THE NATURAL HISTORY OF THE MOJAVE FRINGE-TOED LIZARD,
*UMA SCOPARIA*: THE NORTHERN LINEAGE,
AMARGOSA RIVER, CA

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By

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ABSTRACT

The Mojave fringe-toed lizard (MFTL), *Uma scoparia*, is isolated on the windblown sand dunes of the Mojave Desert. Due to a recent petition to list the Amargosa River populations as Threatened or Endangered under the Endangered Species Act, the three northern populations have attracted increased attention, with an emphasis on the Dumont Dunes population. Dumont Dunes is a compound star dune system (3,885 ha) open to off highway vehicle activity. Also associated with the Amargosa River are Ibex Dunes and Coyote Holes. Ibex Dunes (688 ha) is protected habitat that is part of Death Valley National Park. Coyote Holes is a small (20 ha) sandy outcrop found along the Kingston Wash in protected wilderness.

*Uma scoparia* were surveyed in 2007 and 2008 by walking transects during periods of peak activity. Lizards were found from the base of the dunes to the outskirts of the dune systems, where there was Aeolian sand and scattered vegetation.

MFTLs were observed outside the previously documented ranges, two kilometers north of the Ibex Dunes population and five kilometers southeast of the Dumont Dunes population. Vegetation was a necessary habitat requirement, but it was insufficient to predict lizard occurrence. Observations of lizards decreased from 2007 to 2008, but the difference was significant only at Ibex Dunes ($obs_{IBX07}$=26; $obs_{IBX08}$=3; p=0.011). The decrease in observations at Dumont Dunes was comparable to *U. inornata*, while the reduction in observations at Ibex Dunes was unprecedented. Future surveys should include mark-recapture techniques to examine population dynamics and dispersal tendencies.

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# CHAPTER 1

# INTRODUCTION

## Natural History: Genus *Uma*

Fringe-toed lizards, of the Genus *Uma*, are highly adapted psammophilous lizards that inhabit scattered windblown sand habitats in southwestern North America, from southeastern California to western Arizona and down into north-central Mexico (Norris, 1958; Pough 1974; Schmidt & Bogert, 1947; Williams et al., 1959). The Integrated Taxanomic Information System (2009) currently recognizes six species of fringe-toed lizards in North America: the Mojave (MFTL, *Uma scoparia*), the Coachella Valley (*U. inornata*), the Colorado Desert (*U. notata*), the Yuman Desert (*U. rufopunctata*), the Coahuila Desert (*U. exsul*), and the Chihuahuan Desert (*U. paraphygas*) fringe-toed lizards (Figure 1).

Fringe-toed lizards have multiple morphological adaptations for Aeolian habitats. Scales on the digits are enlarged (Figure 2) to make movement on the sand energy efficient (Carothers, 1986; Stebbins, 1944). The head has several morphological adaptations for sand (Figure 3): the lower jaw is counter-sunk into the upper jaw, the nasal passage is oriented posteriorly, the nasal passage can also be physically constricted, the eyelids have enlarged ‘eyelash’ scales, and the ears are also covered by enlarged scales (Stebbins, 1944).

Fringe-toed lizards also have interesting behavioral adaptations for their dune habitat. Most notable is their sand burial behavior, which was described as quiescent by Pough (1970), meaning the lizards have not been observed to hunt insect prey while buried or actively move like *Chionactis* sp. after reaching an optimal depth underneath the sand. Fringe-toed lizards tend to bury themselves within 4-6 cm of the sand surface (Norris, 1958; Pough, 1970; Stebbins, 1944). Stebbins (1944) thought the behavior was thermoregulatory in nature, but Pough (1970) later rejected this hypothesis and thought that the burial behavior is mainly for cover. While buried, the lizards position their forelimbs posteriorly along their sides to keep sand from collapsing in around the body after taking a breath (Pough, 1970).

Diet has varied in studies, but all agree that fringe-toed lizards are opportunistic, sit-and-wait omnivores. Sand-dwelling invertebrates are an important food item, and the lizards will feed on flowers and leaves when available (Durtsche, 1995; Kaufmann, 1982 Mayhew, 1966a & b; Stebbins, 1944).

Rainfall has been shown to have an indirect impact on fringe-toed lizard reproduction (Mayhew, 1966a & b). Food intake is directly linked with testes size in males, and possibly, female egg production of fringe-toed lizards (Mayhew, 1966a & b). Winter rain in the Mojave Desert has a positive effect on annual germination in the spring (Hereford et al., 2006). Increased annual germination provides a greater food source for ground dwelling arthropods, which results in a larger food supply for insectivorous animals (Dunham, 1980; Mayhew, 1966a & b; Turner et al., 1982). Mayhew (1966a & b) suggested that insects associated with perennial vegetation, which bloom later in the

season than annuals and are still able to flower during droughts because of deeper, perennial water sources, serve as a secondary food source. As a result, reproduction in fringe-toed lizards during drought years is later in the season, producing few juveniles in the fall (Mayhew 1966 a & b).

## Natural History: *Uma scoparia*

The Mojave fringe-toed lizard (MFTL) is found only in the Mojave Desert where deposits of fine, windblown sand exist (Figure 4; Mayhew, 1966b; Norris, 1958; Stebbins, 1944). The habitats of the known populations are associated with present and historical river drainages and sand fields of the Mojave, Amargosa, and Colorado Rivers (Enzel et al., 2003).

The Amargosa river populations (San Bernardino County, California) are found at Ibex Dunes, Dumont Dunes, and Coyote Holes. Ibex Dunes (688 ha, UTM 11 S 557200 m E 3950400 m N) is located east of Saratoga Springs and lies within Death Valley National Park. Dumont Dunes (3,885 ha, UTM 11 S 570400 m E 3949300 m N) is southwest of the Kingston Mountains and is an open off-highway vehicle (OHV) recreation area managed by the Bureau of Land Management (BLM). Coyote Holes (20 ha, UTM 11 S 594400 m E 3944800 m N) is a sandy outcrop within BLM wilderness found at the southern base of the Kingston Mountains along the Kingston Wash (Norris, 1958; Pough, 1974).

The Mojave River Drainage populations (San Bernardino County, CA; Figure 4) include Barstow, Lenwood, Pisgah Crater, Coyote Dry Lake, Cronese Dry Lake, Bitter

Spring, Red Pass Dry Lake, Silver Dry Lake, Afton Canyon, Rasor Road, Devil's Playground, and Kelso Dunes (Murphy et al., 2006; Norris, 1958; Pough, 1974).

Further south, other Mojave fringe-toed lizard populations are found in Pleistocene discharge channels of the Mojave River, Colorado River, or a channel connecting both rivers (San Bernardino County, CA unless noted otherwise) (Enzel et al., 2003). These populations include Amboy Crater, Bristol Dry Lake, Cadiz Dry Lake, Dale Dry Lake, Rice Valley, Pinto Basin, Palen Dry Lake (Riverside County, CA), Ford Dry Lake (Riverside County, CA), and Bouse Dunes (La Paz County, Arizona) (Murphy et al., 2006; Norris, 1958; Pough, 1974).

There is limited literature on the natural history of *Uma scoparia*. Stebbins (1944) researched *Uma* anatomy and ecology, while others have discussed behavior (Carpenter, 1963; Pough, 1970), evolution and systematics (Norris, 1958; Trepanier & Murphy, 2001). Reproduction was studied by Mayhew (1966b). More recently the evolutionary genetics (Gottscho, unpublished; Murphy et al., 2006; Trepanier & Murphy, 2001) and conservation (Center for Biological Diversity & Papadakos-Morafka, 2006; Jennings & Hayes, 1994; Murphy et al., 2006; Otahal et al., unpublished; United States Fish and Wildlife Service, 2008) of *Uma scoparia* have been studied. However, survey data of *U. scoparia* is limited and incomplete (Girard, 2004; Morafka, 2003; Otahal et al., unpublished).

Girard (2004), which was a continuation of Morafka's (2003) research, collected and analyzed survey data of *Uma scoparia* at El Mirage dry lake, Rasor Road, and Dumont Dunes. These sites were selected to investigate if off-highway vehicle (OHV)

activity has had an effect on these populations. At the Rasor Road population, Girard also measured and tested predictive variables of Mojave fringe-toed lizard observations. Data were collected from four 1000 m transects in three varying OHV use areas (low, medium, and high; total transects varied by site) in June and July of 2003 (Girard, 2004). Predictive variables that were measured were perennial vegetation, annual vegetation, 'good' sand, OHV tire tracks, and rodent burrows. No fringe-toed lizards were seen in either year at El Mirage Dry Lake (Girard, 2004; Morafka, 2003), and they suggested the possible extirpation of this population. The results from the 2004 report (Girard) suggest that 'good' sand and rodent burrows were the only predictive variables for observations of *Uma scoparia* at Rasor Road. In addition, if the sand and rodent burrows were removed from the analysis, the only variable (of annuals, perennials, and OHV tracks) that was predictive of fringe-toed lizard observations was presence of annuals (Girard, 2004). OHV activity at Dumont Dunes did not seem to have an affect on lizard observations. *U. scoparia* observations at Dumont Dunes were similar in areas of high and low OHV activity, but observations were lowest in areas of medium OHV activity (Girard, 2004; Morafka, 2003).

More surveys like Girard's and Morafka's studies should be conducted at the different populations of Mojave fringe-toed lizards before making management decisions. Exemplar research would be Barrows (1996, 1997, and 2006) and Chen et al. (2006). These researchers have surveyed and analyzed extensively at least two populations of the Federally Threatened Coachella Valley fringe-toed lizard, *Uma inornata*. They conducted long term (20 yr) surveys of population dynamics (Barrows, 2006) and

constructed predictive modeling on habitat quality and persistence, suggesting for this species that sand source corridors should be preserved and perches for avian predators should be avoided (Barrows, 1996, 1997, 2006; Chen et al., 2006). These studies have been used in management decisions of the Coachella Valley fringe-toed lizard, and similar long-term monitoring studies on *Uma scoparia* could aid agencies like the Bureau of Land Management in making decisions for populations, such as Dumont Dunes.

Despite a lack of survey data and population size estimates, government agencies recognize *Uma scoparia* as a species of special concern by California Department of Fish and Game and a sensitive species by the Bureau of Land Management (BLM) due to the isolated nature of their habitat (California Department of Fish and Game, 2009; Jennings and Hayes, 1994). BLM manages most of the lands where *U. scoparia* can be found, and they allow OHV activity at some sites where the Mojave fringe-toed lizard occurs. Recent genetic research has supported the presence of three unique genetic haplotypes of mitochondrial DNA in the northernmost populations of Mojave fringe-toed lizard, which include Dumont Dunes, Ibex Dunes, and Coyote Holes (Figure 5) (Murphy et al., 2006). This led Murphy et al. (2006) to the conclusion that the Amargosa River populations are a distinct population segment (DPS) in accordance with the Endangered Species Act.

The northern (Amargosa River) populations include Ibex Dunes, Dumont Dunes, and Coyote Holes (Figure 5). At 3,885 ha, Dumont is over five times larger than Ibex Dunes (688 ha) and almost 200 times larger than Coyote Holes (20 ha). Dumont Dunes is open to OHV use, and estimates of OHV activity have exceeded 100,000 people in a single fiscal year (Bureau of Land Management, 2008).

With the recent genetic information and the high levels of OHV activity at the largest dune system of the Amargosa River drainage, there has been concern by conservationists and land management about the effects of OHV activity on the fringe-toed lizard population at Dumont Dunes, and a petition has been sent to the United States Fish and Wildlife Service (USFWS) to take steps in conserving this DPS (Center for Biological Diversity & Papadakos-Morafka, 2006; USFWS, 2008; Murphy et al., 2006). However, most of the information in the petition referenced behaviors, ecology and conservation of the Coachella Valley (*Uma inornata*) and Colorado Desert (*U. notata*) fringe-toed lizards (Barrows, 1996; Barrows, 1997; Barrows, 2006; Barrows et al., 2005; Center for Biological Diversity & Papadakos-Morafka, 2006: Chen et al., 2006; Durtsche, 1995; Luckenbach & Bury, 1983; Pough, 1970; Turner et al., 1984). The petitioners also assumed that Mojave fringe-toed lizards and high OHV activity overlap in the same areas (Center for Biological Diversity & Papadakos-Morafka, 2006). Before government action should be taken at Dumont Dunes, more detailed surveys of the entire dune system for fringe-toed lizard presence needed to be conducted.

This thesis focuses on surveying the Amargosa River populations more completely than previously attempted, while identifying any patterns of behavior and ecology of *Uma scoparia*.

# CHAPTER 2

# MATERIALS AND METHODS

## Study Sites and Transect Placement

*Uma scoparia* were studied at three sites: Dumont Dunes, Ibex Dunes, and Coyote Holes (Figure 5). Dumont Dunes are a 3,885 ha compound star dune system stretching west-to-east, and it has been open to off-highway vehicle activity (OHV) since the 1960s (Figures 6) (Otahal et al., unplublished). Yearly visitors have grown to over 100,000 people (Bureau of Land Management, 2008). Ibex Dunes (Figure 7) is a 688 ha dune system that is oriented north-south and is located to the west of Dumont Dunes. Ibex Dunes are within Death Valley National Park and the Ibex Wilderness area. OHV activity has been prohibited since 1933 when Death Valley was designated a national park under the Antiquities Act. Coyote Holes stretches east-west and at 20 ha is considerably smaller than the other two study sites (Figure 8). It is a sandy outcrop found within BLM wilderness, along the Kingston Wash about 20 km southeast of Dumont Dunes. OHV activity at Coyote Holes has been prohibited since the establishment of the California Desert Protection Act (1944, Public Law 103-433).

This study included 55 transects at Dumont Dunes, 19 transects at Ibex Dunes, and 4 transects at Coyote Holes (Figure 5). Each transect was 750 m long by 10 m wide and spaced at least 150 m apart from each other to ensure independence. The transect

directionality followed the dominant wind direction (Tinant et al., unpublished). BLM provided the start and end waypoints for all transects, except for the four transects at Coyote Holes. The transects at Coyote Holes were established using the same protocol as the other sites but three out of the four transects needed to be shortened from 750 m to 500 m long due to space limitations. All transects were walked twice during the study, once in 2007 and again in 2008. The start and end waypoints were uploaded into a Garmin Rhino 130 GPS/two-way unit, using WGS 1984 datum with 9 m accuracy.

Lizard Counting and Plant Cover

Transects were walked during times of peak activity. The yearly peak activity falls during the breeding season, which begins in March and ends in July, with highest activities occurring in May and June (Mayhew, 1966b). Daily activities peaked during periods when the sand temperatures on the dunes were ideal, ranging between 32$^{o}$C and 49$^{o}$C (Norris, 1958; Pough, 1970; Stebbins, 1944). Observational periods varied depending on sand temperatures, wind, and daylight. Early on in each of the seasons (March and some of April), there was one long period in which MFTLs were active that stretched from late morning until early evening. As the season progressed and the sand temperature rose to 32 $^{o}$C earlier in the day and remained greater than 32$^{o}$C later into the day, the activity window increased until the sand temperatures in the afternoon rose beyond the thermal limit (>49 $^{o}$C), effectively dividing the lizard activity period into two windows. This afternoon divide continued to increase in length until July through August, when the activity periods are shortest. Transects were walked to maximize ideal sand temperatures. Occasionally, transects were walked when temperatures were above

thermal limits due to time constraints. When conditions were too windy (>20 km/h), observations were cancelled for the day. Transects were walked in the evenings occasionally, concluding before sunset.

MFTLs were counted as an observation on a transect only if the lizard originated within a transect. Lizards seen outside of a transect that then ran into the transect were not included in calculations. However, all encountered Mojave fringe-toed lizards were given a waypoint, because of the importance to document where these lizards are active throughout each location. The waypoints were taken as close as possible to where the lizards originated. The MFTLs were identified as an adult or juvenile, using Mayhew's (1966b) definition of an immature or mature adult having a snout-vent length greater than 50 mm (male and female). The locations of lizards were recorded with the GPS unit. Before and after walking each transect and whenever a lizard was observed, the sand temperatures were recorded with a RadioShack infrared thermometer (Cat. No. 22-325). The temperature at the start and end of each transect was taken on the south-facing slope of the nearest hummock (highest sand temperature), while the lizard temperatures were taken as close to where the lizard originated as possible. Potential predators were noted, along with other species of lizards (e.g., zebra-tailed lizard, whip-tail lizard, and desert iguana).

The structure of the *Uma scoparia* habitat was characterized by measuring vegetation. While walking the transects in 2008, perennial plants were recorded with a GPS unit, and the presence of annuals was noted. When a MFTL was seen, the nearest perennial shrub was measured to the nearest half meter by pacing steps or with the GPS

device. Due to the potential for error, the GPS device was only used for measuring plants that were greater than 15 m away from where the lizard was observed. Sand samples were obtained from each site to analyze grain size and composition. The sand grains were sorted using a W. S. Tyler Automated Sand Sifter, Model #R-30050. Sand was sorted into 13 size classes with diameters ranging from 0.053 mm to 0.850 mm. Elemental composition of the sand samples was determined by Dr. John Foster in the Geology Department at California State University, Fullerton.

## Spatial and Statistical Analysis

Google Earth v.5.0.11337.1968 was used to illustrate patterns of lizard presence. The imagery data varied and are stated in the figure captions and on the maps (bottom-center). The lizard data layer was overlaid with satellite photographs and plant data layers. Polygons representing large expanses of vegetation dominated by flowering annual from 2008 were estimated using field notes, observations, photographs, and satellite imagery. Statistical analyses were completed with SPSS v.16.0 and Microsoft Excel (2003 and 2007).

Data were standardized across all of the dune systems by calculating a density of lizards seen (MFTL/ha) per transect. The densities were not normally distributed at each study site; therefore, the means of lizards seen per hectare per transect were compared between the years at each study site using the Wilcoxon signed ranks test. Comparing temperature and time from 2007 to 2008, histograms of sand temperatures and time were prepared for lizard observation and transects. The sand temperatures of when lizards were observed on transects were analyzed further with a two-sample t-Test assuming

equal variance, using the mean difference of start and end transect sand temperatures from 2007 and 2008. The mean distances from vegetation were calculated for each lizard seen in 2008. In addition, the number of *U. scoparia* seen per field day was calculated for both 2007 and 2008.

# CHAPTER 3

# RESULTS

## Lizard Observations

Total Mojave fringe-toed lizards observed, on and off transects, in 2007 and 2008 were 79 and 58 individuals, respectively. *Uma scoparia* were not observed on the large bare dune faces at Ibex or Dumont Dunes. Based on the areas that were searched, Dumont Dunes had more patchy observations (Figure 6). Groups of observations occurred in both years and were focused in the western, southern, and eastern areas of Dumont Dunes (Figure 6). There were 17 transects at Dumont Dunes that had zero vegetation present (Figure 6). All of these transects and the barren dune slopes in between had zero observations of *Uma scoparia*. At Dumont Dunes, there were large areas with zero fringe-toed lizard observations, with 37 out of the 55 (67.3%) transects at Dumont Dunes not having a lizard observation in either year (Figure 6). Similar habitat to areas where the fringe-toed lizards were found extend further south and east than where I surveyed at Dumont Dunes.

At Ibex Dunes, 13 out of the 19 (68.4%) transects had a lizard observation in at least one year. Fringe-toed lizards were found throughout Ibex Dunes in 2007 and primarily in the south and northeast in 2008. No transects at Ibex Dunes had lizards observed on them in both years, but there was one grouping in the southwest with

multiple observations on and off transects in both years (Figure 7). An individual was found two kilometers north of the dune field, expanding the previously known range of the *U. scoparia* population at Ibex Dunes (Figure 7).

Coyote Holes produced very few fringe-toed lizard sightings, but they were present both years (Figures 8). The sample size was too small to notice any patterns in observations, except that all fringe-toed lizards were found where the substrate was windblown sand.

In 2007, 60.76% of the lizards were present on transects ($obs_{07}$=49). In 2008, only 32.76% of the lizards seen were on transects ($obs_{08}$=19). There were two juveniles observed in 2007, while there were none observed in 2008. Field days spent at Dumont Dunes were 12 in 2007 and 13 in 2008, at Ibex Dunes 6 (2007) and 5 (2008), and at Coyote Holes 1 (2007) and 2 (2008). The field days and lizard observations varied by month (Figure 9). The sand temperatures (Figure 10) were not significantly different by year for lizard sightings. Time of observations (Figure 11) followed the same pattern each year.

At Ibex Dunes from 2007 to 2008, there was an 88.9% ($obs_{IBX07}$=27; $obs_{IBX08}$=3) reduction in MFTLs observed. This reduction was significant (Wilcoxon signed ranks test, p=0.011) (Figure 12). Coyote Holes experienced similar reductions in observed lizards with a 62.5% decline ($tot_{COH07}$=8, $tot_{COH08}$=3) in lizards overall, and no MFTLs were seen on transects in 2008; however, the sample size at Coyote Holes was very small. More individuals were seen in 2008 overall at Dumont Dunes ($tot_{DUM07}$=37, $tot_{DUM08}$=40), but lizards on transects decreased by 20.0% ($obs_{DUM07}$=20, $obs_{DUM08}$=16).

## Transects

Transects varied in many aspects. The majority substrate type of almost all transects consisted of windblown sand; however, two transects at Coyote Holes only had a short section, approximately one-fifth of the 500 m transects, that had Aeolian substrate. Many of the transects at Ibex and Dumont Dunes were comprised mostly of the large, barren dune faces (slopes).

The substrate varied from Aeolian sand to coarser grained sand to rocky, mountainous terrain. The sand samples that were analyzed did not seem to have a different elemental composition. The grain sizes sorted similarly for samples from Ibex Dunes, Dumont Dunes and Coyote Holes. The only notable difference in sand grain size was the sample from southern Dumont Dunes, which had a monodispersed particle size range of fine grain sand (0.151-0.212 mm) (Figure 13).

## Vegetation, Rainfall, and Temperature

The vegetation on transects varied from extensive areas having zero vegetation to areas with sparsely scattered *Larrea tridentata* to areas covered with annual vegetation (predominantly desert primrose and sand verbena). In 2008, lizards seen on transects averaged 27.89 m (SD=36.93) from the nearest perennial shrub. When looking at all vegetation (annuals and perennials), the mean distance of lizards seen on transects from the vegetation is 6.37 m (SD=15.72). There was a large increase in annual vegetation in 2008 (Figure 14).

Rainfall data was collected at the nearest weather station in Baker, CA where the average annual rainfall was 10.69 cm from 1971 to 2007. Rainfall was below average in

2006 and 2007 with 8.13 cm and 3.96 cm of precipitation, respectively. Precipitation in 2008 was above average with 11.66 cm (National Climatic Data Center, 2009).

The sand temperatures recorded when fringe-toed lizards were observed on transects were 44.2°C (2007) and 41.5°C (2008) (Figure 10). With the evening transects removed, the time periods when transects were started was about the same (Figure 15). The mean start times of the day transects were 9:29 AM (2007) and 9:54 AM (2008). The discrepancy in mean start times between the years was a result of more transects being walked earlier in the season in 2008 and cooler temperatures in May. The mean temperature in 2007 in Baker, CA was 27.2°C, while the mean temperature in 2008 for the same month was 24.7°C (National Climatic Data Center, 2009). These cooler temperatures could account for the decrease in the mean temperature when *Uma scoparia* were observed. In addition, most of the transects at Ibex Dunes in 2008 were walked in May during these cooler temperatures, while most of the transects at Ibex Dunes in 2007 were walked in June. The mean start sand temperatures at Ibex Dunes are 44.7°C (2007) and 38.9°C (2008).

The difference between the mean sand temperature at the beginning of transects with fringe-toed lizard observations at all sites in 2007 and 2008 was 2.76°C, and the difference between the mean sand temperatures at the end of the transects with lizard observations at all sites in 2007 and 2008 was 3.32°C. Using these differences as the hypothesized difference, the temperatures when lizards were observed in 2007 and 2008 were not significantly different (Student's *t* test: start, $p=0.99$; end, $p=0.58$).

# CHAPTER 4

# DISCUSSION

## Lizard Observations

The goal of this study was to identify where *Uma scoparia* existed at three locations in the Amargosa River drainage. At Dumont Dunes, the lizards were concentrated in the western, southern, and eastern areas near the transects (Figure 6). Zero Mojave fringe-toed lizards were observed on transects that had no vegetation present. At Ibex Dunes, the lizard observations were scattered throughout the dunes system in 2007 and only observed in the south and northeast in 2008 (Figure 7). At Coyote Holes, *Uma scoparia* were found in low numbers at this small outcrop of windblown sand (Figure 8).

Lizard observations also resulted in the expansion of the known range at Ibex (Figure 7) and Dumont Dunes (Figure 16). During an exploratory trip along the historic Tonopah and Tidewater railroad berm in 2006, a fringe-toed lizard was found in a sandy area about five kilometers southeast of Dumont Dunes near the Valjean Hills. BLM biologists took this discovery a step further and expanded the range of the population at Dumont Dunes to include the Valjean Hills (Figure 16) (Otahal et al., unpublished). In 2007, another exploratory trip to the north of Ibex Dunes yielded a MFTL in a sandy outcrop two kilometers north of the previous range (Figure 7).

The importance of vegetation as cover and a food source for *Uma* has been suggested by many (Barrows, 1997 & 2006; Durtsche, 1995; Kaufmann, 1982; Mayhew, 1966a & b; Minnich & Shoemaker, 1972; Pough, 1970), but none of these researchers documented a fringe-toed lizard's distance from vegetation. Including lizards both on and off transects ($tot_{08}$=55), only one Mojave fringe-toed lizard in 2008 was observed more than 33 m from vegetation (at Ibex, 69 m). The mean distance from vegetation was 6.37 m for lizards on transects. However, some transects that were walked had windblown sand and vegetation present, but zero lizards were observed in either year on these transects. This suggests that vegetation presence is necessary but not sufficient to define *Uma scoparia* habitat. If further studies were conducted, I would expect that *Uma scoparia* would be found within 100 m of any vegetation, expanding the habitat requirements beyond Aeolian sand only.

The dominant perennial shrubs encountered in MFTL habitat are creosote bush, *Larrea tridentata*, and white bursage, *Ambrosia dumosa*. Two other perennial shrubs that were found nearest to observed fringe-toed lizards were sandpaper plant, *Petalonyx thurberi*, and saltbush, *Atriplex* sp. Vegetation, I presume, served as cover from predators, and the lizards appeared to use the perennial shrubs as refuge from the heat. Durtsche (1995) found very high amounts, both in quantity and mass, of *P. thurberi* flowers in the stomachs of male *Uma inornata* in the month of May. Durtsche (1995) suggested that MFTLs may be utilizing this plant as a major food source, especially mature males during the breeding season as a cheap energy source. This plant was observed in both years to attract large numbers of arthropods while the flowers were in

bloom from April through June (Figure 17). *P. thurberi* was observed at both Ibex and Dumont Dunes, but it was not present at Coyote Holes. Similarly, Kaufmann (1982) observed mature male *Uma scoparia* regularly feeding on the sand verbena flowers during the breeding season. Dumont Dunes had large expanses of flowering sand verbena in 2008 (Figure 16).

When comparing observations in 2007 to 2008 at all study sites, there were fewer lizards observed in 2008. Dumont Dunes (Wilcoxon signed ranks test, p=0.544) and Coyote Holes (p=0.317) did not show a significant change between 2007 and 2008. However, Ibex Dunes did show a significant decrease (p=0.009) in total MFTLs seen from 2007 to 2008 ($tot_{\mathrm{IBX07}}$=35; $tot_{\mathrm{IBX08}}$=15). The difference is even greater if only looking at lizard observations on transects ($obs_{\mathrm{IBX07}}$=27; $obs_{\mathrm{IBX08}}$=3, p=0.011). This large decrease in lizard sighting at Ibex appears to be either an anomaly or a result of a series of events leading to a large decrease in sightings. These events are discussed in further detail below, but they consist of effects of drought, differences in times when transects were walked, differences in temperature, problems with walking transects, or a combination of these factors.

## Food Availability and Rainfall

Mayhew (1966a & b) was able to show that rainfall plays a large part in determining reproductive success of fringe-toed lizards in the following year. For example, if rainfall is below average during the winter of 2005-2006, then there will be less mating occurring during the breeding season of 2006; therefore, there will be fewer juveniles present in the fall of 2006 and spring of 2007. Mayhew (1966a & b) and others

(Hereford et al., 2006; Turner et al., 1982) have discussed that rainfall directly affects food availability. For *Uma notata*, testes size in males was directly related to food intake, and decreased egg production in female *Uma scoparia* coincided with drought years (Mayhew, 1966a & b).

Barrows (2006) demonstrated that rainfall correlates with *U. inornata* population growth, $r = \ln(N_{i+1}/N_i)$. Applying my data to his model, I get negative population growth for both Dumont ($N_{i+1}$=16, $N_i$=21, r =-0.27) and Ibex Dunes ($N_{i+1}$=3, $N_i$=26, r =-2.16). The population growth at Dumont Dunes for 2007 compared similarly to the results of Barrows (2006) in five different years (r =-0.27 +/- 0.1). Also similar to my study, the rainfall in all five of these years was below 50 mm. However, the negative population growth at Ibex Dunes for 2007 was unequalled in 20 years of data by Barrows (2006). The year that comes closest had a population growth of approximately -1.9, with an annual rainfall of 20 mm (Barrows, 2006). Rainfall in 2007 was 39.6 mm (National Climatic Data Center, 2009).

Morafka (2003) found the following numbers of fringe-toed lizards per transect (1000 m) during a drought year: 0.583 (low OHV), 0.250 (moderate OHV), and 0.500 (high OHV). In comparison, the number of lizards seen per ha at Dumont Dunes in 2007 (Figure 12) is similar to Morafka's data for low and high OHV activity areas. Girard (2004) found even fewer *Uma scoparia* on the transects (post drought) at Dumont Dunes in both areas of high and low OHV activity, approximately 0.2 fringe-toed lizards per transect, which is comparable to 0.21 *U. scoparia* per hectare in 2008 (post drought) at Ibex Dunes (Figure 12). I am not sure where the transects were placed at Dumont Dunes

in these studies or whether they were placed in the same areas in 2003 and 2004, but the location choice could be why they have low observations on their transects. In 1994 to 1998, Morafka recorded 6.714 fringe-toed lizards per transect at Bitter Spring and 6.156 fringe-toed lizards per transect at Red Pass Dry Lake (Morafka, 2003). I have recorded 5.3 MFTLs/ha (equates to Morafka's and Girard's MFTLs per 1000 m) on one transect at Dumont Dunes and 6.7 MFTLs/ha two different transects (one at Ibex and the other at Dumont) in 2007.

Rainfall during the winters of 2005-2006 and 2006-2007 was below average, and two juveniles were observed in 2007 and zero in 2008. These observations are consistent with Mayhew's (1966a & b) results that suggest low reproductive output during a drought. However, I did not sample during the best season (fall) to count juveniles. There may not have been any juveniles observed in 2008 because of an over-abundant food supply to facilitate rapid growth before I started collecting data. In January 2009, five out of six MFTLs that were found in a single field day at Dumont Dunes were juveniles. Similar relationships with rainfall and reproduction have also been demonstrated with other desert lizard species (Dunham, 1980; Turner et al., 1982).

Three outbreaks of ground dwelling insects were observed at Dumont Dunes in the spring of 2008, which included *Phodaga alticeps* (see below, Figure 18), Say's stink bug (*Chlorochroa sayi*), and pallid-winged grasshoppers (*Trimerotropis pallidipennis*). These large insect emergences in 2008 were not observed at Ibex Dunes or Coyote Holes. Hemipterans and orthopterans like Say's stink bug and the pallid-winged grasshopper

may be linked to reproduction and population growth in fringe-toed lizards (Barrows, 2006; Kaufmann, 1982)

Not recorded in this study was the presence of the fanleaf crinklemat plant, *Tiquilia plicata*, but there have been interesting observations made. Durtsche (1995) found leaves of this plant in the stomach contents of *U. inornata*, but at the time he was unaware of secondary compounds found in this plant. Seigler et al. (2005) found that the cyanogenic glycoside dhurrin is the major secondary compound found in tissue samples of *T. plicata*. At Dumont Dunes in 2008, there were many blister beetles, mostly *Phodaga alticeps* (Meloidae), walking along the ground feeding on *T. plicata* (Figure 18). Beetles of the family Meloidae are known to produce cantharidin, a highly toxic secondary compound that produces blisters when introduced to skin and can lead to death in mammals if ingested (Moed et al., 2001). Both the plant and the beetles were found in the same habitat as *Uma scoparia*. It would be interesting to find out if fringe-toed lizards consume the beetle and if they are then able to break down the secondary compounds produced by either the plant or the beetle.

## Future Research and Conservation

Recently, a petition (Center for Biological Diversity & Papadakos-Morafka, 2006) was investigated by the United States Fish and Wildlife Service (USFWS) to decide whether past data warranted listing the northern Mojave fringe-toed lizard populations as a distinct population segment under the Endangered Species Act (USFWS, 2008). In 2008, USFWS, BLM, and California Department of Fish and Game agreed that a conservation plan would be appropriate, but listing was not yet warranted. A

conservation plan for the Dumont Dunes OHV recreation area was created by BLM in 1990, and it is currently being updated with the Mojave Fringe-toed Lizard Conservation Plan (Otahal et al., unpublished).

Transects work well for large projects with lots of people to share the workload (e.g. horned lizard project) or when research methods are limited (e.g. Coachella Valley fringe-toed lizard) (Barrows, 2006; Wright, 2002); however, walking transects alone was not ideal for this study. In the field, transects are difficult for one person to stay on the correct heading, search for lizards, and record data without additional aid. In the BLM protocol, three people were suggested to manage all the tasks of walking a transect. If a waypoint was set for every 50-100 m along a transect, then I think it would be easier to stay on the route, without a third person navigating.

Other problems that arose with transects were that the statistics tended to be nonparametric, the highly mobile and cryptic nature of fringe-toed lizards, and the variation in habitat quality. Transects were difficult to analyze statistically because there were a lot of zeros. Many of the transects passed through non-habitat producing a lot of zeros in the data. Due to the highly adapted and mobile nature of these lizards, many lizards were likely missed. These lizards were very difficult to see unless the animal moved. Fringe-toed lizards were likely alerted to my presence well before I was aware of theirs, allowing them to move out of my way or enter a burrow. As discussed earlier, the substrate, vegetation, and elevation can all change very drastically within a single transect. This variation would be difficult to quantify and standardize. Perhaps a combination of mark-recapture, walking transects, and quantifying habitat variation

would be a better survey technique for this species. Some habitat variations and data that should be collected include vegetation (annual, biannual, and perennial), sand grain size, relative slope degree and directionality, abundance of rodent burrows, fecal samples, and documenting tracks.

Mark-recapture studies to estimate population size would work best by using an injectible electronic identification microchip (PIT tagging) in a mark-recapture study (Whitfield-Gibbons & Andrews, 2004). Despite evidence suggesting that toe clipping does not affect the running ability of terrestrial lizards (Borges-Landaez & Shine, 2003), toe clippings should probably be avoided with this species for potential negative effects on the running ability of these animals. Carothers (1986) demonstrated that removing the fringes off the toes will reduce acceleration and velocity of *Uma scoparia* on sand. Removing entire toes and the effect on fringe-toed lizards has not been demonstrated, but it should be done prior to any further mark-recapture studies done with toe-clippings. Paints or dyes also have drawbacks in long term studies due to the skin shedding cycle of reptiles. Despite relatively high costs, the PIT tags could be a long-term solution to measure population dynamics at Dumont Dunes and the extent of dispersal within a dune system.

An exclusion study would be a better way to test the effects of current OHV activity on the dunes. Several plots of varying OHV activity areas could be blocked off to take measurement of plant diversity and succession. These exclusion areas should be compared to areas where lizards are found. Some factors to compare and measure should include: soil composition, presence of rodent burrows, presence of boulders/large rocks

that could be used as cover, and contour/directionality (flat, slope, East-facing, leeward, etc.). As supported in this thesis and others, the lizards are very dependent on vegetation, especially annuals when there is rain (Mayhew, 1966a & b; Norris, 1958). As with most other desert organisms, perennial vegetation becomes vital during drought years (Durtsche, 1995; Mayhew, 1966a & b).

If studies are to continue at Dumont Dunes, I would recommend putting in a weather station to measure winter rainfall and ambient temperatures during sampling periods. Baker, CA was the closest weather station with complete data for the study period, but the data was not compared with data from Dumont Dunes to see if there was a correlation.

## Summary of Findings

The seasonal and habitat ranges of the Amargosa River populations of the Mojave fringe-toed lizard are more extensive than previously measured. The population at Ibex Dunes extends 2 km north from the past range to some small sandy outcrops with vegetation. The population at Dumont Dunes follows fingers of habitat east to the Valjean Hills. All of the range expansions occur in protected habitat. The lizards do not occur on the large dunes faces of Dumont and Ibex Dunes and the northern areas of Dumont Dunes where vegetation is absent.

Activity varied from 2007 to 2008, especially at Ibex Dunes, but there were many potentially contributing factors. Windblown sand and a mix of perennial shrubs and annual vegetation are important habitat requirements for the Mojave fringe-toed lizard, but vegetation is not predictive. Surveys of fringe-toed lizards would benefit from long

term research and incorporating mark-recapture methods into walking the transects. For the future, management agencies should take these habitat conditions and expanded range into account when developing mitigation plans.

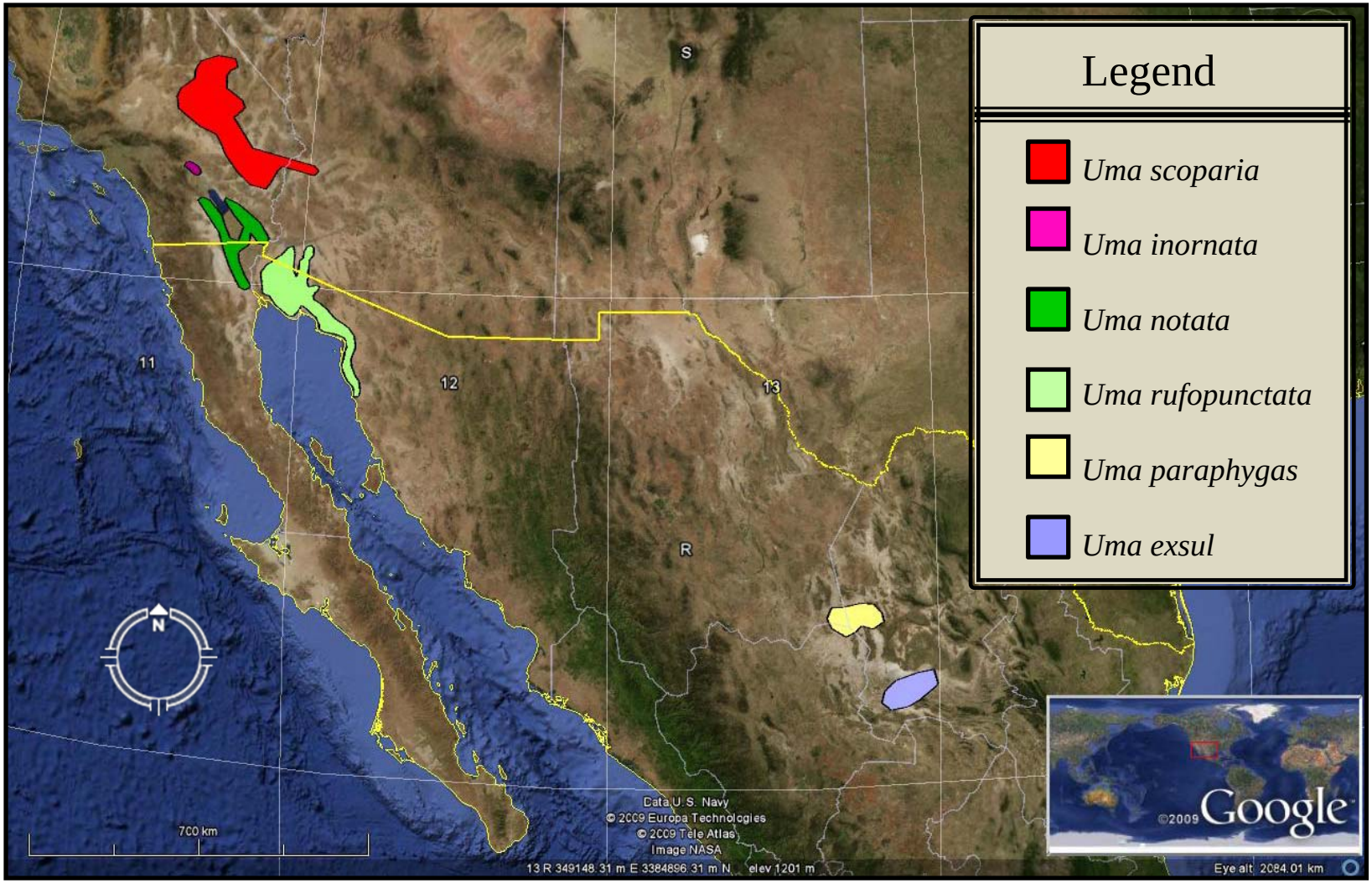


Figure 1: Distribution of the six recognized species of fringe-toed lizard in the Genus *Uma* (Phrynosomatidae). This map is projected on a UTM projection grid with a 700 km scale bar. Imagery obtained from Google Earth, courtesy of ©2009 Europa Technologies, Data U.S. Navy, ©2009 Tele Atlas, and Image NASA.


Figure 2: Picture of enlarged scales on right hind foot of adult *Uma scoparia*. All toes (hind and fore-feet) have posterior-oriented enlarged scales. The 4th digit (shown above) on the hind feet has the largest extensions.


Figure 3: Fringe-toed lizards have several facial adaptations for Aeolian life (*Uma scoparia* pictured). To reduce sand intake when diving into the sand, the lower jaw is counter-sunk below the top jaw, the nasal passages are oriented posteriorly, and a valve can seal the nasal passages shut. The eyelids have enlarged 'eyelash' scales to reduce sand irritation. The ear is covered by enlarged scales.


Figure 4: A map of the extant populations of the Mojave fringe-toed lizard, *Uma scoparia*. The triangles on the map represent the northmost populations of this species and are the study sites for this project. Each shape corresponds with a Pleistocene river drainage. UTM projection, with a 150 km scale bar. Imagery obtained from Google Earth, courtesy of ©2009 Europa Technologies, Data U.S. Navy, ©2009 Tele Atlas, and Image NASA.

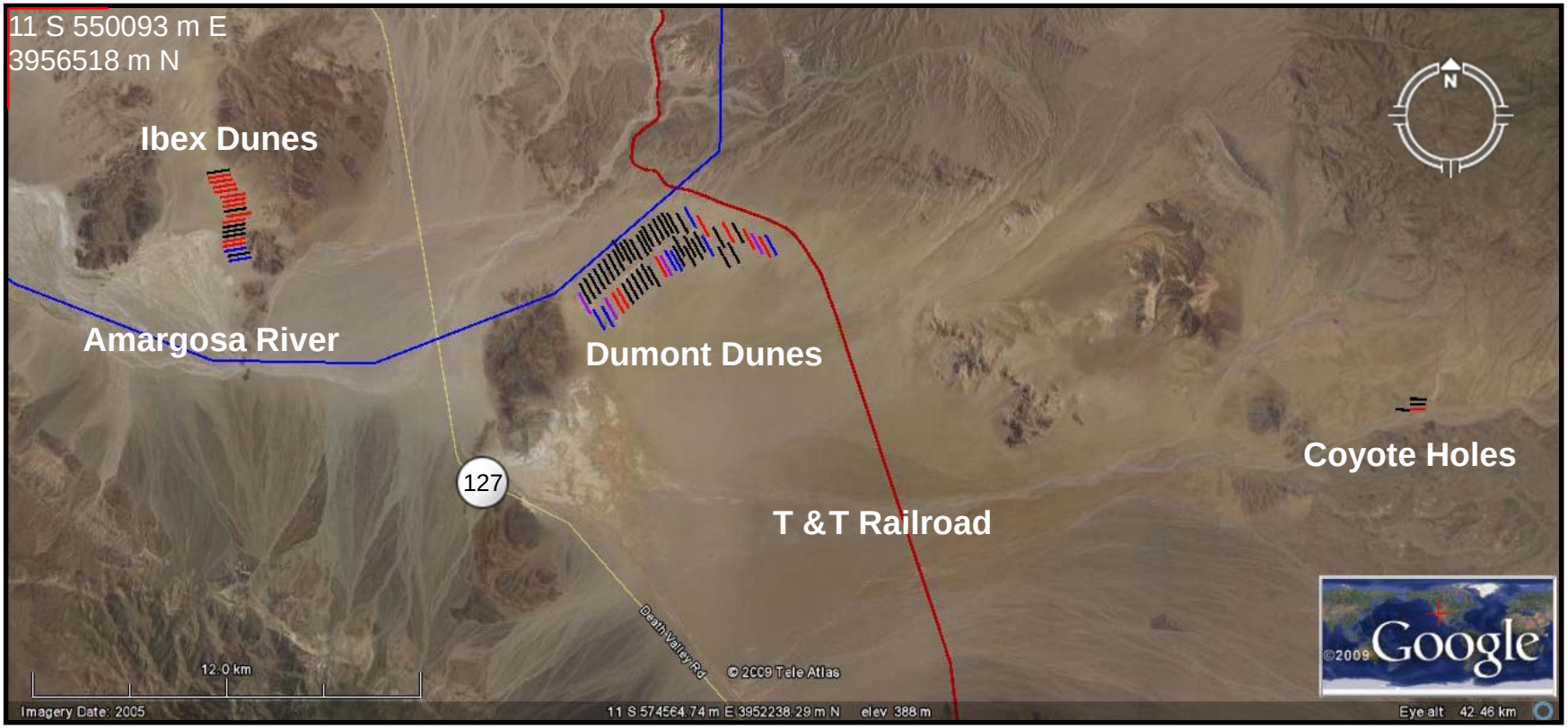


Figure 5: The Amargosa River populations of *Uma scoparia*. The straight, parallel lines represent the transects at each study site. The red transect lines depict the transects with *U. scoparia* observations only in 2007. The blue lines had *U. scoparia* observations in 2008 only. The purple lines had *U. scoparia* sightings in both 2007 and 2008. The black lines did not have *U. scoparia* sightings in either year. UTM projection with a 12.0 km scale bar. Imagery date: 2005, © 2009 Tele Atlas.

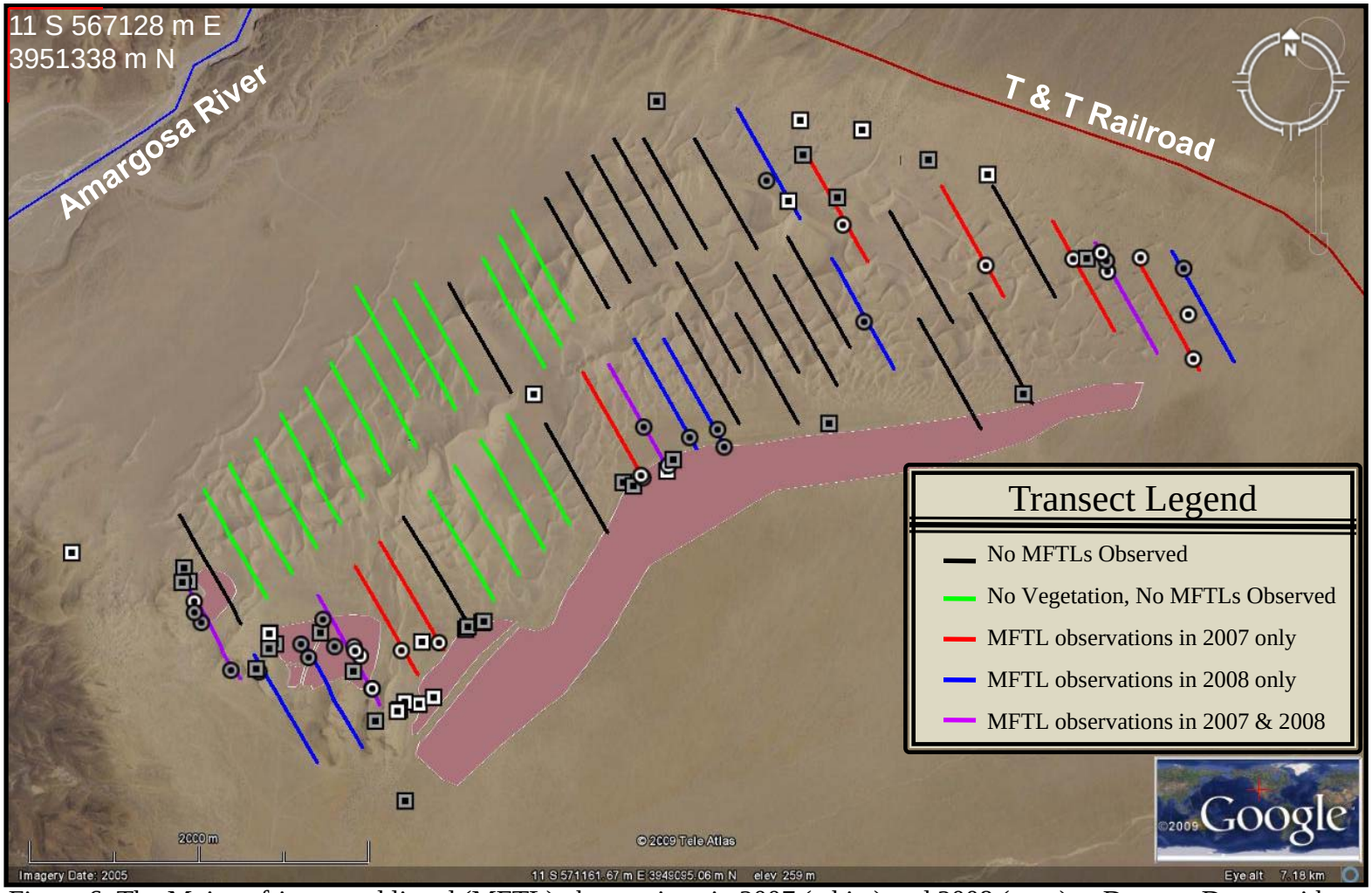


Figure 6: The Mojave fringe-toed lizard (MFTL) observations in 2007 (white) and 2008 (grey) at Dumont Dunes with flower polygons (pale violet-red) and transect layout (straight parallel lines, see legend for color interpretations). The circular waypoints were lizards seen on the transects, and the square waypoints were lizards seen off of the transects. UTM projection with a 2000 m scale bar. Imagery date: 2005, © 2009 Tele Atlas.

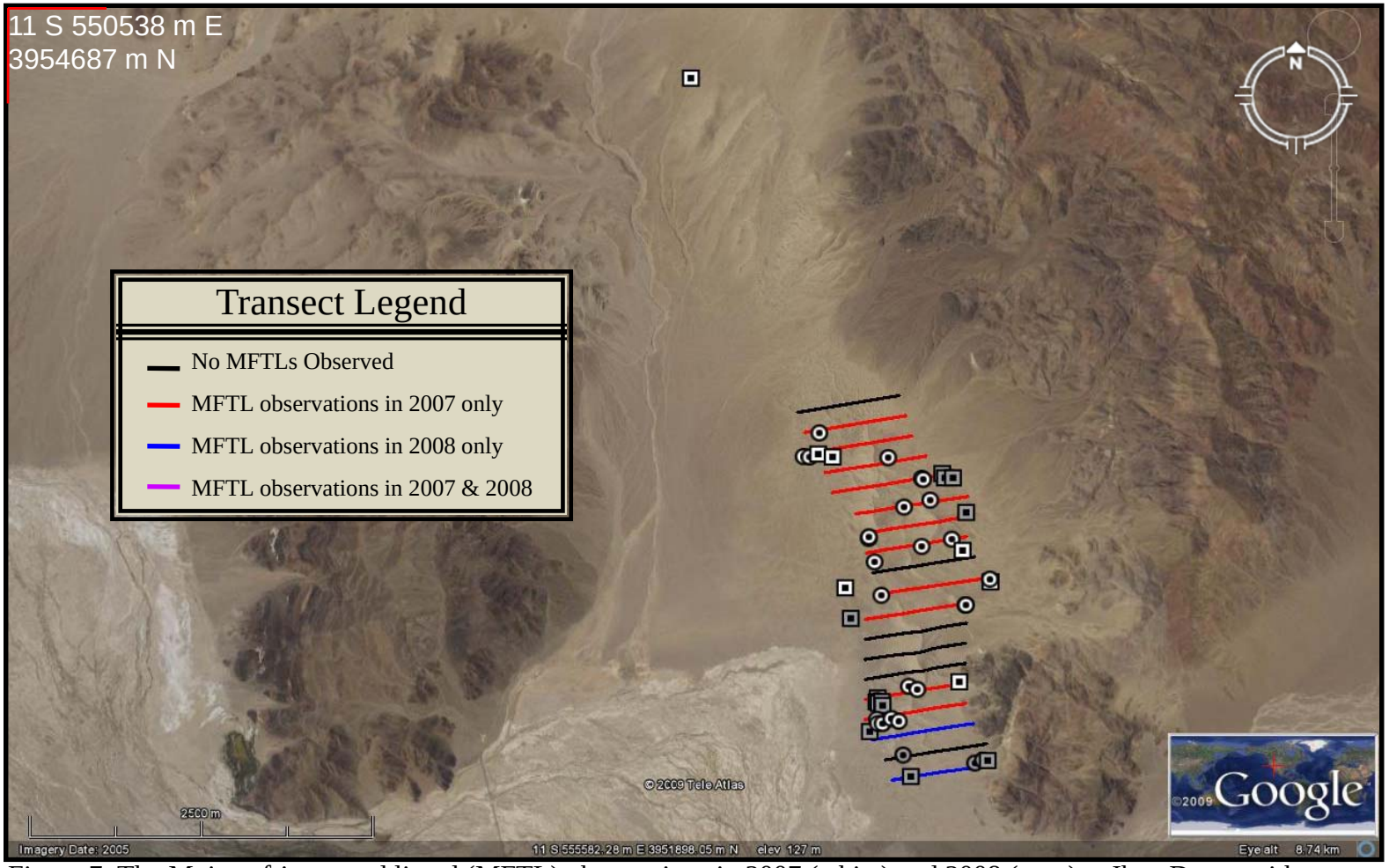


Figure 7: The Mojave fringe-toed lizard (MFTL) observations in 2007 (white) and 2008 (grey) at Ibex Dunes with transect layout (straight parallel lines, see legend for color interpretation). The circular waypoints were lizards seen on the transects, and the square waypoints were lizards seen off of the transects. The northernmost waypoint is 2 km north of the main dune field, extending the previously known range of the Ibex Dunes population. UTM projection with 2500 m scale bar. Imagery date: 2005 , © 2009 Tele Atlas.

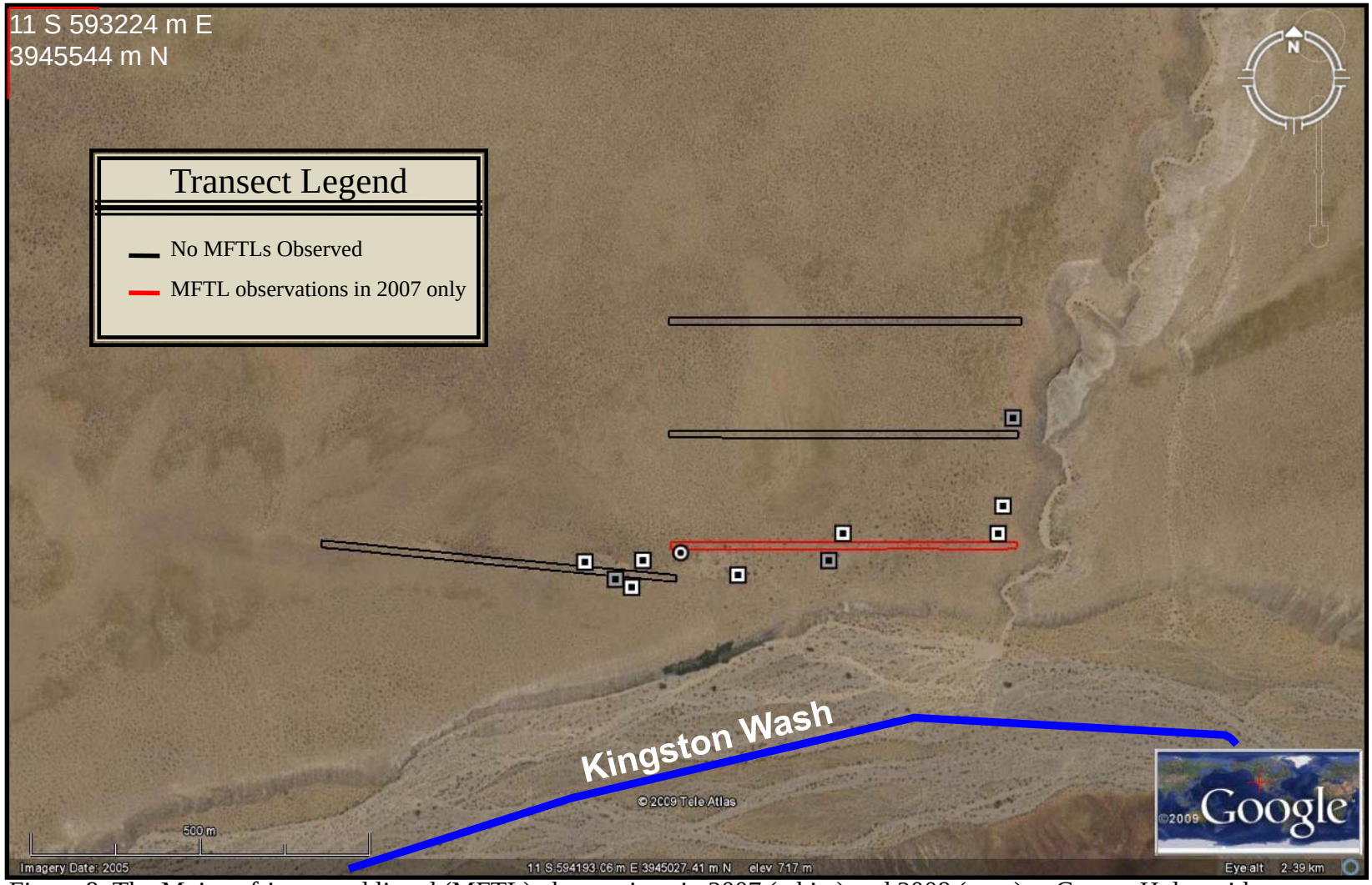


Figure 8: The Mojave fringe-toed lizard (MFTL) observations in 2007 (white) and 2008 (grey) at Coyote Holes with transect layout (straight rectangles). The circular waypoints were lizards seen on the transects, and the square waypoints were lizards seen off of the transects. UTM projection with 500 m scale bar. Imagery date: 2005 , © 2009 Tele Atlas.

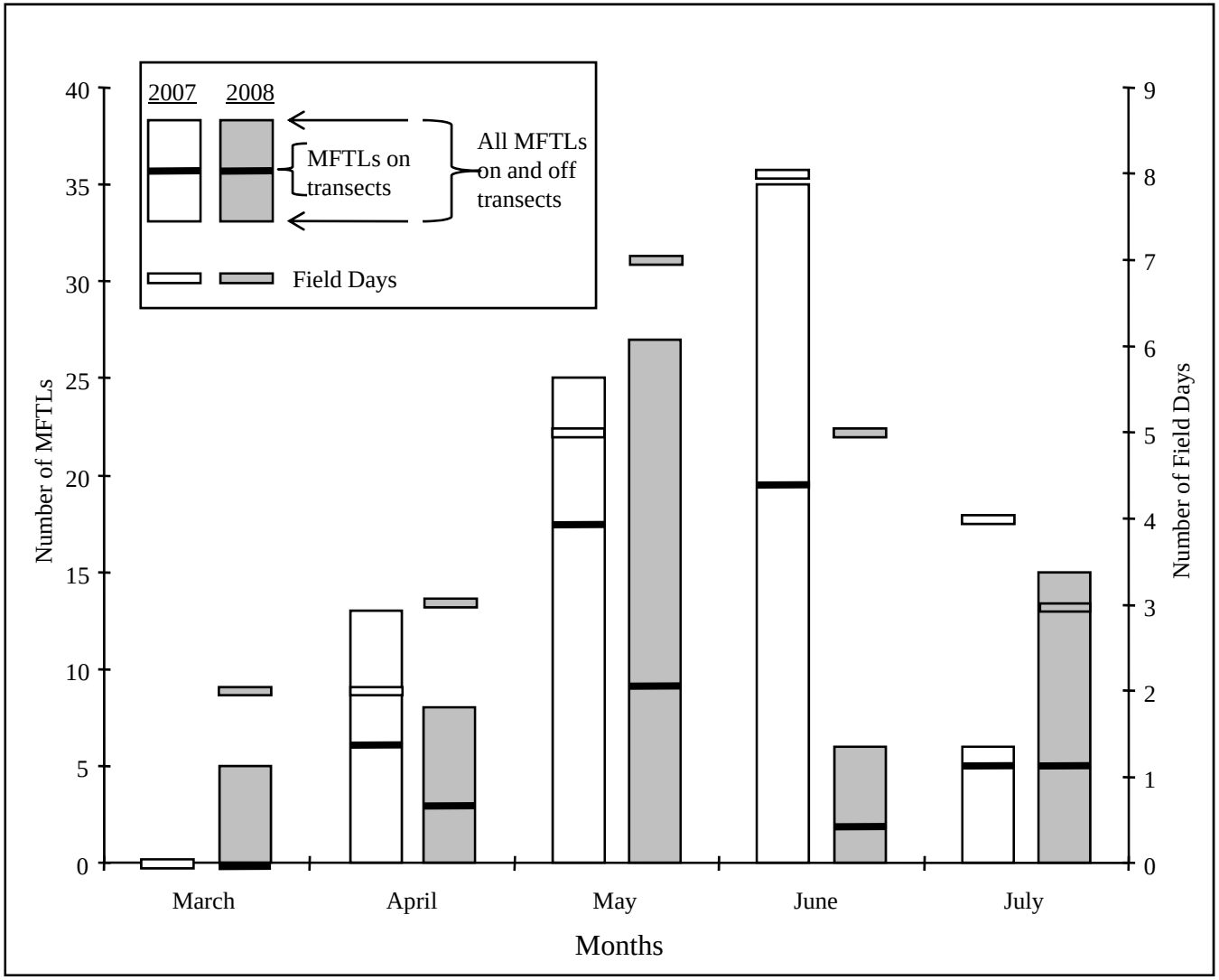


Figure 9: Field days and Mojave fringe-toed lizard (MFTL) observations broken down by month for each field season.

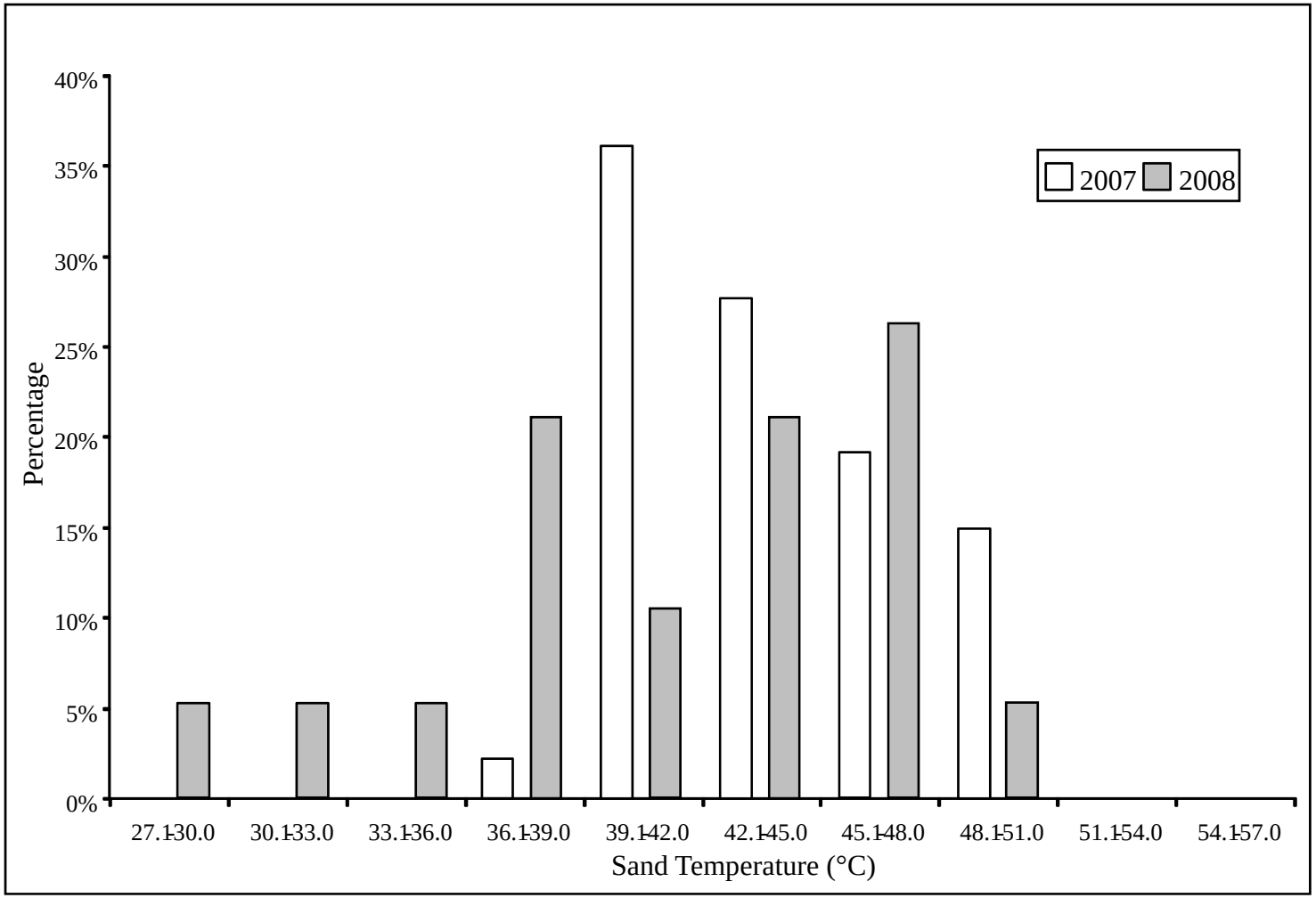


Figure 10: The percent distribution of sand temperatures when *Uma scoparia* were encountered on transects. The mean temperatures were 44.2 °C (2007) and 41.5 °C (2008). This decrease in sand temperature was not significantly different from the variation in the start (p=0.99) and end (p=0.58) sand temperatures of the transects in which the lizards were seen.

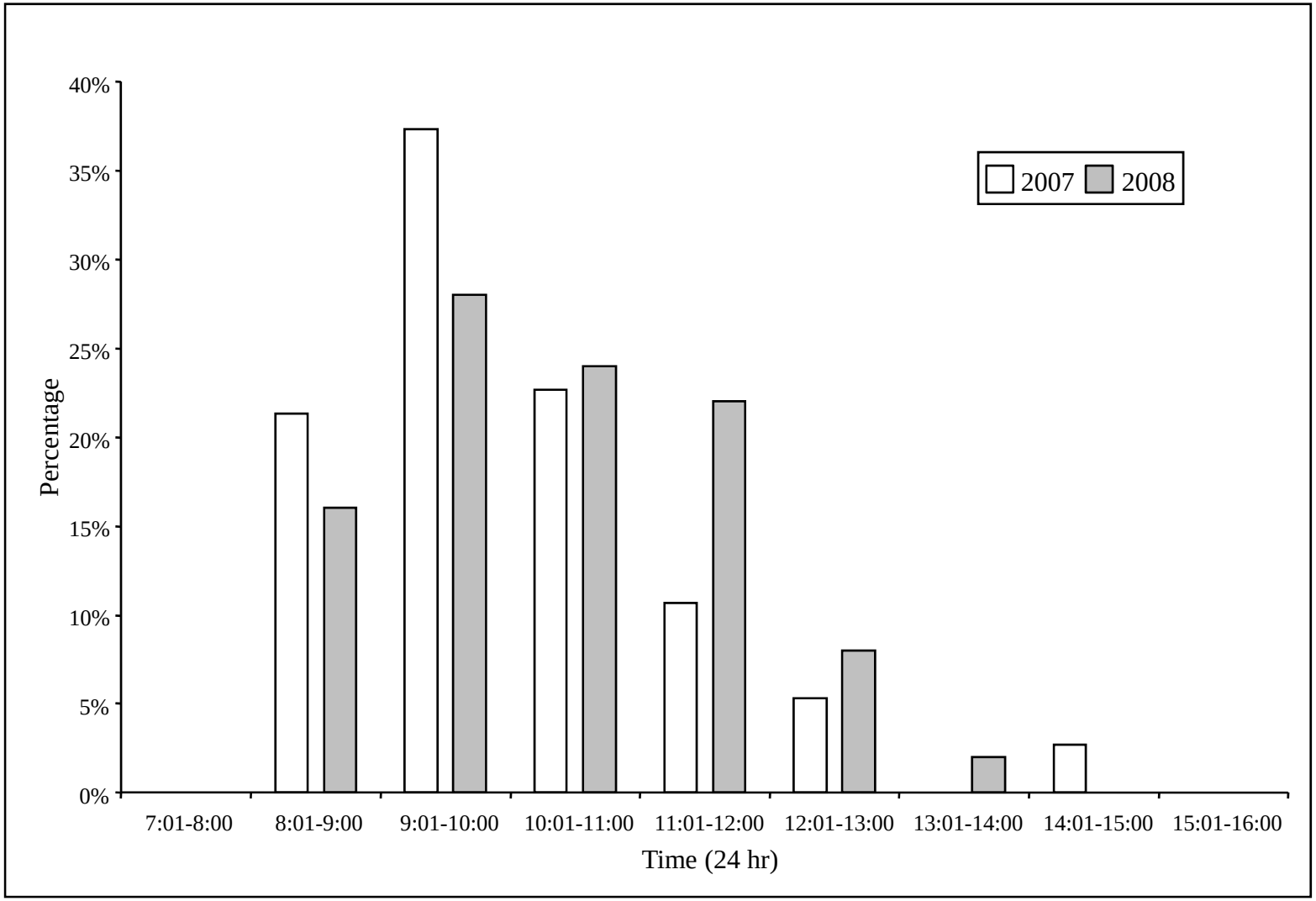


Figure 11: The percent distribution of time periods when *Uma scoparia* were observed, excluding evenings.

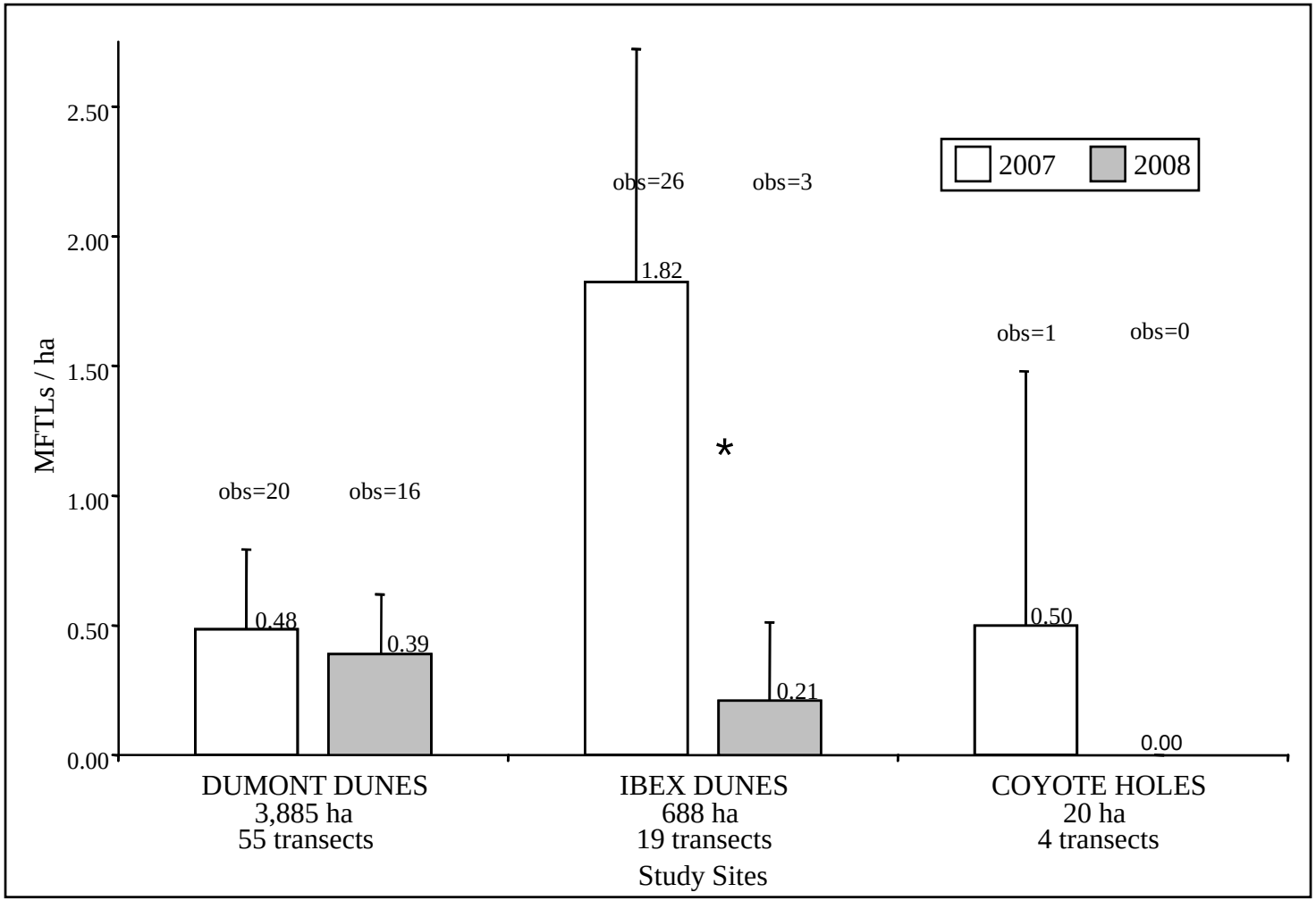


Figure 12: Mean numbers of Mojave fringe-toed lizards (MFTLs) seen per hectare per transect at each study site with 95% confidence intervals (obs=MFTLs seen on transects). Lizards were observed from March through July in 2007 and 2008. The 2007 season was a drought year. In 2008, the rainfall was above the average annual rainfall. Lizard observations at Ibex Dunes was significantly different (Wilcoxon signed ranks test, *p=0.011).

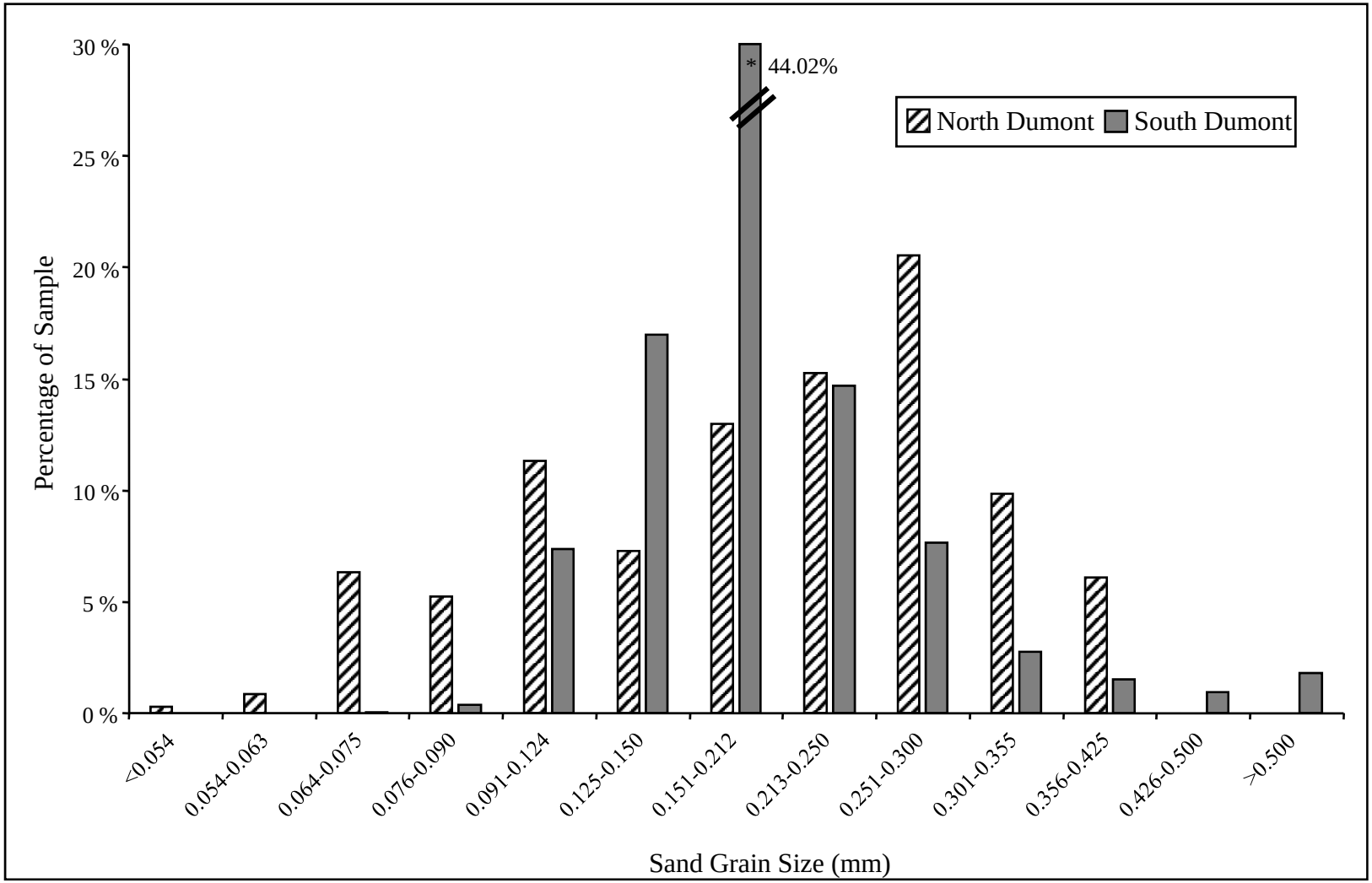


Figure 13: The sand grain size distribution at Dumont Dunes. The southern Dumont Dunes sample is more monodispersed (in particle size) than the sand sample from north Dumont Dunes. A majority of the sand at both locations is classified as fine or very fine grained sand.

Figure 14: Rainfall during the Fall and Winter of 2007-2008 resulted in large expanses of annual blooms throughout the Mojave Desert. Pictured above is a field of annuals in flower at Dumont Dunes. Sand verbena (purple) and desert primroses (white) made up a majority of the flowers present in the dune habitat. This picture was taken in March of 2008.

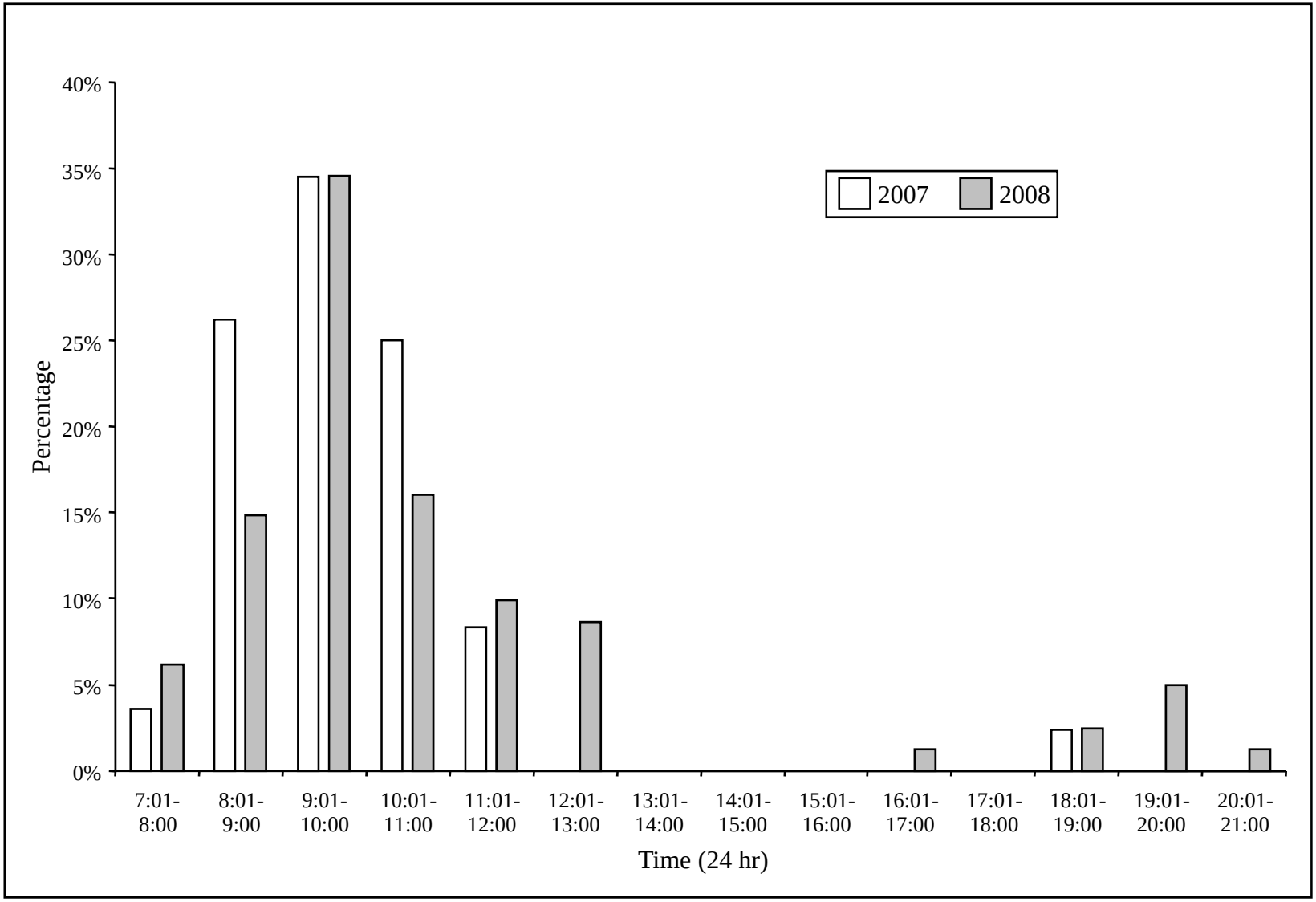


Figure 15: The percent distribution of time periods when transects were started for each season.

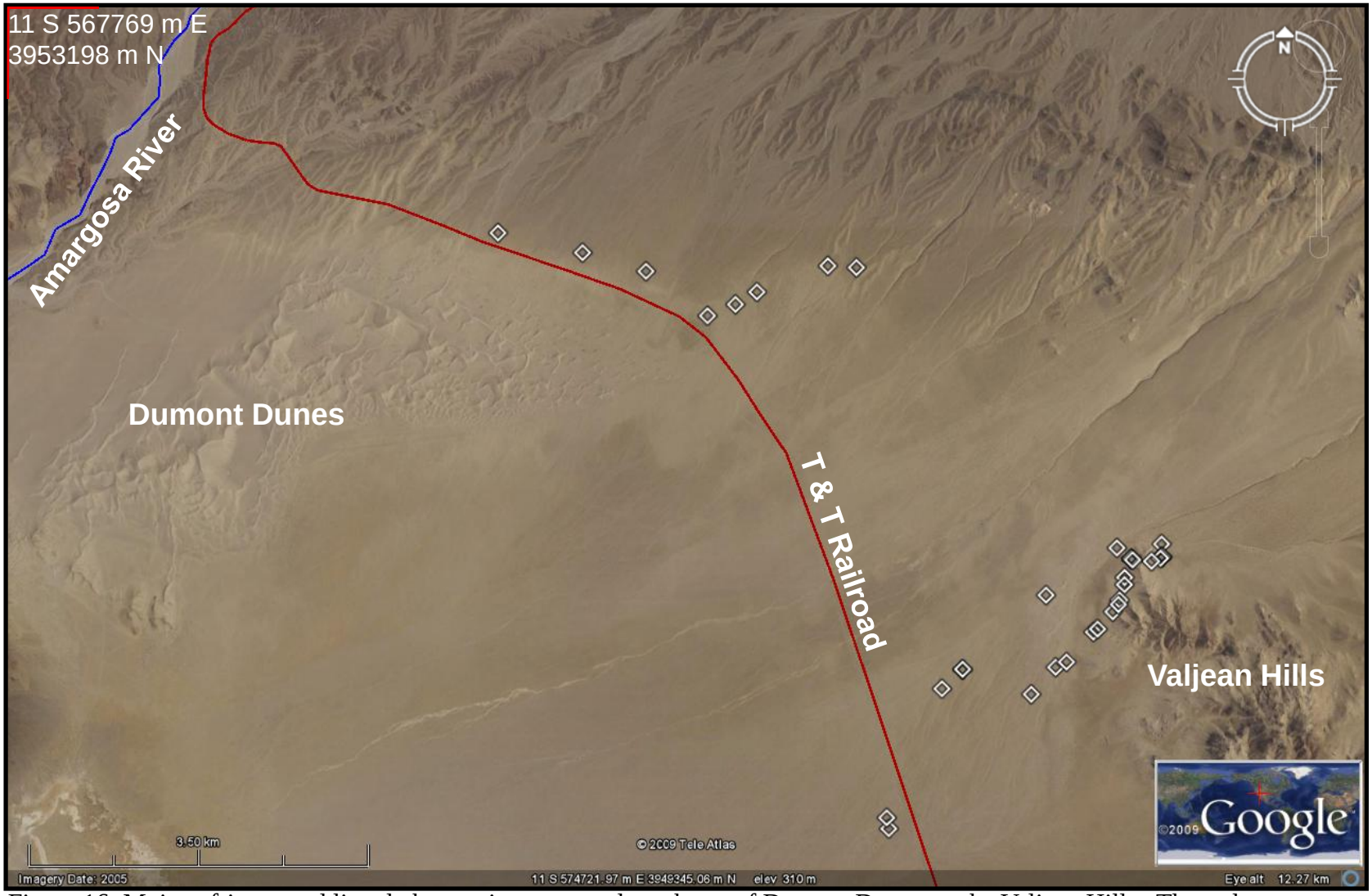


Figure 16: Mojave fringe-toed lizard observations east and southeast of Dumont Dunes, to the Valjean Hills. These data were collected by the Bureau of Land Management. UTM projection with 3.50 km scale bar. Imagery date: 2005 , © 2009 Tele Atlas.

Figure 17: Dipterans and a crab spider on a sandpaper plant (*Petalonyx thurberi*) at Dumont Dunes in 2008. There are actually three dipterans in the frame (circled). The flowers of this plant have been found in the stomach contents of *Uma inornata* (Durtsche, 1995).

Figure 18: A blister beetle (Meloidae), *Phodaga alticeps*, eating the leaves of the fanleaf crinklemat plant, *Tiquilia plicata*, at Dumont Dunes in April of 2008.

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