Demographic Studies of Joshua Trees in Mojave Desert National Parks: Demography With Emphasis on Germination and Recruitment

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A collaborative effort between the U.S. Geological Survey and the National Park Service is establishing long-term Joshua tree monitoring plots in the Mojave Desert. But where are the seedlings?

The study of population change with regard to reproduction, seed dispersal, and germination, establishment, growth, and survival/mortality is known as demography. Demographic studies provide managers with information to assess future trends on the density, distribution, health, and population changes of importance or value, including Joshua trees (*Yucca brevifolia*). Demographic research provides the potential to understand the combined impacts of climate change and land-use practices and determine if strategies for protecting important species are likely to succeed or fall short of management goals and will identify factors that have the potential to de-stabilize populations outside the realm of natural variation so that management strategies can be developed to circumvent challenges for key species, processes, and ecosystems. The National Park Service and US Geological Survey are collaborating to collect demographic information about the demographics of Joshua tree in the Mojave Desert.

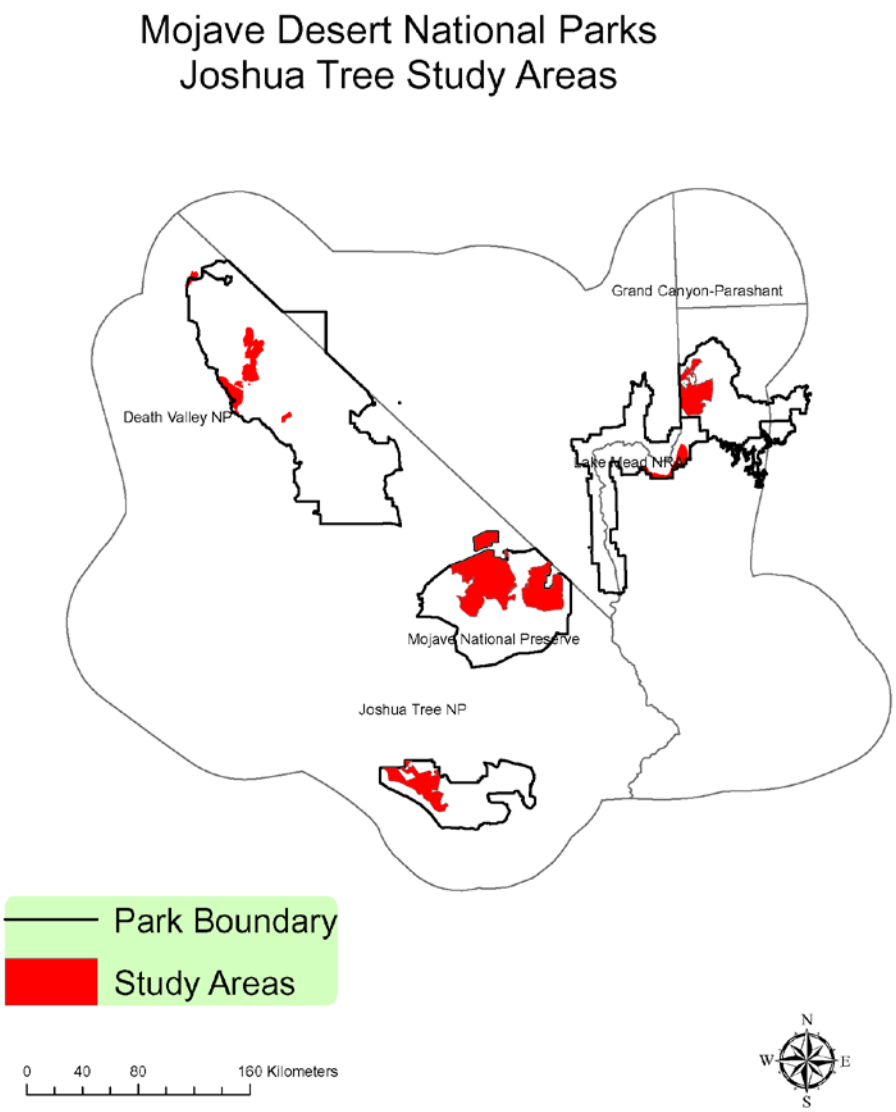

Figure 1. National Park units and the areas surveyed for Joshua trees within each park.

Joshua trees are widespread across the Mojave Desert (*1*) and occur in five National Park Service administrative units (Figure 1,). As the tallest and most massive plant in the low- and mid-elevations of the Mojave Desert, the Joshua tree is a keystone species providing food, shelter and structure to wildlife. Recently the persistence and population status of Joshua trees has come into question primarily due to increased wildfires (*2, 3*) and concerns about how climate variation will affect Joshua trees (*4, 5*).

An example of how fire and climate variation have affected Joshua trees follows. In 1998 the Mojave Desert experienced a wet El Niño cycle that resulted in an abundance of the invasive annual grasses such as red brome (*Bromus madritensis*). In 1999 the 6,000 ha Juniper Fire Complex burned large expanses of Joshua Tree National Park and subsequent monitoring of Joshua

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trees indicated that ~68% died of exposure to fires (*3*). Wildfire immediately reduced survivorship of all Joshua trees <1 m tall, and in the following years reduced the survival of reproducing adults (*3*). Other researchers have found similarly high mortality related to fires (*2*). Most Mojave Desert fires result from increased standing biomass of non-native annual plants (*6*). After the 1999 fire in Joshua Tree National Park a very dry La Niña event occurred in 2002 and resulted in another 9 % of Joshua trees dying from drought – even on unburned sites (*3*). Although mortality due to climate variability/change during the study was substantially lower than losses due to fire, extended drought can cause mortality of even the largest Joshua trees. Wildfire immediately reduced survivorship of all Joshua trees <1 m tall, and subsequently reduced the survival of reproducing adults (*3*). Drought exacerbated these losses with particularly large losses of the smaller size classes (*3, 7*).

The fires also remove cover of perennial plants over large burned expanses reducing the availability of cover for Joshua tree germination and establishment sites (*8*). Gross changes in vegetation cover may also affect the distribution of rodent species (*9*) that can be important to Joshua tree seed dispersal (*10-12*). If climate shifts toward hotter and drier conditions in this region, then it seems likely that mortality will be accentuated, which would cause significant concern for the persistence of Joshua tree populations.

All of the observations described above led resource managers and researchers to consider the capacity for Joshua tree populations to sustain such losses over the long term. In 2007 the National Park Service and USGS initiated a research project designed to establish permanent demographic study plots for Joshua trees on National Park Service lands across the Mojave Desert; identify and quantify seed dispersal mechanisms; and to conduct experiments on germination and establishment under natural conditions. Here, we provide preliminary information about this ongoing project. Information regarding Joshua tree seed dispersal is available in a recently completed thesis (*12*) and will not be reported here.

Study Area – Joshua tree populations were surveyed in five National Park Service administrative units within the Mojave Desert Inventory and Monitoring Network (MOJN), including Joshua Tree National Park (JOTR), Death Valley National Park (DEVA), Mojave National Preserve (MOJA), Lake Mead National Recreation Area (LAME), and Grand Canyon / Parashant National Monument (PARA) (Figure 1). In DEVA, Joshua trees are widely dispersed in several small and isolated stands in the remote northeastern parts of the park: Lee Flat, Hidden Valley, White Top Mountain and the Cottonwood Mountains, and Cowhorn Valley near Loretta Mine Road. JOTR has large relatively well-connected stands north of the Little San Bernardino Mountains, west of the Hexie Mountians and south of Queen Mountain. LAME Joshua trees are located near Mead View on Grapevine Mesa and along the southern border of the park north of Golden Rule Peak. In MOJA, the population is split by the Mid Hills and New York Mountains with one group in the Lanfair Valley and the other surrounding Cima Dome and Ivanpah Mountains and in the Ivanpah and Shadow Valleys. Finally, PARA has a single widely dispersed stand west of the Grand Wash Cliffs and southeast of the Virgin Mountains in the Pakoon Basin. We used a sixth study area on BLM administered lands near Searchlight, Nevada, within the current range of the Joshua tree for manipulative experiments on seed dispersal, germination, and establishment.

Demographic Study Plots – Demographic plots were established in 2007 when field crews verified the distribution of Joshua trees within the five parks. Fifty random plots were established within the range of Joshua trees in each park except in LAME, where 20 plots were used because of its more restricted distribution of the species. Each plot had at least one Joshua tree and when randomly selected sites were found to be without Joshua trees they were abandoned – without trees to measure the plots would not contribute to the study. Each 0.25 ha plot (50 m x 50 m) was searched entirely for Joshua trees of all sizes by two people walking in opposite directions and searching under every shrub and bunchgrass, especially searching for small plants. Initial demographic and growth measurements included height, greatest width and perpendicular width, stem diameter, presence of cloning, flowering state and history, number of leaf rosettes (i.e., terminal branch buds), and associated shrubs and grasses species for Joshua trees less than one meter tall (for cover site analysis). Individual Joshua trees were mapped on each plot.

From 2007 to the present, 3385 Joshua trees were measured within the five parks. JOTR has the highest density of plants per plot, and LAME has the lowest (Table 1). Figure 2 represents a histogram of all the Joshua trees that were measured across five parks. Each bar in the graph represents the number of trees found in each height class. This composite graph of Joshua trees representing all the parks is fundamentally similar to the relative size distribution of other long-lived plants, such as the Giant Sequoia tree (*13*), where there are large numbers of plants in the smallest size classes, moderate numbers of middle-sized plants, followed by greatly reduced numbers of the largest and oldest plants. Fluctuations in the abundance of long-lived plants in the smallest size classes are to be expected, but the pattern and timing of the variation can provide insights into factors that affect future stands of such plants. The

difference in the smallest size classes of Joshua trees are interesting because it may provide a glimpse of how Joshua trees respond to environmental variation in the much harsher Mojave Desert conditions. Such differences in the size distributions of Joshua trees are even more pronounced when the data are singled out for each park, and this is the focus of ongoing analyses.

Focal Trees on Demographic Plots – We randomly selected six focal plots from among the demographic plots at each park to revisit once per year and measure overall height, growth of branches, the addition of new leaves, evidence of flowering/fruiting, and number of branch terminations. Within each of these focal plots, one tree was randomly selected within each of six height classifications <1 m, >1 to 2 m, >2 to 3 m, >3 to 4 m, and ≥4 m tall. When trees of all size classes were not available within a focal plot, we expanded the search to include the nearest tree of required size and collected a GPS datum on the location of those trees. All these trees were measured once; we have only partially re-measured the focal plots of Joshua trees. We plan to visit these focal trees annually during the late-reproductive season (May – June) to measure the previous year's growth.

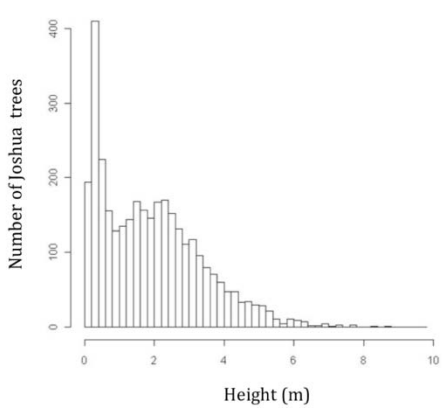

Figure 2. Histogram of Joshua tree size classes in 20 cm increments. Data represent plots located in all of 5 National Park study units combined.

Table 1. Percent vegetation cover in unburned and burned habitats by height class

Park Unit	Number of Plots (N)	Mean Density of Joshua Trees/0.25 ha	Range
All	221	NA	1-85
DEVA	50	15.5 (14.2)	1-85
JOTR	50	23.8 (18.9)	1-28
LAME	20	7.7 (4.9)	2-21
MOJA	50	20.9 (16.0)	1-63
PARA	50	9.3 (7.1)	1-32

Demographic measurements of these trees in relation to climate conditions and other environmental data can shed light on the reproductive health of the meta-populations and help identify areas to focus future research and (or) intensive management. Although results of our analysis of growth rates are incomplete, our initial observations noted a higher incidence of leaf-rosette division in the absence of flowering than we expected (i.e., when the flower buds die the branch typically sprouts laterally to create a 'fork' for continued growth). The work on focal trees has reinforced our observation that the germination and establishment are very rare in most locations within MOJN.

Germination and Establishment of Joshua Trees – Joshua trees do not flower or produce seed regularly, and upon flowering they depend on the yucca moth for pollination (*14*). Instead, Joshua trees produce flowers and seed infrequently and this pattern, known as masting, is an adaptation to avoid seed predators (*15*). Masting only creates fresh seed available for germination every few years, and the longevity of viable seed in the soil seed bank is unknown. Even though we reported what appears to be a robust sample of Joshua trees in the smallest size classes (Figure 2), we never saw a seedling Joshua tree (5 or fewer leaves, but still in the smallest size class – Figure 3) in 3 years of sampling in parks. We hypothesize that 1) we missed the timing of seedlings because we were between masting events, 2) environmental conditions (precipitation and temperature) were not conducive to producing seedlings during our study, 3) they died before detection, or 4) seed predation overwhelmed opportunities for germination.

To test these hypotheses, we began planting Joshua tree seeds experimentally beginning in August 2007. We planted and followed the fates of 5760 seeds to understand seedling germination and survival. Exclosures were placed in pairs with one in the open and the other under the canopy of a creosote bush. Exclosures were 0.5 m x 0.5 m and approximately 0.1 m tall providing ample room to grow for several years. From December 2008 to the present, seedling height and health status have been measured monthly and cages have been checked for new germination, growth, and survival of the seedlings.

Laboratory observations indicate that the seeds we used had greater than 90% germinability at the time of planting. Of the 5760 seeds planted in 2007, 130 (2.3 %) germinated and 22 (16.9 %) of the germinants survived to two years of age. This experiment indicates that although potential germinability was quite high, actual germination of plants, even though they were protected from vertebrate predators, can be quite low. No doubt this is dependent on soil moisture, temperature and also seed predation from invertebrates is likely. We have more recently planted additional cohorts of seeds to fill in data gaps on the germination and establishment success of Joshua trees in a variety of conditions.

Considerations – This research project has begun to provide information required to understand the life history of the Joshua tree throughout a large portion of its range. Like other long-lived

desert organisms, the earliest stages of life history cycles can elude biologists (e.g., desert tortiose, (*16*)). We predicted that a thorough survey aimed at finding the smallest size-classes of Joshua trees with an increased sample size could be more successful than previous attempts where long-term data were collected on smaller cohorts of Joshua trees (e.g., *17, 18*). However locating Joshua tree seedlings in situ has continued to elude us, except during controlled experiments where seeds were sown and tracked. We believe this indicates that recruitment has been quite rare for several years in most of the Mojave Desert. However, the establishment of these permanently marked plots will provide opportunities to capture recruitment should it occur in the future.

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