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Cover Page Footnote

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Mitigation Ponds Offer Drought Resiliency for Western Spadefoot (*Spea hammondii*) Populations

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Abstract.—Synergistic effects of habitat loss, drought, and climate change exacerbate amphibian declines. In southern California urbanization continues to convert natural habitat, while prolonged drought reduces surface water availability. Protection of biodiversity may be provided through mitigation; however, the long-term effectiveness of different strategies is often unreported. As a mitigation measure for building a new development within occupied *Spea hammondii* (western spadefoot) habitat in Orange County, California, artificial breeding pools were constructed at two off-site locations. *Spea hammondii* tadpoles were translocated from the pools at the development site to two off-site locations in 2005–2006. We conducted surveys a decade later (2016) to determine if *S. hammondii* were persisting and breeding successfully at either the original development site or the human-made pools at the two mitigation sites. We also verified hydroperiods of any existing pools at all three locations to see if any held water long enough for successful *S. hammondii* recruitment through metamorphosis.

During our study, no pooling water was detected at two of three main sites surveyed, and no *S. hammondii* were observed at these locations. Twelve of the 14 pools created at only one of the two mitigation sites held water for over 30 d, and we detected successful breeding at seven of these pools. Recruitment in some mitigation ponds indicated that *S. hammondii* habitat can be created and maintained over 10+ yr, even during the fifth year of a catastrophic drought. Therefore, this may also serve as a conservation strategy to mitigate climate change and habitat loss.

Global amphibian declines have been documented since the 1970s and are attributed to various causal factors (Blaustein and Wake 1990; Wyman 1990; Wake 1991; Drost and Fellers 1996; Fisher and Shaffer 1996; Grant et al. 2016), but habitat loss and degradation are cited as the most significant (Denton and Richter 2013; Thompson et al. 2016). In arid regions such as the US southwest, drought and climate change exacerbate declines, especially in regions with extensive urbanization (Diffenbaugh et al. 2015; Neal et al. 2018). The combination of these conditions can make life cycle completion challenging for pond-dwelling amphibians. Southern California is a region with high levels of urbanization that has experienced prolonged drought and is home to a suite of pond-dependent amphibians that have undergone major declines (Griffin and Anchukaitis 2014; Thomson et al. 2016).

In southern California there are four native species of anurans that use ponds or lentic pools for breeding (Fisher and Shaffer 1996). Of these, *Spea hammondii* is the only species

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that primarily uses non-permanent water sources for egg laying and larval development. Furthermore, ponds and vernal pools in this region are often isolated from one another, which makes amphibian populations less likely to recover if habitat is degraded and fragmentation becomes a problem (Denton and Richter 2013; Thomson et al. 2016). Restoration and mitigation can involve creating artificial ponds in adjacent or nearby similar habitat (Pechmann et al. 2001; Searcy and Shaffer 2008; Rannap et al. 2009). However, mitigation ponds/pools often do not mimic natural conditions and processes effectively and may not be successful (Lichko and Calhoun 2003; Arendt and Hoang 2005; Denton and Richter 2013). Conditions such as suitable hydroperiod, temperature, pH, and conductivity often cannot be replicated in artificial ponds but are important for breeding and developing amphibians, which frequently have specific thermal and chemical tolerances during their fully-aquatic stage. For instance, *S. hammondii* require a specific hydroperiod among other conditions for larval development, and this hydroperiod is less likely to occur during periods of drought.

A recent study using both mitochondrial and nuclear markers indicates that *S. hammondii* is comprised of two genetically distinct groups separated geographically by the Transverse Ranges of southern California (Neal et al. 2018). Though not designated as distinct species, the two clusters should be treated as separate conservation units as there is no current gene flow between them (Neal et al. 2018). Furthermore, the southern group has lost significantly more native habitat than its northern counterpart.[1] This study focuses on artificial habitats within the southern part of the range.

Spea hammondii has conservation status at several levels. The species is listed as Near Threatened by the International Union for Conservation of Nature,[2] under review for federal listing by US Fish and Wildlife Service (ECOS January 2020), a California Department of Fish and Wildlife (CDFW) Species of Special Concern, Bureau of Land Management (BLM) Sensitive Species (California Department of Fish and Wildlife 2019), and Natural Community Conservation Plan County of Orange Covered Species (Orange County NCCP/HCP 1995).[3] *Spea hammondii* are small, nocturnal, burrowing anurans. The adults emerge from their burrows to breed during and immediately after rain events. Breeding typically occurs during a short window of time (2–3 wk) but has also been documented multiple times in one season, and time within-season might vary depending on weather patterns (Morey 2005; Morey and Reznick 2004; Ervin et al. 2005; Ervin and Cass 2007; Thompson et al. 2016). Historically, these anurans breed in vernal pools but are also known to take advantage of any seasonal water body, such as road ruts, cattle ponds, and artificial pools. Use of these anthropogenic habitats has been attributed to the fact that in southern California, more than 80% of historical *S. hammondii* habitat has been lost to development (Thompson et al. 2016).[1] Though the minimum time period for larval development in the laboratory was 14 d (Morey and Reznick 2004), in the wild pools must persist for a minimum of 30 d for *S. hammondii* larvae to complete development and metamorphose, regardless of habitat type (natural or anthropogenic; Morey and Reznick

[1] Jennings, M.R., and M.P. Hayes. 1994. Amphibian and reptile species of special concern in California. California Department of Fish and Game, Rancho Cordova, California 255pp.

[2] IUCN Red List. 2016. *Spea hammondii*. The IUCN Red List of Threatened Species 2016: http://www.iucnredlist.org/.

[3] Natural Community Conservation Plan and Habitat Conservation Plan. County of Orange Central & Coastal Subregion Parts I & II: NCCP/HCP. 1995. Prepared for County of Orange Environmental Management Agency (December 7, 1995). 418 pp.

2004). Desiccation of larvae due to pools drying is frequent and widely documented for this species (Feaver 1971; Morey and Reznick 2004; Thompson et al. 2016).

Conservation planning for Orange County identified *S. hammondii* as a species requiring protection. Most of the remaining historical breeding pools in Orange County are on reserves or other protected open space. Three sites; (Irvine Mesa, Shoestring Canyon, and East Orange) are within reserves owned by Orange County (OC) Parks. They are located near the eastern side of OC in the foothills of the Santa Ana Mountains (Fig. 1).

Planned development was expected to affect ten *S. hammondii* breeding pools located at a site in East Orange. As mitigation to offset the development impacts, Glenn Lukos Associates, Inc., a private biological and wetland restoration consulting group, created 15 breeding pools at Irvine Mesa and six more pools at Shoestring Canyon, approximately 6.5 km to the northwest of Irvine Mesa (Fig. 1). *Spea hammondii* egg masses and larvae were translocated from the East Orange site to the mitigation pools at Irvine Mesa and Shoestring Canyon by Glenn Lukos in the winters of 2005 and 2006. Glenn Lukos Associates, Inc. monitored the translocation sites for five consecutive years to determine the success of the relocation. Although the development at East Orange never took place, Google Earth's satellite mapping shows that nine of the ten original natural pools were destroyed likely by agricultural disking sometime between September 2010 and March 2011.[4]

To determine if the mitigation ponds were sustaining *S. hammondii* 10 yr post translocation, we revisited the translocation sites in 2016. Sites were surveyed and assessed for the presence of the *S. hammondii* eggs, tadpoles, and adults at the mitigation ponds of Irvine Mesa and Shoestring Canyon. The original source ponds at East Orange were also assessed. The specific objectives of these surveys were to: 1) determine if *S. hammondii* were present at these sites, 2) determine which mitigation pools remained suitable for *S. hammondii* breeding, and 3) determine the hydroperiods of pooling habitat during the extreme drought.

Materials and Methods

The study area for this project included East Orange, Shoestring Canyon, and Irvine Mesa, within Orange County, California (Fig. 1). We determined *S. hammondii* presence and potential recruitment success using three methods: 1) nighttime visual encounter surveys for adults, 2) daytime visual encounter surveys for evidence of breeding (egg masses and larvae), and 3) monitoring of breeding pools until metamorphosis of the larvae. If pools could not be completely surveyed for larvae by visual inspection alone, we used dip nets to complement the survey. Three nighttime surveys were conducted at each site, targeting adult *S. hammondii*. On rainy nights we initiated surveys at the pools. Following an initial pool search, we walked spiraling outward around the pool at least 50 m into the terrestrial habitat, and searching continued between pools and throughout the site. We spent minimum of 4 hr searching each site during each night survey beginning about one half hour after sunset. We recorded all amphibian species encountered. All adult *S. hammondii* were weighed, measured, and their sex recorded. Additionally, versatile fairy shrimp (*Branchinecta lindahli*) were recorded when present. Daytime and nighttime surveys were conducted every 1–2 wk from 29 December 2015 to 28 April 2016, until *S. hammondii*

[4] Google Inc. 2013. Google Earth (Version 7.1.2.20141) [Computer program]. Available at https://www.google.com/earth/. Accessed 18 April 2016.

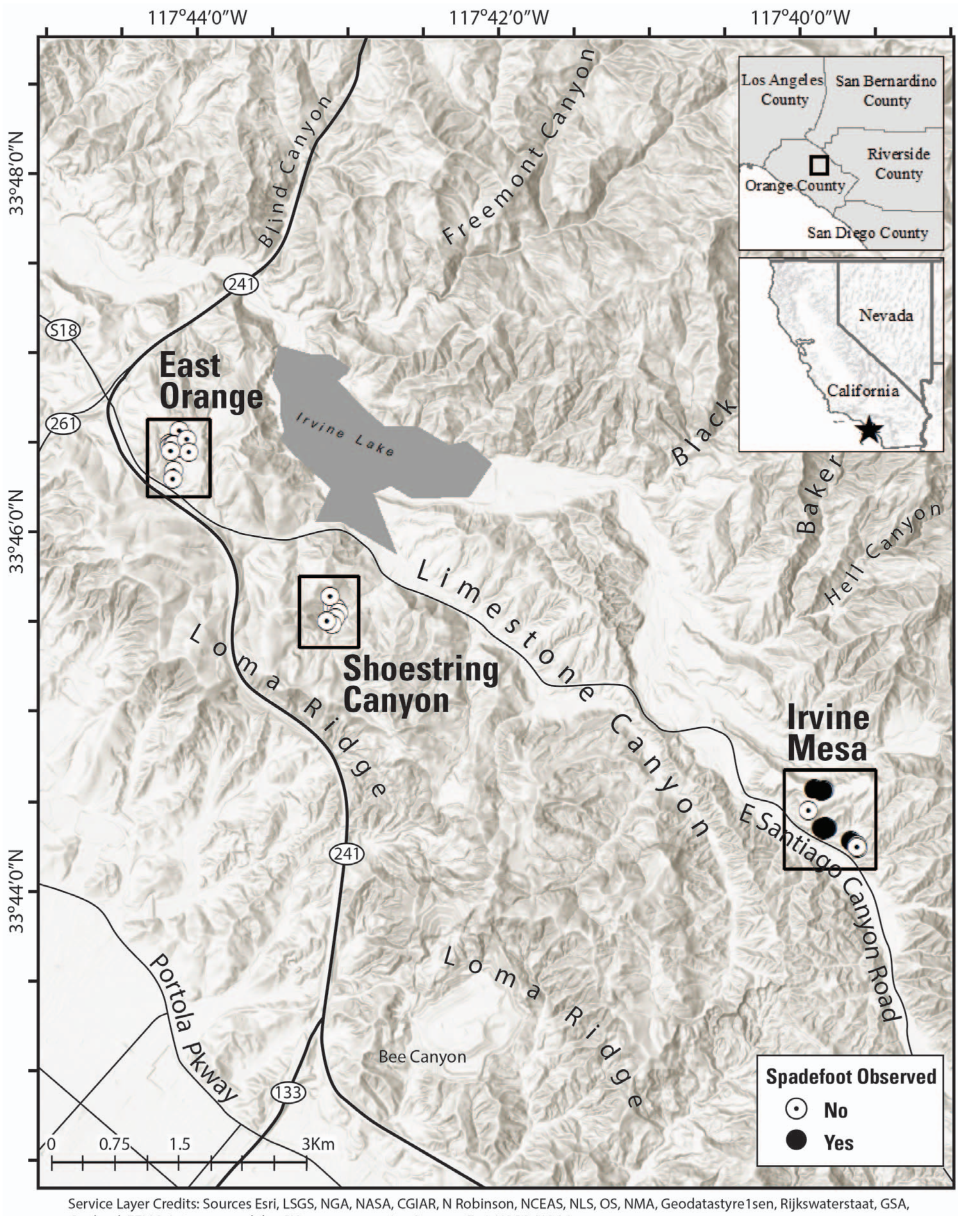

Fig. 1. *Spea hammondii* (western spadefoot) monitoring pools at East Orange donor site, and mitigation sites at Shoestring Canyon, and Irvine Mesa, 2016.

larvae metamorphosed or the pools dried. If the pool dried, monitoring ceased. If there was measurable rainfall afterwards, we resumed monitoring of that pool.

At each pool surveyed, we also recorded pool depth and basic water quality parameters (pH, conductivity, temperature). At pool locations that looked likely to hold water, we installed a water depth gauge and a Stream Temperature, Intermittency and Conductivity

(STIC) logger (Chapin et al. 2014). The water depth gauges we installed were simple 0.5 cm X 6.5 cm X 1.244 m fiberglass stream gauges (Forestry Suppliers Inc, Jackson, MS) fastened vertically to a ~0.6 cm X 61 cm rebar, which was pounded into the lowest point of the pool depression. The PVC had measurement lines at 2 cm intervals that were easy to read at a distance to record depth of water during each site visit. These provided a visual indication of pool depth throughout the breeding and larval development seasons. The STIC loggers are Onset Hobo Pendant temperature and light data loggers (Model UA-002-64) that have been modified to collect relative conductivity when submerged (Chapin et al. 2014). They can also be used to indicate water presence because when STICs are no longer submerged in water the conductivity will be zero (though this must be verified during surveys). Conductance was recorded via modification of the STIC light sensor, which is capable of measuring intensities between 0 and 330,000 lux. The light sensor was removed and two electrodes were attached to the open contacts to record electrical conductivity (EC) corresponding to this same 0–330,000 range, with 0 representing no water (Chaplin et al., 2014). Therefore, STICs have a different electrical conductivity (EC) signal ranging from 0 to 330,000 (formerly lux, but as EC has undefined units), because they record relative conductivity (RC) not specific conductivity (SC). A mathematical conversion provided by Chapin et al. (2014) may be applied post hoc to convert the EC readings to specific conductance (SC) in μS. The STIC measurements were compiled and summarized in Microsoft Excel. We statistically compared pH, conductance, temperature, and hydroperiod between pools with tadpoles and pools without. We used 2-tailed t-tests for each water parameter. Computations were made using Microsoft Excel.

Results

The year 2016 was the fifth year of an extreme drought in southern California and a decade post translocation. In 2016 we surveyed all potential pools that remained from 2006 at the original East Orange location ($n = 10$), plus any newly discovered pools at that site in 2016 ($n = 4$). We also surveyed all pools created in 2006 at the mitigation sites, totaling seven at Shoestring Canyon and 14 at Irvine Mesa. We summarized which pools had *S. hammondii*, which had other anurans and fairy shrimp, what the average water temperatures were, and how long hydroperiods were at each pool (Tables 1–3). Many of the potential pools were simply dry depressions in the landscape that had the structure to hold water after rain events.

We identified five potential *S. hammondii* pools in 2016 at East Orange before the rainy season. One was from the original set of 10 pools surveyed in 2005–2006, and four were newly discovered on the property (Table 1). None held water during the winter of 2016 and no evidence of *S. hammondii* breeding was detected. We did not detect any adult *S. hammondii* during the surveys conducted at the East Orange site (Table 1), although other pond-breeding anuran species were detected.

None of the six mitigation pools at Shoestring Canyon held water during the 2016 rainy season. We found no evidence of *S. hammondii* breeding in any of the pools or in the nearby creek bed. We found no adult *S. hammondii* during the three nighttime surveys conducted at this site. In addition to the six pools built by Glenn Lukos Associates, Inc., we identified another possible pool behind an old berm (Pool 8), however no *S. hammondii* were detected there.

Twelve of the 14 mitigation pools at Irvine Mesa held water for >30 d. During our 2016 surveys, two of the mitigation pools built by Glenn Lukos Associates, Inc. merged

Table 1. Summary of *S. hammondii* (western spadefoot) observed (indicated as "X," not observed indicated as "–") at each monitoring pool in 2016 compared to translocations done in 2006.

Site	Pool	Spadefoot 2006	Spadefoot Egg Masses 2016	Spadefoot Tadpoles 2016	Spadefoot Metamorphs 2016	Spadefoot Adults 2016	Spadefoot Tadpole Desiccation 2016
East Orange	1	–	–	–	–	–	–
(*1-10 were original,*	2	–	–	–	–	–	–
11-14 were newly	3	–	–	–	–	–	–
discovered in 2016)	4	–	–	–	–	–	–
	5	–	–	–	–	–	–
	6	–	–	–	–	–	–
	7	–	–	–	–	–	–
	8	X	–	–	–	–	–
	9	–	–	–	–	–	–
	10*	X	–	–	–	–	–
	11	N/A	–	–	–	–	–
	12	N/A	–	–	–	–	–
	13	N/A	–	–	–	–	–
	14	N/A	–	–	–	–	–
Shoestring Canyon	1	X	–	–	–	–	–
	2	–	–	–	–	–	–
	3	–	–	–	–	–	–
	4	–	–	–	–	–	–
	5	X	–	–	–	–	–
	6	–	–	–	–	–	–
	8**	–	–	–	–	–	–
Irvine Mesa	1	–	X	X	X	–	–
	2	–	–	X	X	–	–
	3	–	X	X	–	–	X
	4	X	–	–	–	–	–
	6	X	X	X	X	–	–
	7	X	X	X	X	X	–
	8	X	–	–	X	–	–
	9***	X	X	X	X	X	X
	10	X	–	–	–	X	–
	12	X	X	X	–	X	–
	13	–	–	–	–	–	–
	14	X	X	X	X	–	X
	15	–	–	–	–	–	–
	16	–	–	–	–	–	–

* Pool 10 at East Orange was the only original pool not disked.

** Pool 8 at Shoestring Canyon was an additional pool. Not one of the mitigation pools built by Glen Lukos.

*** Pool 9 at Irvine Mesa combined with pool 5 and was counted as a single pool during the 2016 rainy season.

(Pools 5 and 9) and we considered them as one pool (Pool 9). We detected *S. hammondii* tadpoles in eight of the Irvine Mesa mitigation pools but documented successful breeding through metamorphosis at only seven of these pools in April 2016 due to desiccation and/or water quality (Table 1). *Spea hammondii* did not breed in all the pools with hydroperiods >30 d (Table 3). Newly metamorphosed frogs documented at Pool 8 may have originated from a nearby pool since we never detected any tadpoles in that pool. Pool 3

Table 2. Summary of other pond-breeding anurans plus fairy shrimp observed during 2016 surveys at each monitoring pool. ("X" indicates observed, "–" not observed).

Site	Pool	*Pseudacris hypochondriaca* (Baja California treefrog)	*Anaxyrus boreas* (western toad)	*Branchinecta lindahli* (versatile fairy shrimp)
East Orange	1	–	–	–
	2	–	–	–
	3	–	–	–
	4	–	–	–
	5	–	–	–
	6	–	–	–
	7	–	–	–
	8	–	–	–
	9	–	–	–
	10	–	–	–
	11	–	–	–
	12	–	–	–
	13	–	–	–
	14	–	–	–
Shoestring Canyon	1	–	–	–
	2	–	X	–
	3	–	–	–
	4	–	–	–
	5	–	–	–
	6	–	X	–
	8	–	–	–
Irvine Mesa	1	X	X	X
	2	X		X
	3	X	X	X
	4	–	–	–
	6	X	–	X
	7	–	–	X
	8	X	–	X
	9	–	X	X
	10	–	–	X
	12	–	–	X
	13	–	–	X
	14	–	–	X
	15	–	X	X
	16	–	–	X

dried before any of the tadpoles completed metamorphosis, and at Pool 12 the high pH and conductance readings we recorded could have contributed to recruitment failure (see below). We documented the presence of desiccated tadpoles at Pools 3, 9, and 14, but some individuals did metamorphose from Pools 9 and 14.

At Pool 12, we recorded a higher average pH (9.29) than at the other pools, and a higher average conductivity (169 µS/cm) than at all pools but one (Pool 16, which had no tadpoles). The tadpoles in Pool 12 appeared smaller than those in other pools, and no metamorphosed *S. hammondii* were documented there. Pool 12 held water for 116 d, therefore hydroperiod was not a limiting factor (Morey and Reznick 2004). The pH at Pool 12 was significantly higher compared to all the other pools (mean $= 8.05 \pm 0.55$ vs. mean $= 9.29 \pm 1.08$; $n = 9$; $t = -3.276$; $p = 0.01$). When Pool 12 was excluded from the analysis,

Table 3. Summary of pool hydroperiods and water temperature for each monitoring pool, 2016.

		Consecutive Days Wet[1]			Water Temperature,°C[1]		
Site	Pool	1st Period[2]	2nd Period	3rd Period	Average	Low	High
East Orange	1	N/A	–	–	–	–	–
	2	N/A	–	–	–	–	–
	3	N/A	–	–	–	–	–
	4	0	–	–	–	–	–
	5	N/A	–	–	–	–	–
	6	N/A	–	–	–	–	–
	7	N/A	–	–	–	–	–
	8	N/A	–	–	–	–	–
	9	0	–	–	–	–	–
	10	N/A	–	–	–	–	–
	11	0	–	–	–	–	–
	12	0	–	–	–	–	–
	13	N/A	–	–	–	–	–
	14	N/A	–	–	–	–	–
Shoestring Canyon	1	0	–	–	–	–	–
	2	0	–	–	–	–	–
	3	1	–	–	–	–	–
	4	0.2	–	–	–	–	–
	5	0	–	–	–	–	–
	6	0	–	–	–	–	–
	8	1	0.33	–	–	–	–
Irvine Mesa	1	132	10+	–	14.21	3.79	33.63
	2	113	–	–	13.75	4.41	33.95
	3	9	40	18	13.26	3.47	30.15
	4	2	11	3	11.9	1.76	27.96
	6	120	–	–	13.3	4.73	32.7
	7	118	–	–	14.08	4.21	32.39
	8[3]	120	–	–	N/A	N/A	N/A
	9	69	34	–	13.78	4.1	33.12
	10	51	20	5	12.57	2.41	28.36
	12	116	–	–	13.5	3.68	32.91
	13	19	3	–	10.87	4.52	21.57
	14	113	–	–	12.69	2.94	31.06
	15	3	48	17	13.59	6.27	29.95
	16	4	52	14	12.41	– 2.26*	31.27

[1] Data from STIC loggers installed in pools.
[2] Periods delineate the number of consecutive days a pool was wet.
[3] STIC battery failed. Wet period is an estimate based on monitoring surveys.
* Pool was dry during this time. Temperature of the ground was below freezing.
N/A designates a pool where no STIC was installed. Pools that did not hold water have 0 consecutive days wet.

pH did not differ significantly between pools with tadpoles and pools without (mean = 8.10 ± 0.61 vs. mean = 7.85 ± 0.30; $n = 26$; $t = 1.32$; $p = 0.20$). Likewise, conductivity did not differ significantly for pools with tadpoles compared to pools without (mean = 113.49 ± 3896.18 vs. mean = 162.22 ± 13430.07; $n = 20$; $t = -1.73$; $p = 0.10$). Pool 16 had the highest average conductivity (293.33 μS/cm), and despite having a hydroperiod of 52 d, *S. hammondii* did not breed in the pool. Temperature was significantly warmer for pools with tadpoles compared to pools without (mean $= 13.57 \pm 0.24$ vs. mean $= 12.27 \pm 0.10$; $n = 6$; $t = 2.73$; $p = 0.04$). Finally, hydroperiod was significantly longer for pools with tadpoles compared to pools without (mean $= 104.56 \pm 889.53$ vs. mean $= 36.20 \pm 384.70$; $n = 12$; $t = 5.16$; $p = 0.0003$).

Discussion and Conclusions

Many factors affect the availability of water for pond-breeding amphibians in southern California. The multi-year drought peaking between 2012 and 2015 affected the availability of vernal pool habitat for *S. hammondii* regionally, and climate change suggests unpredictable availability of surface water for the long term with the potential for more drought and anomalous weather patterns (Duellman 1999; Carey and Alexander 2003; Green 2016). Drought affects amphibian breeding in ephemeral systems more directly than in perennial ones since there are no alternative breeding locations within these systems (Miller et al. 2012). Though the planned development at East Orange did not occur, subsequent agricultural disking likely destroyed the vernal pool habitat there. Mitigation measures had already been put in place, and although many of the mitigation pools were unsuccessful in hosting *S. hammondii* breeding and larval development, seven of the pools held water long enough, with satisfactory thermal and chemical conditions, to allow breeding and recruitment for this species in 2016, 10 yr after mitigation. This result is promising not only for the populations that were translocated, but it has implications for pond-breeding species that are affected by climate change since we detected successful recruitment five years into a drought.

Even though we did not detect *S. hammondii* at the East Orange site during the winter of 2016, we cannot be certain this species has been eliminated. The 2015–2016 rainy season provided slightly more rain (24.82 cm) than the 16-yr average of 24.51 cm, but it may have been inadequate to fill the natural pools at East Orange. Online data show these rain events occurred during the appropriate time of year (December–May) to trigger breeding, however a recent study shows that late abundant rains may not be enough to trigger breeding if pools have not filled prior to these events (Shedd and Hansen unpub. data)[5]. For comparison, in the first year of Glenn Lukos Associates, Inc. translocation efforts (2005) the site received 46.61 cm of rain.[5] Despite the destruction of the original pools, the East Orange site could still provide suitable breeding habitat for *S. hammondii* if there was enough rain to sufficiently saturate the soil and several restoration efforts were implemented. At East Orange, removing the drain at Pool 4 could facilitate water retention, and removing vegetation at Pools 12–14 could transform these depressions into functional *S. hammondii* breeding habitat. If subsequent surveys indicate that no *S. hammondii* persist at East Orange, repatriation of this species from the mitigation site at Irvine Mesa back to East Orange could be considered.

Though no water was present at Shoestring Canyon during our surveys, a small population of *S. hammondii* may persist there as well. *Spea hammondii* breeding was reported by consultants visiting the site at two pools in Shoestring Canyon during the 2009–2010 rainy season; however, biologists also reported that pools did not last long enough for the tadpoles to reach metamorphosis (T. Bomkamp and J. Meyer pers. comm). The longevity

[5] California Department of Water Resources. 2016. California Data Exchange Center, Fremont Canyon weather station, Lat. 33.81110, Long. -117.70800. Available at http://cdec.water.ca.gov/cgi-progs/stationInfo?station_id=FMC. Accessed 11 April 2016.

of *S. hammondii* is not known though accounts of other spadefoot species estimate lifespans of up to 13 yr (Lannoo 2005). If adults are still present at Shoestring Canyon they could have bred in years when precipitation was timely and sufficient (Fisher et al. 2018). In winter of 2016 the pools at Shoestring Canyon were overgrown with vegetation, which may have contributed to their failure to hold water. To provide viable breeding habitat at this site, pools would likely have to be restored, including control of the invasive grasses around pools and in the surrounding upland habitat. Furthermore, the soil at the bottom of the pools may be too porous to hold water. Soil compaction and/or the installation of an artificial liner could facilitate water retention to provide adequate hydroperiod for *S. hammondii* to reach metamorphosis (T. Touré and T. Bomkamp pers. comm).

Although only four adult male *S. hammondii* were observed during surveys at Irvine Mesa, the many eggs and larvae at this site suggest that there is a persistent population here. Female anurans are generally less conspicuous than males, especially during the breeding season when males are calling (Thompson 2016), which is likely the reason we found eggs, larvae and metamorphs but only male adults. Additional surveys could provide an estimate of the population size and recruitment success. Data collected on pH, conductivity, temperature and hydroperiod at the pools having water show that only hydroperiod and temperature were significant predictors of spadefoot breeding. However, we had few pools with water, so a larger sample size would be desirable to help to reinforce or refute these data.

While most pools at the East Orange site were destroyed, and the region was experiencing unprecedented drought, the mitigation measures undertaken by Glenn Lukos Associates, Inc. in 2005–2006 established a population of *S. hammondii* at one of two mitigation sites. More remarkably, the population has persisted >10 yr post-translocation despite continued drought. With sufficient rain and continued protection of this habitat, the population at Irvine Mesa has the potential for recruitment adequate to provide individuals for re-patriation of the original East Orange site and possibly additional areas within the region. The long-term success of this translocation shows that mitigation pools can provide alternative breeding habitat for *S. hammondii* despite severe drought. Mitigation ponds may offer drought resiliency for unpredictable fluctuations caused by climate change.

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