Desert Research Institute

Black Rock Playa, Northwestern Nevada: Physical Processes and Aquatic Life

Kenneth D. Adams and Donald W. Sada

May 24, 2010

Summary

The Black Rock Playa is affected by a multitude of processes, and flooding is one of the more important. Black Rock Playa floods occur every few years or sometimes more frequently. When the playa does not flood for a few years or more in a row, the surface can transform from a hard, durable surface to one that is soft and loose. During periods of frequent flooding and when the playa surface is firm, minimal wind-driven erosion occurs. Enhanced wind erosion likely occurs when the playa surface is soft and loose. This enhanced erosion occurs naturally but may be exacerbated by human activities that disrupt the fragile crust found on the playa when it is in its soft state.

Playas are harsh environments for aquatic life because they are infrequently flooded by turbid, saline, and alkaline water that is followed by drought that may last many years. When flooded, playas support phytoplankton, bacteria, other microbes, and crustaceans that are a rich food resource for migrating birds. Most of the aquatic species on the Black Rock Playa are branchiopods – including fairy shrimp, tadpole shrimp, and water fleas. All of these animals have a common life history where eggs lie encased in dry playa soil and do not hatch until the playa is flooded for enough time for adults to grow and reproduce.

Recreational use of the Black Rock Playa by vehicles and long-term camping decreases branchiopod egg abundance. In playa systems, the effect of human use on branchiopod populations is likely to be greatest when: (1) areas of the playa with highest egg density are impacted, (2) large portions of playa are affected, (3) frequency of reproduction is reduced by lengthy periods between inundation, and (4) egg abundance declines due to years of cumulative activity between inundations. The effects of use on the Black Rock Playa also may be compounded by annual, incremental transition from a hard, consolidated playa immediately following inundation to an increasingly soft and loose playa.

Use of the Black Rock Playa has increased during the past 25 years, and it is now annually visited by tens of thousands of people and thousands of vehicles. The most intense use is focused at Black Rock City, which covers only three percent of the playa. Other uses are comparatively short-term and involve fewer people, but their impact on branchiopods may be equivalent because these activities disturb a much greater area than Black Rock City.

—The Black Rock Playa in northwestern Nevada is one of the largest, flattest, surfaces on Earth—

Introduction

Desert playas are dynamic, harsh ecological systems that are exposed to lengthy aridity, strong winds, and occasional inundation by salty, turbid, alkaline water during periods of high precipitation. Knowledge of playas comes from a number of studies examining their characteristics such as hydrology, geologic processes, soils, and dust emission. When they are dry, their openness makes them attractive for hiking, vehicle travel, military activity, and other uses that disturb soils. When they are wet, they sustain a variety of life forms.

The Black Rock Playa (BRP) in northwestern Nevada is one of the largest, flattest, surfaces on Earth – covering approximately 2,600 km^2 (Figure 1). This flatness is largely because the playa represents the former bed of Lake Lahontan, an ancient lake that occupied many of the basins

On the front cover: The Black Rock Playa; *photograph by Kenneth M. Epp.*

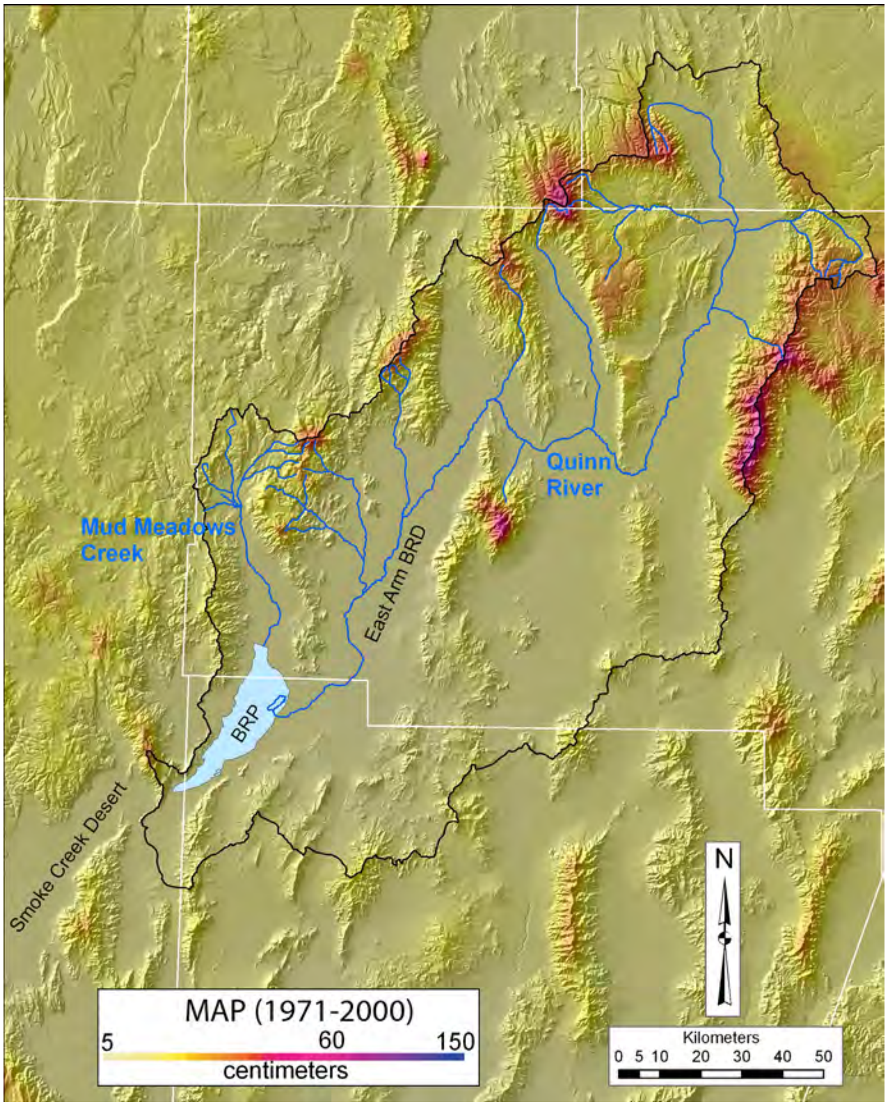

Figure 1. Map showing the drainage basin (thin black line) of the Black Rock Playa (BRP) and mean annual precipitation (MAP) in the region. The Quinn River and Mud Meadows Creek are shown by thin blue lines. Thin white lines are county boundaries. BRD = Black Rock Desert.

in northwestern Nevada approximately 15,000 years ago. A number of large mountain ranges and other areas of natural and cultural interest surround the playa, together forming an expansive area now recognized as the Black Rock Desert–High Rock Canyon National Conservation Area. The unique character of the playa probably is controlled by a combination of factors including climate, hydrology, tectonic setting, and past geologic history. Natural attributes of the BRP and surrounding Black Rock Desert (BRD) are increasingly attractive to a variety of user groups including off-highway vehicles, rocket enthusiasts, Burning Man, historic trail enthusiasts, and land sailors. The cumulative effects of all of these users are not well known. Here we document the physical processes that operate on the playa, how these processes affect and interact with the ecology of the playa, and how humans might be affecting these processes.

Physical setting: The Black Rock Desert is in northwestern Nevada (Pershing and Washoe Counties) and lies at approximately 1190 m elevation. The playa is dry during summer (Figure 2) and inundated only when winter and spring precipitation in the Quinn River and Mud Meadows drainages, and the surrounding landscape, supply sufficient water (Figure 3).

The playa is characteristically wet during winter and early spring (even during years without inundation) when deep mud makes vehicle travel impossible. Durability and hardness of the playa surface changes between periods of inundation. In years of inundation, the playa is hard during the following summer and evidence of vehicle traffic is minimal, which suggests the surface is relatively durable. Durability and hardness decrease annually between inundations. The cumulative decline in these factors is evidenced by decreasing presence of hard, compact playa soil and increasing occurrence of puffy soils and transitory ripples. Visual evidence of vehicle traffic is also increasingly pronounced during these periods.

Hydrology: Water from the watershed is necessary for inundation, and inundation does not occur from single precipitation events. Maximum water depth (as determined from satellite imagery) between late 1972 and 2008 was approximately 1 m (Figure 4), which equaled a maximum surface area of approximately 300 km^2 with a volume of about 15,000,000 m^3 (Figure 5). Depths of 0.5 m occurred 15 times during the period from December 1972 through December 2008. Depths approximating 1 m occurred only three times during this period. The playa soil is dominated by clay (Table 1).

Table 1. Typical particle size distribution of BRP soils.

Particle Size	Weight Percent
Sand (>62.5 um)	3.1
Silt (15 - 62.5 um)	10.4
Silt (3 – 15 um)	21.2
Clay (<3 um)	65.3

Figure 2. Black Rock Desert playa in summer.

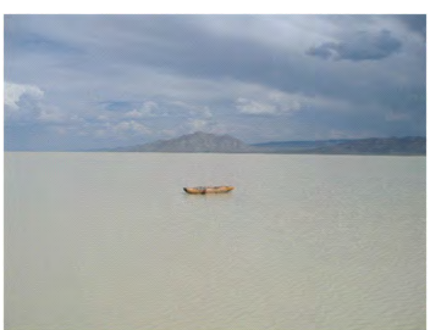

Figure 3. Black Rock Desert playa when it was inundated during spring 2006.

Topography: In contrast to some other parts of the Basin and Range, the BRD is more dominated by basins than ranges. The BRP is in the middle of three integrated basins that extend for about 180 km from the south end of the Smoke Creek Desert to the north end of the east arm of the BRD (Figure 1). All three basins represent the lake bed of ancient Lake Lahontan, but only BRP possesses the extreme flatness for which it is famous.

The very flat part of the BRP extends about 50 km in a northeast-southwest direction and ranges from 4 to12 km wide. Approximately 300 km^2 of the playa lies within the elevation range between 1190.2 and 1191.2 m (Figure 4). Although the active Black Rock fault zone bounds the southeastern margin of the playa and separates the BRP from the east arm of the BRD, tectonics do not seem to control micro-topography of the playa itself.

Climate: The climate of the BRP (measured at Gerlach, Nevada) is semi-arid with mean annual precipitation of about 17 cm (6.75 in). Maximum summer temperature rarely exceeds 35^{o} C (95^{o} F), and minimum winter temperatures are often below –20^{o} C (–4^{o} F). Summers are warm with a July daily mean temperature of 24^{o} C (75° F) and winters cool with January daily mean temperatures of about 1.6^{o} C (35° F). Prevailing winds at Bluewing Mountain, located about 25 km S-SE of the playa, are from the NW-SE; but significant winds likely come from all directions at certain times of the year. The average lake evaporation rate is about 127 cm/yr.

Human use: Intensity of human use varies across the playa. Recreational use is greatest during the summer and autumn along the Soldier Meadows/Double Hot Springs Road and Trego Road (primarily vehicle traffic use), and at Black Rock City (foot traffic, camping, and relatively light vehicle traffic annually for a minimum of six weeks during late summer). Use is lowest in remote areas that are distant from paved or graded roads that border west and east sides of the playa. The duration and frequency of use of the playa has increased in the past 25 years, but little is known about the influence of these activities on playa soils and ecology.

Project objective: The potential impact of human activity on the playa is of concern to agencies charged with management of this resource. We conducted studies beginning in 2006 to assess physical processes operating on the BRP, identify its aquatic life, and gain insight into how both are affected by camping and vehicle travel. Precipitation during 2006 was relatively heavy, maximum water depth over the playa was approximately 0.6 m, and approximately 150 km^2 of the playa was inundated during the winter and early spring (Figure 3). This level of inundation had not occurred since 2001. Since 2006, playa lakes have been smaller than about 30 km^2 in size.

Physical Processes Shaping the Black Rock Playa, Northwestern Nevada

Methods

We combined field observations, sediment sample collections, and topographic surveys with remote sensing observations and mapping to document physical processes operating on the BRP. Field observations from the Jungo playa, a much smaller playa located to the east of the BRP, also were included for comparison. It quickly became apparent that the hydrology of the BRP is a major controlling factor on physical processes. Therefore, we reconstructed a detailed flooding history of the playa for the last 35 years from Landsat satellite imagery, which became freely available during our study.

Satellite imagery: We viewed satellite imagery (Landsat) for the years 1973–2008, ordered through the U.S. Geological Survey (USGS). Landsat scenes of the BRP were collected by NASA with a frequency of about every 16 days, but the number of scenes downloaded and processed for each year ranged from zero (1991) to 15 (1995), depending on the presence and duration of a lake as well as image quality (cloudiness); approximately 195 images were downloaded. Scenes were stretched to accentuate water. Once stretched, the clipped scenes were imported into mapping software (ArcGIS®) where the changing extent of the lake was mapped through time.

Topography: Playa topography largely controls the frequency of inundation for any given point. Therefore, details of that topography need to be known. Up to this point, the most detailed topography was from existing topographic maps (USGS, 1:24,000 scale). Depending on the quadrangle, contour intervals range from 5 to 20 feet. These contour intervals are clearly inadequate to document the subtle topography of the playa so we

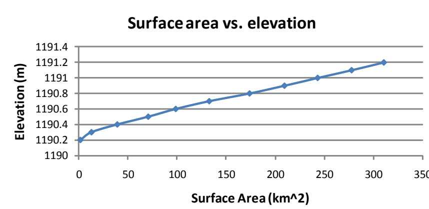

Figure 4. Water level elevation and surface area relationships for BRP inundation.

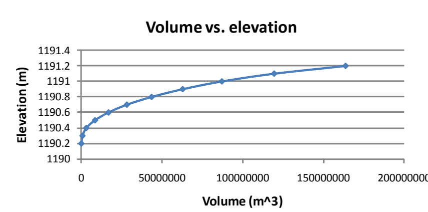

Figure 5. Water volume and surface elevation relationships for BRP inundation.

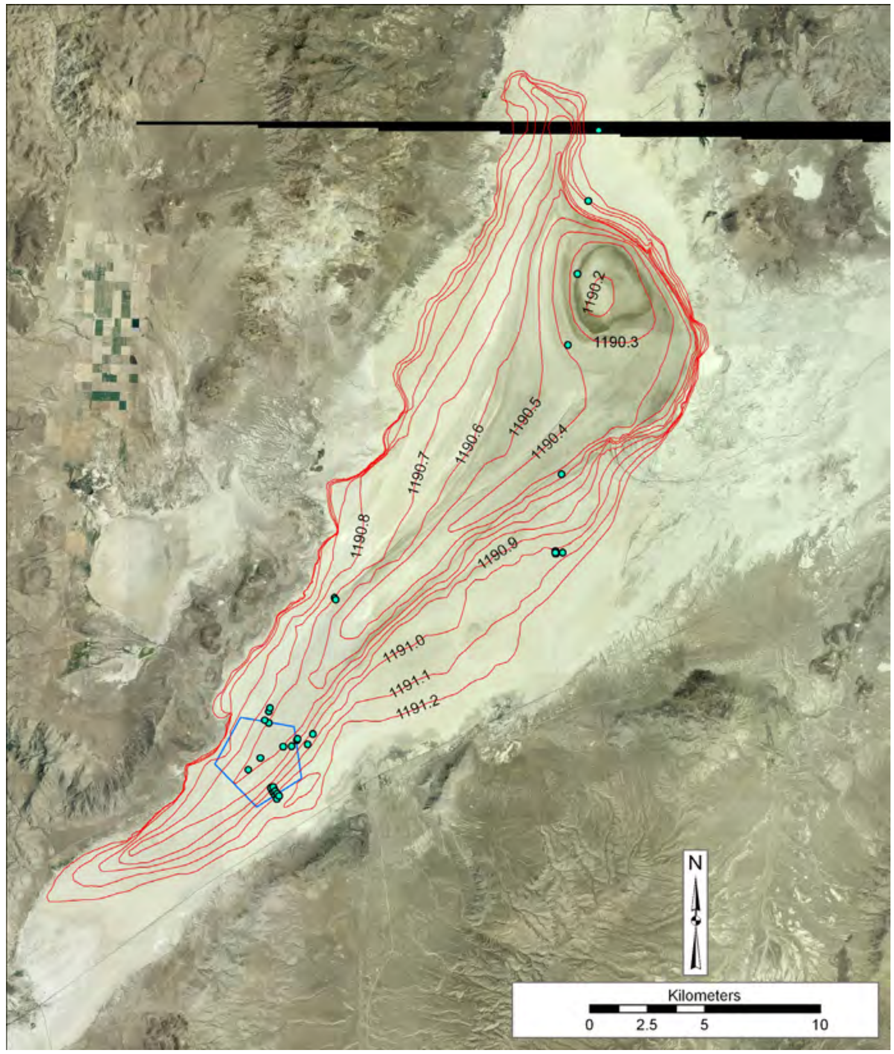

Figure 6. Detailed topographic map of the Black Rock Playa with 10 cm contour interval (red lines) between 1190.2 m and 1191.2 m. The outline of Black Rock City from 2003-2004 is shown by a thin blue line. Note that it lies within the central "channel" of the playa. The location of sediment samples is shown by green dots. The background is U.S. Dept. of Agriculture imagery from 2006.

performed a more detailed topographic survey using a survey-grade global positioning system (GPS; Thales Navigation). The GPS instruments were operated with a base station set up over benchmarks with a rover mounted to a vehicle roof rack. The GPS system has a stated accuracy and precision of $\leq$ 1 cm in the manner we used. We conducted surveys on four separate days with the results merged into a single file for plotting purposes. Results from a 2001 high precision GPS survey were added to the file; approximately 26,000 survey points were collected in total. Figure 6 presents the contour map of the Black Rock Playa.

Sediment samples: We collected sediment samples from the playa surface at multiple localities (Figure 6). In some places, paired samples were collected from a thin surface layer (mud curls) and the underlying playa. All samples were analyzed for particle size distributions and subsets were also analyzed for chemistry at laboratories at the Desert Research Institute (DRI).

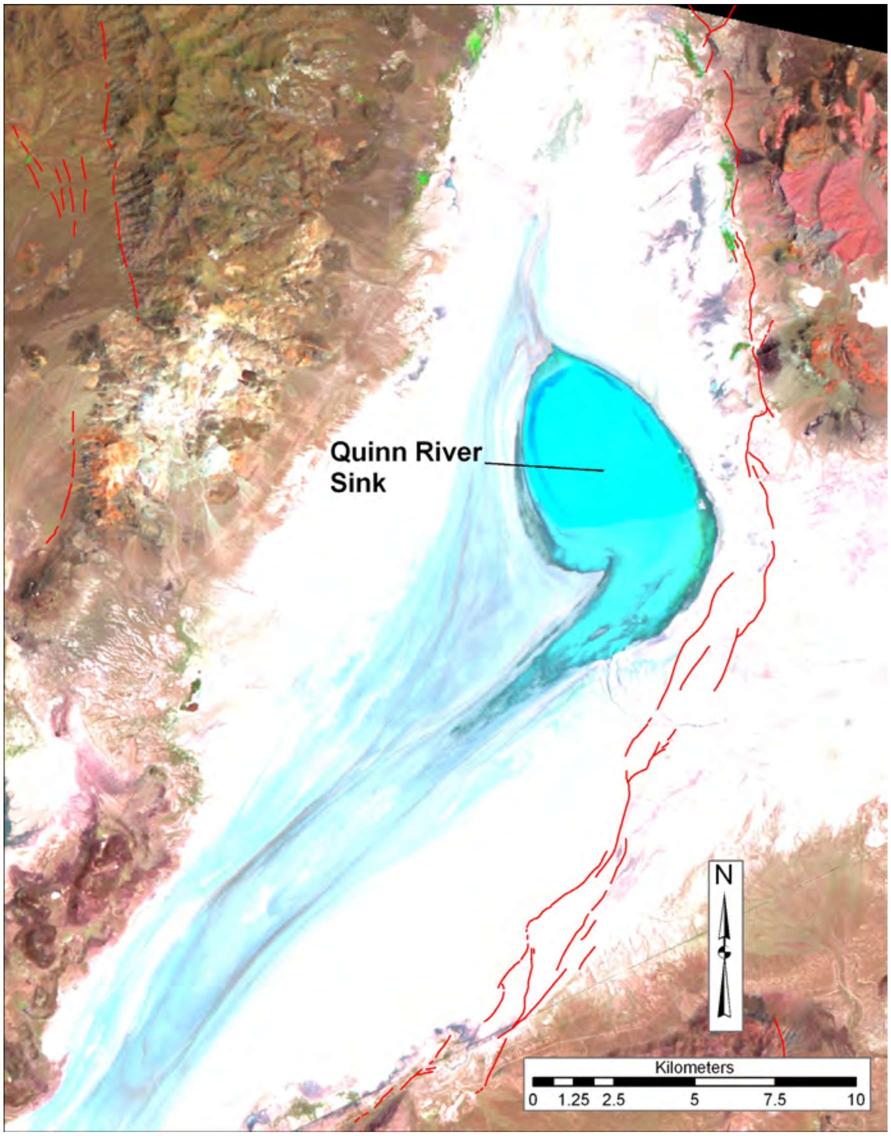

Figure 7. Map of the BRP showing the broad channel extending to the SW from the Quinn River Sink in relation to the location of the Black Rock fault zone (thin red lines). Landsat image is from July 11, 2006.

Results

Topography: The topography of the BRP is extremely flat. The playa itself covers about 480 km^2 ($\leq$ 1192 m), with approximately 310 km^2 of the playa lying between 1190.2 m and 1191.2 m (Figure 4). There is, however, a subtle channel that extends along the long axis of the playa in a NE-SW direction. This channel is several kilometers across and from 20 to 30 centimeters deep. Although it is imperceptible on the ground, the channel shows up well in satellite imagery (Figure 7) and has a controlling influence on the location of standing water on the playa.

The playa is alternately fringed by alluvial fans, sand dunes, and other wind-produced features. The dunes are often "cemented" in place by hard crusts, which can be disrupted by off-highway vehicle (OHV) travel. The southeast and east sides of the playa are bounded by the west dipping Black Rock fault zone, but the lowest part of the playa is approximately 5 km to the west (Figure 7). The east arm of the Black Rock Desert has been uplifted relative to the west arm, which has led to incision by the Quinn River.

Lake formation and desiccation: The hydrology of the BRP is largely controlled by flow down the Quinn River (QR) and Mud Meadows Creek (MMC) (Figure 1). Secondary sources of water on the playa include local precipitation and inflow from small drainages and springs on the playa's periphery. Both the QR and MMC derive their flow primarily from mountains that receive far more precipitation than the playa itself (Figure 1).

Flooding of the playa and growth of lakes do not occur every year. Although usable Landsat imagery was not complete for this 37-year period (due to cloud cover and unavailability), the record of lakes growing and evaporating is reasonably clear. There have only been five years out of the last 37 when a lake has not formed on the BRP. During four other years, however, only a small lake (<2 km^2) has formed.

Lakes typically form early in the year (January-February) and are commonly obscured by ice and snow at this time. Lakes reach their greatest extent in late spring or early summer when snowmelt reaches its peak. Although rare, there have been a few occasions when lakes have lasted through an entire calendar year, as in 1983. More typically, however, even the largest lakes dry up by mid-summer. This is no surprise as the lake evaporation rate for the playa is about 127 cm/yr, and maximum lake depth during the period of record is only about 1 m.

Particle size distributions and chemistry: The BRP is primarily composed of fine-grained sediments dominated by silt- and clay-sized particles (Table 1). Fine sand accounts for a small percentage of each sample (0.8 to 10 wt %), but all samples are dominated by clay (51.5 to 92.4 wt %). With the number of samples collected and their locations (Figure 6), we found no apparent pattern to particle size distributions on the playa. Patterns may emerge, however, based on additional sampling.

The geochemistry of BRP sediments is dominated by SiO_2 and Al_2O_3, with lesser amounts of the other major rock-forming constituents, which is what is expected for a large drainage basin surrounded by mountain blocks primarily composed of igneous and sedimentary rocks. The pH of the playa sediments is basic, ranging from 9.97 to 10.21. Soluble salts, such as sodium chloride (NaCl), constitute a relatively small percentage of the sediments (0.64 to 1.94 wt %) with the amount of carbonate ranging from 7.5 to 11.5 wt %.

In terms of mineralogy, quartz, micas, calcite, feldspar, and various types of clay are the most common minerals found within playa sediments. Less than two micron clay minerals from one sample location were vermiculite, illite, and kaolinite. Some of these clays exhibit shrink-swell properties when dried and wetted, which may contribute to loosening of surface crusts that in turn may liberate sediment for wind transport.

Eolian features: During the last 10 years, visitors to the BRP have noted small ripple-like features on the playa (Figure 8). These bedforms have been variously described as playa serpents, serpent gardens, desert snakes, reefs, mini dunes, incidental dunes, and transient dunes. Based on their morphology, sedimentologic characteristics, and grain size, as outlined below, we refer to these features as granular ripples. Many explanations have been offered to explain how the ripples form including frost- or salt-heaving, tectonic deformation, wind-driven water from flash floods, and wave action in a shallow lake (http://sites.google.com/site/blackrockdune

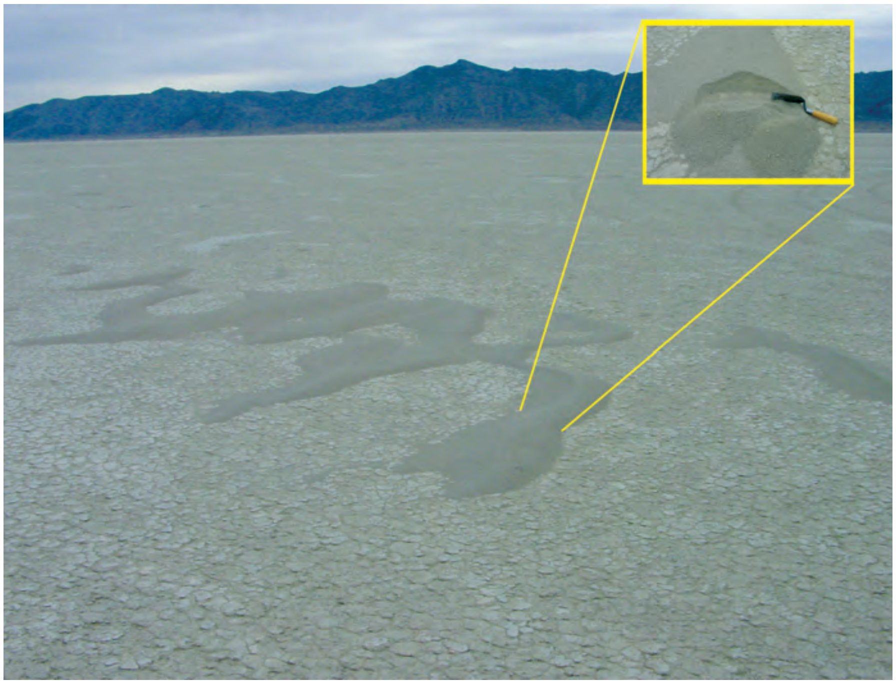

Figure 8. Fresh, granular eolian ripples (aka playa serpents or transient dunes) formed on the playa on April 4, 2007. A return trip to the exact same spot on May 31 of that year found that the ripples were one.

s/#Sarriugarte2008). There also have been various explanations as to why they form, with many focusing on increased vehicle/OHV use, Burning Man, and other human activities – although some have suggested that the granular ripples are the result of natural processes.

In all of the conjecture on the origin and causes of the ripples, a few key observations on their physical characteristics, timing of formation, locations, and general trends in the surface characteristics of the playa itself will help inform the debate. The first documented case of bedforms on the BRP apparently was from Neal (1972) who photographed a small field of sand ripples on the playa at some point in 1970 or earlier. The next time that bedforms were noted on the playa was 1999 (author's observations), although there may be additional anecdotal information that they formed earlier. Since that time, ripples have been a regular fixture on the playa, although it is unclear how often new ones form.

Granular ripples are typically expressed as a series of irregular, semi-parallel ridges that have amplitudes ranging from several centimeters to about 20 cm and wavelengths of several decimeters up to about 1 m or so. The long axes of the ripples are commonly oriented NW-SE, or transverse to the prevailing southwesterly winds, but an exhaustive survey has not been done. In some patches, the crests of ripples decrease in amplitude to the northeast. The ripples are primarily composed of one to several millimeter-sized angular aggregates of clay and silt. Some ripples also contain lesser amounts of similar-sized rock granules. The granular sediment is arranged in faint, horizontal laminations or is more commonly massive. These features typically have a coherent crust, characterized by desiccation polygons usually smaller than the polygons formed on the surrounding playa. In places, desiccation polygons defining the playa surface can be traced directly beneath the ripples.

Figure 9. In the same general area as that shown in figure 8, there were two generations of eolian ripples on the playa. The older generation has a crust on them, whereas the younger generation is still completely granular.

On April 4, 2007, patches of fresh, granular ripples were found on the playa near the 3 mile entrance (Figure 8) but did not appear to be associated with established playa roads in the area. These ripples shared all of the characteristics of ripples commonly found on the playa except that they were not covered with a crust. Instead, each ripple was composed of loose, granular aggregates of silt and clay particles. In places, these fresh ripples overlay older, crusted ripples, indicating that the ripples formed at different times (Figure 9). Additional active ripples, but of a smaller scale, were noted along playa roads and within the BRC site after Burning Man in 2006.

These observations have led to a conceptual model for the formation and preservation of the ripples. All of the ripples examined, both on the BRP and Jungo playa, appear to be composed of small aggregates of playa sediment with lesser amounts of rock fragments of similar size. This suggests a local sediment source of loose playa material and possibly an additional sediment source for the rock fragments from distal alluvial fans impinging on or adjacent to the playa.

During the last 17 years, and probably longer, different parts of the surface of the BRP have alternated between a hard, durable surface and a somewhat soft, loose, granular surface. From anecdotal observations, the playa is hard and durable most of the time but in the summer of 2004, for example, it seemed that much of the playa was soft and vehicle tires sank several centimeters into the loose material. Although the playa does commonly have a thin crust over the loose material when it is in its “soft” state, this crust is easily disrupted by vehicles or other types of disturbance yielding a voluminous sediment supply.

A separate sediment source is created by deposition of a thin layer of mud after the seasonal lakes evaporate. For example, the lake that formed in spring 2006 left a thin layer of clay sediment that formed “mud curls” upon drying (Figure 2). These mud curls are apparently broken into millimeter-sized fragments and easily transported by the wind. How long the wind takes to break up the mud curls is unknown, but the process also may be helped by vehicles driving over the surface. The fresh ripples observed on April 4, 2007 were composed of millimeter-sized fragments, but no lake formed in spring 2007. This may indicate that deposits of the ephemeral lakes can supply sediment for more than a single year or there are other sources of the sediment, such as when parts of the playa surface become loose and granular. Once the ripples are formed, they are likely short-lived unless precipitation falls. Wetting these features causes a protective crust to form upon drying that greatly enhances their preservation. Based on the above scenario, it is likely that ripples form much more frequently than people suspect, but are only preserved when a rain "cements" them in place.

Current hypotheses as to why the playa surface transforms from a hard, durable surface to a loose, puffy, and non-durable surface and back again have to do with the frequency of flooding and effects of precipitation and ice crystal growth on playa sediments. The hard, durable state of the playa probably is caused by relatively frequent flooding, whereas transition to the soft, puffy state may be caused indirectly by a lack of frequent flooding. We pose three hypotheses that may explain this transition. The first is that repeated saturation of the playa surface by rainfall and subsequent drying causes certain clay minerals to swell and shrink, thus disrupting the surface. The second hypothesis is similar, but saturation by rainfall causes dissolution of soluble salts that recrystallize upon drying. The third hypothesis is that surface disruption is caused by growth of needle ice in the playa sediments. Needle ice are small (1-3 cm), vertically oriented crystals of ice that form just below the soil surface when the ground is saturated and the air temperature is below freezing. Deciphering which of these processes or combinations of processes is responsible for loosening surface sediments of the playa will require further study.

Human impacts: There is little doubt that human usage of the BRP has increased dramatically during the last two decades, but the impacts of this increase in visits are poorly understood. One of the more visible impacts of visitors is from tracks left by their vehicles. There are several established roads on the playa that have been used for decades. These routes are typically inset 10-20 cm into the surrounding playa, and their surfaces covered by loose, granular playa sediment. Often, small ripples are found on and adjacent to these routes indicating that the roads are actively eroding because frequent passage of vehicles crushes playa sediment into pieces small enough to be transported by the wind. Spatial distribution of the larger ripples (described above), however, does not seem to be associated with the roads.

Away from the roads, single vehicle tracks are ubiquitous across the playa by the end of the summer season. Although we did not perform a detailed analysis, it seems likely that single vehicle tracks are typically ephemeral and only last until the next flooding event when the playa is firm. During times when the playa is soft, as in summer 2004, vehicles sink deeper into the surface, and these tracks may persist for longer than a single season. In addition, vehicle tracks may last longer in areas that are not flooded on a regular basis.

To investigate cumulative effects of Burning Man on erosion of the playa, a repeat GPS topographic survey was performed on part of the road network within BRC before and after the event in 2006. Comparison of the results of the surveys conducted on August 26, 2006 and September 13, 2006 indicates no measurable change in elevation of BRC roads. At least the change is less than 1 cm, which is the stated accuracy and precision of the GPS system used in the surveys. There was, however, abundant evidence of wind erosion at Burning Man in 2006 and 2007 in the form of crushed playa sediment, fresh granular ripples, and wind-transported sediment accumulating along various parts of the perimeter fence. Probably not all of the sediment accumulating along the perimeter fence in 2007 came from BRC because dust storms with saltating particles up to about shoulder height were observed to approach BRC from the southwest on August 30 and 31, 2007. This indicates a source of sediment upwind from BRC, although surface disturbances within BRC certainly contributed to the sediment budget of the dust storms. Therefore, repeated use of the same BRC site through time, in the absence of flooding events, may lead to measurable human-caused erosion within the confines of BRC.

Figure 10. Adult fairy shrimp, similar to those occupying the Black Rock Desert playa when it is inundated (courtesy of http//www.sasionline.org/arthrzoo/pshrm.jpg).

Physical Processes Discussion

The Black Rock Playa is a dynamic landform that is affected by a multitude of processes. One of the more important processes that controls the character of this surface is its flooding history, which occurs every few years or sometimes more frequently. When the playa does not flood for a few years or more in a row, the surface can transform from a hard, durable surface to one that is soft and loose. The exact processes involved in this transformation are currently uncertain, but they may have to do with wetting by precipitation and subsequent swelling and shrinking of clay minerals, salt crystal growth, ice crystal growth, or some combination of these processes. During periods of frequent flooding and when the playa surface is firm, minimal wind-driven erosion probably occurs. Enhanced wind erosion likely occurs when the playa surface is soft and loose. This enhanced erosion occurs naturally but may be exacerbated by human activities that disrupt the fragile crust found on the playa when it is in its soft state. When the playa floods, thin layers of sediment are deposited that counteract the effects of wind erosion. These physical processes and their timing should be considered when evaluating the durability of the playa and its resistance to human impacts.

Figure 11. Adult tadpole shrimp, similar to those occupying the Black Rock Desert playa when it is inundated (courtesy of http//www.sasionline.org/arthrzoo/pshrm.jpg).

Black Rock Desert Aquatic Life

Playas are harsh environments for aquatic life because they are infrequently flooded by turbid, saline, and alkaline water that is followed by drought that may last many years. When flooded, they support phytoplankton, bacteria, other microbes, and crustaceans that are a rich food resource for migrating birds. In the arid southwestern U.S., most of the aquatic species on playas are crustaceans in the Class Branchiopoda, which includes fairy shrimp, tadpole shrimp, and water fleas (Figures 10 - 12). All of these animals have a common life history where eggs lie encased in dry playa soil and do not hatch until the playa is flooded for enough time for adults to grow and reproduce. In the northern Great Basin, flooding occurs during the winter, eggs hatch during spring, and adults rapidly reach sexual maturity and reproduce before a playa dries in late spring or early summer.

Figure 12 . Adult water flea, similar to those occupying the Black Rock Desert playa when it is inundated (photo courtesy of K. Acharya, DRI).

Playas are difficult for people to access when they are flooded, hence public use is low during these times and aquatic life is undisturbed by human activities. When they are dry, many playas are frequently, and often heavily, used for recreation. Studies on playas in southern California and other parts of the Southwest found that branchiopod eggs are crushed by recreational vehicles. No studies have considered the influence of other activities, such as camping, on eggs.

Branchiopod eggs are concentrated in the upper 15 mm of playa soil, and they can be passively dispersed across the landscape by wind and other animals. As a result, many species are widely distributed, but each species occurs where playa water chemistry and water quantity requirements support its hatching, growth, and reproduction.

In 2006, we found adults of four different branchiopods, including two types of fairy shrimps (Figure 10) (*Branchinecta mackini* and *B. gigas*), a tadpole shrimp (Figure 11) (*Lepidurus lemmoni*), and a water flea (Figure 12) (*Moina* sp.) on the playa. Fairy shrimp were the most common, and all of these species are widespread and common occupants of many Great Basin playas. *Branchinecta mackini* is relatively small (< 2 cm long), eats plankton and microbes, and is generally more tolerant of a wider range of environmental conditions than *B. gigas*. *Branchinecta gigas* is relatively large (up to 5 cm long) and is a predator that eats other branchiopods. Tadpole shrimp are relatively large (up to 3 cm) and omnivorous. They forage by digging through sediment to eat algae and other branchiopods. Fairy shrimp and tadpole shrimp reproduce by broadcasting their eggs which float in the water before settling on the sediment. Water fleas are small zooplankton (0.2 mm–2.0 mm long) that occupy many lakes and other freshwater systems throughout the world. They eat phytoplankton, bacteria, and other small organisms. Most individuals are female and most species reproduce asexually at least part of the time. Water flea eggs are either maintained in an internal brood chamber for incubation or encased within a "leathery" capsule that can survive lengthy drying.

Methods

We examined the effect of recreational vehicles and camping on Black Rock Playa branchiopod eggs by collecting playa soil during 2006 and 2007 (Figure 13), and counting the number of intact eggs in each sample in the laboratory. The impact of different types and intensities of human use on intact egg abundance was determined by: (1) comparing egg density along heavily used roads and adjacent virgin playa; (2) comparing egg density in Black Rock City roads and camping areas before and following the Burning Man Festival; and (3) quantifying changes in egg density in a track that was created through repeated travel of a pickup truck traveling 24 km/hr (15 mph) over previously undisturbed playa. Lower intact egg density in areas affected by human use is believed to indicate that these activities may reduce the number of viable eggs and detrimentally affect branchiopod reproductive success and population size. Reference to 'eggs' in this report will always refer to intact eggs, unless otherwise stated.

Figure 13. Collecting playa soil samples that were taken to the laboratory where Branchiopod eggs were removed and intact eggs counted.

Study Findings

We collected a total of 966 intact fairy shrimp and 401 water flea eggs from 87 playa soil samples during the summers of 2006 and 2007. Egg abundance differed across the playa. They were most common in lower parts of the playa where flooding is most frequent and water is deepest during floods. They were least common in higher areas where flooding was less frequent and shallow. During our sampling, they were most abundant in Black Rock City, at elevation 1190.7 m (near the lowest part of the playa) and in an area flooded more than 15 times between late 1972 and late 2008. Reasons for spatial differences in egg density are unknown, but they may be caused by differences in site elevation (hence frequency and duration of inundation) and soil chemistry.

Comparison of egg abundance on a heavily used road and undisturbed playa: Trego Road is heavily used by people crossing the playa, and tracks showing its route are incised into the playa as much as 15 cm. Eggs were less abundant in the track than on surrounding undisturbed playa (Figure 14). While indicating that this level of vehicle activity reduces egg abundance, these differences were not statistically significant. It is difficult to discern if eggs were in the track because they had survived vehicle use or if they were captured in track depressions during wind events. An answer to this could be provided by comparing egg density in ruts following inundation and before vehicle use, and by creating study plots to determine how active egg dispersal is during wind events.

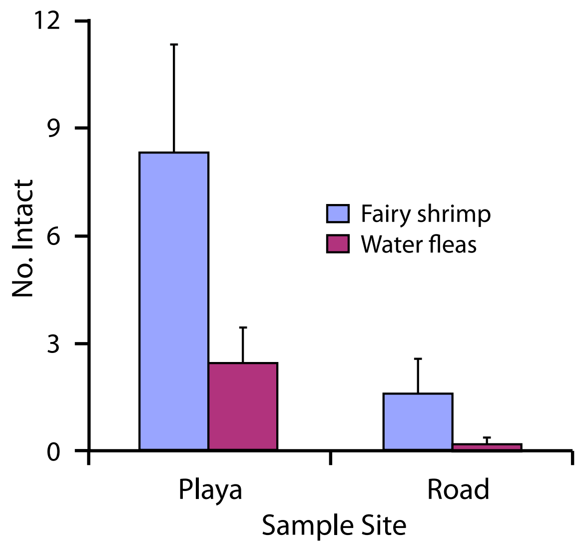

Figure 14. Mean number of intact fairy shrimp and water flea eggs in soil samples collected in the Trego Road track (Road) and adjacent virgin playa (Playa) during autumn 2007.

Black Rock City roads and camping areas: The Burning Man Festival decreased fairy shrimp egg abundance in Black Rock City roads and camping areas but had little effect on water flea egg abundance (Figure 15). Approximately 30 percent fewer fairy shrimp eggs were found in Black Rock City roads following the Festival, and approximately 50 percent fewer fairy shrimp eggs were found in camping areas following the Festival. Although there were differences in egg abundance before and following the Festival, the differences were statistically significant only for eggs in camp areas. Differences in water flea egg abundance before and following the Festival were minor in camp areas and roads (Figure 15).

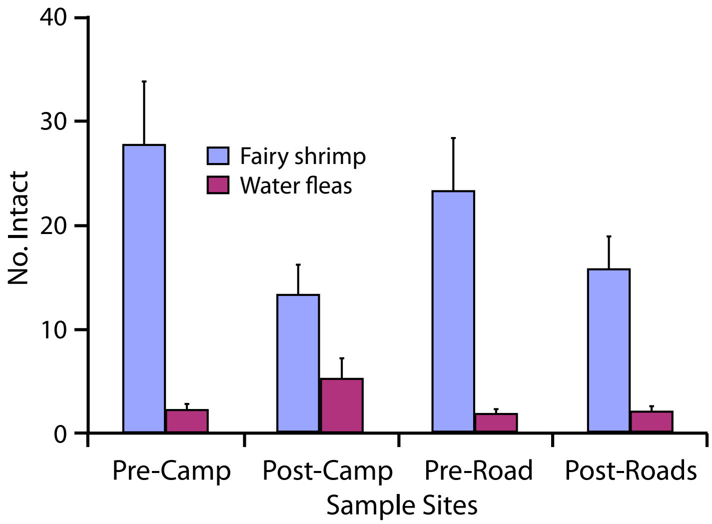

Figure 15. Mean number of intact fairy shrimp and water flea eggs in soil samples collected in Black Rock City camp areas and roads before and after the Burning Man Festival.

Little change in water flea egg abundance suggests that they may be more resilient to disturbance than fairy shrimp eggs. Effects on fairy shrimp eggs were greater in camping areas than roads, which may be attributed to Festival operations. Travel on roads is limited to foot and bicycle traffic during the Festival, and most vehicle travel occurs only when participants access and leave camping sites before and after the event. The influence of road use on eggs also may be moderated by comparatively light use and dust abatement that sprays water on roads at least twice daily. Observations made during the event, and during sampling before and following the event, suggest that dust abatement on roads may stabilize playa soils and thereby minimize the influence of disturbance. This stability was indicated by soil hardness and the presence (albeit weak) of soil polygons on roads, which characterize an undisturbed playa. These conditions contrasted with camping areas where there was no dust abatement, soils were sandy and loose, and polygons were not present following the Festival. This suggests that periodic wetting may armor playa soils and protect eggs.

Experimental track: This test was conducted on a portion of undisturbed playa where the abundance of fairy shrimp eggs was lower than observed at either Black Rock City or adjacent to Trego Road. Water flea eggs were more abundant at this track than other portions of the playa. There was visual evidence of this experiment altering the playa (Figure 16). However, results indicated that vehicle travel had no influence on fairy shrimp or water flea egg abundance (Figures 17 and 18). These findings were not consistent with findings on southern California playas, or with differences observed in Black Rock City and along Trego Road. Reasons for the absence of effects in the experimental track are unknown, but they may be attributed to a number of factors. Our study used a vehicle that applied approximately 2/3 of the downward force of the vehicle used in southern California, which may have been less force than is required to damage Black Rock Desert eggs. Black Rock Desert soils also may provide a matrix that is more resilient to disturbance than matrices at playas with other soil types. Our work also was conducted at a site where fairy shrimp

Figure 16. Photograph of the vehicle track created during the Experimental Track test at the 50 meter point following 100 passes of a 2007 Chevrolet Colorado Crew Cab truck traveling 24 km/hr (15 mph).

egg density was relatively low, which may be attributed to its location at the upper limit of the 2006 flood. This may have been a poor location for conducting the study because the small number of eggs may have reduced the ability to more accurately discern the response of branchiopods to the effects of vehicle travel.

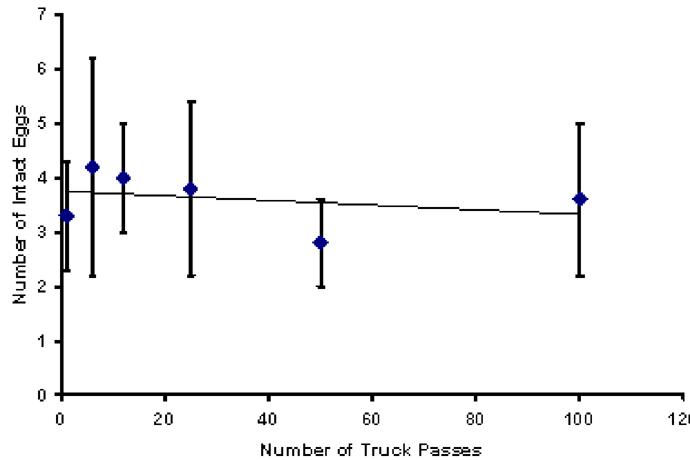

Figure 17. Mean density of fairy shrimp eggs (± 1 SE) in playa samples collected from the experimental track on the BRP during summer 2007.

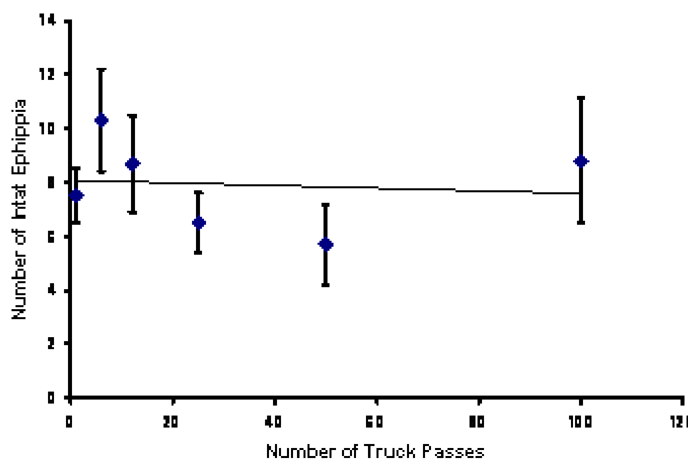

Figure 18. Mean density (± 1 SE) of water flea eggs in playa samples collected during the Experimental Track study on BRP during summer 2007.

Biology Discussion

Playas were first described in the scientific literature by G.K. Gilbert in 1890 in his description of Lake Bonneville in the northeastern Great Basin. He was intrigued by the geological formation, aridity of the region, and evidence of past more mesic climates shown by ancient shoreline terraces carved on mountains surrounding most playas. Since this description, playas have intrigued most visitors and many are now used for a variety of activities.

Black Rock Playa during a dust storm. *Photograph by Richard Briggs.*

Although there is commonality among playas as ancient, dry lake beds, they vary widely in many factors including soils and hydrology. These factors, and characteristics of the surrounding geology, influence hydrologic and geologic processes, soil composition and density, and water chemistry. These factors also affect playa ecology by creating distinctive, individual physicochemical environments, which is a primary factor affecting structure of branchiopod assemblages. Biological surveys have examined only a few Great Basin playas, and a complete list of playa branchiopod species cannot be compiled for the region. However, collections from several playas in northern Nevada document the presence of *B. gigas*, *B. mackini*, and *L. lemmoni*, which suggests that species collected during our 2006 and 2007 studies on the BRP are relatively widespread in the region.

A number of studies have examined the effects of mechanical human uses on desert upland systems and documented changes in vegetation and soil density that effectively alter functional characteristics of vegetation communities and soil properties. Others also observed that human footsteps exert forces on soils that may reach 1,000 Newtons, particularly in the region of heal contact. These forces decreased with soil depth in sandy soils, but they decreased less with depth in loam soils with higher quantities of silt and clay. Few have examined the effects of disturbance on playa soils and their biota. One study found that approximately 30 percent of fairy shrimp eggs were damaged or destroyed on Bicycle Dry Lake playa (San Bernardino Co., CA) with 20 passes by a 1974 Toyota Corolla Sedan (weighing 972 kg and exerting a downward force of approximately 3 kg/cm^2). In a laboratory study involving eggs from eight branchiopod species and examining the force required to crush individual eggs, researchers found that vulnerability differed among taxa but that forces less than one Newton were capable of damaging dry eggs and less than 0.1 Newton damaged eggs when wet.

Recommendations

Studies examining physical processes and biology of the Black Rock Desert Playa from 2006 - 2008 found that human activity may affect these components of playa dynamics. These studies were conducted over three years and therefore provide weak consideration of temporal variability in physical processes and biology and how long term human use may affect these components. This information is needed to develop recommendations that may be needed to identify management goals, purposes, and strategies. We recommend the following studies be conducted over the next 3 years to clarify these issues:

1. Determine factors influencing branchiopod egg distribution on the playa by examining relationships between factors including egg density, playa elevation, and soil density over large portions of the playa.
2. Assess relationships between soil density, the magnitude of dust events, and the potential influence of wind events on branchiopod egg dispersal.
3. Determine the cumulative influence of years of human use on branchiopod egg density.
4. Determine causes of transition of playa from a hard, durable surface to one that is loose and puffy.
5. Better refine the relationships between specific playa locations and inundation frequency.