ecology of mosses. *Bryologist* 105: 204–218.

Stages of sporophyte phenology illustrated:

Stage 1 – Embryonic:



Stage 2 – Seta Elongation:

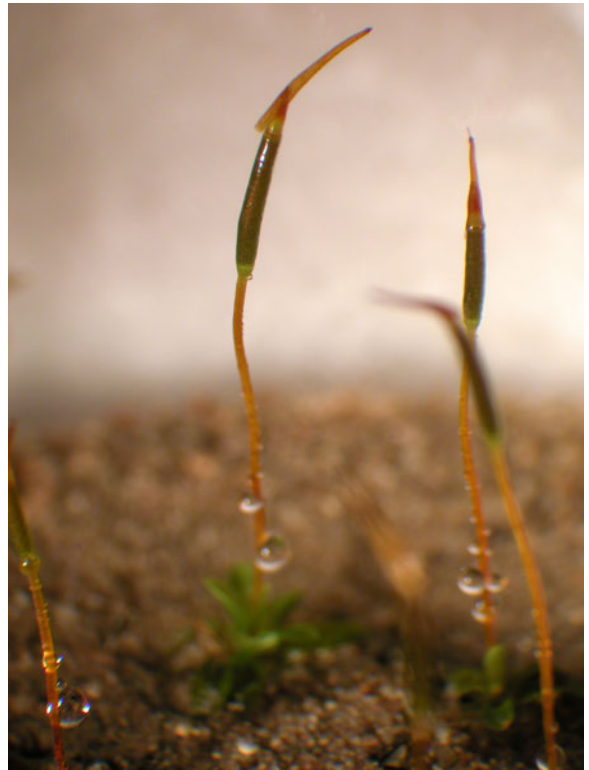


Stages of sporophyte phenology illustrated:

Stage 3 – Capsule Expansion:



Stage 4 – Capsule Brown (Post-meiotic):



Stages of sporophyte phenology illustrated:

Stage 5 – Capsule Deoperculate:

