# RARE ALLUVIAL SANDS OF EL MONTE VALLEY, CALIFORNIA (SAN DIEGO COUNTY), SUPPORT HIGH HERPETOFAUNAL SPECIES RICHNESS AND DIVERSITY, DESPITE SEVERE HABITAT DISTURBANCE

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ABSTRACT—We characterized the species richness, diversity, and distribution of amphibians and reptiles inhabiting El Monte Valley, a heavily disturbed, alluvium-filled basin within the lower San Diego River in Lakeside, California. This rare habitat type in coastal southern California is designated as a critical sand resource by the state of California and is currently under consideration for a large-scale sand mining operation with subsequent habitat restoration. We conducted field surveys from June 2015 to May 2016 using drift fence lines with funnel traps, coverboard arrays, walking transects, and road driving. We recorded 1,208 total captures, revealing high species richness and diversity, but with marked unevenness in species' abundances. Snakes were the most species-rich taxonomic group (13 species representing 11 genera), followed by lizards (11 species representing 9 genera). After the southern Pacific rattlesnake (*Crotalus oreganus helleri*), the California glossy snake (*Arizona elegans occidentalis*) was the second most frequently detected snake species ($n = 23$ captures). Amphibian species richness was limited to only three species in three genera. Despite the relatively limited 12-month sampling period, a longstanding drought, and severe habitat disturbance, our study demonstrates that El Monte Valley harbors a rich herpetofauna that includes many sensitive species.

RESUMEN—Caracterizamos la riqueza de especies, diversidad y distribución de anfibios y reptiles que habitan El Monte Valley, una cuenca con alto grado de disturbio y llena de aluvión en la parte baja del río San Diego en Lakeside, California. Este raro tipo de hábitat en la costa sur de California ha sido designado como un sitio crítico de depósitos de arena para el estado de California y actualmente está bajo consideración para una operación de extracción de arena a gran escala con la posterior restauración de hábitat. Realizamos muestreos de campo de junio 2015 a mayo 2016 utilizando líneas de cercas de desvío con trampas de embudo, láminas de madera en el suelo, transectos a pie, y búsquedas en auto. Registramos un total de 1,208 capturas, revelando una alta riqueza y diversidad de especies, pero con una notable disparidad en la abundancia de especies. Las serpientes fueron el grupo taxonómico con mayor riqueza de especies (13 especies representando 11 géneros), seguido por lagartijas (11 especies representando 9 géneros). Seguido de la víbora de cascabel peninsular (*Crotalus oreganus helleri*), la culebra brillante (*Arizona elegans occidentalis*) fue la segunda serpiente detectada con mayor frecuencia ($n = 23$ capturas). La riqueza de especies de anfibios se limitó a sólo dos especies en tres géneros. A pesar de que el muestreo se limitó a un periodo de sólo 12 meses, una prolongada sequía, y un alto grado de disturbio del hábitat, nuestro estudio demuestra que El Monte Valley abriga una riqueza herpetofaunística que incluye varias especies sensibles.

Large portions of the southwestern United States, particularly coastal areas of western San Diego County, California, near the USA-Mexico international border, have undergone rapid development that has either eliminated or encroached upon what little is left of alluvial sand and gravel habitats. These habitats are generally found in river and stream valleys, at the base of topographic features where there is a pronounced change in slope, and in intermountain valleys (Weber, 1963; Bates and Jackson, 1987; Rosenshein, 1988). Deposits typically consist of variable grain sizes that are compactable, but retain good internal drainage. This feature makes them a preferred substrate for numerous reptiles and amphibians occurring within the region, particularly those with burying or burrowing tendencies such as the southern California legless lizard (*Anniella stebbinsi*), the California glossy snake (*Arizona elgans occidentalis*), Blainville's horned lizard (*Phrynosoma blain-*

*villii*), the Gilbert skink (*Plestiodon gilberti*), and the western spadefoot (*Spea hammondii*) (Mosauer, 1932; Lemm, 2006; Stebbins and McGinnis, 2012). The physical attributes of these deposits subject them to human exploitation, given that sandy or gravelly deposits, if deemed to be of high enough quality, are preferred aggregates for fill or as bases for pavement and infrastructure. In terms of tonnage and dollar value, sand and gravel extraction is the most lucrative type of mining in San Diego County (Land Use and Environment Group, San Diego County, http://www.sandiegocounty.gov/pds/procguid.html#mineralresources).

The El Monte Valley in Lakeside, California, is an alluvium-filled basin (~400 ha; 32.875213°N, 116.881355°W) that lies within the natural flood plain of the lower San Diego River watershed and has been designated as a critical sand resource by the California Geological Survey (Weber, 1963). It is situated in the coastal foothill section of the Peninsular Ranges Geomorphic Province (Norris and Webb, 1990; Harden, 1998) and lies on an east-west trajectory approximately just below El Capitan Reservoir in San Diego County. Due to construction of the El Capitan Dam in 1934, surface water flow is nonexistent through the modern-day valley; however, because it falls within the flood plain of the San Diego River and is surrounded by steep, granitic hillsides, slope erosion and fluvial sediment transport before the dam's construction led to the accumulation of large sand, silt, and gravel deposits on the valley floor.

Historically, portions of El Monte Valley were used for agriculture and small-scale sand mining, including one mining operation that created a river channel for flood control (3–6 m below the surrounding property, varying in width from 75 to 120 m). In 2000, the San Diego Planning Commission approved a proposal to develop two 18-hole golf courses in a degraded central section of the valley, but in 2005 the project was terminated prematurely due to economic downturn. Substantial habitat grading and excavation of several large pits had already occurred before the project was terminated, and no efforts to restore the habitat were ever made in the aftermath of these activities. Many areas are now overrun with nonnative annual grasses (e.g., slender wild oat [*Avena barbata*] and cheat grass [*Bromus tectorum*]), invasive weeds (e.g., Russian thistle [*Salsola tragus*] and Sahara mustard [*Brassica tournefortii*], and large stands of eucalyptus (e.g., river red gum [*Eucalyptus camaldulensis*]) and saltcedar (*Tamerix ramosissima*), although small sections that escaped grading have retained patches of intact costal scrub (predominantly black sage [*Salvia mellifera*], California buckwheat [*Eriogonum fasciculatum*], and deer weed [*Lotus scoparius*]). Plans for a large-scale sand mining operation (anticipated extraction volume is ~5.73 million $m^3$, or 6.8 MT) and recontouring of the valley are currently under consideration. Sand extraction (~1 million MT/year) and subsequent habitat restoration are proposed to be completed in phases over 16 years (San Diego County Planning and Development Services, project ID PDS2015-MUP-98-014W2, http://www.sandiegocounty.gov/pds/, revised scoping letter dated 11 March 2016).

Because of the extensive loss of alluvial sand habitats in western San Diego County and the affinities of several protected reptile and amphibian species to this habitat type, we conducted field surveys in El Monte Valley from June 2015 to May 2016 to provide an up-to-date characterization of the herpetofauna inhabiting this area. We placed emphasis on determining the presence-absence of *A. e. occidentalis*, a newly listed species of special concern by the California Department of Fish and Wildlife (Thompson et al., 2016). It occurs in arid scrub, grasslands, and chaparral with sandy or gravelly substrates, and was once abundant in coastal San Diego County (albeit nonuniformly distributed; Klauber, 1946). The type locality for *A. e. occidentalis* is La Jolla, California (Blanchard, 1924), part of the city of San Diego, and 60% of the specimens used by Klauber (1946) to validate the original classification of *A. e. occidentalis* (Blanchard, 1924) were from the "cliffs above the surf" in the cities of Leucadia, Encinitas, Cardiff, Solana Beach, and Pacific Beach. Because of extensive urbanization, artificial night lighting in urban areas, and other forms of disturbance, the species is now extirpated near the coastline (Perry and Fisher, 2006). This study had three main objectives: 1) to quantify the species richness and diversity of reptiles and amphibians inhabiting this now-rare habitat type in San Diego County, 2) to specifically determine whether *A. e. occidentalis* still occurs within the El Monte Valley, and 3) to generate a dataset for establishing habitat restoration goals. We also compared reptile and amphibian species richness in the valley with other sites previously surveyed by the U.S. Geological Survey (USGS) across San Diego County (Fisher and Case, 2000; Case and Fisher, 2001).

Materials and Methods—To assess spatial variation in species richness and diversity and to quantify survey effort, we partitioned the study site into five sampling sections (Fig. 1). We refer to these as "sections" for the remainder of the report, with Sections 1 and 5 representing the western and easternmost sampling areas, respectively. Section 1 is bounded to the west by Hansen Pond (although one sampling area was placed in a narrow band of habitat between Hansen Pond and Willow Road on the north side of the valley; Fig. 1), and Section 5 is bounded to the east by Hazy Meadow Lane. Elevation ranges from approximately 120 to 150 m across the study area.

We used four survey techniques, each described under separate subheadings below. We vouchered at least one representative of every species with photographs and recorded latitude-longitude data (WGS-84) for all captures or incidental observations. For *A. e. occidentalis*, two species of racers in the genus *Coluber*, and the long-nosed snake (*Rhinocheilus lecontei*), we excised a small tissue sample (<5.0 mm of the tail tip) and

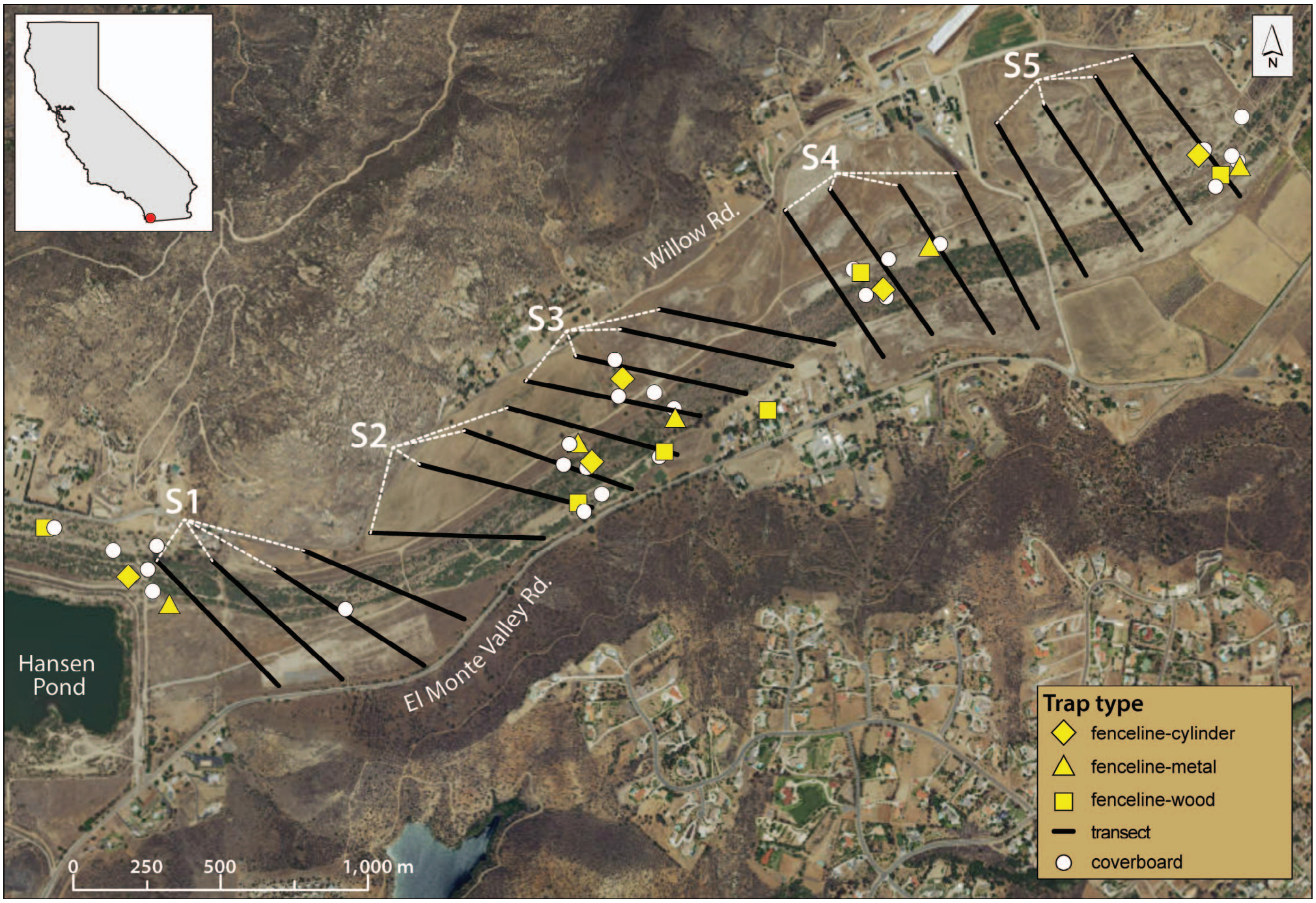


FIG. 1—Sampling locations within El Monte Valley, Lakeside, California (gray dot on the inset map shows the approximate location of El Monte Valley). Dashed white lines connect the four walking transects with the respective section identifier.

stored the tissue in 95% ethanol for ongoing or planned DNA studies on these taxa. We also collected tissue samples from most animals found dead on the roads. All tissue collections were authorized under California Scientific Collecting permits issued to J. Q. Richmond (SC-002294), C. Rochester (SC-003850), and USGS Western Ecological Research Center San Diego Entity Permit (SC-00838).

*Drift Fence Trap Lines*—We used 15 m of 41-cm-tall nylon shade cloth to construct drift fence lines for trapping reptiles and amphibians (Fig. 2). The fence was intended to disrupt animal movement, such that snakes, lizards, toads, etc., intercept the fence line and move along its base toward either end where a funnel trap is positioned to capture them (Fisher et al., 2008; Willson and Gibbons, 2009; Fitzgerald and Yantis, 2012). We used 10–15 wooden stakes pounded into the ground to hold the fence upright and stapled the shade cloth to each stake. We buried 5 cm of the shade cloth in the ground to prevent animals from crawling underneath it.

In all five sections we installed three separate fence lines, each with a different trap type (Fig. 1). We experimented with different trap types to assess possible differences in their ability to capture animals: two of these were "box trap" designs (46 cm × 5 cm × 20 cm, length × width × height), with one type consisting of a manufactured aluminum frame and the other consisting of a wooden frame and 6.4-mm hardware cloth. The third trap type was a cylindrical design with funnel cones at both ends of the trap, also constructed using 6.4-mm hardware cloth (Fisher et al., 2008). For the box design, one trap was placed at both ends of the fence line, whereas with the cylindrical design a pair of traps was placed on opposite sides of both ends of the fence (Fig. 2).

We conducted trapping surveys once per month over a 5-day sampling period. Traps were set on the first day, usually a Monday, and removed from the field on the fifth day. We checked the traps each morning, and released all animals at the site of capture after recording species identity, sex, age and class and extracting a tissue sample from individuals of those species listed above.

*Coverboard Arrays*—We placed five coverboard arrays in each sampling section because reptiles and amphibians commonly use cover objects for shelter and thermoregulation (Kuhnz et al., 2005; Lettink and Cree, 2007; Willson and Gibbons, 2009; Fitzgerald, 2012). Each array consisted of five coverboards that varied in size, shape, thickness, and construction material (plywood or particleboard). We placed the coverboard arrays in proximity to the drift fence lines, with each array spaced at approximately 3–5-m intervals. We attempted to blend the coverboards with the natural environment by placing them over rodent burrows, raking sand on top of them, and or placing them close to vegetation.

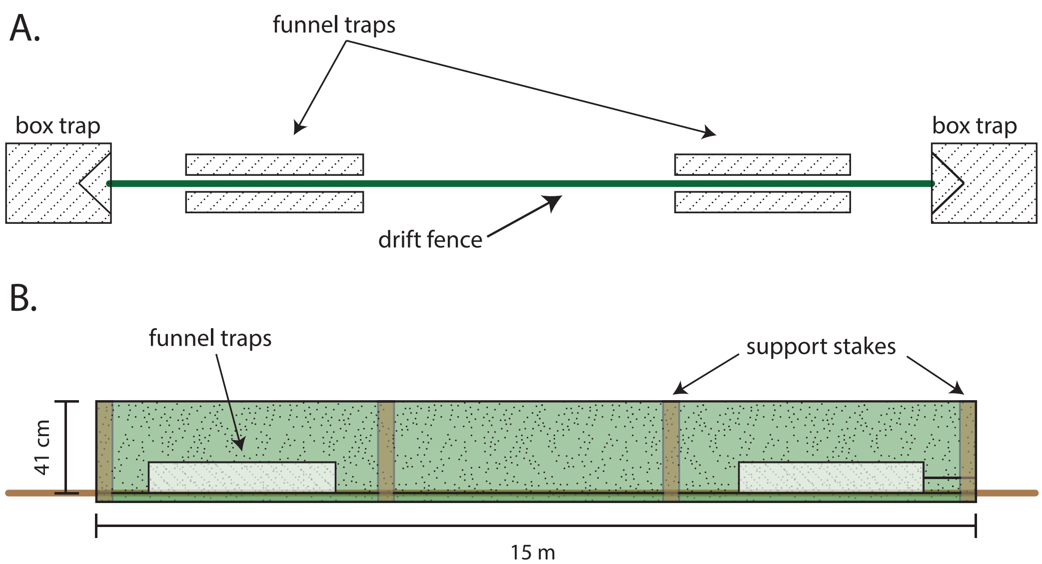


Fig. 2—Top (A) and side views (B) of a standard drift fence line with traps in place. The top view shows the different configurations for box and cylindrical funnel traps (a given drift fence line had one or the other trap type, not both). In (B), the drift fence is buried ~5 cm below ground to prevent animals from crawling underneath it.

We checked the boards on the second and fourth days of each trapping survey and recorded any animals underneath them. When time allowed, surveyors also checked a subset of coverboards that were already in place at the study site in Section 2.

*Nighttime Walking Transects*—We conducted four 500-m nighttime walking transect surveys within each sampling section two nights each month (two transects per section per night), each beginning within an hour after dark. Transects were largely perpendicular (i.e., north-south) to the main watercourse and traversed multiple vegetation zones (Fig. 1). Each survey involved two observers, spaced 8–10 m apart, using headlamps and hand-held flashlights to locate animals on the ground. We used four additional nighttime walking surveys to augment the findings of the main study, specifically on nights that were predicted to have optimal weather conditions for reptile and amphibian activity (minimal moonlight with early evening temperatures between ~25 and 28°C).

*Night Driving*—After sunset and before each nighttime walking survey, we slowly drove (~15–25 km/h) from the intersection of El Monte Valley Road/Lake Jennings Park Road to the east end of El Monte Valley Road, and then back to the starting point of the walking survey in Section 5 to search for animals on the road. We repeated the same drive at the end of the walking surveys (usually between 0100 and 0300 h). On two occasions, we did the final night drive out of the valley on Willow Road, a dirt road that runs parallel to El Monte Valley Road, but is on the opposite side of the valley. Snakes have been documented on both roads during previous surveys conducted by USGS or other volunteers. Night driving has also been demonstrated as an effective sampling technique for *A. elegans* in the southwestern USA (Klauber, 1946) and for snakes in general (Jones et al., 2011).

*Species Diversity*—We calculated three indices commonly used to describe the species composition within a community. These indices included species richness ($H_{sr}$, Eq. 1), the Shannon entropy ($H_{Sh}$, i.e., Shannon-Wiener index, Eq. 2), and the Gini-Simpson index ($H_{GS}$, Eq. 3):

$$H_{sr} \equiv \sum_{i=1}^{S} p_i^0 \tag{1}$$

$$H_{Sh} \equiv -\sum_{i=1}^{S} p_i \ln p_i \tag{2}$$

$$H_{GS} \equiv 1-\sum_{i=1}^{S} p_i^2 \tag{3}$$

In these equations, $p_i$ is the population frequency of the $i$th species, and $S$ is the total number of species. Species richness ignores unevenness in frequencies (i.e., it accounts only for species' presence-absence), but is useful when detection of rare species is just as important as the most common. The Shannon entropy favors neither rare nor common species disproportionately, but instead weighs each species exactly by its frequency in the sample. The Gini-Simpson index favors the more dominant species because it involves the sum of the squares of the frequencies, so rare species contribute little to the total. Because the Shannon entropy and the Gini-Simpson indices are measures that account for species unevenness in different ways, they must be converted to effective numbers of species to reflect true diversities that we could then compare across sampling sections (MacArthur, 1965; Jost, 2006). The Shannon entropy is converted to an effective number of species (i.e., true diversity) by taking the exponential: $\exp(H_{Sh})$; the Gini-Simpson index is converted by subtracting it from unity and inverting: $1/(1 - H_{GS})$. With these conversions, the units then reflect the number of species predicted for that community if all species were equally common (Jost, 2006).

We also report the Hill numbers (i.e., true diversity ${}^qD$) for different orders of the diversity $q$. The Hill numbers measure the sensitivity of diversity indices to species unevenness by modifying how the weighted mean of the species' proportional abundances

TABLE 1—Summary data for reptile and amphibian captures in El Monte Valley, Lakeside, California (June 2015–May 2016). Columns indicate the number of captures based on the different survey methods (FLT = drift fence line traps; CB = coverboard; WT = walking transect; ND = night driving; INC = incidental sighting). "Section" indicates all sampling sections where a particular species was captured, including incidental sightings (INC).

| Common name | Scientific name | FLT | CB | WT | ND | INC | Total | Section |
|---|---|---|---|---|---|---|---|---|
| Snakes | | | | | | | | |
| Southern Pacific rattlesnake | *Crotalus oreganus helleri* | 12 | 1 | 27 | 1 | 12 | 53 | 1–5 |
| California glossy snake[a] | *Arizona elegans occidentalis* | 3 | 9 | 3 | 0 | 8 | 23 | 1, 3–5 |
| San Diego gopher snake | *Pituophis catenifer annectens* | 6 | 0 | 4 | 6 | 6 | 22 | 1–5 |
| California kingsnake | *Lampropeltis californiae* | 9 | 1 | 1 | 2 | 1 | 14 | 1–5 |
| Red racer | *Coluber flagellum piceus* | 5 | 3 | 1 | 0 | 4 | 13 | 1, 2, 4, 5 |
| California striped racer | *Coluber lateralis* | 4 | 4 | 0 | 1 | 1 | 10 | 1–5 |
| Southwestern threadsnake | *Rena humilis humilis* | 0 | 0 | 3 | 0 | 3 | 6 | 1–3 |
| Red diamond rattlesnake[a] | *Crotalus ruber* | 0 | 0 | 0 | 1 | 2 | 3 | 1 |
| Long-nosed snake | *Rhinocheilus lecontei* | 0 | 1 | 0 | 0 | 1 | 2 | 2 |
| San Diego nightsnake | *Hypsiglena ochrorhyncha klauberi* | 0 | 1 | 0 | 0 | 0 | 1 | 4 |
| Western black-headed snake | *Tantilla planiceps* | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| San Diego ringneck snake | *Diadophis punctatus similis* | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| Coast patch-nosed snake[a] | *Salvadora hexalepis virgultea* | 0 | 0 | 0 | 0 | 1 | 1 | 2 |
| Lizards | | | | | | | | |
| Side-blotched lizard | *Uta stansburiana* | 100 | 289 | 2 | 0 | 17 | 408 | 1–5 |
| Orange-throated whiptail[b] | *Aspidoscelis hyperythra* | 116 | 12 | 1 | 0 | 44 | 173 | 1–5 |
| Western fence lizard | *Sceloporus occidentalis* | 94 | 57 | 1 | 0 | 3 | 155 | 1–5 |
| Coronado skink | *Plestiodon skiltonianus interparietalis* | 7 | 58 | 0 | 0 | 3 | 68 | 1–5 |
| Coastal whiptail[a] | *Aspidosceles tigris stejnegeri* | 18 | 5 | 0 | 0 | 6 | 29 | 1–4 |
| Southern California legless lizard[a] | *Anniella stebbinsi* | 1 | 15 | 0 | 0 | 1 | 17 | 1–3, 5 |
| San Diego banded gecko[a] | *Coleonyx variegatus abbotti* | 0 | 0 | 5 | 0 | 6 | 11 | 1 |
| Granite night lizard | *Xantusia henshawi* | 0 | 8 | 0 | 0 | 0 | 8 | 5 |
| Blainville's horned lizard[a,b] | *Phrynosoma blainvillii* | 1 | 0 | 0 | 0 | 4 | 5 | 1, 4 |
| Gilbert's skink | *Plestiodon gilberti* | 1 | 3 | 0 | 0 | 0 | 4 | 1, 2 |
| Southern alligator lizard | *Elgaria multicarinata* | 2 | 1 | 0 | 0 | 1 | 4 | 2, 3 |
| Amphibians | | | | | | | | |
| Western toad | *Anaxyrus boreas* | 4 | 0 | 21 | 6 | 37 | 68 | 1–5 |
| Western spadefoot[a] | *Spea hammondii* | 2 | 1 | 31 | 2 | 12 | 48 | 1, 3–5 |
| Baja California treefrog | *Pseudacris hypochondriaca* | 0 | 0 | 10 | 0 | 1 | 11 | 2–5 |
| Total | | 385 | 469 | 111 | 20 | 174 | 1,159 | |

[a] Listed species of special concern by the California Department of Fish and Wildlife.
[b] Species covered in the San Diego Multiple Species Conservation Program.

is calculated (Hill, 1973; Jost, 2006). The general equation for diversity is written as follows:

$$qD \equiv (\sum_{i=1}^{S} p_i^q)^{1/(1-q)} \tag{4}$$

At $q = 1$, the weighted geometric mean of the $p_i$ values is used, where each species is weighted by its proportional abundance. When $q > 1$, greater weight is given to abundant species, whereas at $q < 1$ greater weight is given to rare species. At $q = 0$, the species weights cancel out their proportional abundances, such that ${}^0D$ equals the actual number of species (i.e., species richness). In sum, increasing $q$ increases the effective weight of the most abundant species, leading to a smaller true diversity (${}^qD$) value at higher $q$ if the frequencies are uneven.

RESULTS—Over the 12-month sampling period, we conducted 48 days of fence line trapping, 24 nighttime walking surveys totaling 120 km, inspected 125 coverboards on 24 separate occasions, and drove approximately 746 km searching for reptiles and amphibians on roads in the El Monte Valley. These techniques revealed high species richness for herpetofauna within the survey area ($n_{total}$ = 27; Table 1). This high richness included two species that are covered in the San Diego Multiple Species Conservation Program, the orange-throated whiptail (*Aspidoscelis hyperythra*) and *P. blainvillii*. We detected 7 species that are listed as species of special concern by the California Department of Fish and Wildlife: *S. hammondii*, *A. stebbinsi*, San Diego banded gecko (*Coleonyx variegatus abbotti*), *P. blainvillii*, red diamond rattlesnake (*Crotalus ruber*), Coastal whiptail (*Aspidosceles tigris stejnegeri*), coast patch-nosed snake (*Salvadora hexalepis virgultea*), and *A. e. occidentalis*. Representatives of some of these species are presented in Fig. 3. Two recently killed animals (*S. hammondii* and *A. stebbinsi*), apparently due to equestrian traffic based on hoof prints on top of the carcasses, were also recovered on hiking trails.

Table 2 summarizes the captures for each trapping technique, partitioned by sampling section. Coverboards generated the highest number of captures, followed by fence line trapping, and then walking transects. We found that gentle raking through the sand underneath the coverboards resulted in captures for *A. stebbinsi*, *P. gilberti*, and *A. e. occidentalis* that would have otherwise gone unnoticed. The highest number of detections occurred in Section 4 toward the east end of the study area ($n = 287$), followed by the adjacent Section 3 ($n = 273$), and then Section 1 ($n = 260$) at the west end closest to Hansen Pond. Section 5, the portion of the valley that had been graded and excavated for the golf course project, had the fewest observations ($n = 150$). Of the 27 native reptile and amphibian species documented, no single sampling technique detected all species. We detected 9 of 11 lizard species using four different survey methods—fence line trapping, coverboards, walking transects, and incidental observation—although the four methods did not detect all of the same nine species. We detected snake species most often by incidental observation ($n = 10$ of 13 total), typically while walking, but not specifically on a transect survey. Incidental observations also accounted for the highest number of total species reported ($n = 22$ of 28, or 79%), although most of these 22 were also detected by other methods (one invasive turtle species is included here for 28 species total; see last paragraph, this section). These results indicate that all survey techniques were necessary to appropriately characterize the species richness and diversity within the study area.

The most species-rich taxonomic group was snakes, with 13 species representing 11 genera. We detected more than half of all snake species in four or more sampling sections (~54%). The most common snake was the southern Pacific rattlesnake (*Crotalus oreganus helleri*) ($n = 53$ independent observations), whereas the least common were the San Diego nightsnake (*Hypsiglena ochrorhyncha klauberi*), *D. p. similis*, the western black-headed snake (*Tantilla planiceps*), and *S. h. virgultea* ($n = 1$ each; Table 1). Based on the total number of observations, fence line trapping and walking transects were the most effective survey techniques for snakes. *Arizona elegans occidentalis* was the second most common snake species after *C. o. helleri*. We captured 23 *A. e. occidentalis* in four of the five sections of the valley, including neonate and adult individuals. Because we marked all *A. e. occidentalis* individuals by excising a small tissue sample from the tail (leaving a permanent marking), we were able to determine that 20 were unique individuals. One snake was a highly unusual "red" color morph (Fig. 3F) that, to our knowledge, has never been documented for this species (although the phenotype seemed to be an anomaly in this particular individual given that no others were found to have it).

For lizards, we detected 11 species belonging to nine genera, seven of which occurred in four or more sampling sections (~63%). The most common by far was the side-blotched lizard (*Uta stansburiana*; $n = 408$ captures), followed by *A. hyperythra* ($n = 173$), and then the western fence lizard (*Sceloporus occidentalis*; $n = 155$). The least common lizard was the Granite night lizard (*Xantusia henshawi*); we observed a single juvenile of this species underneath the same coverboard in Section 5 for five consecutive sample periods (almost certainly the same individual). Drift fence trapping and coverboards were the most effective sampling techniques for lizards (Table 1).

Amphibian species richness was low, with only three species in three genera observed on night walks or during night drives (Table 1). We did not detect any salamanders. The most common amphibian was the western toad (*Anaxyrus boreas*; $n = 68$), followed by the western spadefoot ($n = 48$). We detected the third species, the Baja California treefrog (*Pseudacris hypochondriaca*), only by call because the frogs seemed to be restricted to one or more artificial water bodies on the north side of the valley on private property. We detected all three species in four or more sampling sections.

We also recovered the mummified remains of a nonnative aquatic turtle in Section 4, the red-eared slider (*Trachemys scripta elegans*). This species is popular in the pet trade, and individuals are often released in to local lakes and ponds where they compete with native species.

*Species Diversity*—The number of detections did not always predict species richness, and species richness was not always a good predictor of species diversity. For example, despite the high number of detections in Section 4, this section was the least diverse among all in terms of effective numbers of species (based on the Shannon entropy and Gini-Simpson indices; Table 3). The Gini-Simpson index also indicated that the probability that two randomly captured individuals represent unique species was only 0.64 for Section 4, the lowest of all sections. In contrast, Section 5 had the fewest detections and the lowest species richness, yet species diversity was highest overall, and the probability that two randomly captured individuals represented different species was considerably higher at 0.87 (Table 3).

For lizards and snakes, species richness was highest in the westernmost sampling sections near Hansen Pond (Sections 1 and 2), and it was lower, but roughly equivalent, across the three remaining sections to the east (Table 3). There were too few amphibian captures to determine whether any spatial trends in species richness might exist for frogs or toads. When considering all taxa, we found a nearly 25% reduction in species richness when comparing the west end of the study area to the east end (Section 1 vs. 5; Table 3; Fig. 4). In contrast, the opposite was true for species diversity; the effective number of species based on the Shannon entropy indicated a nearly


FIG. 3—Representatives of the different reptile and amphibian species in the El Monte Valley, California. All photographs are of actual animals captured during the course of this study. A) *Coluber flagellum piceus*; B) *Coluber lateralis*; C) *Crotalus ruber*; D) *Crotalus oreganus helleri*; E) *Arizona elegans occidentalis*, standard morph (with food bolus at midbody); F) *A. e. occidentalis*, red morph; G) *Lampropeltis californiae*; H) *Rhinocheilus leconti*; I) *Pituophis catenifer annectens*; J) *Rena humilis humilis*; K) *Coleonyx variegatus abbotti*; L) *Phrynosoma blainvillii*; M) *Plestiodon skiltonianus interparietalis*; N) *Aspidosceles tigris stejnegeri*; O) *Anniella stebbinsi*; and P) *Spea hammondii*. Photo credits: Jeff Nordland (B, C, O); Jonathan Richmond (D, E, G, H, I–K, M, P); Jeremy Sebes (A); Nathan Smith (F, L, N).


Fig. 3—Continued.

4% increase in species diversity at the east end of the valley versus the west (the Gini-Simpson index suggests that the increase was as high as 20%). This incongruence between richness and diversity confirms a degree of dominance in this community.

For true diversities, the most pronounced shift in $^{q}D$ for all sections is between the diversity order of 0 and 1 (Fig. 4), so even the initial weighting of species by their exact frequencies had a pronounced effect on diversity estimates. The degree of unevenness is displayed by the

TABLE 2—Number of detections of reptiles and amphibians in the El Monte Valley, California, for each sampling technique by section from June 2015 to May 2016; AB = assorted boards that were not part of the official USGS study design; Inc. = incidental observations not within one of the five sampling sections, and/or when moving between walking transects. A value of 0 indicates that the area was surveyed but that no observation was made; dash (—) indicates that observations were not possible for that technique. Totals include some incidental observations with unknown species identities.

| Method | Inc. | AB | Road | Section 1 | Section 2 | Section 3 | Section. 4 | Section 5 | Total |
|---|---|---|---|---|---|---|---|---|---|
| Coverboard | — | 24 | — | 107 | 68 | 92 | 160 | 48 | 499 |
| Fence line | — | — | — | 85 | 101 | 90 | 73 | 36 | 385 |
| Incidental | 5 | — | 0 | 48 | 20 | 58 | 39 | 17 | 187 |
| Transect | 0 | — | — | 19 | 9 | 33 | 13 | 42 | 116 |
| Road driving | — | — | 9 | 1 | 2 | 0 | 2 | 7 | 21 |
| Total | 5 | 24 | 9 | 260 | 200 | 273 | 287 | 150 | 1,208 |

magnitude of the difference in ${}^qD$ between $q$ =0 vs. infinity. For example, this difference in Section 5 is substantially less than in Section 4, indicating more unevenness in Section 4. Equivalency in species' abundances in Section 5 exceeded that in any of the other sampling sections, whereas Section 4 showed the greatest dominance. This explains why diversity was high in Section 5, even though species richness was low.

DISCUSSION—Since 1995, the USGS has conducted reptile and amphibian surveys at 320 unique sampling locations within 23 different study sites in San Diego County (Fisher and Case, 2000; Case and Fisher, 2001; Rochester et al., 2010). These sites extend from the USA-Mexico international border north to the border with Orange County, and from the coastline east to Santa Ysabel in the Peninsular Range. Nearly 52,000 species observations have been documented during this effort, with approximately 3,700 representing snakes of various species. Of the ~3,700 snake records, only one record has been of *A. e. occidentalis* (from Camp Pendleton) until this study in El Monte Valley.

TABLE 3—Numbers of species for each taxon across all five sampling sections in El Monte Valley, California, followed by diversity indices for each section (based on numbers of captures for each species captured): $H_{sr}$ = species richness; $H_{Sh}$ = Shannon entropy; $H_{GS}$ = Gini-Simpson index; effective = effective number of species based on the specified index. A value of 0 indicates that the area was surveyed but that no observation was made.

| Taxa | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 |
|---|---|---|---|---|---|
| Frogs | 0 | 1 | 1 | 1 | 1 |
| Toads | 2 | 1 | 2 | 2 | 2 |
| Lizards | 9 | 8 | 7 | 6 | 6 |
| Snakes | 10 | 9 | 6 | 7 | 7 |
| Turtles | 0 | 0 | 0 | 1 | 0 |
| $H_{sr}$ | 21 | 19 | 16 | 17 | 16 |
| $H_{Sh}$ | 2.22 | 1.86 | 2.03 | 1.64 | 2.26 |
| $H_{GS}$ | 0.84 | 0.77 | 0.81 | 0.64 | 0.87 |
| $H_{Sh}$ (effective) | 9.19 | 6.45 | 7.58 | 5.15 | 9.54 |
| $H_{GS}$ (effective) | 6.29 | 4.27 | 5.13 | 2.76 | 7.75 |

The 12-month survey effort at El Monte Valley documented 27 native reptile and amphibian species, compared to the 44 native species documented across coastal San Diego County over the past 20 years at the 23 USGS study sites. El Monte Valley ranks ninth in species richness compared to these other study sites; however, all eight sites with higher species richness have been sampled for five or more years, and only one site was shown to have *A. e. occidentalis*. Yet in only 12 months of sampling, El Monte Valley has a species count that ranks it well ahead of many of the conserved lands within the San Diego County preserve system. This is in spite of the fact that this survey was conducted during the fifth year of an exceptional drought (USGS, California Water Science Center, http://ca.water.usgs.gov/data/drought/drought-resources.html), and despite the severe habitat disturbance on large portions of the El Monte Valley floor.

Of further significance is that more than half of the species in each taxonomic group were detected in four or more sampling sections, suggesting that these animals use most of the available space within the valley (Table 1). However, there were substantially fewer species detections in Sections 2 and 5 compared to the other sampling areas (Table 2), possibly because they contained some of the most severely and recently disturbed habitat. In particular, reptiles and amphibians wholly avoided the basements of several large, excavated pits in Section 5 (approximately 8–12 m in depth); these pits have extremely steep margins and little vegetation within them, and what little there is consists almost exclusively of nonnative weeds (Fig. 1).

Although Section 2 had the second lowest detection rate, the westernmost parts of the valley (Sections 1 and 2) did have slightly higher species richness for lizards and snakes compared to the east (Table 3). This is likely because the western portion of the valley contacts a much larger, contiguous piece of undisturbed land that extends to the northeast toward El Cajon Mountain, providing

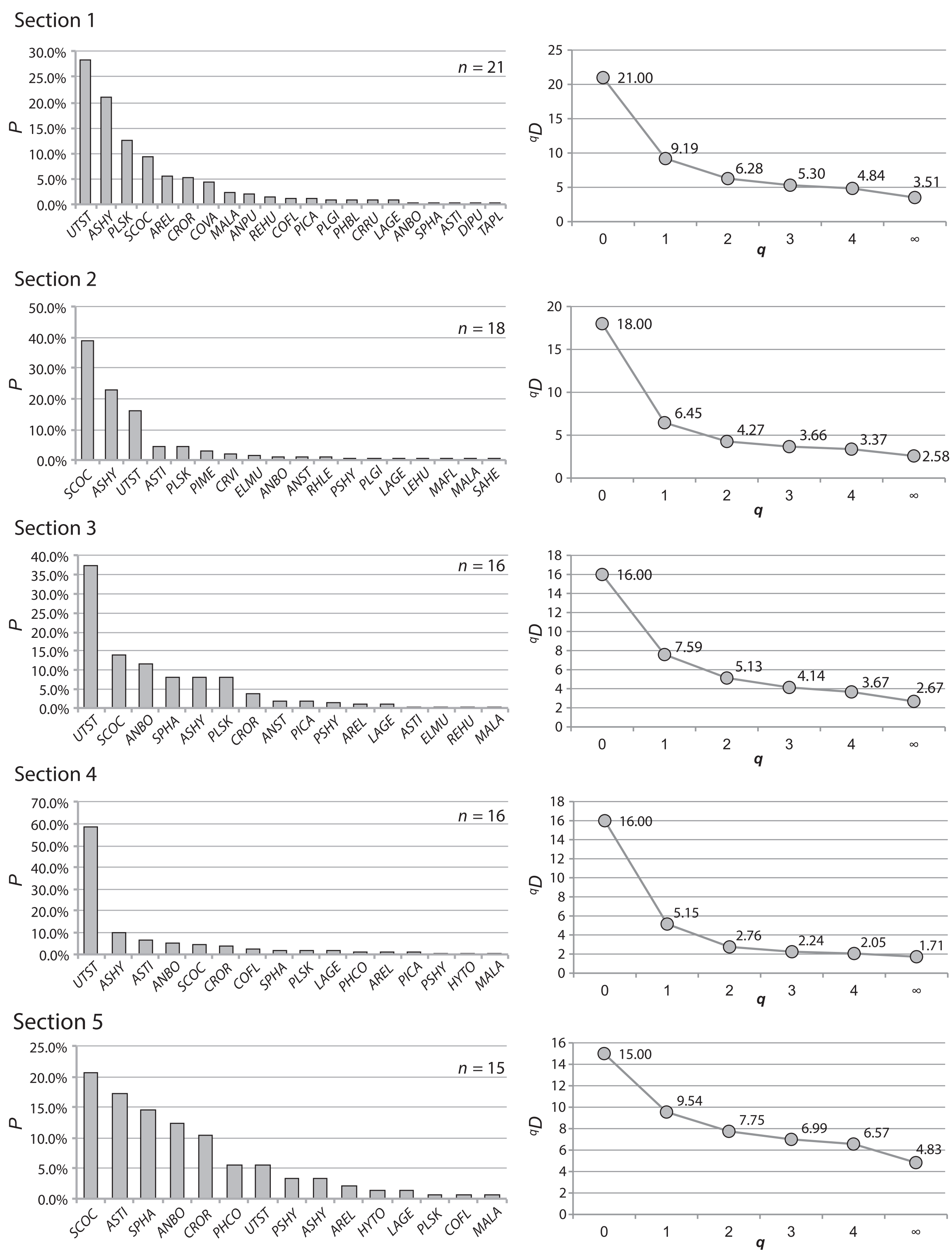


Fig. 4—Proportional distribution of species (left) and true diversities $^qD$ for different orders of diversity $q$ (right) for each sampling section in El Monte Valley, California (arranged from west [top] to east [bottom]). In the left panel, the *y*-axis denotes the proportional abundances; the *x*-axis denotes four-letter species identifiers, where the first pair of letters is the first two letters of the genus and the second pair is the first two letters of the species listed in Table 1 (i.e., PHBL = *Phrynosoma blainvillii*).

greater opportunity and fewer obstacles for animals to disperse into and out of the valley in this general area.

*Incongruence between Richness and Diversity Measures*—A main goal of the study was to document the presence-absence of reptiles and amphibians within the study area, especially *A. e. occidentalis*. As such, we consider the rarest elements of this fauna to be equally important as the most common; thus, species richness is an important measure to take into account. We also were able to evaluate species diversity, a measure that incorporates not only presence-absence information but also abundance. The question then becomes, which diversity index is most useful? When there is a degree of dominance in the community, the Shannon effective number of species will be less than the species richness, and the Gini-Simpson effective number of species will be less than the Shannon effective number of species. This is because species richness ignores dominance, the Shannon entropy weighs dominance exactly by the frequency of each species, and the Gini-Simpson index disproportionately weighs the dominant species more heavily than rare species. Thus, the greater the dominance in the community, the greater the differences between these three numbers (the exact pattern displayed for El Monte Valley).

Because we measured the diversity of different portions of a single community, the trio of indices we examined provides much more information about each sampling section than any single measure, supporting the use of all three (Jost, 2006; Jost et al., 2010). With this information, we were then able to quantify the degree of unevenness within and among the different sampling sections by looking at the drops in the true diversity $^{q}D$ among the different orders $q$ (Fig. 4). This explains why, for example, Section 5 had the lowest species richness, but the highest species diversity. An important finding of these analyses is that although there is high species richness in El Monte Valley, the herptile community is dominated by a relatively small number of common species that, in turn, influences the estimates of diversity. We note that even the common lizard species are of conservation significance given that they are a main prey resource for *A. e. elegans* (see "*Notes on A. e. occidentalis*"), and that one of these species (*A. hyperythra*) is covered under the San Diego Multiple Species Conservation Program because of its restricted distribution in southern California.

These analyses can further be used as a conservation tool should monitoring studies continue to take place in El Monte Valley, a practice we recommend given the sensitivity of the fauna, the current level of habitat disturbance, and the potential for large-scale sand mining followed by habitat restoration. Not only can the different indices be compared for each section over time, but also the trends in diversity across the valley floor and possible changes within the herptile community itself. This information would be especially useful for monitoring the effects of disturbance due to the proposed sand extraction or other forms of habitat loss, and for measuring the effectiveness of restoration projects. Direct mortality impacts from ongoing recreation in the valley are currently unmeasured/unmitigated (e.g., equestrian traffic and off-highway vehicle use) and could also be integrated into future monitoring. The sampling techniques and study design used for this survey easily could be reimplemented to pursue such efforts.

*Notes on* A. e. occidentalis—We observed *A. e. occidentalis* in four of the five sampling sections, including some of the most disturbed parts of the valley. Many of the 23 observations were in old agricultural plots that have been plowed or graded within the two past decades, and two were in otherwise "disturbed" or "developed" habitat. This is consistent with the observations of Klauber (1946) on *A. e. occidentalis* more than 70 years ago, where individuals were often found in association with uncultivated grasslands or cultivated fields. This suggests that as long as there is a suitable matrix of sandy habitat and appropriate prey resources, *A. e. occidentalis* will occupy intervening or surrounding areas of lower habitat quality.

The sample of *A. e. occidentalis* in El Monte Valley seems to be a self-sustaining, long-term population rather than a chance observation of a few anomalous individuals, given the large number of captures and the presence of both neonate and adult individuals. This work also provides evidence that the *A. e. occidentalis* population in El Monte Valley represents the largest concentration of the species in coastal San Diego County. Given that county-wide surveys conducted by the USGS have recorded only a single individual of this species over a 20-year period, it is remarkable that this study resulted in 23 *A. e. occidentalis* captures in only 12 months, nearly all of which were unique individuals. Although the historical presence of *A. e. occidentalis* in this part of the county is well documented (Klauber, 1946), its contemporary status was unknown at the outset of this study. The first USGS records for *A. e. occidentalis* in El Monte Valley were in 2001 during opportunistic road surveys ($n = 3$). We were also provided with georeferenced location data on six additional *A. e. occidentalis* road mortalities in El Monte Valley between July 2009 and June 2013, all confirmed with date-stamped photos (T. Henry, pers. observ.); however, the 2-year time gap between this last sighting and the current study, combined with the drought and general habitat degradation within El Monte Valley, left some question as to whether *A. e. occidentalis* still persisted in the area.

In addition to the alluvial sands and gravel, part of the snake's success in El Monte Valley is likely due to the lack of artificial night lighting associated with more urban areas and the abundant prey resources available to it. The overwhelming majority of the diet for *A. elegans* is composed of lizards and small mammals (Rodríguez-Robles et al., 1999). Klauber (1946) cites two of the most common lizard species in El Monte Valley (*U. stansburiana* and *S. occidentalis*) as preferred prey items for *A. e.*

*occidentalis*, and we observed numerous small rodent species in our snake traps and during nighttime walking surveys (deer mice [*Peromyscus sp.*]; shrews [*Sorex sp.*]; kangaroo rats [*Dipodomys sp.*]; pocket gophers [*Thomomys bottae*]). The abundance of lizards also serves as the main prey resource for *R. lecontei*, a species that commonly co-occurs with *A. elegans* throughout its range (Klauber, 1946; Rodríguez-Robles et al., 1999). Thus, we recommend that the conservation of even common lizard species be carefully considered in the long-term land and wildlife management planning for El Monte Valley.

*Caveats on Survey Techniques*—Given that the main emphasis of this work was to document species presence-absence, several limitations of the data should be noted. First, with the exception of *A. e. occidentalis*, two species of racer in the genus *Coluber*, and *R. lecontei*, recaptures could not be identified because we did not permanently mark all of the animals. Recapture proportions likely differ depending on the species because some have higher site fidelity and smaller home ranges than others. Regardless, the most abundant species in El Monte Valley were consistent with expectations based on previous county-wide survey data collected by the USGS and with general knowledge about the herpetofauna of the area (Fisher and Case, 2000; Case and Fisher, 2001; Lemm, 2006; Rochester et al., 2010). Recaptures would have the greatest effect on diversity measurements, whereas species richness would be unaffected. This would be a concern if we were comparing diversity with other studies that accounted for recaptures; however, the units of comparison for this study (i.e., sampling sections) were surveyed using the same techniques, and there is no reason to expect different recapture rates for any species across the study area.

A second limitation of the data involves the relatively short, 12-month duration of the study, and the fact that southwestern North America was in its fifth year of an exceptional drought. The combination of these factors probably led to an underestimation of species richness, and perhaps more so on species diversity. The 20 years' worth of USGS survey data from 23 county-wide localities shows that reptile and amphibian species richness continues to increase for several years from the time that a site is first sampled. Therefore, extended multiyear sampling under more normal climate conditions might result in additional species detections and higher capture rates in El Monte Valley, particularly for amphibians. This would have a pronounced effect on species diversity because greater numbers of captures for the rarer taxa would decrease the degree of dominance as measured over the 12-month sampling period.

Although we compared this study to other USGS survey efforts across San Diego County, the sampling techniques have not been consistent across all surveys. Previous USGS efforts have relied heavily on pitfall traps, drift fence, and the same cylindrical funnel traps used in this study to sample reptiles and amphibians; nighttime walking transects and coverboard searches have not been a part of the traditional protocol. For this study, we used these two techniques instead of pitfall trap arrays because of limited preparation time (i.e., the timing of when funds became available and when we could start) and the labor intensity involved with installing the pitfall arrays. At the same time, walking transects and coverboard arrays have proven effective for sampling reptiles and amphibians, and the fence line and funnel trap efforts in El Monte Valley were clearly successful at detecting *A. e. occidentalis*. Had *A. e. occidentalis* been present at any of the other 23 USGS pitfall sites, this same sampling technique should have been sufficient to document the species. We call attention to the variety of survey techniques that were necessary to characterize the species richness and diversity in El Monte Valley, a finding with important implications for monitoring herptile communities in sensitive habitats.

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