

Circular growth patterns in Southern California desert plants

David K. Lynch
dave@caltech.edu

ABSTRACT—A Google Earth search of southern California deserts revealed thousands of plants growing in circular patterns. Hundreds of areas were found that contained dozens of same-species plant rings. Subsequent field inspection revealed at least four species of ring-forming plants: creosote (*Larrea tridentata*), Mojave yucca (*Yucca schidigera*), honey mesquite (*Prosopis glandulosa*) and fourwing saltbush (*Atriplex canescens*). Creosote rings were the most common and the newly-discovered mesquite rings were the largest, up to 170 meters in diameters and 11 meters high. Mesquite rings formed nabkhas (coppice dunes). Creosote and yucca rings grow as clones but it is not known if mesquite and saltbush are clones. Field inspection also revealed a number of grass rings that are as yet unidentified species.

Introduction

Many plants are known to grow in circular patterns like the letter “O.”¹⁻⁴ These rings are characterized by a periphery of living plant surrounding a central region that is relatively empty of plants or may contain dead branches

of the earlier plant, a so-called “necrotic zone”. Growth is radially outward from a central point, presumably the location of the original plant. Such patterns occur all over the world and even in the ocean.⁵ Best known are the circular rings of mushrooms called “fairy rings.”⁶

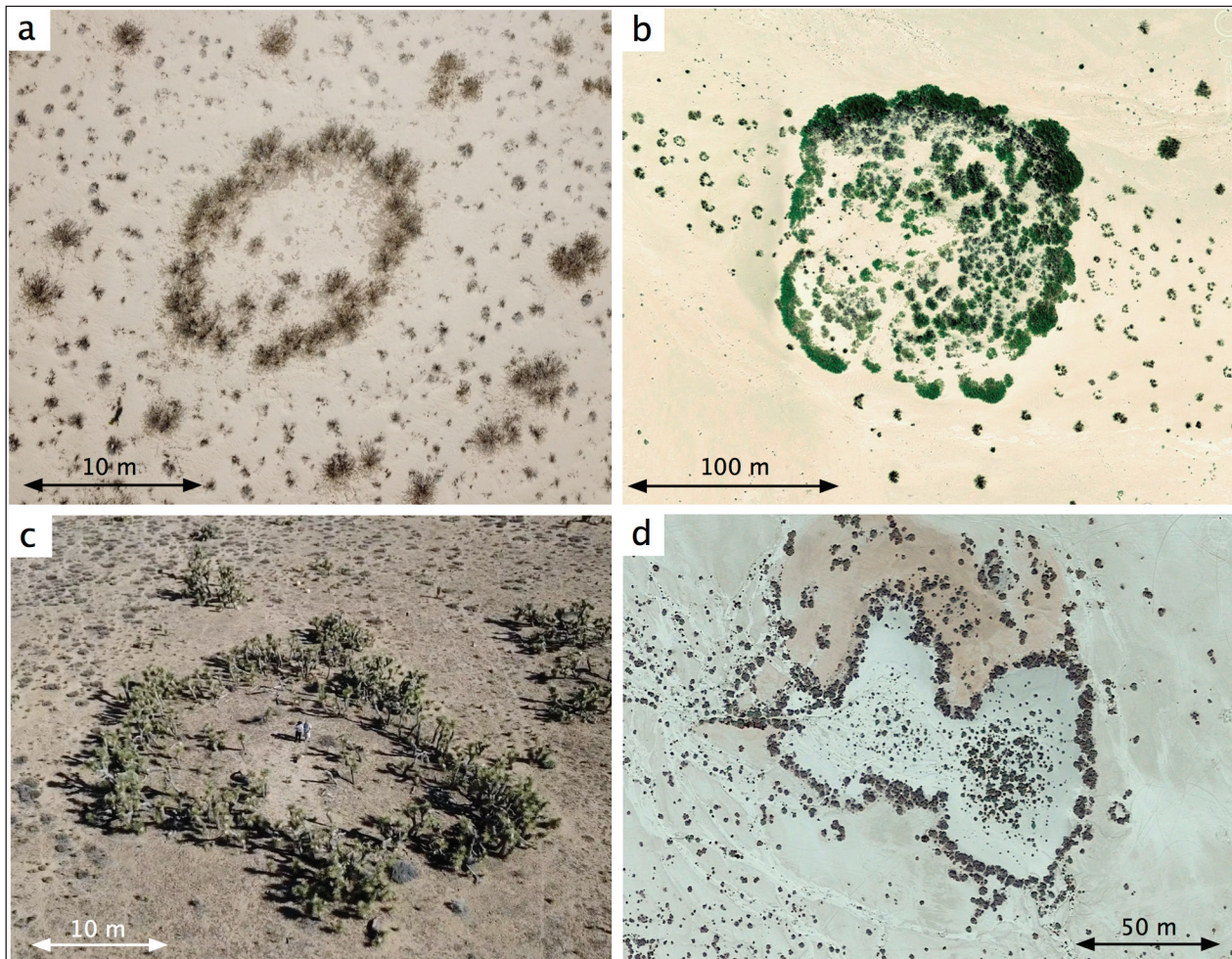


Figure 1. Examples of plant rings. (a) Drone image of a creosote ring (*Larrea tridentata*) in Johnson Valley. (b) Google Earth image of a honey mesquite ring (*Prosopis glandulosa*) near Zzyzx. (c) Oblique drone image yucca ring (*Yucca schidigera*) in the western Mojave. (d): Google Earth image of a fourwing saltbush ring (*Atriplex canescens*) near Lenwood, CA.

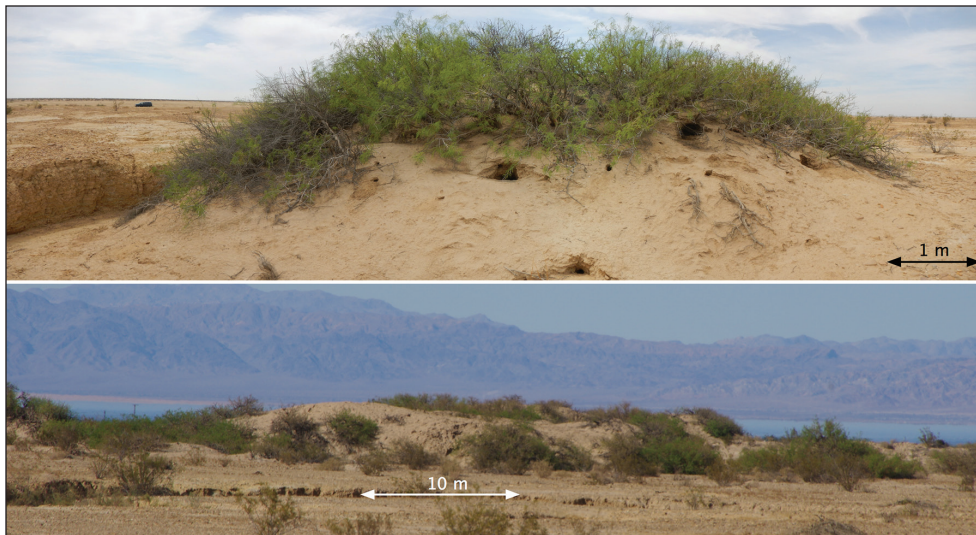


Figure 2. (Upper): Small honey mesquite nabkha. Note the burrow entrances— evidence of bioturbation— and absence of other plant species that contribute significantly to the nabkha. (Lower): Large honey mesquite nabkha near the Salton Sea. Both showed prominent ring structure.

In southern California deserts, creosote bush (*Larrea tridentata*)^{7,8} and Mojave yucca (*Yucca schidigera*) were previously known to form circular clone rings^{9,10} (Figure 1). Field inspection of the rings including drone imagery allowed plant identifications to be made, as well as to investigate and document the rings' ecological contexts. In this paper I report the results of the survey including the discovery of two new ring forming plants and the subsequent field findings, and discuss many aspects of plant rings.

The survey

Starting in March 2018, the author spent several hundred hours examining Google Earth imagery across the southern California deserts at a magnification sufficient to show rings greater than about a meter in diameter. When they were found I zoomed in to examine the rings in detail and searched the surrounding areas for rings. The survey was limited to southern California deserts south of latitude N36.8°, or roughly the latitude of Independence, CA. The Google Earth search was followed up by field inspection of many rings and ring fields.

Results

In addition to creosote and yucca rings, the survey revealed thousands of plant rings and several new species of ring formers: honey mesquite (*Prosopis glandulosa*), fourwing saltbush (*Atriplex canescens*) and a number of ground hugging grasses that are yet to be identified (Figure 1). Only two rings of saltbush were found and they occurred in an area that appeared to be composed soil disturbed by man. Consequently, they could not be analyzed statistically.

Most rings were found to have elevated interiors. Creosote rings had the least elevated centers and mesquite rings had the most. Significantly elevated rings (> 0.5

m) usually formed nabkhas.^{11,12} Nabkhas (coppice dunes) are isolated, aeolian landforms and ecosystems that result when plants capture and hold wind-blown sand to build mounds (Figure 2). The mounds become self-sustaining and grow as other species of plants and animals take root, find shelter, and prosper in the agreeable environments. Bioturbation in nabkhas— usually mesquite—is common and mesquite often forms the crown and sides of the nabkha. In general, the larger the mesquite ring diameter,

the taller the nabkha (Figure 3).

Rings tend to occur in wide open, flat, horizontal areas, typically on the distal parts of fans. Yucca rings and low grass rings are common in mountainout areas; creosote rings are less common, and other species are rare or unknown.¹³ Mesquite rings are found in a somewhat wider range of environments, with sandy Holocene surfaces near active drainages being common. Creosote rings are rarely found on old proximal Pleistocene fans, steep fans

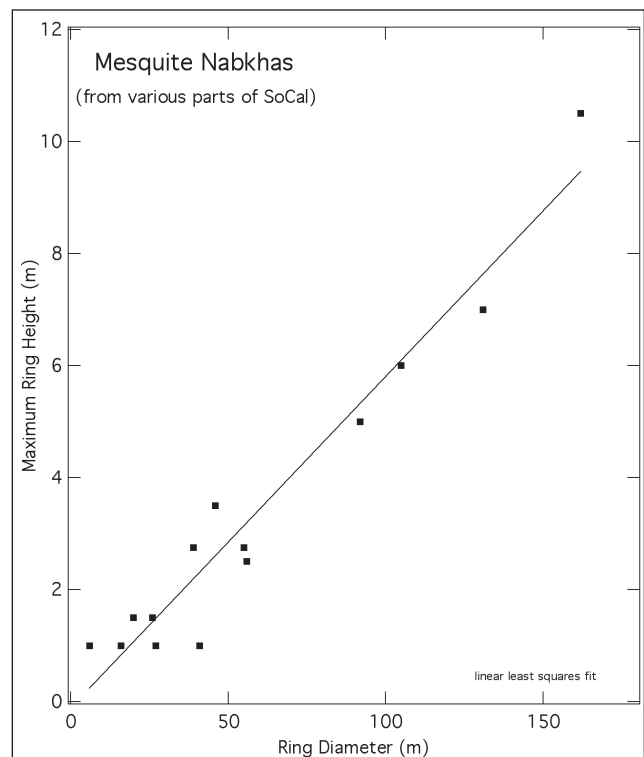


Figure 3. Mesquite nabkha ring height vs. ring diameter, and least squares linear fit.

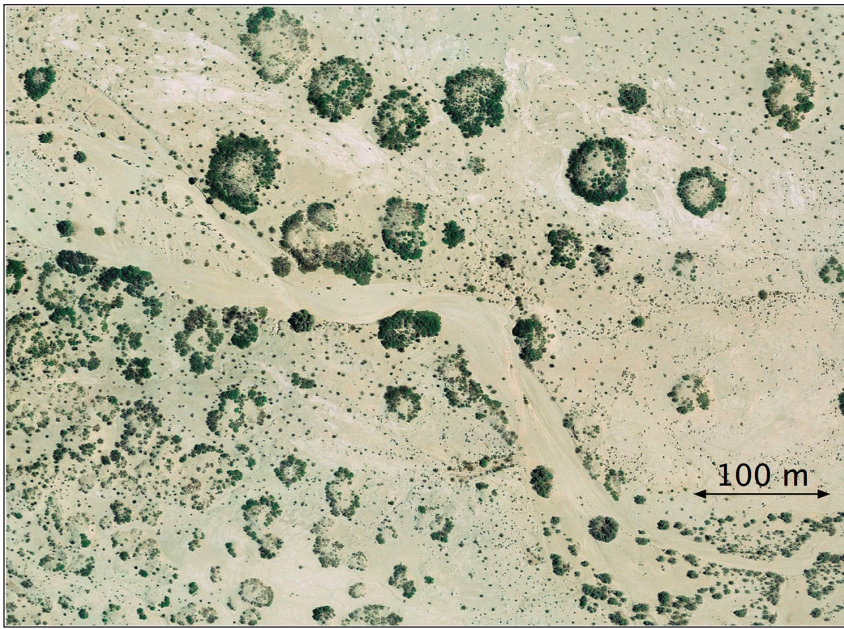


Figure 4. Portion of a large mesquite ring field in lower Fish Creek Wash, Imperial County, CA.

where bar and swale microtopography are readily evident, or in active drainages.¹⁴ Rings in a given area are almost invariably made of a single species: while mesquite rings may be found in large fields of creosote, creosote is rarely found in a mesquite ring, and vice versa. Nor do creosote and mesquite rings overlap.

There was a wide variety of ring morphologies. Many were complete, continuous closed loops like circles and ellipses. Others were incomplete circles. Some rings did not contain an empty “necrotic zone” but were filled to some degree by plants, some different than those on the periphery. Some had lobe-like structures. Many were not perfectly circular but were nonetheless discrete, isolated and well enough defined to warrant inclusion here. The color inside the circles was often different than on the outside, usually due to grasses. Some rings showed

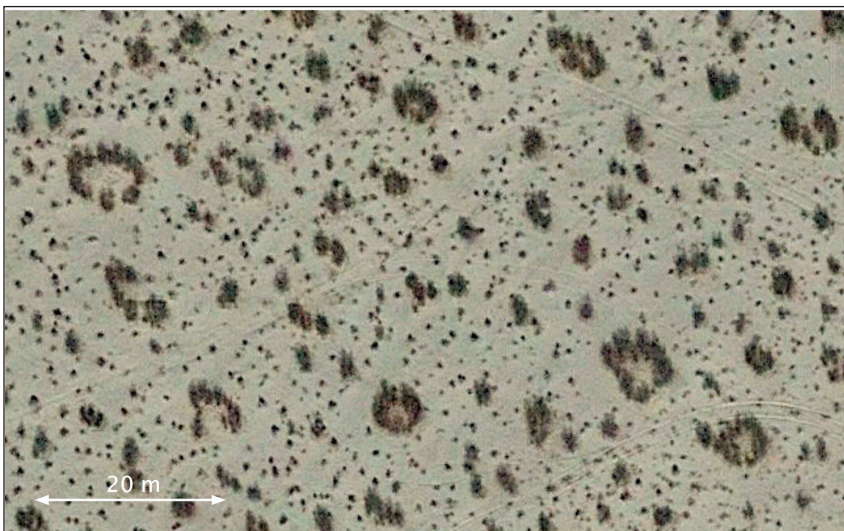


Figure 5. Creosote ring field in the Soggy Dry Lake area.

depleted plant numbers immediately surrounding them (Figure 4, 5).

Based on historical Google Earth imagery going back about 20 years, there was no discernable change in any ring. Thus, the rings must grow slowly and be relatively old, probably having sprouted at least hundred years ago. Studies by a number of groups suggest that creosote rings could be thousands of years old.^{7,14}

Ring fields

Many plant rings were found to occur in clusters, or “ring fields” (Figure 4, 5). They were composed of dozens to hundreds of plant rings, all of the same species. Approximately 150 ring fields were identified in the Colorado and Mojave deserts as well as in places like the Saline Valley, Owens Valley, and Death Valley. Ring fields are a few hundred meters to several kilometers in size. While the occasional ring may

be found almost anywhere, ring fields are not distributed randomly across southern California.

Creosote rings usually occur in flat, level open country with large areas of them being present in the Lucerne Valley, the southern Mojave between Victorville and Palmdale, the area west of Trona, and the western Mojave west of Rosemond. Creosote nabkha fields are found near Palm Springs. Most of the creosote fields are “sparse” in the sense that only a small fraction of the creosote is growing in rings (Figure 5).

Mesquite ring fields, on the other hand, tend to be “dense:” virtually every mesquite plant is part of a ring (Figure 4). These rings preferentially occur in endorheic basins associated with dry lakes or alkali flats where there is little or no slope ($<1^\circ$). They are found near but never in dry lakes or alkali flats, and may grow on proximal fans. Mesquite rings are never found in mountains, topographically rugged terrain, or dry lakes, but may occur on fans with deeply incised channels or bar and swale topography.

Most ring fields seem to be associated with environmental gradients or transitional regions, i.e., where the soil color changes across the field or within a few hundred meters of it. This is particularly true for mesquite, though a few creosote rings also occur near environmental gradients, especially when the creosote forms nabkhas.

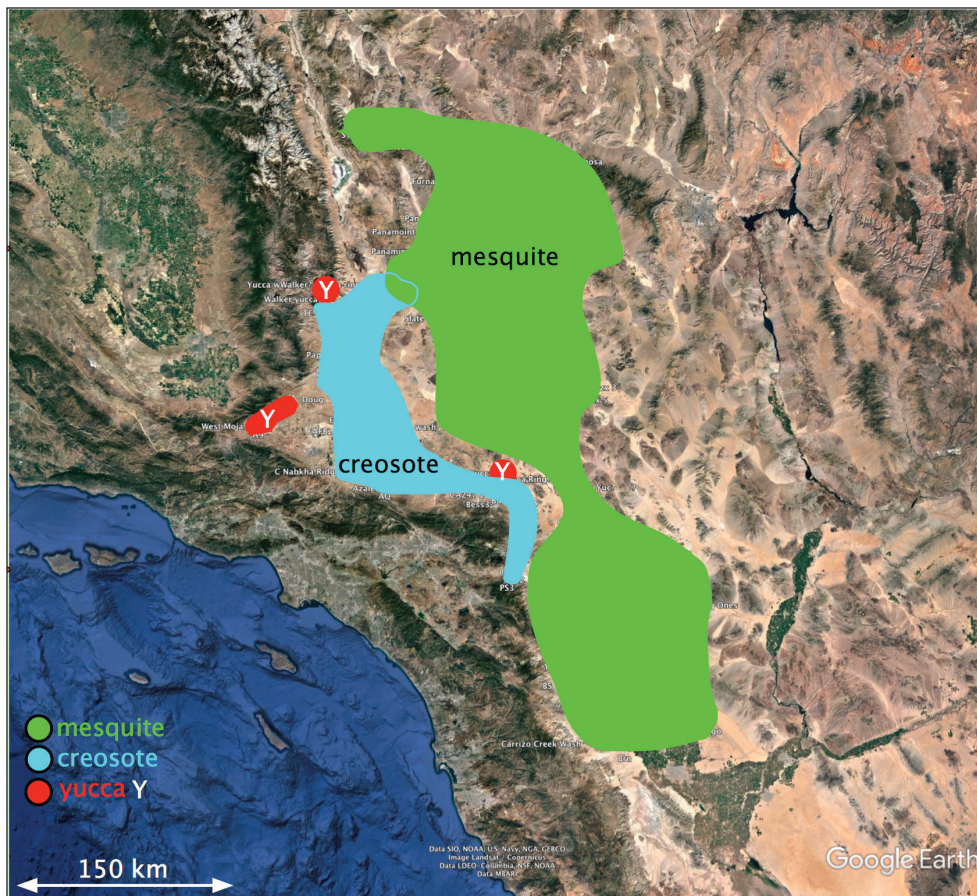


Figure 6. Approximate ranges of mesquite, creosote and yucca ring fields. Ranges of mesquite and creosote ring fields almost never overlap.

Rings with distinctive morphologies tend to occur together: thin rings, filled rings, lobe-like rings, etc. Different rings structures rarely occur together. A number of creosote ring fields contained interrupted circles like in the shape of the letter “C”, all oriented in the same direction, perhaps related to the prevailing winds. In some ring fields, a significant fraction and perhaps most of the plant mass appears to be in rings.

Ring field distribution

Though widely scattered across southern California, ring fields are not randomly distributed. Creosote and mesquite ring fields are the most common, yet their ranges rarely overlap (Figure 6). Creosote is found to the west and mesquite to the east. No ring fields are found near the Colorado River. Yucca ring fields—of which only a few are known—show no systematic pattern of distribution and are found in some mountainous regions. The largest and most numerous yucca ring fields lie immediately south of the western Garlock Fault.

Discussion

Radial growth away from a central “seed” location is the simplest possible growth pattern in both 2D and 3D spaces. It is seen on every scale from microscopic (in petri dishes) to hundreds of meters. Although the detailed

growth mechanisms may differ somewhat, all are related to competition for resources and how these resources change as the rings grow. Depending on the species and growth conditions, cloning may be an important factor.

It has been claimed that creosote rings are clonal,⁷ but only one has been tested. Yucca rings in controlled environments prefer cloning (vegetative reproduction) to sexual reproduction,⁹ but those in the wild have not been tested. It is not known if mesquite and saltbush are clonal because to our knowledge neither has been examined on a genetic level.

Based on historical Google Earth imagery going back about 20 years, there was no discernable change in any ring. Thus, the rings must grow slowly and be relatively old, probably having sprouted

hundreds and maybe thousands of years ago. Mesquite grows relatively quickly compared to creosote and this may explain why creosote is rarely found in mesquite rings: The mesquite simply grows too fast and covers the creosote.

Creosote grows very slowly, ~0.8 mm/yr radially outward.^{7,14} Therefore large rings must be relatively old, many thousands of years. For continuous growth over such time scales, the soil must be stable. This explains why creosote rings are not found on steep slopes or active drainages where erosion can change the surface topography fast enough to disrupt roots. While people have theorized that creosote rings must be growing in old stable Pleistocene soils, McAuliffe et al.¹⁴ have shown that most of the large creosote rings in the Soggy Dry Lake Creosote Ring Preserve (Johnson Valley, San Bernardino County), including King Clone, are rooted in distal fan Pleistocene soils that have been covered by Holocene soils. This may further explain why creosote rings are not found in old Pleistocene soils:¹⁵⁻¹⁷ such soils usually have impenetrable calcic and argillic horizons that prevent creosote roots from penetrating deep enough to reach year-round water.

Regarding clones in their relatively small study area, McAuliffe et al.¹⁴ say, “The greatest concentration of

large clones occur in medial or distal parts of fans on young surfaces. Alluvial deposits that may be as little as a few centuries old constitute the surfaces where the largest clones are found, yet ages of large clones like the ones at that site have been estimated to be on the order of at least several thousand years (Vasek, 1980a).” After lengthy analysis, McAuliffe et al. conclude that the plant germinated on older (now buried) Pleistocene surfaces that are now covered by younger Holocene sediments, perhaps aeolian in nature. We can surmise that germination took place before significant calcic or argillic horizons had developed.

Mesquite is a different story. It grows much faster than creosote, many cm per year, and may live only 100 years. Therefore, all mesquite trees are young, and certainly much younger than any nearby creosote bush. This probably explain why most mesquite nabkhas have no creosote growing in them: creosote grows too slowly to avoid being covered up by the faster growing mesquite and associated coppice dune.

Plant growth patterns discussed here seem to have three types or stages: (1) single plant, (2) single plant ring, and (3) ring fields. Yet the question “Why do some plants grow in rings, while others do not” remains to be unraveled. Many answers have been suggested.¹⁻⁴ While all seem reasonable, no one of them seems to explain all ring situations. An equally intriguing question is this: “Why do some ring-forming plants grow in ring fields in some places but not in others?” Are soil or other environmental gradients involved?

Conclusions

The recognition of ring fields is the major contribution of this paper. I have identified at least two new species of ring forming plants, mesquite and fourwing saltbush. Many mesquite rings grow as coppice dunes. The largest field of yucca rings is not in the Upper Johnson Valley Preserve but rather in the western Mojave. Different species of rings fields rarely overlap.

Acknowledgements

I am thankful for the help and discussions provided by David M. Miller, Chris Spounias, Lauria Lynch-German, George Jefferson, Larry Hendrickson, and Tom Schweich.

References

1. Bonanomi, G., G. Incerti, A. Stinca, F. Carteni, F. Giannino, S. Mazzoleni, Ring formation in clonal plants, *Community Ecology*, 15 (1) 77-86 (2014)
2. Sheffer, Efrat, Hezi Yizhaq, Moshe Shachak, Ehud Meron, Mechanisms of vegetation-ring formation in water-limited systems, *Journal of Theoretical Biology* 273, 138-146 (2011)
3. Sujith Ravi, Paolo D’Odorico, Lixin Wang and Scott Collins, Form and Function of Grass Ring Patterns in Arid Grasslands: The Role of Abiotic Controls, *Oecologia*, 158, (3), 545-555, (2008)
4. Lanta, V., Stepan Janecek and Jiri Dolezal, Radial growth and ring formation process in clonal plant *Eriophorum angustifolium* on post-mined peatland in the Sumava Mts, Czech Republic, *Ann. Bot. Fennici*, 45, 44-54 (2008).
5. Borum, Jens, Ane Løvendahl Raun, Harald Hasler-Sheetal, Mia Østergaard Pedersen, Ole Pedersen, Marianne Holmer, Eelgrass fairy rings: sulfide as inhibiting agent, *Marine Biology*, 161(2) 351-358 (2014)
6. https://en.wikipedia.org/wiki/Fairy_ring
7. Vasek, Frank C., Creosote Bush: Long-Lived Clones in the Mojave Desert, *American Journal of Botany*, 67(2), 246-255 (1980)
8. Draft Environmental Impact Report and Statement for West Mojave Plan, Appendix D3.3 Soggy Dry Lake Creosote Rings, US Dept Interior (2003). See also https://books.google.com/books?id=FP8xAQAAMAAJ&pg=PA34-IA27&lpg=PA34-IA27&dq=yucca+clone+rings+johnson+valley&source=bl&ots=wT8CSEDzfl&sig=cg41uyH40zyOb4kNRMXIvnx_aPw&hl=en&sa=X&ved=2ahUKewid-_WsiM3fAhUIqoMKHYSYCNg4ChDoATAAegQIChAB#v=onepage&q=yucca%20clone%20rings%20johnson%20valley&f=false
9. <https://www.fs.fed.us/database/feis/plants/shrub/yucsch/all.html#INTRODUCTORY>
10. Draft Environmental Impact Report and Statement for West Mojave Plan, Appendix D3.4 Upper Johnson Valley Yucca Rings, US Dept Interior (2003)
11. <https://en.wikipedia.org/wiki/Nabkha>
12. El-Sheikha, Mohamed A., Ghanim A. Abbadi, Pietro M. Bianco, Vegetation ecology of phytogenic hillocks (nabkhas) in coastal habitats of Jal Az-Zor National Park, Kuwait: Role of patches and edaphic factors. *Flora* 205 (2010) 832-840 (2005)
13. Jessey, David R. and Robert E. Reynolds, Landscape evolution at an active plate margin: a field trip to the Owens Valley, *Proceedings of the Desert Symposium*, 14, mile mark 77.7, (2009)
14. McAuliffe., J. R., P. Hamerlynck and C. Eppes, Landscape dynamics fostering the development and persistence of long-lived creosotebush (*Larrea tridentata*) clones in the Mojave Desert, *Journal of Arid Environments*, 69(1),96 (2007)
15. McAuliffe, J.R., Landscape evolution, soil formation, and ecological patterns and processes in Sonoran Desert bajadas. *Ecological Monographs* 64, 111-148. (1994)