Pre-adult Ecology and Conservation Assessment of the Western Spadefoot Toad (*Spea hammondii*)in Orange County, California
Project Proposal

Photo Credit: Joanna Gilkeson, USFWS

Jen Mendez
Michelle dela Cruz
Jessica Rath
Phillip Samples

Masters of Conservation and Restoration Science
University of California, Irvine
3108 Biological Sciences III, Irvine, CA 92697

TABLE OF CONTENTS

ABSTRACT

The southern California population of native western spadefoot toads (*Spea hammondii*) have steadily declined over the last few decades while effective management plans have remained largely undeveloped. Although listed as a federal and state species of concern and a target species in the Orange County Natural Community Conservation Plan, persisting gaps in knowledge about its life cycle and habitat interactions has limited its conservation and recovery efforts. We propose a research study at Crystal Cove State Park and Laguna Coast Wilderness Park to examine the larval and juvenile ecology of this species and how knowledge of these vulnerable life stages can inform future recovery plans. We will conduct surveys based on current best practices for amphibian research and develop a larval and juvenile assessment protocol specific to the Crystal Cove and Laguna Coast Wilderness areas. Results from this project will help us better understand the western spadefoot toad and provide a framework for future research and monitoring that will sustain and increase local populations of this enigmatic toad.

We acknowledge that we are proposing to conduct research on the ancestral homelands of the Kizh, Tongva, and Acjachemen people.

EXECUTIVE SUMMARY

Nearly endemic to California, the western spadefoot toad (WST) historically ranged from the vicinity of Redding in Shasta County, southward, to Mesa de San Carlos in northwestern Baja California, Mexico. Extensive habitat alteration has resulted in the WST becoming extirpated from most of its historical range, resulting in this species being listed as a Species of Special Concern under the California Department of Fish and Wildlife (CDFW). WSTs are highly dependent on two types of habitats: terrestrial habitats for burrowing and vernal pools for breeding. With continued habitat alteration and the loss of these two vital habitats, spadefoot toad populations are reduced, as individuals no longer have the resources available to survive and reproduce.

Currently, studies are being conducted in Orange County (OC), California, at two sites with the largest known remaining vernal pools within the OC area; Crystal Cove State Park (CCSP) and Laguna Coast Wilderness Park (LCW). California State Parks and Natural Communities Coalition (NCC) began a restoration project to specifically boost the WST's existing population by providing additional habitats and terrestrial buffers in CCSP and LCW. However, little is known about the Spadefoot's life cycle and history, specifically in their early life stages. Spadefoot toads have the highest mortality rate in their early larval state, but the answer as to why remains unknown.

In collaboration with CCSP and LCW, we propose a research project on the ecology and behavior of pre-adult WSTs at CCSP and LCW to address Goal 2 of the RFP. Our goal is to help sustain and increase local WST populations by advancing our understanding of this species for management plans that improve early-stage survivorship. Our project consists of two studies at CCSP and LCW to meet the following objectives:

1) Assess current populations in existing vernal pools and newly constructed pools
2) Identify key factors and vulnerabilities of WST larval ecology
3) Identify key factors and vulnerabilities of juvenile dispersal to upland habitats

To assess current WST populations, and to better understand their larval ecology, we will utilize a visual encounter survey protocol specific to amphibians' larval state to accomplish biological monitoring. This survey protocol involves visual encounter surveys and the use of dip nets to gather data. Additionally, vernal pools will be quantitatively measured for the following: water depth, pool circumference, temperature, dissolved oxygen, conductivity, pH, and turbidity. Once larvae have been detected, we will observe their foraging behavior and morphological development.

For juvenile dispersal, mark-recapture surveys, and dispersal assessments will be conducted for one year. Dispersal assessments will require locating and monitoring routes between breeding sites and upland habitats. Monitoring stations will be established along identified routes and systematically selected based on toadlet sightings, ground moisture, low vegetation, and accessibility.

With this new proposed project, we expect to provide new ecological and behavioral data based on the WST's early life stages. Filling in the gaps of knowledge in the WST's most vulnerable state will aid in both current and future management decisions pertaining to the conservation of the WST, a Species of Species Concern.

1. INTRODUCTION & BACKGROUND

1.1 Life History of Western Spadefoot Toad

The western spadefoot toad (*Spea hammondii*), a small, nocturnal, burrowing anuran, is a CDFW Species of Special Concern in addition to being a Bureau of Land Management sensitive species, and a species subject of status review for protection under the Endangered Species Act of the U.S Fish and Wildlife Service (USFWS). Historically, the western spadefoot toad (WST) was distributed from south Shasta County in northern California throughout the Great Central Valley, Sierra Nevada foothills, and coastal California extending from southeast to northwestern Baja California, Mexico (Morey, 2005). Currently, WSTs have been extirpated throughout most of the lowlands of southern California (Stebbins, 1984) and from many historical locations within the Central Valley (Jennings & Hayes, 1994)(Fig. 1). Populations of this species have been severely reduced due to extensive habitat loss from agricultural practices and urban development, which accounts for 80% loss of this species range in southern California alone (Baumberger et al., 2019). This amount of habitat alteration has led this species to be listed as a California Species of Special Concern.

Endemic to California, the WST is a desert adapted terrestrial amphibian, primarily spending most of its life inhabiting lowlands, river floodplains, washes and vernal pools (Baumberger et al., 2019). However, they also occur in foothills and mountains, preferring areas of open vegetation and short grasses such as foothill grasslands, open chaparral, and pine-oak woodlands (USFWS, 2005). Spadefoot toads require both aquatic and terrestrial habitat components in close proximity within the dispersal distance of the species (Fig. 2). Adult spadefoots spend most of their time underground in burrows and emerge primarily on rainy nights to feed and breed in vernal pools (Baumberger et al., 2019). However, like most amphibians, WSTs require a certain level of moisture retention to avoid desiccation, which is oftentimes challenging in arid environments. The spadefoot is also an opportunistic breeding species that synchronizes its reproduction with infrequent and unpredictable rainfall (Denver, 1998). After a warm rainfall in the winter and spring, this species emerges from their burrows and remains active on the surface from October to November, when enough rain has fallen (Morey & Guinn, 1992).

Apart from the dependency of rainfall, as mentioned above, spadefoot toads need both terrestrial and aquatic habitats in order to complete their life cycle. The amount of land conversion occurring within the WST's range is resulting in habitat that is no longer suitable for successful recruitment and reproduction, thus, leading to population declines.

1.2 Crystal Cove Site and Laguna Coast Wilderness History

Crystal Cove State Park and Orange County's Laguna Coast Wilderness Park form the largest contiguous parcel of California Sage Scrub in Orange County and are home to some of the last remaining vernal pools in the county (Baumberger et al., 2019) (Fig. 3). LCW was formed by the County of Orange in 1993 and is managed by Orange County Parks. The 7,000 acre park lies within a coastal canyon located in the San Joaquin Hills near the city of Laguna Beach. CCSP lies just north of LCW and shares adjacent borders. CCSP was established by the state of California in 1979 and is one of Orange County's largest remaining examples of open space and features a 3.2 mile stretch of beach, 2,400 acres of backcountry wilderness, and an offshore underwater area.

CCSP active adaptive management strategies include collaborating across state, county, and regional agencies for ecological management and monitoring, including working with LCW on shared conservation goals. Although agriculture, grazing, and land development degraded both CCSP and LCW native habitat, multiple long-term restoration projects at CCSP are now reestablishing native California grassland and Coastal Sage Scrub. In 2019-2020, a series of artificial seasonal pools with hydroperiods of 80 days were built at CCSP to supplant the natural pools and road ruts that supply habitat for WST larval development. While CCSP Natural Resource Management monitors the success of the habitat restoration efforts, they do not have enough information on WST larval stages to create a protocol specific to this early life survival (Crystal Cove State Park, 2021).

Based on 2003 surveys of the WST by USGS, recommendations were made to create additional WST breeding habitats in CCSP and LCW areas that had current or historic populations (Fisher et al., 2004). In 2020, the California State Parks, in collaboration with the NCC, began a restoration project to specifically boost the WST population by providing additional habitat to meet the specific needs of this species. The project's three seasonal ponds and the restoration of 10.48 acres of adjacent upland areas of Coastal Sage Scrub plans to provide breeding grounds and adult habitat throughout the park and thus increase the toad's chances for successful breeding and healthy population growth. Expanding artificial habitat throughout Orange County outside of park boundaries is plausible given the success of this project. Therefore, we have also included a habitat suitability assessment at a regional level across Orange County for further establishment of WST habitat (Fig. 4).

1.3 Need for the Project

As stated by the U.S Fish and Wildlife Service (2020), development and land conversion would likely increase given projected human population growth, which would limit availability of aquatic breeding pools and underground burrows for WST individuals. Development can directly destroy aquatic breeding pools and underground burrows, or alter the hydrology such that aquatic breeding pools may not form where a population once existed (USFWS, 2020). With the loss of these two vital habitats, abundance, dispersal, and reproduction within the population are reduced as individuals no longer have the resources available to survive and reproduce. However, studies have shown that vernal pools and other temporary wetlands may be optimal for breeding due to the absence or reduced abundance of both native and nonnative predators that may require permanent ponds (USFWS, 2005). Specifically in CCSP, studies are being conducted to determine the adequate terrestrial buffers for the spadefoot toad's existing population that are key to ensuring the viability of their populations (Baumberger et al., 2019). WSTs need opportunities for dispersal among multiple breeding pools to create metapopulations that allow for gene flow, which is vital to prevent inbreeding.

Although there are ongoing studies determining viable habitat and buffers for the WST, much about the life cycle and history for this species remains unknown. In particular, the spadefoot toad's larval stage ecology is poorly understood. Conservation plans benefit strongly from specific information about particular species of concern (Baumberger et al., 2019), therefore, filling in the gaps of knowledge within the spadefoot toad's early life cycle will aid in current conservation efforts being conducted at CCSP and the adjacent LCW and provide insight into what this species needs in order to survive and grow into maturity. Understanding the vulnerable life stages of the WST will help prioritize conservation of habitat, develop active adaptive management strategies, and assess resources to improve local toad population health in all of its life stages.

1.4 Gaps of Knowledge

While WST life expectancy is ten to twelve years, most will not survive past larval stage or become juveniles and leave the pools to find their first burrows (Stebbins & McGinnis, 2018). Amphibians experience high mortality rates at both these larval and juvenile stages (Feaver, 1971), yet little is known about the WSTs early life. CCSP and LCW Natural Resource Management need to establish routine monitoring methods to be compliant with permit requirements. Understanding both the larval stage ecology and juvenile dispersal will aid the organization in developing these protocols and thus improving recruitment of this sensitive species.

Although adult WSTs are known to forage on a broad variety of small invertebrate prey items, the diet of WST larvae remains unknown (USFWS, 2020). As larvae of both southern spadefoot toads (*Scaphiopus holbrookii*) and plains spadefoot toads (*Spea bombifrons*) consume planktonic organisms, algae, and fairy shrimp, it is widely presumed WST larvae share a similar diet, however this has yet to be definitively proven (USFWS, 2020). Additionally, the dynamics of larval competition, between both conspecifics and other co-occurring amphibian species has yet to be studied. Adult and juvenile WSTs compete with co-occurring amphibian species, like the pacific tree frog (*Pseudacris regilla*), California tiger salamander (*Ambystoma californiense*), and western toad (*Anaxyrus boreas*) for the same food sources (USFWS, 2020). Likewise, larval WST are believed to face the same competition, but this has not been studied.

Finally, both plains spadefoot and New Mexico spadefoot (*Spea multiplicata*) larvae are polyphenic and will differ morphologically depending on specific diet, developing into two behaviorally distinct morphs: carnivores and omnivores (Bazazi et al., 2012). The carnivorous, or cannibalistic, morph will consume their own species, either dead or alive, and the omnivorous morph will consume various plant, animal, and detritus matter (Bazazi et al., 2012). The cannibal morph obtains a thyroid hormone from the consumption of live prey, which thereby induces a carnivorous phenotype (Bazazi et al., 2012). WST larvae share this polyphonic trait (USFWS, 2005), but the prevalence of this behavior has yet to be quantified.

It is imperative we understand how diet induces morphological changes, as this will shed light on how this sensitive life stage is affected by its surroundings and available food sources. This work will also contribute to knowledge of amphibian movement ecology that is essential to understanding distribution of biodiversity in changing environments (Joly, 2019).

2. SCOPE OF WORK

2.1 Goals and Objectives

We propose a research project on the ecology and behavior of pre-adult WSTs at CCSP to address Goal 2 of the RFP. Our goal is to help sustain and increase local WST populations by advancing our understanding of this species for management plans that improve early-stage survivorship. Knowing vulnerable life stages allows conservation managers to prioritize habitats for protection, develop active adaptive management strategies, and assess resources to improve local toad population health. Our project consists of two studies at CCSP and LCW to meet the following objectives:

1) Assess current populations in existing vernal pools and newly constructed ponds
2) Identify key factors and vulnerabilities of WST larval ecology
3) Identify key factors and vulnerabilities of juvenile dispersal to upland habitats

2.2 Project Activities

2.2.1 Larval Ecology

We will be utilizing a visual encounter survey protocol, developed for conducting larvae surveys in the field, to accomplish biological monitoring (Fisher et al., 2004). This survey protocol involves walking the perimeter of the pool while scanning for WST larvae and egg masses (Fisher et al., 2004), and if pools cannot be thoroughly visually surveyed, dip netting will be supplemented to complete the search. During this survey, all species and life stages observed will be recorded, and all amphibian species will be swabbed for presence/absence of the chytrid fungus (*Batrachochytrium dendrobatidis*). All surveyed pools will also be quantitatively measured (Fisher et al., 2004). Measurements will include water depth, pool circumference, temperature, dissolved oxygen, conductivity, pH, and turbidity.

Observation of foraging behavior and morphological development will commence, once WST larvae have been detected (Fellers & Freel, 1995). This entails observing and recording the prey items WST larvae consume, with the categories being: planktonic organisms, algae, and scavenged dead organisms.

WST larvae interactions will be measured by recording the number of co-occurring species present in pools, and recording the abundance of available food sources (i.e. prey items). Using these data, we will be able to draw a connection between the presence of co-occurring species and the amount/type of available WST larval food (e.g. higher abundance of co-occurring species results in less available WST larval food).

We will quantify the frequency of differing morphs by sampling via dip netting. This is accomplished using a long wooden handled pole with an attached nylon fine mesh aquarium net to scoop WST larvae from pools (Fisher et al., 2004). Larvae morph will be recorded as either: carnivore or omnivore. The carnivore morph is readily distinguished by the presence of enlarged mouths and jaw muscles, while the omnivore morph is identified by its social behavior (i.e. large group aggregates) (Pough et al., 2016). At the end of the survey, the abundance of both morphs will be compiled. Data collection on morph occurrence and frequency will yield insights on the factors that affect larval diet.

2.2.2 Juvenile Dispersal

Western spadefoots require upland terrestrial habitat and seasonal vernal pools to complete their life cycle. This study focuses on observation and data collection on toadlets and juveniles. Bull (2009) differentiates juveniles as being older and larger compared to toadlets which have not overwintered yet. Given the novelty of our research project, we will use the terms juveniles and toadlets interchangeably to facilitate a broader understanding of young WSTs. Toads with less than 37 mm snout-vent lengths, the minimum range for adult toads, will be considered toadlets in our observations (USFWS, 2005).

Surveys. Baseline mark-recapture surveys based on methods by Bull (2009; Appendix Outline 1) will be conducted in year 1 of the study at two existing breeding sites with histories of high use. For our study, we will primarily search for toadlets in the afternoon within 1.5 km upland of the breeding pool to assess existing abundance and monitor pools for mark-recapture opportunities. Secondarily, we may conduct recapture surveys at night, every other week, given sufficient equipment and rainfall. We will record various GPS and other environmental data at each survey such as the number of usable burrows for toadlets (Appendix Outline 1). Holes between 2 and 10 cm wide and deeper than 10 cm would indicate a usable burrow. Our survey methods are comparatively restricted due to the intensity of work, limited resources and personnel, and testing of new protocols for this species.

Dispersal. Baseline toadlet dispersal assessments based on methods by Bull (2009; Appendix Outline 2) will also be conducted in tandem with the mark-recapture surveys. Dispersal assessments will require locating and monitoring routes between breeding sites and upland habitat as shown in Figure 5 (Appendix). Three monitoring stations will be established along identified routes and systematically selected based on toadlet sightings, ground moisture, low vegetation, and accessibility. Travel beyond identified routes will be assessed by placing 50 m transects perpendicular to each route and counting observed toadlets 2 m beyond the transect line. As with the surveys, general environmental characteristics as listed in Appendix Outline 2 will be recorded during dispersal monitoring events.

2.3 Proposed Timeline

2.3.1 Larval Ecology

Resource managers will be conducting observational surveys in CCSP and LCW. The breeding season typically begins in January and will last until May; however, the timing of rains may vary (USFWS, 2005). As such, surveys will begin shortly after adequate rains have been received, and sufficient water has been collected to form potential breeding pools (Fisher et al., 2004) Three artificial pools have been recently constructed in CCSP, with the hopes of promoting natural WST dispersal and recruitment from the adjacent San Joaquin Hills populations. These pools also have recently restored coastal sage scrub upland habitat that will hopefully be utilized by adult WSTs in the future. In summary, we will be surveying both naturally occurring pools and recently constructed artificial pools in order to maximize our data collection.

Each pool in which larvae are detected will be surveyed for at least 30 days, from the time of initial larval detection, as this is the minimum amount of time WST larvae need to mature and metamorphosize. Due to the inherent variability of seasonal southern California rains, and the increased unpredictability of climatic patterns due to climate change (Iacobellis et al., 2016), our surveys will be conducted annually for several years in an effort to account for seasonal variation in precipitation and to produce robust data.

By gathering data on larval foraging behavior, interactions with co-occurring species, and morphological type frequency we will elucidate the forces that promote these behaviors and will ultimately yield insight into this species conservation requirements.

2.3.2 Juvenile Dispersal

Juvenile surveys will begin half-way through the breeding season in March to monitor existing juvenile populations. We will begin exploring upland habitat, potential juvenile dispersal routes, and areas for monitoring stations along the routes. Surveys will be conducted weekly for each site, in 4-6 hour shifts, in the afternoon, and immediately during or after rain events when emergence is likely (Ruibal et al., 1969). Abundance surveys will cease around June or July, or when substantial larval transformation is observed. Toadlets may only remain in the immediate area of their pool for several days before moving upland (Butte RCP, 2019). Therefore, careful monitoring of larval development will be vital to the timing of our dispersal study. Weekly observations will continue for each site but will focus on marking and recapturing new toadlets from each pond.

2.3.3 Table 1: Projected Timeline for the WST project

Dates	**Project Status**	**Description**
December 2021	Site assessment, permit acquisition, baseline population surveys	Analyzing site conditions, acquiring necessary permits and preparing required documents, and conducting preliminary surveys to identify WST populations.
January 2022 (start date often varies seasonally, dependent upon adequate amounts of rain) - June 2022 (end date varies seasonally as well, dependent upon rate at which pools dry out)	Larval Ecology Surveys	Continuous monitoring of pools containing larvae. Once larvae have been found, we will continually survey for 30 days.
March 2022 - July 2022	Juvenile Abundance Surveys; begin marking newly transformed toadlets; identify possible routes and locations for monitoring stations	Monitoring existing juvenile presence upland from breeding sites. Establish monitoring stations. Observe presence of new juveniles at breeding ponds for marking.
June 2022 - August 2022	Larval Dispersal Surveys; continue mark and recapture of toadlets	Continuous monitoring of larval dispersal patterns (per Bull 2009 protocol). Larvae and juveniles will leave pools and seek refugia. Dispersal has yet to be quantified.
August 2022 - October 2022	Survey Protocols Assessment and Training	Discuss successes and areas for improvement of survey methods. Revise methods as needed. Check in with staff about continual monitoring.
September 2022 - December 2022	Data Analysis and Finalizing Report	Completing data analysis, reporting results, writing conclusions, periodically checking site conditions, and maintaining site if necessary.

3. ASSESSMENT PLAN

3.1 Expected Outcomes

The specific outcomes of our project will be:

1) New ecological and behavioral data on larval and toadlet stage WST
    a) As noted in Section 2.1
2) Larval/toadlet protection recommendations
3) A framework for future larvae/toadlet surveys specific to CCSP and LCW
4) Publishing our findings in a peer-reviewed journal

3.2 Metrics of Success

After identifying presence and absence of larval stage species at 10 natural and artificial pool sites during appropriate weather, we will conduct 30 days of observation using FWS protocols. Success will be measured by completion of the following milestones:

- detection of strong sample size of egg clusters at one of more of both artificial and natural pools
- identification and summary of larval stage diet
- observation and summary of behavior of omnivore and carnivorous morphs
- observation and summary of larval intra- and inter-specific competition
- observation and summary of toadlet and juvenile dispersal from pool to upland burrowing sites
- discuss and review the results with CCSP and LCW field personnel to create criteria for management protocols

CONCLUSION

In conclusion, by accomplishing our specific objectives, we will ultimately be advancing the knowledge of this California Species of Special Concern as well as enhancing conservation practices surrounding the WST. Our study addresses critical gaps of knowledge in the WST life history, specifically larval ecology and dispersal. These two topics have yet to be quantified and are virtually unknown, making successful WST conservation incredibly challenging. Additionally, the WST larval stage is extremely sensitive and susceptible to high rates of mortality. By focusing on this life stage, our study will elucidate how WST larvae behave and interact with their environment. Such knowledge provides a foundation for future research on improving the WST population in Orange County. We recommend a future demographic population viability analysis to determine whether targeted conservation action on early life stages of the WST would be an effective approach. As a result, we will obtain a better understanding of the factors that influence larvae and juvenile dispersal, which will ultimately guide ongoing conservation practices. Our results will provide both CCSP and LCW with the knowledge to ensure ideal conditions are met that facilitate the enhancement of population numbers for the WST.

LITERATURE CITED

Baumberger, K. L., Eitzel, M. V., Kirby, M. E., & Horn, M. H. (2019). Movement and habitat selection of the western spadefoot (*Spea hammondii*) in southern California. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0222532

Bazazi, S., Pfennig, K. S., Handegard, N. O., & Couzin, I. D. (2012). Vortex formation and foraging in polyphenic spadefoot toad tadpoles. *Behavioral Ecology and Sociobiology*, 66(6), 879-889. https://doi.org/10.1007/s00265-012-1336-1

Bull, E. L. (2009). Dispersal of newly metamorphosed and juvenile western toads (Anaxyrus boreas) in northeastern Oregon, USA. *Herpetological Conservation and Biology*, 4(2), 236-247.

Butte Regional Conservation Plan. (2019). Final BRCP: Appendix A.11 Western Spadefoot Toad (*Spea hammondii*), pages A.11-1-A.11.8. Retrieved from http://www.buttehcp.com/documents/Documents/AFinal%20BRCP%20June%202019/15_App_A_Species_Accounts_Final_clean.pdf

Crystal Cove State Park. (2021). Natural Resource Management. Crystal Cove State Park. Retrieved from http://www.crystalcovestatepark.org/

Denver, R. J. (1998). Hormonal correlates of environmentally induced metamorphosis in the Western spadefoot toad, *Scaphiopus hammondii*. *General and comparative endocrinology*, 110(3), 326-336.

Feaver, P.E. (1971). Breeding Pool Selection and Larval Mortality of Three California Amphibians: *Ambystoma tigrinum californiense* Gray *Hyla regilla* Baird and Girard and *Scaphiopus hammondi hammondi* Girard. Master's Thesis. Fresno State College, Fresno, CA.

Fisher, R. N., Trenham, P. C., Compton, S. L, Backlin, A. R., Hathaway, S.A., & Touré, T. A. (2004). Habitat assessment and baseline surveys for the western spadefoot (*Spea hammondii*) and the western pond turtle (*Emys marmorata*) on the Irvine Ranch Land Reserve. U. S. Geological Survey technical report. 50 pp.

Iacobellis, S., Cayan, D., Abatzoglou, J., & Mooney, H. (2016). Climate. In Mooney, H., Zavaleta, E., & Chapin, M. (Eds.), *Ecosystems of California* (pp. 9-26). Oakland, California: University of California Press. Retrieved February 24, 2021, from http://www.jstor.org/stable/10.1525/j.ctv1xxzp6.7

Jennings, M. R., & Hayes, M. P. (1994). Amphibian and reptile species of special concern in California (p. 255). Rancho Cordova, CA: California Department of Fish and Game, Inland Fisheries Division.

Joly, P. (2019). Behavior in a changing landscape: using movement ecology to inform the conservation of pond-breeding amphibians. *Frontiers in Ecology and Evolution*, 155(7). https://doi.org/10.3389/fevo.2019.155

Morey, S. R. *Spea hammondii.* In: Lannoo, M.J. editor. (2005). *Amphibian Declines: The Conservation Status of United States Species*. University of California Press, 514-517.

Morey, S. R. & Guinn, D. A. (1992). Activity patterns, food habits, and changing abundance in a community of vernal pool amphibians. In Williams, D. F., Byrne, S., Rado, T. A. (Eds.). Endangered and sensitive species of the San Joaquin Valley, California: their biology, management, and conservation. California Energy Commission, 149-158.

Orange County Parks. (2021). Laguna Coast Wilderness Park History. Orange County Government. Retrieved from https://www.ocparks.com/parks/lagunac/history

Pough, H., Andrews, R., Crump, M., Savitzky, A., Wells, K., & Brandley, M. (2016). *Herpetology* (4th Edition). Sinauer Associates.

Ruibal, R., Tevis Jr, L., & Roig, V. (1969). The terrestrial ecology of the spadefoot toad *Scaphiopus hammondii*. *Copeia*, 571-584.

Stebbins, R. C. (1984). *A Field Guide to Western Reptiles and Amphibians*. Second Edition. Boston: Houghton Mifflin Company.

Stebbins, R. C., & McGinnis, S. M. (2018). *Peterson Field Guide to Western Reptiles & Amphibians*. University of California Press.

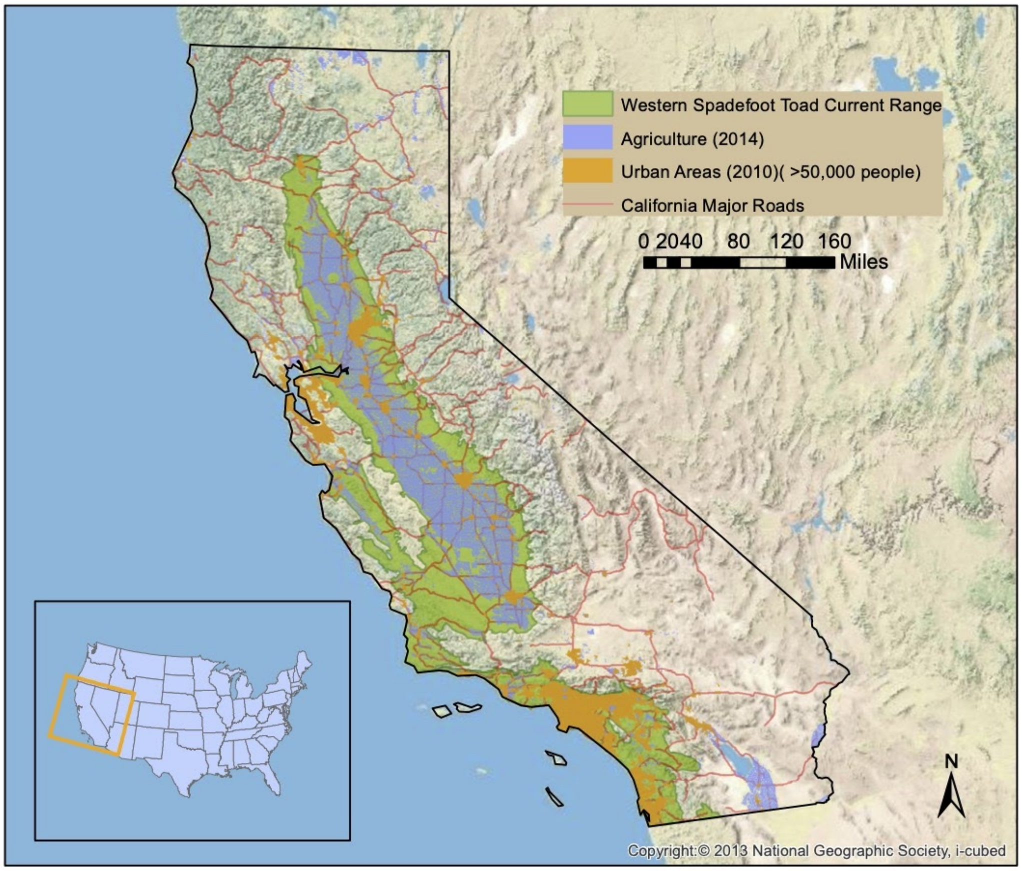
U.S. Fish and Wildlife Service. (2005). Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon. Portland, Oregon. xxvi + 606 pages, II220-II234.

U.S. Fish and Wildlife Service. (2020). Species status assessment report for the western spadefoot toad (*Spea hammondii*), Version 1.0. Dated 2021. U.S. Fish and Wildlife Service, Sacramento Fish and Wildlife Office, Sacramento, California.

APPENDIX

Major Threats Within the Western Spadefoot Toad's (*Spea hammondii*) Current Range in California

Prepared by: Jennifer Mendez



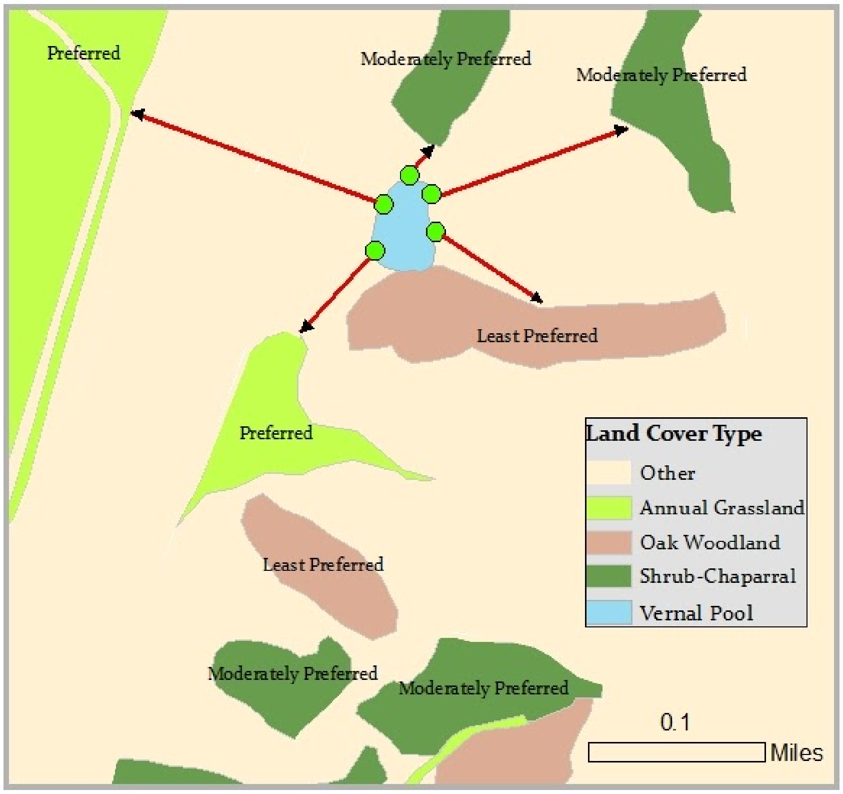
Endemic to California, Western Spadefoot Toad populations have been severely reduced due to agricultural practices and urban development, which accounts for 80% loss of habitat in Southern California alone.

This amount of habitat alteration has resulted in the Spadefoot Toad's listing as a Species of Special Concern.

Figure 1. Current Range
Map of the western spadefoot toad’s current range with land conversions that led to the species decline.

Western Spadefoot Adult Dispersal

By Phillip Samples



The Western Spadefoot Toad (WST), represented by the green circles, is a California Species of Special Concern. Adult toads live underground in burrows for the majority of the year, only to emerge to the surface during the rainy season. Upon surfacing, adults will migrate to vernal pools to breed. Adult females will lay eggs in pools that will hatch in 3-4 days. Tadpoles will develop in the pools and eventual metamorphosize into juveniles. Juveniles will disperse once the vernal pool has dried out, although research regarding this behavior is extremely limited. In late summer, adults will migrate back to nearby burrows (Thomson et al., 2016). This species will burrow in a variety of habitats but prefers grasslands, follwed by chaparral, and lastly oakwoodlands (Baumberger et al., 2019).

Disclaimer:
This is a representation of a vernal pool in Orange County, not the site of an actual vernal pool. Location information is limited due to the senstive nature of this species.

The San Joaquin Hills of Orange County are located in Southern California, and support a few populations of WST. This low mountain range encompasses both Crystal Cove State Park and Laguna Coast Wilderness, the sites of our study.

Figure 2. Adult Dispersal
Map of adult dispersal patterns, highlighting habitat preference and providing an illustration of the WST life cycle.

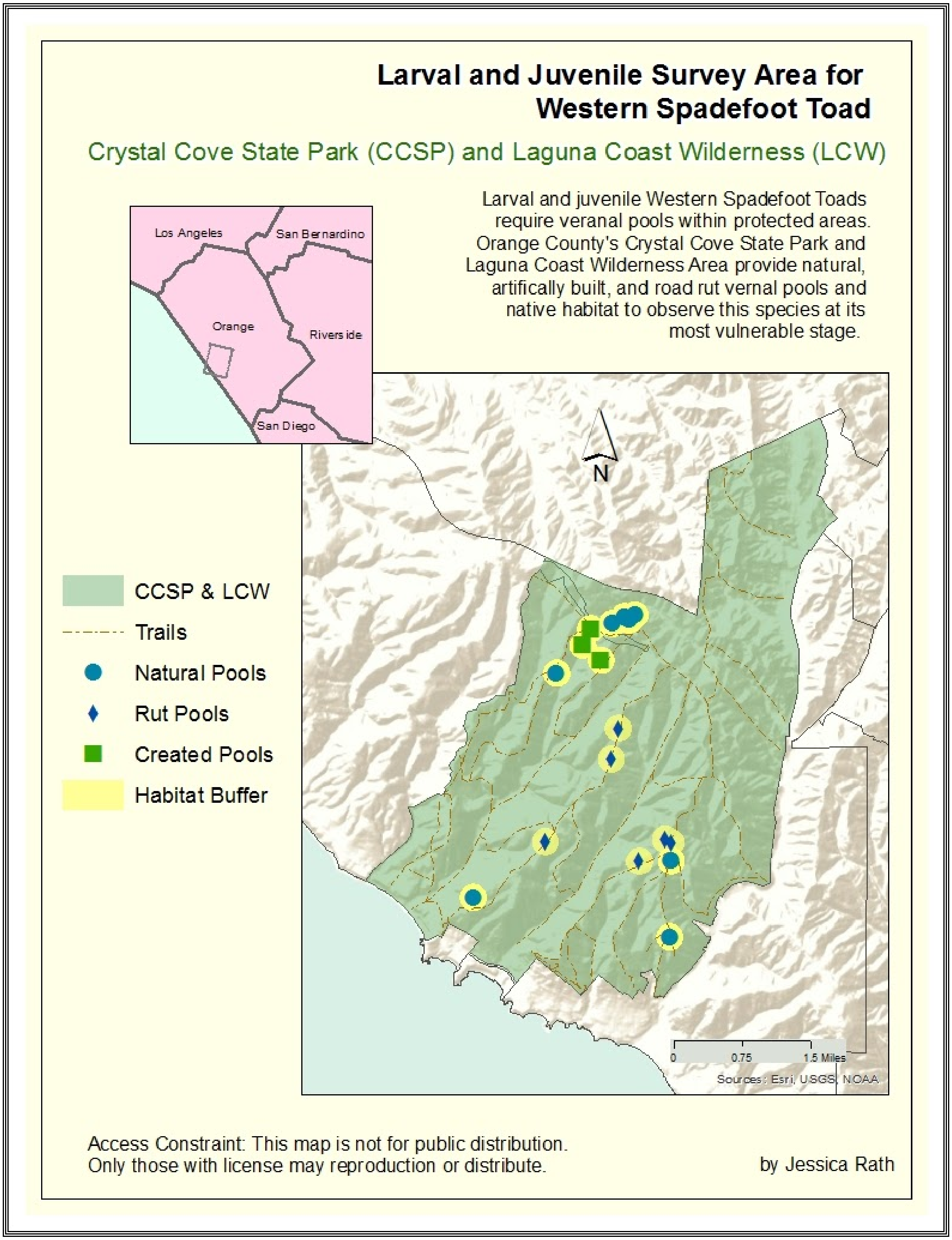


Figure 3. Map of Crystal Cove State Park and Laguna Coast Wilderness contiguous area of vernal pools and upland habitat buffer zones for the western spadefoot toad larval and juvenile surveys.

Western Spadefoot Toad - Orange County Habitat Suitability

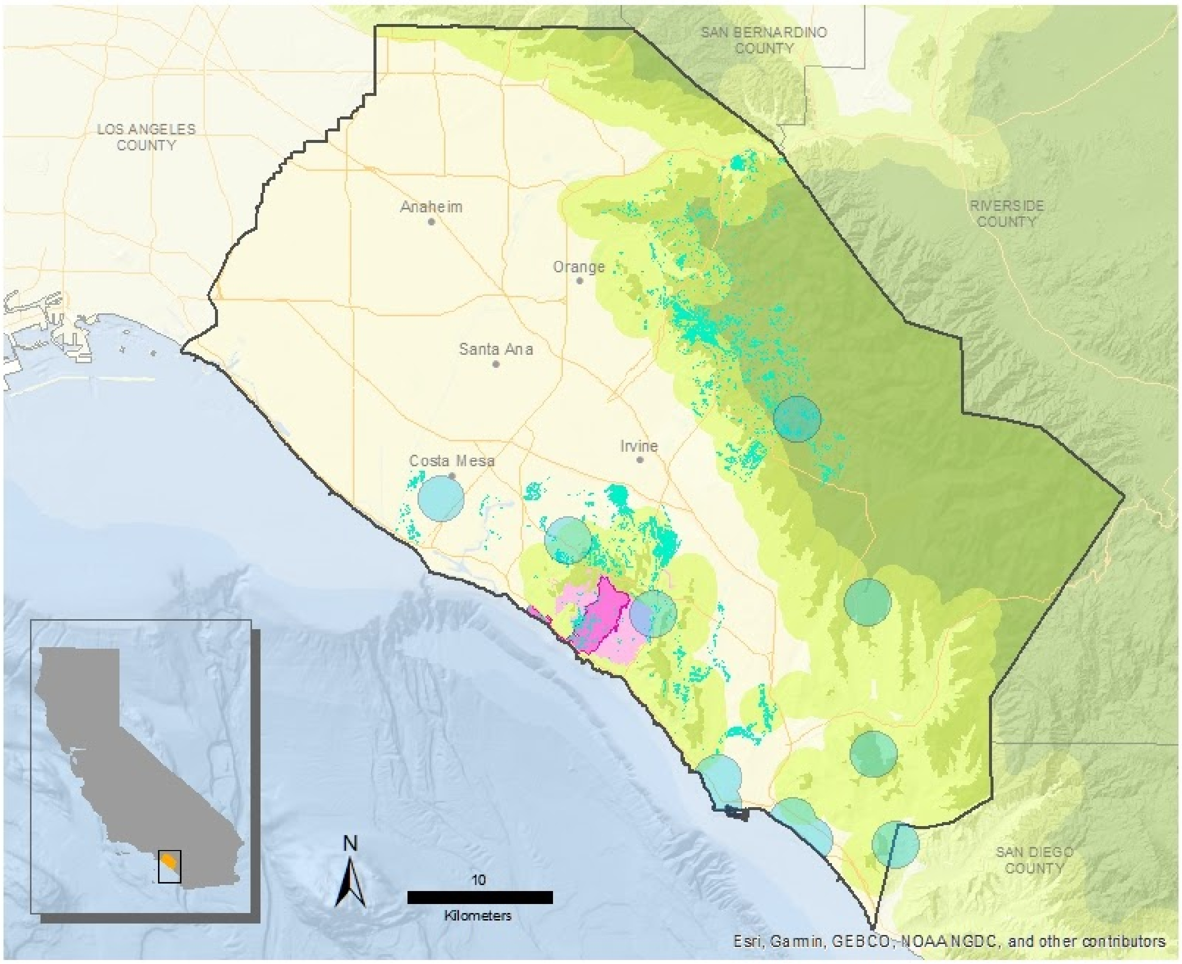


Figure 4. Western spadefoot toads (*Spea hammondii*) require lowland vernal pool habitats in their breeding and larval stages. As pools evaporate and once larvae metamorphose, they disperse into upland habitat and overwinter in underground burrows. While maximum dispersal distances are unknown, it is assumed they can travel up to around 1.5 km from their vernal pool as juveniles (Butte RCP, 2019).

- Crystal Cove State Park (CCSP)
- Laguna Coast Wildnerness (LCW)
- Historical Vernal Pool Sites (1989)
- Grassland & Ephemeral Wetland
- Major Roads

Habitat Elevation

- Lowland (LL)
- LL Dispersal Range
- UL Dispersal Range
- Upland (UL)

Optimal Sites for Habitat Restoration:

1. Lowland dispersal range
   - Natural/artificial vernal pools *(required)*
   - Within proximity of historical vernal pools
2. Upland dispersal range
   - Annual grassland/wetland *(most preferred)*
   - Sage scrub *(moderately preferred)***
   - Oak woodland savannah *(least preferred)*
3. Outside of CCSP and LCW
4. Distanced away from major roads

Author: Michelle dela Cruz, UC Irvine, March 2021 |

Figure 4. Orange County Habitat Suitability for possible artificial ponds outside of park boundaries.

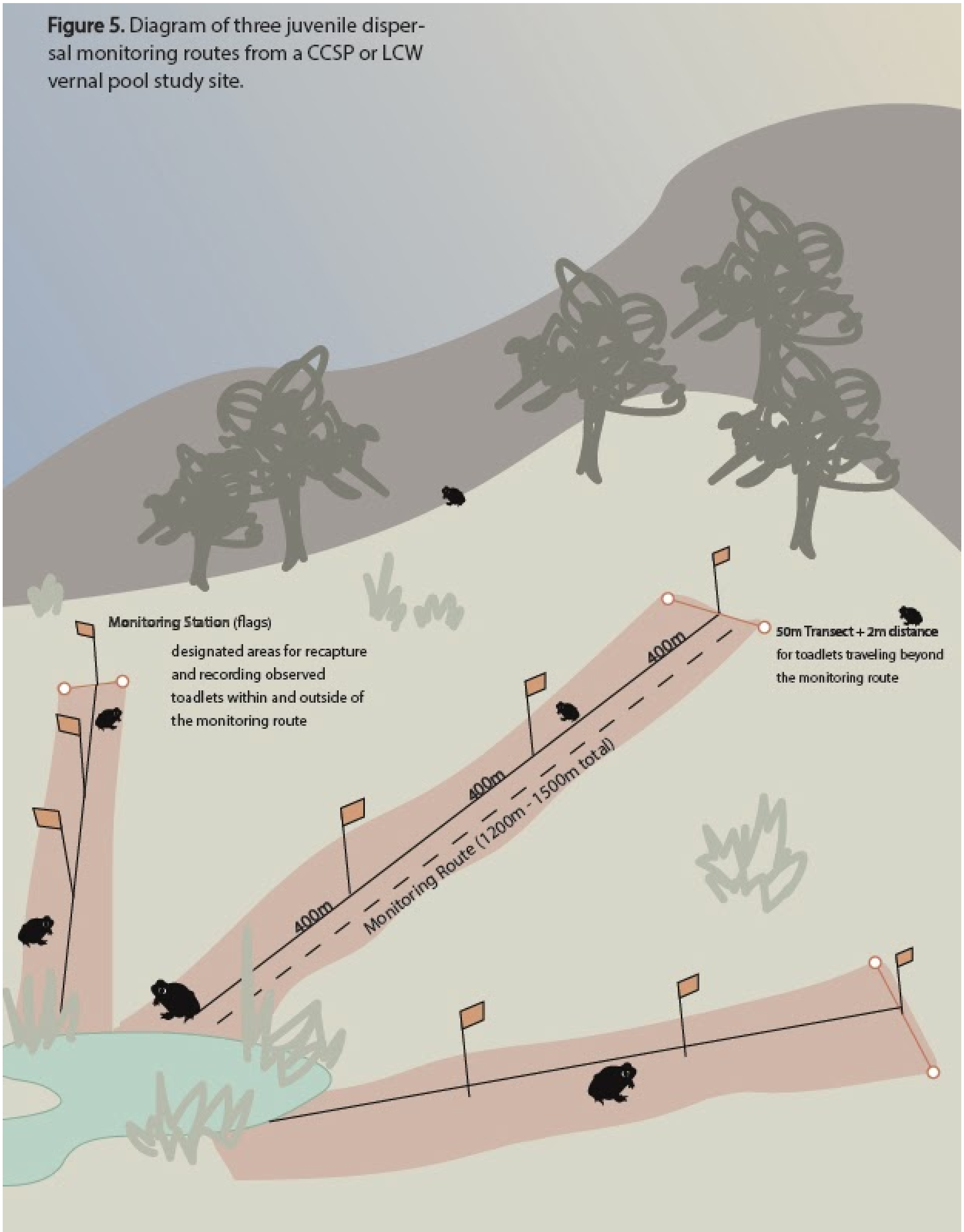


Figure 5. Diagram of juvenile dispersal monitoring routes, conducted in the evening when WSTs are most active.

Outline 1: Toadlet Survey Method (Bull 2009)

1. Searches conducted within 1-3km of breeding reservoirs
    a. Seasonal daytime surveys over 2 years
        i. Checked ground surface, under rocks/logs, seeps/springs, springs
    b. Seasonal nighttime surveys less often, once per week or month
2. Mark-Recapture at two sites
    a. Marked smaller toadlets with visible implant elastomer
    b. Marked larger toadlets with 8mm Passive Integrated Transponder (PIT) tags
    c. Attempted recapture every 2 weeks
3. Document characteristics of mark-recapture sites
    a. Date
    b. UTM
    c. Number of toads observed
    d. Vegetation type
    e. Distance/direction to oviposition site in m
    f. Distance to water and water type
    g. Ground cover type/percent/height
    h. Slope and aspect
    i. Number of burrows/shelters a toadlet could use (>2cm diameter hole)

Outline 2: Toadlet Dispersal Method (Bull 2009)

1. Monitoring
2. Classification
    a. Toadlets are younger than juveniles
    b. Snout-vent length range in mm
    c. Mass limit range in mm
3. Locating routes of dispersal
    a. Walking accessible roads, trails, drainages
    b. Water flowing within 2km of reservoir
    c. If spotted up a drainage, searched .5km beyond farthest toad
    d. Monitored 3 breeding sites every 1, 2, and 4 weeks
4. Establish 3-4 monitoring stations 200-400m apart
    a. Document toadlet movement once a week
    b. Stations selected with 4 characteristics
        i. Drainage areas with toadlets within a week after dispersal
        ii. Water/moist soil
        iii. Low vegetation to facilitate counting
        iv. Accessibility
    c. Based on toadlet rehydration requirements
5. Determining rate of travel
    a. Mark and recapture
    b. Toadlets captured within 50m radius at one site
    c. Marked with visible implant fluorescent elastomer tags
    d. “Batch” marked, unique color per drainage
    e. Recaptured toadlets: Determine distance from original capture site/# of days since marked
6. Document travel outside of drainage
    a. 50m transect perpendicular to drainage
    b. Counted toadlets 2m outside of the transect line
    c. Searched 40 transects in year 0
    d. Searched 23 transects in year 1
7. Document general habitat characteristics of drainages used for dispersal
    a. Intermittent/permanent
    b. Wetted channel width
    c. Channel substrate (% gravel/cobble/boulder)
    d. Distance to open road
    e. Ground cover (type, height % cover)
    f. Grazing presence
    g. Percent canopy closure
    h. Slope aspect and gradient