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Dear USFWS,

As requested by the Service, I am providing my peer review of the Species Status Assessment (SSA) of the Western Spadefoot Toad (WST, *Spea hammondii*), Version 1.0. I understand that the Service is not seeking advice on policy or recommendations on the legal status of the species, and that instead you would like me to focus on scientific uncertainties and accuracy in the report. You specifically ask me, as a peer reviewer, to focus on three issues:

(1) Has the Service assembled and considered the best available scientific and commercial information relevant to this species?

(2) Is the analysis in the SSA of this information correct?

(3) Are the scientific conclusions drawn reasonable in light of this information?

I have gone through the SSA line by line, and provide my input in three forms. First, I attempt to address the three questions as outlined in your request for information and repeated above in this letter. Second, I have made a number of line-or-section comments, and those are listed at the end of this document. And third, I have made relatively extensive annotations on the SSA itself in track changes in word. I attach that annotated document to this email as a second attachment.

Broad reviewer comments (Shaffer):
Synopsis: Overall, this document clearly represents a great deal of work, and I applaud the Service for the job it has done. In providing a scientific peer review, I always consider two broad questions. First, is the literature and knowledge review accurate and complete? That is largely your first question. Second, are the interpretations of that information reasonable, or the best that they can be? That is your second and third questions, above. Obviously, the first is easier to evaluate than the second, since any interpretation involves judgements about the data and how to use it. But I will do my best to apply my best scientific judgement to the document and its conclusions. Fortunately, I know most of the *Spea hammondii* literature quite well, and members of my current and former lab group (Kevin Neal in particular, but also Robert Fisher, Bob Thomson, Amber Wright, and Carlos Davidson among others) have made major contributions to this literature.

At the broadest level, I feel that this SSA is a start on a review of the WST, but it draws conclusions that I sometimes do not feel are justified by the data as presented. I also feel that some data and analyses were not included or were under-utilized. This is not catastrophic, but I do feel that another round of analysis is appropriate before conclusions, like those in the SSA, are finalized.

Several very important issues and concerns include: 1) a very heavy reliance on Fis (inbreeding coefficients) rather than Ne (effective population size) when determining the health of populations, 2) the severe loss of habitat in the northern clade over the seven year period (2005-2012), which Table 3 shows to be an astonishing loss of 26%, or 246,279 acres. This is on top of an estimated several million acres that have already been lost, and does not account for the losses in the nine years since the last estimate provided, 3) the estimate that 53 acres (which is then rounded down to 40 acres) is sufficient to maintain a WST population with essentially no demographic or ecological support for that very small number, 4) the conclusion that disease (ranavirus and *Bd*) are not problems because they have not been reported (this strikes me as a classic example of "Absence of evidence is not evidence of absence,"), 5) both natural (California tiger salamander, CTS) and non-native exotic predators are considered to be of little importance even though there is overwhelming evidence to the contrary, and 6) the very large body of unpublished, but extremely relevant data that exists and could shed light on the health of the species has not been discussed in collaboration with academic, USGS and state agency biologists. Taken together, I feel that the relatively rosy picture that leads to the conclusions that WST is in reasonably strong shape is overly optimistic and needs to be re-assessed.

I detail my reasons for my thinking below, and do so with the hope that the Service will be able to reevaluate some of its conclusions. I also emphasize that I share these thoughts and comments not because I feel that the Service has done a poor job or has not acted in the best interests of communicating and evaluating the available science. I do feel that this document and its conclusions could be improved. I hope that my comments are taken in that light.

<u>(1) Has the Service assembled and considered the best available scientific and commercial information relevant to this species?</u>

In terms of accuracy and completeness, certain parts of the literature are discussed and evaluated in detail, but other, equally or more important parts were either missed or ignored. One important example is the Species of Special Concern status accounts, which include assessments of threats, research needs, and many other key findings. The Jennings and Hayes (1994) Amphibian and Reptiles Species of Special Concern monograph is cited many times (as it should be), but the Thomson et al. (2016) official update of Jennings and Hayes, is never cited or discussed. I cannot imagine why not. It is the official replacement and update of Jennings and Hayes.

I also found examples of parts of a paper or study being embraced and emphasized, while others seem to be downplayed, sometimes without any obvious reason or rationale. To take one example: Neal (2018, 2019), which you cite heavily, identifies two clades that are essentially different species, and major phylogroups that you use to define genetic units for management and recovery. That makes sense, and I particularly applaud your consideration of northern and southern clades as essentially distinct species (which I feel certain will be the taxonomic conclusion after the requisite quantification of morphological variation in museum collections is complete). But Neal (2019) also shows (particularly in Chapter 2, a detailed assessment of Orange County populations) that essentially each breeding pond or spatially adjacent cluster of ponds is definable and distinct. This is important, for it implies that the unit of management is often these very small clusters of breeding sites, not just the large units as summarized herein in Figure 8 (vernal pool ecosystem regions) or Figure 9. Neal also documents that these isolated

ponds have tiny effective population sizes. The analysis in Chapter 2 (which is in press pending minor revisions, and should be officially in press at the *Journal of Heredity* by the end of April 2020) is essential—it demonstrates that the unit of management and recovery is the breeding pond or very closely associated set of breeding ponds, and it gives a much more realistic, population-level analysis of the health of these ponds. And that assessment is that they are not genetically healthy. But that part of Neal (2019) is ignored.

Another important paper that is never cited or mentioned is Wright et al. 2015 (Wright, A. N., R. J. Hijmans, M. W. Schwartz, and H. B. Shaffer. 2015. Multiple sources of uncertainty affect metrics for ranking conservation risk under climate change. Diversity and Distributions 21:111-122). A less important, but still noteworthy follow-up is Wright et al. 2016 (Wright, A. N., M. W. Schwartz, R. J. Hijmans, and H. Bradley Shaffer. 2016. Advances in climate models from CMIP3 to CMIP5 do not change predictions of future habitat suitability for California reptiles and amphibians. Climatic Change 134:579-591.) These papers discuss climate change predictions and their ecological impacts for California reptiles and amphibians, including *Spea hammondii*. These papers are based on a 2013 report, *California Amphibian and Reptile Species of Future Concern: Conservation and Climate Change*, that is freely available on the CDFW website. It discusses and maps WST current and future range predictions, and in fact shows that the species appears to be relatively unaffected by future climate change models. However, it also shows that WST has one of the highest Anomaly Scores of any species, (see Table 8) which should be taken into consideration in any analysis. In addition, as Neal et al. (2018) showed (see their Figure 4), maxent models for southern WST do not predict the range of northern WST and vice versa, suggesting that the predictions in the 2013 CDFW report should be redone for each separately. This work should absolutely be included.

Finally, I know that there is a large body of unpublished work and reports that should be included in this SSA. Robert Fisher from USGS has shared some of it with me, and although I have not had access to most of it, it is important data that should be included, evaluated, and considered. I have talked to Cathy Baumberger about her updated movement data, which is very extensive. Given that it is the crucial piece of data that went into the 53 acre assessment, I strongly recommend that these new data be incorporated into the review.

Other papers or projects that I am aware of are mentioned in my annotated copy of the paper.

<u>(2) Is the analysis in the SSA of this information correct?</u>

There are many ways to evaluate the accuracy of "analysis", making this a hard question to answer in light of such a large document. Some of the analysis of information is certainly correct. Treating northern and southern WST as different entities (perhaps different species) is proactive and correct, and while all of the evidence in support of this decision is not listed (Neal 2019 Chapter 3 in particular should be emphasized, since it is the strongest data), the analysis is correct. Many other analyses are correct. Many are not, or could be improved. I list many of the smaller details about which I think that a reanalysis might be useful at the end of this document and on my annotated copy of the document. Below, I list a few of the more important areas where I do not agree with the analysis as I understood it.

a) The base range map is not correct, and in fact is not the one that is cited. In particular, the statement (line 170) that WST occur "throughout the coast ranges" is an overstatement. So is the implication of the species occurring regularly up to 4500 feet elevation, which suggests a broader elevational range than is realistic (Fisher and Shaffer 1996 show the historical and current average elevational at 200-300 m, or under 1000 feet; there may well be one errant, and possibly incorrect record at 4500 feet, but it certainly is not usual). The base map is disturbing for me. The legend (lines 190-195) say that this is a conglomerate map, although I would have assumed it was built primarily on the CDFW's CWHR map. But if you look at that CDFW map, you'll see that the map in this document is too generous in its depiction of the range of WST. Better than constructing a new map, I recommend using the one from Thomson et al. (2016) on p 131 of that document. That map was constructed by the CDFW and includes all current records and, as the text in that book explains (see text starting on p. 15 of Thomson et al. 2016) **the maps are constructed to over, rather than under-estimate range sizes.** As the *Spea hammondii* map shows, the species is absent from the coast ranges except for the Salinas Valley and the adjacent inner coast ranges to the east, and between the southern part of the SF Bay area and the northernmost end of the Sacramento Valley there are two localities, each of which are single ponds in northern Yolo County (I believe I discovered both of these). This gives a more nuanced, and I believe more accurate view of the species than the map currently being used.

b) Abundance. Neal (2019) provides general data on effective population sizes, which are probably the best real estimates we have in most cases. His numbers are very low, and very consistent. They average around 5 for northern and under 4 for southern WST populations. If we take the often-correct rule of thumb of 5-10 times Ne as a guess of the census sizes, these are very small numbers, even for large vernal pools. This is consistent with Thomson et al., (2016) who note "Recent surveys of Mather Airport (formerly Mather Air Force Base) in Sacramento County estimated that breeding adults numbered in the few dozens" (p 133). Additional unpublished data may be available from recent work by USGS, but the estimates noted above are consistent and demonstrate tiny populations that are very susceptible to stochastic loss ranging from drought to intermittent death from natural and invasive predators.

c) Disease. In the section on disease (8.7, lines 693-706) you say that "Western spadefoot toads are currently not known to be significantly impacted by any identified diseases.", and therefore (lines 1526-1528) "The threats of chemical contaminants and potential disease were not considered under the future scenarios because there is no evidence that these threats are impacting the species now or will in the future." However, there is evidence in a close congener (see lines 699-702) and you often use such data in other analyses when specific data on WST are not available. In another paper that was not cited, Peralta et al. (2018) found evidence of *Bd* in every species of pond-breeding amphibian in northern Baja that could be tested. The only species that they could not find as adults, and therefore could not swab test, was WST, but the reasonable inference is that they are carriers, and perhaps negatively impacted, in Baja. And, as Thomson et al. (2016) state, there simply is no evidence in California. Making the strong claim that this shows that disease is not an issue for concern seems to me to be a mis-analysis of the available data, which are admittedly very thin.

d) Size and number of "viable" populations. Lines 836-857. This is a critical part of any population analysis, and really is the heart and soul of establishing what a species requires to

survive with healthy populations. The approach taken here is to 1) take the longest distance moved from a breeding pond, based on a very small radio transmitter study, 2) calculate the number of acres that would require if it were a circle with radius from a breeding pond defined by the distance in 1), 3) round that number down (from 53 to 40 acres), 4) assume that any such block of habitat is a viable population, and 5) declare that some number of such blocks ensures larger-landscape viability. Countering this approach, work on some of the same landscapes and well-established in the published literature, show for CTS that estimates of transmitter movement were *a full order of magnitude smaller than those based on more accurate drift fence data* and vastly underestimated the amount of upland habitat needed to sustain a CTS population (the number went from about 150 m to about 2000 m radius). In addition, my understanding from Baumberger, who has conducted additional, more extensive transmitter studies, are that her new data confirm much greater habitat use. Combine that with taking the 53 acre calculated patch size, for reasons of convenience rather than scientific justification scaling it down to 40 acres (a 25% decrease), and claiming, with no justification, that such patches constitute adequate habitat to support an isolated population in perpetuity seems like an inappropriate analysis. In fairness, the document does say that "more science is needed", but the message in the analysis is clear—there are lots of little 40 acre patches, so the species is fine.

<u>(3) Are the scientific conclusions drawn reasonable in light of this information?</u>

As should be obvious from my evaluation of the literature and analyses, I do not thing that the conclusions are always reasonable, and I would strongly encourage that the scientific conclusions be reconsidered.

For the northern WST, the combination of truly staggering habitat loss documented in Table 3, combined with the tiny Neb estimates, analyses from Fisher and Shaffer 1996, and clear, enormous areas of complete extirpation in many entire counties in the Sacramento Valley and severe declines in the San Joaquin due to habitat loss suggest to me that existing protections as an SSC are not working. Additional data from the USGS, CDFW, and other partners could provide critical insights and should be assembled in a workshop or group data-gathering and analysis setting. Another critical conclusion, which is that preserves established for other species will cover WST, is never justified, particularly in light of Morey (1998, cited also in the Amphibiaweb species account) showing the often-negative correlation between CTS and WST at the pond level; CTS are WST predators, and larval CTS regularly eat most or all of the WST tadpoles before metamorphosis. We have clear evidence of this based on four years of data from the Purisima Mitigation Bank in northern Santa Barbara County, although those data are unpublished. However, the conclusions in Table 4, that only one of 10 northern WST regions has a "low" condition, and that most of the vernal pool regional areas are in reasonable shape is not warranted.

For the southern WST, I disagree even more strongly with the conclusions. Table 5 indicates that the four "populations" are all in moderate to moderate-high condition (or unknown for Baja). No analyses of habitat loss, like that in Table 3, are provided for the southern WST, perhaps because pretty much all of the available habitat is already protected. However, particularly in San Bernardino and Riverside Counties, habitat is still being lost, and in southern California, every acre counts. The same is true for the small patch of habitat in northwestern Los Angeles County

(it is otherwise extirpated from the county) and adjacent Ventura County. The map of historical and CNDDB records in Thomson et al. (2016) tells this story. Jennings and Hayes (1994) estimate that 80% of the available habitat in southern California for the species was lost by the 1990's. I do not know the status of the most recent WST surveys on critical areas like Camp Pendleton, but I do know that the Proctor Valley populations in San Diego County are facing challenges from new development plans. The combination of exceeding small Neb estimates, extensive habitat loss, the potential for disease and exotic predator impacts, and the inevitable edge effects that come from intense development and isolation of habitat patches makes me not agree with the conclusion that southern California *Spea hammondii* are in moderate or better condition throughout their range. I **strongly suggest that these data be re-evaluated, in consultation with key research labs and other agency and regulatory partners.**

I have also appended my more specific comments to the end of this letter, after my signature line, and I have attached my marked-up version of version 1 of the SSA. However, please note that I have not gone through the document and made corrections line-by-line. I started out trying to do so, but then decided that the SSA was not, in my mind, at a point where such word-by-word editing was the best use of my time.

Once again, I hope that you take these comments as what they are meant to be—my best and most honest assessment of this SSA as a scientist with decades of experience with the WST, the coauthor and leader of the ARSSC document for the CDFW, and the leader of the lab where essentially all of the molecular genetics work on the species has occurred. The USFWS has done an incredible job of pulling together a great deal of information, and I really do admire that work. However, there are also places for improvement before decisions are made, and I have tried to emphasize some of those places.

As always, if I can provide any additional information, do not hesitate to contact me by voice (530-902-3078) or email (brad.shaffer@ucla.edu).

Sincerely,

H. Bradley Shaffer
Distinguished Professor, Ecology and Evolutionary Biology &
Institute of the Environment and Sustainability
Director, La Kretz Center for California Conservation Science

SEE DETAILED COMMENTS, STARTING ON THE NEXT PAGE

My more specific notes are below. Note, some of these have already been mentioned above. Sorry about any repetition.

You need to cite and make use of:

Thomson, R. C., A. N. Wright and H. B. Shaffer. 2016. California Amphibian and Reptile Species of Special Concern (University of California Press 390 + *xv* pages)

You define:

Resiliency describes the ability of a species to withstand stochastic disturbance.

Redundancy describes the ability of a species to withstand catastrophic events; it's about spreading risk among multiple populations to minimize the potential loss of the species from catastrophic events. Redundancy is characterized by having multiple, resilient populations distributed within the species' ecological settings and across the species' range.

Representation describes the ability of a species to adapt to changing environmental conditions over time. It is characterized by the breadth of genetic and environmental diversity within and among populations. For WST, representation was measured by assessing the genetic diversity and unique ecological settings across the species' range. Representation is discussed at the species level.

I would say that representation should be discussed at the level at which migration and gene flow occur. That is definitely not at the species level, but rather at the local pond/poll level in most cases for WST.

Line 135, This distinction was further supported by electrophoretic analysis conducted by Sattler (1980; pp. 605, 608–609) and by allozymic and morphological analyses conducted by Wiens and Titus (1991, pp. 21, 25–26).

Also add that Neal, 2019 used RADseq data and also supported this species distinction, see figure 3.2, page 120. He also showed that S. intermontane is sister to S. hammondii.

Figure 1 legend is not correct. It says: *Figure 1: Genetic clustering (A) and Mitochondrial and Nuclear DNA analysis (B) of Spea hammondii showing separation between Northern and Southern occurrences at the Transverse Range (dotted line) (Adapted from Neal et al. 2018).* However, panel B is just mitochondrial DNA, while panel A is just nuclear.

Species description, see also Thomson et al 2016.

Line 168-169, to my knowledge there is a record at 4500 feet in San Diego County. However, it is a gross misstatement to say that the normal range of the species is anything like 0-4500 feet in the Sierra. Fisher and Shaffer (1996) show that the historical average distribution was more like 200 m elevation, and that current is roughly 350 m.

Line 170: *Spea hammondii* does not occur "throughout the Coast Ranges" as stated. It is restricted pretty much to flat areas in the Salinas Valley and associated inner coast range valleys. See most current map in Thomson et al., 2016, p. 131.

Lines 176-179, and map (figure 2) over-inflate both the historic range of the species and it's currently occupied range. See Thomson et al. 2016 for the most accurate map of both the range and locality information that I'm aware of (p 131).

Lines 262-264, you say "Although WST has been observed to inhabit and breed in wetlands altered or created by humans, survival and reproductive success in these pools have not been evaluated relative to that in unaltered natural pools." However, one set of ponds in Orange County, created specifically for WST, has been quite successful at Irvine Mesa. See Neal, 2019 (and Neal et al., in press in Journal of Heredity) demographically. Genetically they are quite depauperate, but they are used.

Lines 330-343: You mention that natural vernal pools are optimal, which I agree is often true. However, you fail to mention that over a large part of the range, all pools are often shared with CTS, *Ambystoma californiense.* When they are shared, *Spea* become prey for predatory CTS larvae and very few survive to metamorphosis. This is an important consideration when viewing CTS as an umbrella for *Spea* protection in the range of the northern WST clade. Morey published on this, see Morey 1998, or Ampbiaweb's species description.

Line 345 and beyond. The data cited for *S. multiplicate* may or may not be relevant to *S. hammondii*, and may differ between northern and southern clades. Given how opportunistic breeding is in the southern clade, from late autumn to mid-summer depending on rains, it seems impossible that they spend 8-10 months/year in a state of torpor. SE Arizona, the area cited here, is Sonoran desert, a very different habitat from relatively coastal southern California. Using this information for *S. hammondii* should be taken with a great deal of caution.

Figure 4. Please use a more accurate map of the range (see Thomson et al. 2016). That will change your calculations to some extent.

Lines 406-408: Again, stating, and working with this 8-10 months of dormancy should be taken with a very large grain of salt. The literature is essentially non-existent on this subject, but using Sonoran Desert data for areas that routinely receive much more precipitation and far milder temperatures is not appropriate.

Lines 436-438: Again, they cannot "speed up" metamorphosis. If they could, then the massive die-offs routinely seen when pools dry early would not occur. Time to metamorphosis has some flexibility and is temperature dependent to some extent. You should modify this language.

Line 462: you mean inbreeding, not interbreeding, I think.

Section 7.2.3 Abundance: you discuss data from Neal on effective population sizes. A general rule of thumb from the literature, which is only that—a general rule of thumb, is that census population sizes are often about 5-10 times effective sizes. Another very general rule of thumb is

the 50/500 rule (Franklin, 1980) which states that populations with effective population sizes of less than 50 are in immediate danger of extinction from inbreeding, while those less than 500 are in danger from longer-term effects of genetic drift. See http://assets.press.princeton.edu/chapters/s12_9242.pdf

This puts the Ne numbers of Neal into perspective, and should be taken very seriously. If you abide by the 50/500 rule at all, then no population of WST so far studied is even close to healthy.

Section 7.3.1, Representation. You correctly describe the major groups or regions identified by Neal (2019), and I agree that these should serve as guidelines for major management units. However, Neal (2019) also shows that variation among much smaller regions exists, and that in fact individual ponds may often be isolated genetically. See figure 3.8 (for southern clade) and figure 3.5 for northern clade. This point is particularly well explored in Neal (2019) chapter 2, which is now essentially in press in the Journal of Heredity. As Neal says (p 45-46 of Neal 2019), "The PCA (Fig. 2.3) revealed additional structure than was indicated by the optimal FastStructure results… Ultimately, most breeding sites, even those in very close geographic proximity, showed some genetic isolation, suggesting relatively restricted movement among sites and strong breeding philopatry." This says that, in terms of resilience and representation, individual breeding sites that are isolated from other such sites are the appropriate unit of conservation rather than just the large-scale units. That is where the low effective population size estimates become so important.

Section 8.1, Development. This relies extensively on Jennings and Hayes, 1994, rather than Thomson et al. 2016. No reason is given for this. This is about 30 years out of date, and development has progressed very rapidly during that time. Brehme et al. (2018, Brehme, C.S., Hathaway, S.A. & Fisher, R.N. An objective road risk assessment method for multiple species: ranking 166 reptiles and amphibians in California. *Landscape Ecol***33,** 911–935 (2018). https://doi.org/10.1007/s10980-018-0640-1) is totally ignored and not cited, but it places risk from road mortality for *S. hammondii* as **High**. I agree with the general conclusion that development is a huge issue for the species, and that it will continue to accelerate risk, population isolation and extinction risk. Also Davidson et al (2002) show that surrounding urban development, and surrounding agricultural development, are the primary predictors of *Spea hammondii* declines, at least as of 30 years ago. This is not mentioned in this section. It should be.

Section 8.3, line 616. Unclear what it means to be "out of balance" with native predators. However, as Morey has noted, interactions between native, endangered CTS and *S. hammondii* are such that during good rain years in locations where they overlap, CTS prey very heavily on spadefoot larvae. We certainly have noted this in the Purisima Land Bank in Santa Barbara County. The point is that if CTS mitigation lands "count" for *Spea* protection, this is a very important consideration.

Line 637, the statement "The extent at which nonnative predators is impacting WST populations is unknown." is an overstatement. Based on the text immediately above that line, including the references to Fisher and Shaffer (1996) showing that lower elevation populations have been eliminated, and the well-known absence of WST in the presence of any introduced fishes,

including mosquitofish, centrarchids, and others, any reasonable assessment of the literature would conclude that non-native predators are negatively impacting WST. There is also an unpublished thesis chapter by Robert Fisher that is finally being resurrected for publication showing the strong negative correlation between introduced fishes and native amphibians.

Lines 705-706, states "WST does not appear to be significantly impacted by any observed disease." However, the literature, including the recent summary by Thomson et al. (2016) clearly states that we simply do not know anything about disease. For example, Peralta et al. (2018) state that of all the pond-breeding amphibians in their Baja surveys, only *Spea hammondii* had no captures, and therefore no information. This is a case where a lack of information is not the same as a lack of impact. This is a mis-statement of the literature in my view.

Section 8.8, effects of climate change. See Wright et al. 2015.

Figure 7. Why do nonnative predators affect prey, but not WST themselves? That seems like a major oversight.

Lines 836-857. This is a critical part of the analysis, where habitat blocks of a relatively arbitrary size (40 acres, even though the calculations say 53 acres, and no reason for this 25% decrease is given or suggested), and 50 blocks is suggested to provide high habitat condition. I saw absolutely no justification for this number. Later, the document does say that more science is needed, but given the strikingly low effective population sizes associated with vernal pools in Orange county preserved lands, it is not clear why these numbers were used.

Lines 868-879: I would probably use the Ne estimates, rather than Fis estimates, to judge population health. They are less ambiguous to interpret. (And by the way, Fis is not measured as a percentage, as seems to be the case in the SSA document.) This is done in lines 888 – 903. However, for completely arbitrary reasons, "Based on comparison to other similar species, low condition was determined to be less than 20 breeders in a population, moderate condition 20 to 50 breeders in a population, and high condition more than 50 breeders in a population. The high condition falls within the measure of effective population size for other pond-breeding amphibians including black toad, *(Bufo exsul*), California tiger salamander, Yosemite toad, and California red-legged frog (Wang 2009, pp. 3852–3853; Wang *et al*. 2011, p. 914–915, 918; Wang 2012, pp. 1033–1034; Richmond *et al*. 2013, p. 815)." However, **all of these species are endangered/special concern**, and so this is essentially saying that if WST have declined roughly as much as other endangered, listed amphibians, then they are deemed to be in reasonable demographic health? This makes very little sense. Again, the standard in conservation biology (which is at least based on some theory) is Franklin's 50/500 rule, as noted above. By that criterion, Ne < 50 is critically low, whereas here it is interpreted as "high condition". I see no justification for this.

Species Status Assessment Report
for
Western Spadefoot
(*Spea hammondii*)
Version 1.0

Photo provided by Chris Brown (U.S. Geological Survey)

Month, 2020

Sacramento Fish and Wildlife Office

Acknowledgements

This document was prepared by the U.S. Fish and Wildlife Service's Sacramento Field Office with assistance from the Pacific Southwest Regional Office and the Western Spadefoot Toad Species Status Assessment Team (Carlsbad Field Office and Ventura Field Office). Additionally, valuable peer reviews of a draft of this document were provided by XXXXX, and other partners. We appreciate their comments, which resulted in a more robust status assessment and final report.

Recommended Citation:

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

EXECUTIVE SUMMARY

The U.S. Fish and Wildlife Service (Service) was petitioned to list the western spadefoot toad as endangered or threatened under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531–1543) (Act), in April 2012 by the Center for Biological Diversity. In July 2015, the Service published a 90-day finding that the petition presented substantial scientific or commercial information indicating that listing may be warranted for the western spadefoot toad (80 FR 37568, July 1, 2015). Therefore, a review of the status of the species was initiated to determine if the petitioned action is warranted. Based on the status review, the Service will issue a 12-month finding for the western spadefoot toad.

This report summarizes the results of the Species Status Assessment (SSA) completed for the western spadefoot toad. To assess the species' viability, we used the three conservation biology principles of resiliency, redundancy, and representation (together, the 3 Rs). These principles rely on assessing the species at an individual, population, and species level in order to determine whether the species can maintain its persistence into the future and avoid extinction by having multiple resilient populations distributed widely across its range. The western spadefoot toad occurs throughout its known historical range associated with vernal pools and upland habitat. There are two genetically distinct, allopatric clades that show no evidence of interbreeding divided by the Transverse Range in California. In this assessment we refer to them as the northern western spadefoot toad clade, and the southern western spadefoot toad clade. For this SSA, western spadefoot toads were assessed at a regional level as a surrogate to the population level separated by 14 unique vernal pool regions. Each vernal pool region likely serves more as a metapopulation for western spadefoot toad, but each region is unique in its biological communities and the abiotic features, such as soils and geomorphology, that make up the vernal pools within the region. For western spadefoot toad, resiliency was measured by assessing the individual needs of aquatic breeding pools, underground burrows, seasonal rains, and small invertebrate prey, as well as the population needs of reproduction, dispersal, and abundance.

Our analysis of the past, current, and future influences on the western spadefoot toad needs for long term viability revealed that there are several factors that contribute to the current condition and pose a risk to future viability of the species. These risks include development, overabundance of vegetation, nonnative predators, drought, noise disturbance, and effects of climate change. Under current conditions, we predict the northern western spadefoot toad clade has two regions with high resiliency, six regions with moderate resiliency, one region with low-moderate resiliency, and one region with low resiliency. The northern western spadefoot clade current has redundancy, the ability to withstand a catastrophic event, with multiple populations distributed across the landscape with a moderate to high current probability of persistence. Populations exist throughout a range of ecological settings with some genetic diversity currently giving the northern western spadefoot clade representation. We predict the southern western spadefoot toad clade has one region with moderate-high resiliency, two regions with moderate resiliency, and one region where the resiliency is unknown. The southern western spadefoot clade current has redundancy, the ability to withstand a catastrophic event, with multiple

populations distributed across the landscape with a moderate to high current probability of persistence. Populations exist throughout a range of ecological settings with some genetic diversity currently giving the species representation.

The influences to viability described above play a large role in the future resiliency, redundancy, and representation of the western spadefoot toad. If regions lose resiliency (i.e., the ability to support multiple breeding pools), they are more vulnerable to extirpation, with resulting losses in representation and redundancy. The rates at which future stressors may act on specific regions and the long-term efficacy of current conservation actions (i.e., conservation strategies) are unknown. Therefore, we forecasted how possible future conditions could impact the resiliency, redundancy, representation, and overall condition of the western spadefoot toad. In order to assess future condition, we have developed three future plausible scenarios. The following is a description of the three future scenarios, the status of the western spadefoot toad when analyzed under each scenario, and a summary of the assumptions we made under each scenario:

Scenario 1: Factors that are currently having an influence on western spadefoot toad regions increase in severity. Under Scenario 1, we project the northern western spadefoot toad clade would have two regions with moderate resiliency, three regions with low-moderate resiliency, and five regions with low resiliency. We project the southern western spadefoot clade to have two regions with low-moderate resiliency, one region with low resiliency, and one region where the resiliency is unknown. Both the northern and southern western spadefoot clades would have reduced redundancy and representation from current condition, with multiple populations having a low probability of persisting in the future. Assumptions made under Future Scenario 1 include:

1. Development would likely increase on the landscape given projected increases in human population, which would decrease the availability of aquatic breeding pools and underground burrows for individuals, negatively impacting the populations needs of reproduction, dispersal, and abundance.
2. Overabundant vegetation and nonnative predators would likely increase from lack of proper management which would decrease western spadefoot toad ability to fully utilize aquatic breeding pools, negatively impacting the population needs of reproduction and abundance.
3. The effects of climate change would result in a warmer and dryer future, with an increase in extended periods of drought decreasing seasonal rains, which would then decrease the availability of aquatic breeding pools, negatively impacting reproduction, dispersal, and abundance.

Scenario 2: Factors that are currently having an influence on western spadefoot regions continue at the current trend into the future. Future scenario 2 assesses the current conservation efforts continuing into the future. Under Scenario 2, we project the northern western spadefoot toad clade would have one region with high resiliency, one region with moderate-high resiliency, six regions with moderate resiliency, one region with low-moderate resiliency, and one region with low resiliency. We project the southern western spadefoot toad clade would have two regions with moderate resiliency, one region with low-moderate resiliency, and one region where the

resiliency is unknown. The representation and redundancy for both the northern and southern clades would likely only be slightly reduced from current condition, with a majority of the regions likely to persist in the future. Assumptions made under Future Scenario 2 include:

1. Development would likely increase, but would avoid essential vernal pool habitat due to other listed species that occur within the habitat, having similar impacts as the current condition on aquatic breeding pools and underground burrows.
2. The management of overabundant vegetation and nonnative predators would continue at current levels, having similar impacts as current condition to aquatic breeding pools.
3. The effects of climate change would result in a warmer and dryer future. Although droughts are expected to increase into the future under this scenario, the assumption is that they would occur periodically and allow time in between drought years for average rain years. In this scenario there will likely be reduced seasonal rains in general, reducing the pool duration of aquatic breeding pools, and negatively impacting reproduction, dispersal, and abundance.

Scenario 3: Similar to the continuation scenario, but with decreased greenhouse gas emissions, reducing the effects of climate change. Under Scenario 3, we project the northern western spadefoot clade would have two regions with high resiliency, six regions with moderate resiliency, one region with low-moderate resiliency, and one region with low resiliency. We project the southern western spadefoot clade to have one region with moderate-high resiliency, two regions with moderate resiliency, and one region where the resiliency is unknown. The representation and redundancy for both the northern and southern clades would likely be similar to current condition, with a majority of the regions likely to persist in the future. Assumptions made under Future Scenario 3 include:

1Development would likely increase, but would avoid essential vernal pool habitat due to other listed species that occur within the habitat, having similar impacts as the current condition on aquatic breeding pools and underground burrows.

2The management of overabundant vegetation and nonnative predators would continue at current levels, having similar impacts as current condition to aquatic breeding pools.

3The effects of climate change would result in only a slightly warmer and dryer future, within the range of adaptability for the western spadefoot toad having only minor impacts on seasonal rains and aquatic breeding pools.

Over the next 30–40 years, we believe Scenario 2 is the most likely to occur. We believe this scenario is the most likely because threats are likely to continue at the current trend with similar conservation efforts that are currently taking place. We believe Scenario 1 is less likely to occur, but is plausible to consider in the event of a future where more extended periods of drought take place. We believe Scenario 3 is less likely to occur given the current trajectory of greenhouse gas emissions.

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1.0 INTRODUCTION

We, the U.S. Fish and Wildlife Service (Service), are reviewing the status of the western spadefoot toad (WST; *Spea hammondii*) in response to a petition (CBD 2012, entire) to list the species under the Endangered Species Act of 1973, as amended (Act). As part of this process, we are using an integrated and conservation-focused analytical approach, the Species Status Assessment (SSA), to assess the species' biological status for the purpose of informing our decision under the Act. The initial product of this process is this document, the SSA Report. As envisioned by our guidance document, the Species Status Assessment Framework (Service 2016, entire), an SSA Report begins with a compilation of the best information available on the species (taxonomy, life history, and habitat) and its ecological needs at the individual, population, and/or species levels based on how environmental factors are understood to act on the species and its habitat. Next, an SSA Report describes the current condition of the species' habitat and demographics, and the probable explanations for past and current changes in abundance and distribution within the species' ecological settings (that is, areas representative of geographic, genetic, or life history variation across the range of the species). Lastly, an SSA Report forecasts the species' response to plausible future scenarios of environmental conditions and conservation efforts (Rowland *et al*. 2014, entire). Overall, an SSA Report uses the conservation biology principles of resiliency, redundancy, and representation (collectively known as the "3Rs" (Shaffer and Stein 2000, pp. 308–311)) as a lens through which we can evaluate the current and future condition of the species (Smith *et al*. 2018, entire). Ultimately, an SSA Report characterizes a species' ability to sustain populations in the wild over time based on the best scientific understanding of current and future abundance and distribution within the species' ecological settings.

An SSA Report is, in essence, a summary of the information about a species and, simultaneously, a biological risk assessment to aid decision makers who must use the best scientific and commercial information available to make policy-guided decisions. The SSA Report provides decision makers with a scientifically rigorous characterization of the species' biological and conservation status, focusing on the likelihood of whether the species will sustain populations within its ecological settings while also explicitly acknowledging uncertainties in that characterization. The SSA Report does not result in a decision directly, but it provides the best scientific and commercial information available for comparison to policy standards to guide decisions under the Act.

1.1 Previous Federal Actions

On July 11, 2012, we received a petition from the Center for Biological Diversity (CBD; CBD 2012, entire), requesting that 53 species of amphibians and reptiles, including WST, be listed as endangered species or threatened species and that critical habitat be designated for those species under the Act. On July 1, 2015, we published a 90-day finding in the *Federal Register* affirming that the petition presented substantial scientific or commercial information indicating that the petitioned action may be warranted for the western spadefoot toad (80 FR 37568–

37579). Our conclusion was based on information in the available literature suggesting that there may be threats to the species from (1) habitat alteration and destruction; (2) disease or predation; (3) inadequacy of existing regulatory mechanisms; and (4) other factors including non-native species predation and competition, and climate change. As part of that finding, we solicited information from governmental agencies, Native American Tribes, the scientific community, industry, and any other interested parties, on various aspects of the species' biology; any potential threats to the species, including possible effects from climate change; any past and ongoing conservation measures; and any information that may help us designate critical habitat for the species, should we determine that listing the species is warranted and that designating critical habitat for the species is prudent and determinable. In addition, although the WST is not listed as an endangered or threatened species under the Act, we did include the species within our final Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, entire). The recovery plan outlines conservation and management actions to be taken to help conserve the western spadefoot toad and its habitat. If the Service determines the species is warranted as threatened or endangered under the Act, a proposed rule will be published in the *Federal Register* with appropriate opportunities for public input.

1.2 California State Listing Status

The State of California currently does not include the WST as a state-listed threatened or endangered species under the California Endangered Species Act (CESA). The California Department of Fish and Wildlife (CDFW), on its Special Animals List, considers the WST as a "Species of Special Concern" with a global and state ranking as a vulnerable species (G3 and S3—at moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors) (CDFW 2019, entire).

2.0 METHODOLOGY

This document draws scientific information from resources such as primary peer-reviewed literature, reports submitted to the Service and other public agencies, species occurrence information in Geographic Information Systems (GIS) databases, and expert experience and observations. It is preceded by and draws upon analyses presented in other Service documents including the 90-day finding (80 FR 37568 37579) and the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, entire). Finally, we coordinated closely with our partners engaged in ongoing WST research and conservation efforts including wildlife professionals from Federal and State agencies, universities, and private entities. This assures consideration of the most current scientific and commercial information available regarding the status and conservation of the western spadefoot toad. Throughout this report, we refer specifically to information on the WST. When supporting biological information is not specifically available for WST or is general in nature and applies to one or more of the other spadefoot toad species outside of range of WST, we refer to that information as pertaining to "spadefoot toad(s)" or it is otherwise noted.

2.1 Analytical Framework

The SSA framework (Service 2016) summarizes the information assembled and reviewed by the Service, incorporating the best scientific and commercial data available, to conduct an in-depth review of a species' biology and threats, evaluate its biological status, and assess its resources and conditions needed to maintain long-term viability. For the purpose of the assessment, we define the viability of the WST as its ability to sustain populations in the wild currently and into the future for approximately 30–40 years. This timeframe represents estimates of mid-century climate projections and human population and development projections for California. Using the SSA framework, we consider what the species needs to maintain viability through an assessment of its resiliency, redundancy, and representation (Wolf *et al*. 2015, entire; Smith *et al*. 2018, entire). This SSA Report documents the results of our analysis for the WST and serves as the biological underpinning of the Service's forthcoming decision on whether the species warrants protection under the Act.

Throughout the assessment, the SSA uses the conservation biology principles of resiliency, redundancy, and representation as a lens to evaluate the current and future condition of the species. The term of resiliency, redundancy, and representation are defined below.

Resiliency describes the ability of a species to withstand stochastic disturbance. Resiliency is positively related to population size and growth rate and may be influenced by connectivity among populations. Generally speaking, populations need abundant individuals within habitat patches of adequate area and quality to maintain survival and reproduction in spite of disturbance. For WST populations, resiliency was measured by assessing the individual needs of small invertebrate prey, aquatic breeding pools, underground burrows, and seasonal rains, as well as the population needs of reproduction, dispersal, and survival. Resiliency is discussed at the population level.

Redundancy describes the ability of a species to withstand catastrophic events; it's about spreading risk among multiple populations to minimize the potential loss of the species from catastrophic events. Redundancy is characterized by having multiple, resilient populations distributed within the species' ecological settings and across the species' range. For WST, redundancy was measured by assessing the number and location of resilient populations across the species' range. Redundancy is discussed at the species level.

Representation describes the ability of a species to adapt to changing environmental conditions over time. It is characterized by the breadth of genetic and environmental diversity within and among populations. For WST, representation was measured by assessing the genetic diversity and unique ecological settings across the species' range. Representation is discussed at the species level.

3.0 SPECIES BACKGROUND

3.1 Taxonomy

Spadefoot toads are commonly considered members of the family Pelobatidae (Stebbins and McGinnis 2012, pp. 154–158; California Herps 2019). However, some resources have recently reclassified spadefoot toads to the family Scaphiopodidae (AmphibiaWeb 2019, unpaginated; Santos-Barrera *et al*. 2018, unpaginated). Two closely related genera of spadefoot toads have been recognized, *Scaphiopus* and *Spea* (Wiens and Titus 1991, p. 21). Western spadefoot toads are officially recognized within the genus *Spea* (Crother 2017, p. 23)), although many literature sources reference *Scaphiopus* as the genus. Species relationships within *Spea* have been difficult to define due to morphological homogeneity among species. At least four species in the genus *Spea* are currently recognized, WST (*Spea hammondii*), plains spadefoot (*Spea bombifrons*), Great Basin spadefoot (*Spea intermontana*), and Mexican spadefoot (*Spea multiplicata*) (Wiens and Titus 1991, p. 21; AmphibiaWeb 2019). The western spadefoot toad (*Spea hammondii*) was first described and named by Spencer F. Baird in 1859, from a specimen collected by Dr. J.F. Hammond near Redding, California (Baird 1859, p. 12). At that time up into the latter part of the 20th century, the species was regarded as having a broad geographic range from California to western Texas and Oklahoma with a distributional gap in the Mojave Desert of California (Storer 1925, p. 148). However, Brown (1976, p. 759) identified morphological, vocalization, and reproductive differences between eastern (Arizona eastward) and western (California and Baja California populations), justifying species recognition for each. The California population retained the name *Spea hammondii* (with a common name of western spadefoot toad (WST)) while the remainder of the populations were designated as *Spea multiplicata* (southern spadefoot toad). This distinction was further supported by electrophoretic analysis conducted by Sattler (1980; pp. 605, 608–609) and by allozymic and morphological analyses conducted by Wiens and Titus (1991, pp. 21, 25–26).

3.2 Genetics

Recent genetic work has found that the northern and southern distributions of WST, separated by the Transverse Range in California, and are two genetically distinct, allopatric clades that show no evidence of interbreeding, and are likely two separate species (Neal *et al*. 2018, p. 937–943; Neal 2019, p. 114; Figure 1). However, because separation of the species has not been officially accepted by the scientific community, for our purposes in this SSA, we are assessing the two clades (Northern Clade and Southern Clade) as separate entities that are a part of the single species *Spea hammondii*.

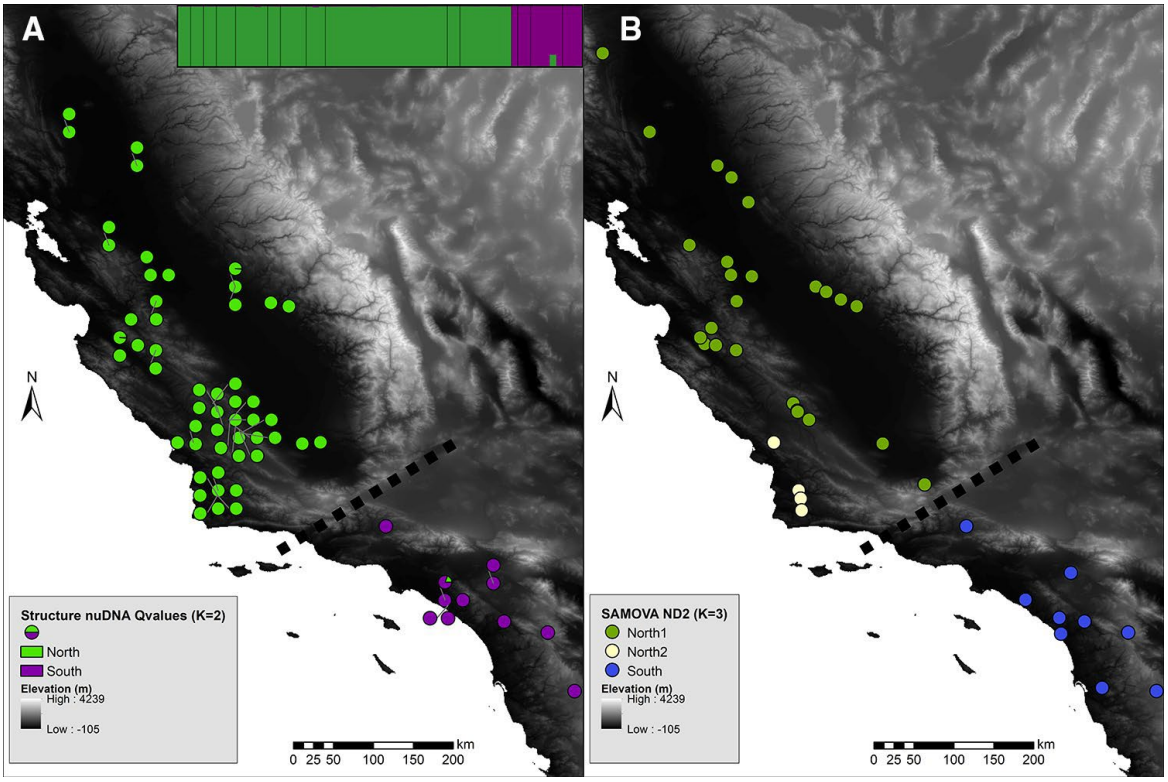

Figure 1: Genetic clustering (A) and Mitochondrial and Nuclear DNA analysis (B) of Spea hammondii showing separation between Northern and Southern occurrences at the Transverse Range (dotted line) (Adapted from Neal et al. 2018).

3.3 Species Description

The WST ranges in size from 3.8 to 6.3 centimeters (cm) (1.5 to 2.5 inches (in.)) snout to vent length (Stebbins and McGinnis 2012, p. 156). They are dusky green or gray on their backs and often have four irregular light-colored stripes, with the central pair of stripes sometimes distinguished by a dark, hourglass-shaped area. The skin tubercles (small, rounded protuberances) are sometimes tipped with orange or are reddish in color, particularly among young individuals (Storer 1925, pp. 148–149; Stebbins 1985, p. 57; Stebbins and McGinnis 2012, p. 156). The iris of the eye is usually a pale gold. The abdomen is white in color without any markings. Spadefoot toads have a wedge-shaped, glossy black "spade" on each hind foot, used for digging. The call of WST is hoarse and snore-like, and lasts between 0.5 and 1.0 second (Stebbins 1985, p. 57; Stebbins and McGinnis 2012, p. 156). Spadefoot toads are distinguished from the true toads (genus *Bufo*) by their cat-like eyes (their pupils are vertically elliptical in bright light but are round at night), the single black sharp-edged "spade" on each hind foot, teeth in the upper jaw, and rather smooth skin (Stebbins 1985, p. 56; Stebbins and McGinnis 2012, p. 154). The parotid glands (large swellings on the side of the head and behind the eye) are absent or indistinct on spadefoot toads (Stebbins and McGinnis 2012, p. 154). There are currently no known morphological differences between the northern and southern WST clades.

4.0 RANGE AND DISTRIBUTION

The historical range of WST is from the vicinity of Redding in Shasta County, California, southward to northwestern Baja California, Mexico (Stebbins and McGinnis 2012, p. 157). They have been found at sites from sea level up to 1,385 meters (m) (4,500 feet (ft)) in the Sierra Nevada foothills (Stebbins and McGinnis 2012, p. 157). In California, WST ranges throughout the Central Valley, and throughout the Coast Ranges and the coastal lowlands from San Francisco Bay southward to Mexico (Stebbins and McGinnis 2012, p. 157). In Mexico, WST occurs from the international border to approximately El Rosario near Mesa de San Carlos, but may occur even farther south in some of the larger arroyos (McPeak 2000, p. 15; Grismer 2002, pp. 84–85; iNaturalist 2020, unpaginated). Genetics from the northern and southern populations of WST, divided by the Transverse Range, indicate two genetically distinct, allopatric clusters that likely make up two species (Neal *et al*. 2018, pp. 937–938; Neal 2019, p. 114). Figure 2 displays the range of the WST (map projections from CDFW's California Wildlife Habitat Relationships WST map in California, and International Union for Conservation of Nature's projection), divided into the northern and southern WST clades.

Currently, the species is patchily distributed throughout its historic range. However, the WST is thought to be extirpated throughout most of the lowlands of southern California and from many historical locations within the Central Valley (Stebbins 1985, p. 67; Jennings and Hayes 1994, p. 96). In the northern WST range, the largest declines have been observed in the Sacramento Valley and San Joaquin Valley, while declines have been more modest in the Coast Ranges (Fisher and Shaffer 1996, p. 1387). A species distribution model for the northern WST range (north of Santa Barbara) found the areas predicted to have suitable habitat are patchily distributed along the foothills surrounding the Central Valley and in the southwestern quarter of the northern WST range including the Salinas Valley (Rose *et al*. 2020, entire).

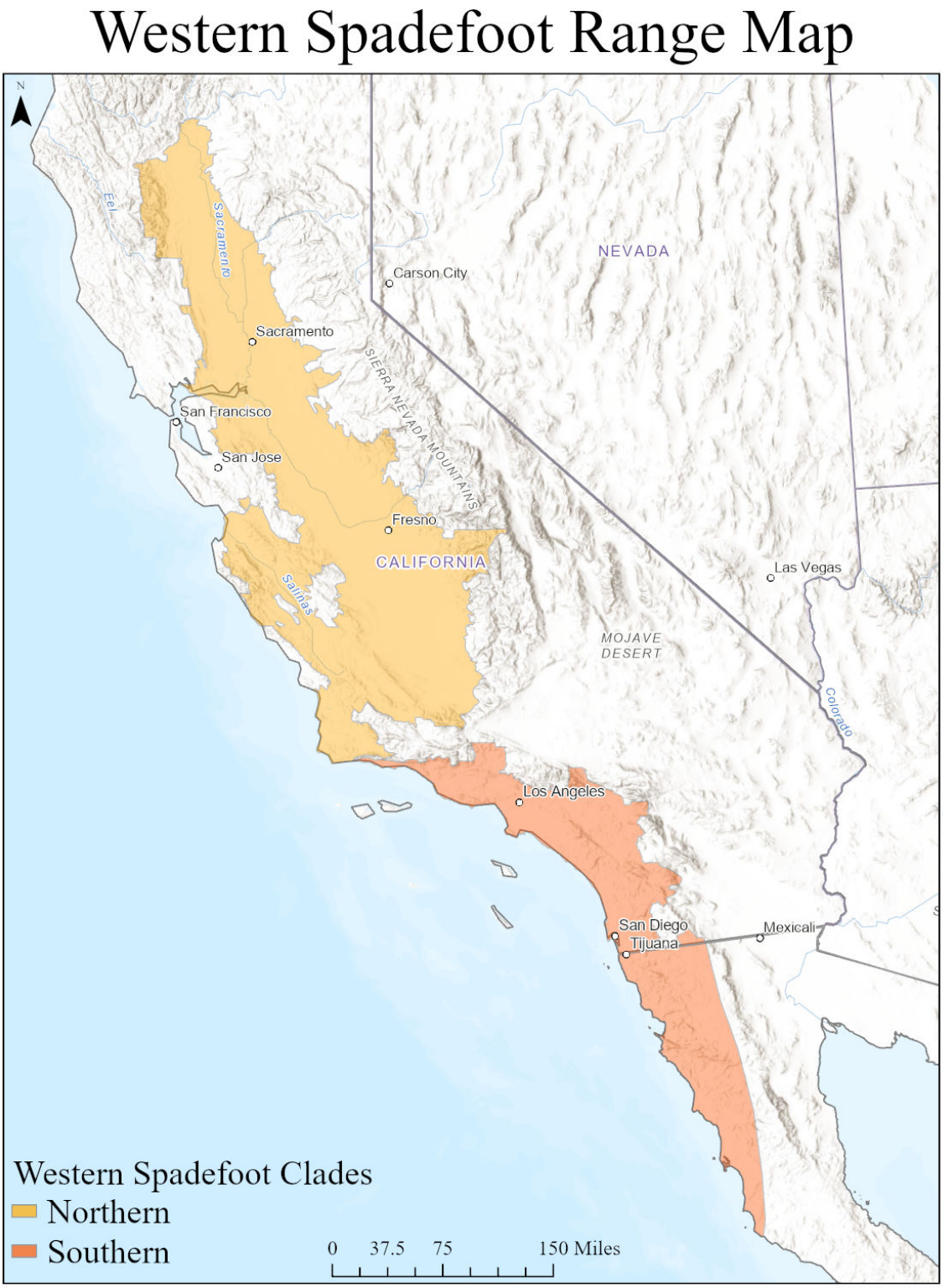

Figure 2: Range map projections for western spadefoot toad using the CDFW's California Wildlife Habitat Relationships (CWHR) and International Union for Conservation of Nature

(IUCN). The yellow region represents the portion of the range considered to be the northern western spadefoot clade and the orange region represents the portion of the range considered to be the southern western spadefoot clade.

5.0 LIFE HISTORY

Western spadefoot toads are primarily terrestrial, and inhabit underground burrows. Western spadefoot toads typically burrow approximately 1 m (3 ft) below ground during the dry season to avoid temperature extremes and desiccation (Stebbins and McGinnis 2012, p. 157). During a majority of their life cycle, WST remain in a torpor state in underground burrows in upland areas surrounding their aquatic (breeding) habitat (Ruibal *et al*. 1969, p. 581). Spadefoot toads emerge from their burrows to forage and breed in ephemeral pools following seasonal rains in winter and spring (Dimmitt and Ruibal 1980a, p. 21; Jennings and Hayes 1994, p. 94). Emergence is likely related to a sound or vibration cue from the rain (Dimmitt and Ruibal 1980a, p. 26). Most surface activity is nocturnal, presumably to reduce water loss (Morey 2000, p. 1). Depending on temperature and annual rains, WST breeding and oviposition occurs from January to May, most often in temporary pools and drainages from winter or spring rains (Stebbins 1985, p. 57). It is unknown if individuals are able to breed consecutive breeding seasons or even more than once during a breeding season. Laboratory experiments have found that water temperatures in pools must be between 9 and 30 degrees Celsius (°C) (48–86 degrees Fahrenheit (°F) for WST embryos to successfully develop (Brown 1966, p. 746). Field observations suggest breeding calls are audible at great distances and serve to bring individuals together at suitable breeding sites (Stebbins 1985, p. 57). During breeding, highly vocal aggregations of more than 1,000 individuals may form (Jennings and Hayes 1994, p. 94). Amplexus, the copulatory embrace by males, is pelvic (Stebbins 1985, p. 56). Females deposit eggs in numerous, small, and irregular cylindrical clusters of 10 to 42 eggs, with an average of 24 eggs (Storer 1925, p. 157; Stebbins and McGinnis 2012, p. 156). Eggs range in size from 1.0–1.7 millimeter (mm) (0.04 to 0.07 in) and are light olive-green or sooty on top and light colored on the bottom (Stebbins and McGinnis 2012, p. 156). The egg clusters are laid in two jelly envelopes with an outer diameter of 3.2 to 5.7 mm (0.1 to 0.2 in) (Stebbins and McGinnis 2012, p.156). Females may lay 300–500 eggs in one season (Morey 2005, p. 515). Eggs are deposited on plant stems or pieces of detritus in temporary rain pools, or sometimes in pools of ephemeral stream courses (Storer 1925, p. 156; Stebbins and McGinnis 2012, p. 156). Eggs hatch in 0.6 to 6 days depending on the temperature (Brown 1967, p. 747). Field observations have found that at relatively high-water temperatures, approximately 21 °C (70 °F), WST eggs may fail to develop, possibly due to a fungus that thrives in warmer water temperatures and invades toad eggs (Storer 1925, p. 158; Brown 1967, p. 746). Larval (tadpole) development can be completed in 3 to 11 weeks depending on food resources and temperature, but must be completed before the pools dry (Burgess 1950, p. 49–51; Feaver 1971, p. 53; Morey 1998, p. 86). Larval development occurs more rapidly in drying pools (Feaver 1971, p. 53; Morey 1998, pp. 86–89). The turbid water sometimes found in the aquatic pools provide cover for larvae (Morey 2005, p. 515). Metamorphosing larvae may leave the

water while their tails are still relatively long (greater than 1 cm (0.4 in.)), and move toward suitable terrestrial burrowing habitat (Storer 1925, p. 159).

Age of sexual maturity is unknown, but considering the relatively long period of subterranean dormancy (8 to 10 months), individuals may require at least 2 years to mature (Jennings and Hayes 1994, p. 94). Based on laboratory studies, increased food availability may cause males to reach sexual maturity sooner (~one year from metamorphose) than males that receive lower amounts of food (Morey and Reznik 2001, pp. 510, 513, 515). Regardless of food levels, females have not been found to reach sexual maturity by one year based on the presence/absence of eggs, therefore females likely do not reach sexual maturity until the second breeding season after metamorphosis (Morey and Reznik 2001, pp. 510, 513, 515). Longevity of WST is unknown, but skeletochronology from Couch's spadefoot toads (*Scaphiopus couchii*) estimates the female lifespan to be approximately 13 years and the male lifespan to be approximately 11 years. Figure 3 displays the known life history of WST. There are currently no known life history differences between the northern and southern WST clades.

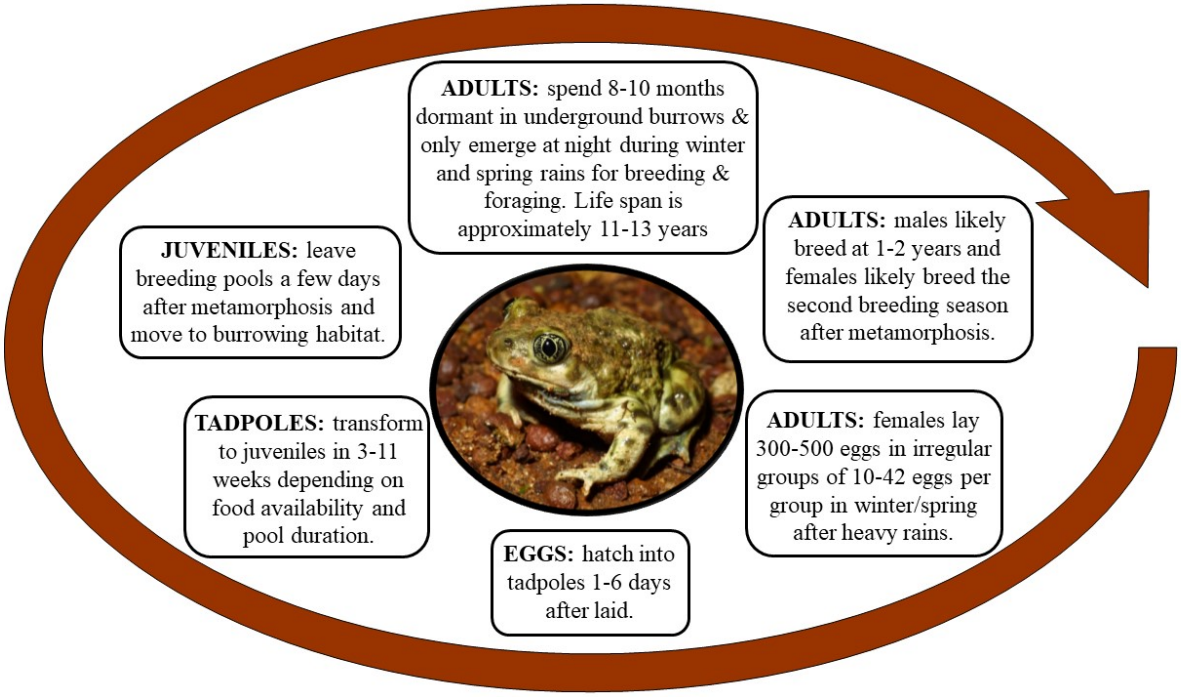

Figure 3: Western spadefoot toad life history diagram.

6.0 HABITAT

Western spadefoot toad habitat is primarily open treeless grasslands, scrub, or mixed woodland and grassland where aquatic breeding habitat is available (Stebbins and McGinnis 2012, p. 157). Western spadefoot toads require both aquatic and terrestrial habitat components in close proximity, within the dispersal distance of the species (See Dispersal Habitat section), to meet all life history requirements. Spadefoot toads are primarily terrestrial, and require upland

habitats for feeding and for constructing burrows for long dry-season dormancy (See Life History section). Aquatic habitat is used for breeding and developing larvae and typically includes temporary vernal pools, sand or gravel washes, and small streams that are often seasonal (Stebbins and McGinnis 2012, p. 157). However, eggs and larvae of WST have been observed in a variety of permanent and temporary wetlands, both natural and altered, including rivers, creeks, artificial ponds, livestock ponds, sedimentation and flood control ponds, irrigation and roadside ditches, roadside puddles, tire ruts, and borrow pits, indicating a degree of ecological plasticity (CNDDB 2019). Although WST has been observed to inhabit and breed in wetlands altered or created by humans, survival and reproductive success in these pools have not been evaluated relative to that in unaltered natural pools. Temporary wetlands may be optimal aquatic breeding habitat due to reduced abundance of both native and nonnative predators, many of which require more permanent water sources (Jennings and Hayes 1994, p. 96; Stebbins and McGinnis 2012, p. 158). Although climate tends to differ throughout the range of WST that may cause minor differences in habitat between the northern and southern species, there are currently no identified differences in habitat characteristics between the two species. See **Individual Needs** section below for more information on aquatic and terrestrial habitat for WST.

6.1 Dispersal Habitat

Little is known regarding the land surface types WST are able to move across or distance that WST may range from aquatic resources for dispersal. A study looking at movement of WST individuals in an Orange County population found that the mean distance moved away from breeding pools was 40 m (±37) (131 ft), with the longest movement of an individual being 262 m (860 ft) (Baumberger 2013, p. 14). Research on amphibian conservation suggests that average habitat utilization falls within 368 m (1,207 ft) of aquatic habitats (Semlitsch and Bodie 2003, p. 1221).

7.0 SPECIES NEEDS

In this section we synthesize the information from the preceding sections to highlight the overall needs of the WST. We start with the individual level needs, then move to the population level, and then finally to the species level. Needs for each level addresses that level; for example, if the needs of the species cannot be met, the species condition will decline and may eventually go extinct. The needs are cumulative across levels. That is, if the needs of an individual cannot be met, then that individual will not survive, and as such, it will not contribute to a population. Therefore, if the needs of individuals in a population are not met over time, the population will not persist. Similarly, if the needs of a population cannot be met, that population will not persist, and in turn, it will not contribute to the species persistence. Thus, failure to meet individual-level or population-level needs (on a large enough scale) can ultimately lead to species extinction as well.

If the needs of individuals in a population are being met, allowing for an adequate population size and with sufficient rate of growth, then that population is resilient. The number

of resilient populations and their distribution (and their level of connectivity) will determine the species' level of redundancy. Similarly, the breadth of genetic or environmental diversity within and among populations will determine the species' level of representation. Thus, for the species to sustain populations in the wild over time, the populations need to be able to withstand stochastic events (to have resiliency), and the species' as a whole needs to be able to withstand catastrophic events (to have redundancy) and to adapt to changing environmental conditions (to have representation). There are currently no known differences in species needs between the northern and southern WST clades, therefore the species needs identified in this SSA apply to both.

7.1 Individual Needs

We assessed the best available information to identify the resource needs to support individual fitness at all life stages for WST. For the purpose of this SSA, the needs that were considered most significant include aquatic breeding pools, underground burrows, seasonal rains, and small invertebrate prey. Table 1 summarizes the individual resource needs of WST by life stage and resource function.

Table 1: Individual needs for all life history stages of the western spadefoot toad.

Individual Need	Life Stage	Resource Function
Aquatic Breeding Pools	Eggs, Tadpoles, Juveniles, Adults	Breeding, Feeding, Sheltering
Underground Burrows	Juveniles, Adults	Sheltering
Seasonal Rains	Adults	Breeding, Feeding
Small Invertebrate Prey	Tadpoles, Juveniles, Adults	Feeding

7.1.1 Aquatic Breeding Pool

Vernal pools are the primary aquatic breeding environment for WST (Storer 1925, p. 153). Vernal pools are ephemeral wetland habitat that form in areas where rainwater is restricted from downward percolation due to an impermeable surface or subsurface layer (Keeler-Wolf *et al*. 1998, p. 9). The restrictive layer may be a hardpan, clay pan, or bedrock depending on geographic region and local geology. The pools fill during the rainy season, with inundation varying annually depending on the amount of rainfall. Typical pond depth is 2–48 cm (0.8–19 in) (Barbour *et al*. 2007, p. 23). Most vernal pools are concentrated on the alluvial terraces extending west from the base of the Sierra Nevada foothills, and elevated terraces adjacent to stream and slough channels within the Great Valley basin, basin rim, and margins of the Sacramento-San Joaquin Delta (Holland 1978, pp. 3–5). In the central Coast Range vernal pools are known from Los Angeles County north to Contra Costa County (Service 2005, pp. I-9–I-10, I-12). In southern California (Orange, Riverside, and San Diego Counties) and northern Baja California, Mexico, pools occur either on gently sloping mesas standing above the primary drainages or in valleys at the low end of a watershed (Bauder and McMillan 1996, p. 56; Service 1998, pp. 1–20). Although vernal pools are considered the primary aquatic breeding habitat, eggs and larvae of WST have been observed in a variety of permanent and temporary wetlands, both natural and altered, including rivers, creeks, artificial ponds, livestock ponds, sedimentation and flood control ponds, irrigation and roadside ditches, roadside puddles, tire ruts, and borrow pits, indicating a degree of ecological plasticity (CNDDB 2019). Neither rates of survival nor reproductive success have been documented to fully understand the use and relative importance of altered habitats.

In order for WST to utilize the aquatic breeding pools, water temperatures must be between 9 and 30 °C (48–86 °F) (Brown 1966, p. 746). Eggs are laid in the aquatic breeding pools and larvae are solely aquatic until metamorphosis occurs 3–11 weeks after hatching, depending on food availability and pool duration. Larvae are able to increase their rate of metamorphosis to some extent to avoid desiccation from drying pools (Burgess 1950, p. 49–51; Feaver 1971, p. 53; Morey 1998, p. 86). Turbid water sometimes found in vernal pools allows for protection of eggs and larvae from predators (Morey 2005, p. 515). Since vernal pools are ephemeral, they may be optimal aquatic breeding habitat due to reduced abundance of both native and nonnative predators, many of which require more permanent water sources (Jennings and Hayes 1994, p. 96; Stebbins and McGinnis 2012, p. 158). The aquatic breeding pools are necessary for WST adults to disperse and reproduce, and for eggs and larvae to survive.

7.1.2 Underground Burrows

Western spadefoot toads are almost completely terrestrial and enter water only to breed. During a majority of their life cycle, WST are dormant and estivate (summer dormancy) and remain in a torpor state in underground burrows in upland areas surrounding their aquatic (breeding) habitat (Ruibal *et al.* 1969, p. 581). This is a behavioral mechanism used by some amphibians to maintain moisture, slow metabolism, and avoid the excessive heat and dry period occurring from late spring through early fall when resources are limiting or environmental conditions are not favorable (Withers and Cooper 2019, p. 952). Research from spadefoot toads in southeastern Arizona (*Spea multiplicata*) has found that they remain dormant for 8 to 10 months in burrows 20–90 cm deep; during the approximate two-month active season, when toads emerge at night from seasonal rains, they are found in more shallow underground burrows of approximately 2–10 centimeters (Ruibal *et al*. 1969, pp. 571, 575–583). As stated above, WST typically burrow approximately 1 m (3 ft) below ground during (Stebbins and McGinnis 2012, p. 157). Spadefoot toads are able to dig their own burrows by digging backwards into soil using their foot spades (Stebbins and McGinnis 2012, p. 154). Burrow sites tend to have a high amount of duff or dead vegetation from previous years (Baumberger 2013, p. 25). Burrows are constructed in soils that are relatively sandy and friable as these soil attributes facilitate both digging and water absorption (Ruibal *et al*. 1969, p. 581; Baumberger 2013, p. 27). A certain level of moisture in the soil is required for burrowing individuals to avoid desiccation, but the required level of moisture is unknown. The permeable skin of the toads allows water absorption from the soil (Ruibal *et al*. 1969, p. 582). Spadefoot toads may retain urea to increase the osmotic pressure within their bodies, which prevents water loss to the surrounding soil and even facilitates water absorption from soils with relatively high moisture tensions (Ruibal *et al*. 1969, p. 582; Shoemaker *et al*. 1969, p. 585). The underground burrows are necessary in order for WST adults to survive. The availability of and access to suitable upland habitat likely influences the ability of adults to disperse and reproduce. If the upland habitat does not provide the capability to allow for underground burrows, is not accessible, or outside the dispersal capabilities of WST from aquatic breeding pools, then individual needs are not fulfilled.

7.1.3 Seasonal Rains

Development of aquatic breeding pools is dependent on seasonal rains that occur in the winter and spring. The amount of rain annually can determine the number and depth of pools available (Pyke 2004, p. 123). A majority of pools fill directly from precipitation, but some fill from the surrounding watershed once soils are saturated (Hanes and Stromberg 1998, p. 38). In addition, the vibrations from seasonal rains are likely the environmental cue for spadefoot toads to emerge from underground burrows (Dimmitt and Ruibal 1980a, p. 26). Precipitation in California is highly variable from year-to-year (Dettinger *et al*. 2011, p. 445). California has a Mediterranean climate characterized with cool, wet winters (October through April) and warm, dry summers (Dettinger *et al*. 2011, p. 446). The difference between a “wet” year and a “dry” year in California can be accounted for by a few well-timed storms (Dettinger *et al*. 2011, p. 445). Even within the range of WST, annual average rainfall varies with northern areas typically receiving progressively more rainfall (PRISM 2012). Figure 4 shows the 30-year precipitation

average from 1981–2010 within the range of WST. Average annual precipitation ranges from as little as approximately 10 centimeters (cm) (4 inches (in)) up to 102 cm (40 in) in higher elevation areas on the peripheral of the projected range (Fig. 4). Northwestern Mexico has high meteorological heterogeneity, as observed in spatial and seasonal variability of precipitation making it difficult measure the average annual precipitation (Gutierrez *et al.* 2010, p. 133). Historic records from San Pedro Martir in Baja California measured average annual rainfall for the area to be around 18 cm (7 in) (Hastings and Turner 1965, p. 208). Seasonal rains are necessary as a dispersal que for adult individuals to disperse and reproduce and is necessary to maintain water levels in pools long enough for WST eggs to hatch and tadpoles to metamorphose to juveniles.

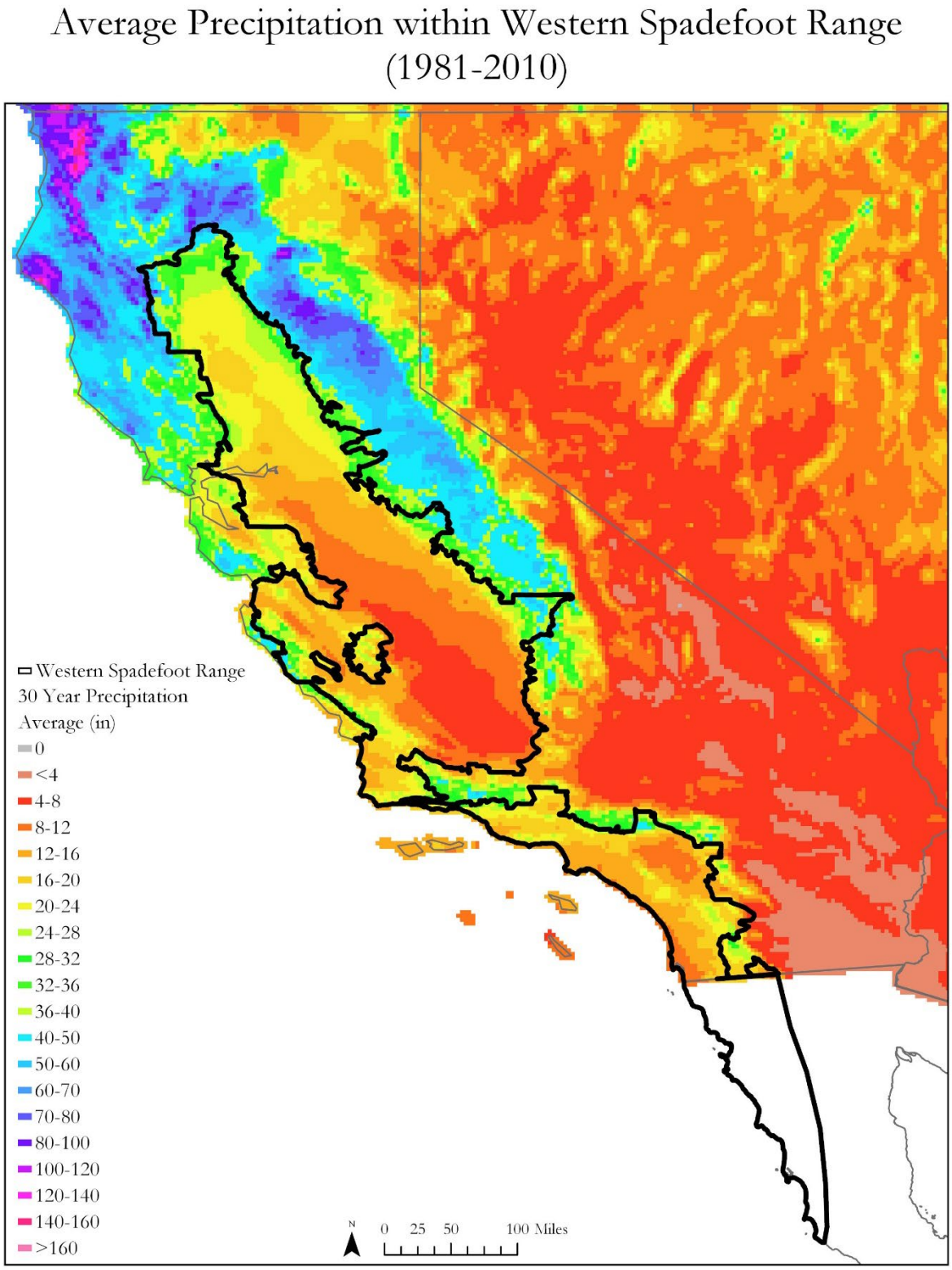

Figure 4: The 30-year average precipitation within the range of western spadefoot. Precipitation data from PRISM Climate Group at Oregon State University (PRISM 2012).

7.1.4 Small Invertebrate Prey

Adult WST forage on a variety of small invertebrate prey. Stomach content examinations have found food that includes grasshoppers, true bugs, moths, ground beetles, predaceous diving beetles, ladybird beetles, click beetles, flies, ants, and earthworms (Morey and Guinn 1992, p. 155). Adult WST can consume 11 percent of their body mass during a single feeding (Dimmitt and Ruibal 1980b, p. 857). Adults must be able to acquire sufficient energy for their long dormancy period of 8 to 10 months in only a few weeks (Seymour 1973, p. 435; Dimmit and Ruibal 1980b, pp. 858–861). Food for WST larvae are unknown. However, the larvae of plains spadefoot toads (*Scaphiopus bombifrons*) consume planktonic organisms and algae, fairy shrimp, and will scavenge dead organisms, including other spadefoot toad larvae (Bragg 1962, p. 144; Bragg 1964, pp. 17–23). Adult, juvenile, and presumably larval WST consume food items that are also used by other co-occurring amphibians including: pacific tree frog (*Pseudacris regilla*), California tiger salamander (*Ambystoma californiense*), and western toad (*Anaxyrus boreas*) (Morey and Guinn 1992, p. 155). Therefore, resource competition may occur depending on food abundance. Availability of small invertebrate prey is necessary for the survival of WST adults, juveniles, and larvae.

7.2 Population Needs: Resiliency

At the population level, we used the best information available to assess the resources, circumstances, and demographics that most influence the resiliency of a WST population. Resiliency describes the ability of a population to withstand stochastic disturbance. Resiliency is often positively related to population size and growth rate and may be influenced by connectivity among populations. If a species is resilient, we assume there exists sufficient suitable habitat in a condition to support large and stable enough populations such that the species can withstand stochastic events. Stochastic events that may impact WST populations include weather anomalies, such as years of low precipitation. A variety of factors may regulate WST population levels. These factors may be density-dependent (e.g., habitat quality, habitat abundance) or density-independent (e.g., climate). Figure 5 is a conceptual model that shows how the individual needs discussed in the previous section influence the demographic needs, which ultimately affect population resiliency.

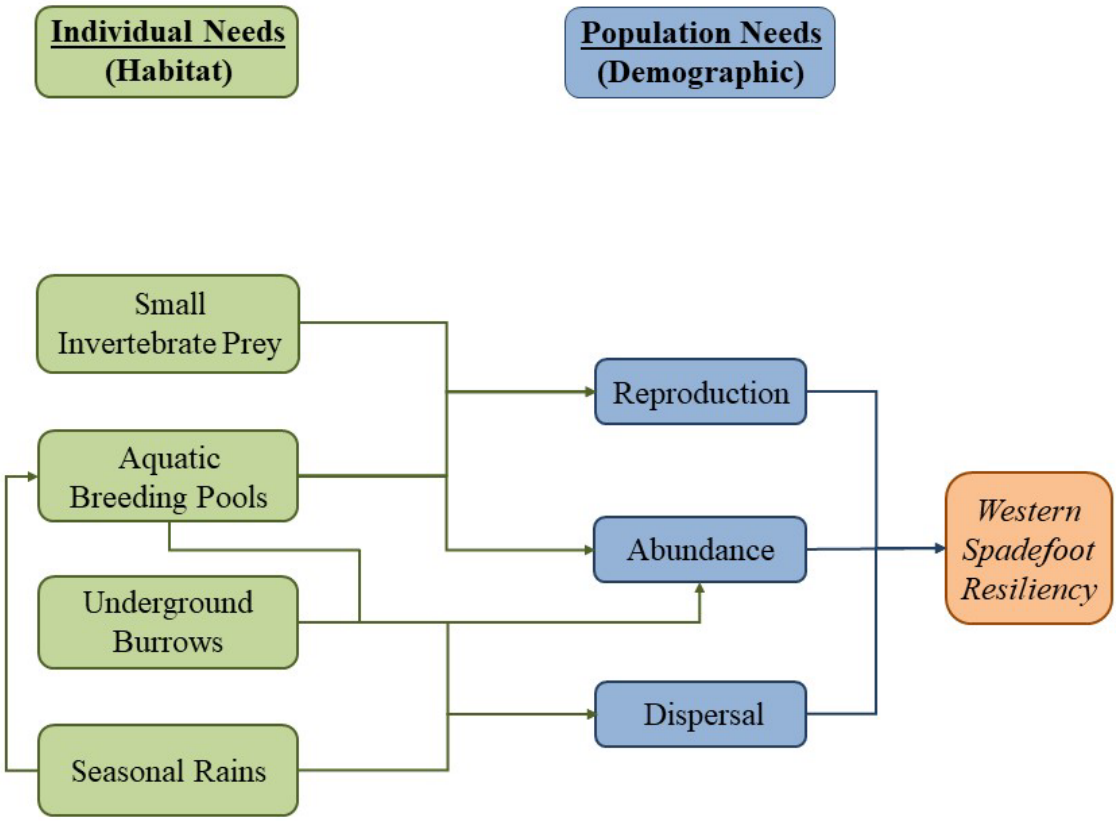

Figure 5: Conceptual model showing the relationship between individual needs and population needs, and how they influence resiliency of western spadefoot toad populations.

7.2.1 Reproduction

Spadefoot toads emerge from burrows to breed following rains in the winter and spring. Adults breed and lay eggs in aquatic pools. Tadpoles rely on aquatic pools and can speed up metamorphosis if necessary when pools begin drying (Feaver 1971, p. 53; Morey 1998, pp. 86–89). Larval development can be completed in 3 to 11 weeks depending on food resources and temperature, but must be completed before the pools dry (Burgess 1950, p. 49–51; Feaver 1971, p. 53; Morey 1998, p. 86). Annual reproductive success varies with precipitation levels, with success being lower in drier years (Fisher and Shaffer 1996 pp. 1394–1395). Longer periods of larval development have been associated with larger size at metamorphosis (Morey 1998, p. 86). Pools that persist for longer periods would permit longer larval development, resulting in larger juveniles with greater fat reserves at metamorphosis (Morey 1998, p. 86). Larger individuals have a higher fitness level and survivorship (Pfennig 1992, p. 1408). During dry years there may be fewer pools available for breeding and a shorter time period for tadpoles to develop. The rate of reproductive success needed for a population of WST to persist is unknown. Individuals within a population must have aquatic breeding pools for reproduction to be successful.

7.2.2 Dispersal

Western spadefoot toads must disperse between aquatic breeding pools and underground burrows during the breeding season Adults disperse from underground burrows to aquatic breeding pools in order to reproduce. After the breeding season, adults and juveniles must disperse back to underground burrows for shelter during the hot, dry summer. Seasonal rains are the environmental cue that initiates the breeding dispersal (Dimmitt and Ruibal 1980a, p. 26). The maximum dispersal distance of WST is unknown. A study looking at movement of WST individuals in an Orange County population found that the mean distance moved away from breeding pools was 40 (±37) meters (m) (44 yards (yd)), with the longest movement of an individual being 262 m (287 yd) ((Baumberger 2013, p. 14). When looking at several amphibian species, the average maximum core terrestrial area used from breeding wetlands was found to be 290 m (317 yd) (Semlitsch and Bodie 2003, p. 1221). The WST needs opportunities for dispersal and interbreeding among multiple breeding pools. Dispersal between breeding pools creates metapopulations that allow for gene flow, which is vital for preventing inbreeding. Habitat corridors between breeding sites are necessary for continued gene flow. In order for dispersal to be successful, individuals in a population must have seasonal rains, aquatic breeding pools, and underground burrows available. The aquatic breeding pools and underground burrows must be within dispersal distance for the population to successfully reproduce.

7.2.3 Abundance

A certain number of individuals is necessary to sustain a viable population of WST. However, it is unknown how many WST individuals are necessary in order to maintain a viable population. Abundance estimates are not available for this species, but effective number of breeders has been measured at breeding pools throughout both the northern and southern WST clades. Although effective number of breeders is not a count of individuals, it can provide insight into the number of individuals that are contributing to the population size in a single cohort. The average effective number of breeders measured in the northern populations of WST (north of the transverse mountains) was found to be 5.25 individuals ranging from 2.3 to 18.3, and in the southern populations the average effective number of breeders was 4 individuals ranging from 1.4 to 20.7 (Neal 2019, p. 113). Effective population size, which is a more generational calculation of individuals contributing to population size, has only been measured in a small portion of the WST range in Orange County within the southern clade. Measured effective population size was found to vary from 1.2 to 63.8 individuals (Neal 2019, pp. 64–66). In comparison to other pond-breeding amphibians the effective population size measured for WST are very low (Funk *et al*. 1999, pp. 1633, 1637; Wang 2009, p. 3848; Wang *et al*. 2011, p. 914; Wang 2012 pp. 1033–1034; Richmond *et al*. 2013, p. 815). It is unknown if the small effective number of breeders that were measured for WST are due to small populations or inbreeding. It is hypothesized the low number of effective breeders could be due to recent drought years throughout the WST range and that the species has likely not always had a low number of effective breeders per population (Neal 2019, p. 32). Occurrence data from Baja Mexico collected as recently at 2019 indicates that WST are present in Mexico, but abundance information is not available (Peralta and Valdez 2020, pers. comm.). To maintain sufficient

abundance for a viable WST population, individuals must have the all the individual needs as discussed in the previous section including small invertebrate prey, aquatic breeding pools, underground burrows, and seasonal rains.

7.3 Species Needs

At the species level, we assessed the representation and redundancy of the northern WST clade and the southern WST clade to ultimately better understand the species' viability. Representation is the ability of a species to adapt to changing environmental conditions and redundancy is the ability of a species to withstand catastrophic events. Viability is defined as the ability of WST to sustain populations in the wild over time. Using the SSA framework, we describe the species' viability by characterizing the status of the species in terms of its representation and redundancy.

7.3.1 Representation

As discussed above, representation describes the ability of a species to adapt to changing environmental conditions over time. In other words, representation attempts to characterize a species' evolutionary adaptability to its environment. Because this is often difficult to discern, we use the breadth of environmental and genetic diversity within and among populations as a surrogate for evolutionary adaptability. Within the northern WST clade, three genetic clusters have been identified: populations north of the Sacramento-San Joaquin Delta, populations south of the Sacramento-San Joaquin Delta in the central valley, and populations on the central coast (Neal 2019, p. 115). Within the southern WST clade, two genetic clusters have been identified: populations in Ventura, Los Angeles, and Orange counties; and populations in San Diego County (Neal 2019, p. 115). Additionally, the geographic range within just the northern WST clade and within just the southern WST clade varies in habitat type and climate, indicating some tolerance for adaptation to change. The northern portion of California's central valley and the coastal regions within the range of the northern clade receive more rain and have cooler average temperatures than the southern portion of California's central valley within the northern WST clade (Prism 2012 (Figure 4; WRCC 2020). The southern WST clade has a range of climatic conditions in the large area between Ventura, California and down throughout the northwestern portion of the Baja Peninsula in Mexico with differences in precipitation and temperature between populations closer to the coast and those that are further inland (Gutierrez *et al.* 2010, p. 133; Prism 2012 (Figure 4); WRCC 2020). Furthermore, unique vernal pool regions have been identified within the WST range, ten within the northern WST clade and three within the southern WST clade. (Keeler-Wolf *et al*. 1998, p. 12). Each identified vernal pool region is unique in the biological communities and the abiotic features, such as soils and geomorphology, that make up the vernal pools within the region (Keeler-Wolf *et al*. 1998, p. 13). Each WST clade has representation from the variation in climatic conditions and the unique biotic and abiotic features across the range.

7.3.2 Redundancy

Redundancy refers to the ability of species to withstand catastrophic events (such as a rare destructive natural event or episode involving many populations). Redundancy is about spreading the risk and can be measured through the duplication and distribution of populations or meta-populations across the range of the species. The greater the number of meta-populations a species has distributed over a larger landscape, the better it can withstand catastrophic events. Catastrophic events that could impact both northern and southern WST include extended drought periods or the spread of a deadly disease. Implications of these events are discussed in more detail in the "INFLUENCES TO VIABILITY" section below. Multiple populations within the northern WST and the southern WST are distributed throughout the ranges as described above. The wide distribution of both clades provides varying habitat, climatic, and genetic differences which improve the redundancy of both northern WST and southern WST.

8.0 INFLUENCES TO VIABILITY

We use the term *threat*, in a general sense, to refer to actions or conditions that may be or are reasonably likely to negatively affect individuals of a species. Threats includes actions or conditions that have a direct impact on individuals (direct impacts), as well as those that affect individuals through alteration of their habitat or required resources (stressors). Threats may encompass—together or separately—the source of the action or condition or the action or condition itself. A threat's significance depends upon a population-level assessment of the scope and severity and the related imminence, one or more of which could be reduced through existing conservation practices or management activities. In our overall analysis of the impacts of threats on WST, we consider all the threats together cumulatively, regardless of the threat's magnitude or extent.

Below we assess the influence of development, overabundance of vegetation, nonnative predators, chemical contaminants, noise disturbance, disease, and effects of climate change on WST resiliency, redundancy and representation. We carry forward only the influences that are determined to potentially threaten WST populations. We address threats that may affect the species in the future separately as part of the scenarios discussed in the Future Condition section, below. In this section, we evaluate the significant past, current, and future influences that are impacting WST resiliency, redundancy, and representation. These influences impact individual, population, or species needs, ultimately affecting the viability of the species. All influences are known to effect both the northern WST and the southern WST, unless otherwise noted.

<u>8.1 Development</u>

Western spadefoot toad populations likely suffered dramatic reductions in the mid to late 1900s when urban and agricultural development were rapidly destroying natural habitats in the Central Valley and southern California (Jennings and Hayes 1994, p. 96). In southern California,

561 within the southern WST clade, over 80 percent of the habitat once known to be occupied by
562 WST has been developed or converted to uses that are incompatible with successful reproduction
563 and recruitment (Jennings and Hayes 1994, p. 96). Soils supporting vernal pools within the
564 southern WST clade were never extensive in comparison to the central valley of California, and
565 large-scale development has significantly reduced vernal pool habitat in the Southern WST clade
566 (Bauder and McMillan 1996, p. 56; Service 2005, p. I-17). In northern and central California,
567 within the northern WST clade, loss of habitat has been less severe, but estimates suggest that
568 over 30 percent of the habitat once occupied by WST has been developed or converted to
569 agriculture (Jennings and Hayes 1994, p. 96). Comparing extant vernal pool habitat from 2005 to
570 2012 within the northern WST clade, an estimated 6,758 acres of vernal pool habitat was lost per
571 year due to agricultural and urban development (Witham *et al*. 2014, pp. 1, 4–5). Development
572 can directly destroy aquatic breeding pools and underground burrows, or it can alter the
573 hydrology such that aquatic breeding pools may not form where a population once existed. With
574 the loss of aquatic breeding pools and underground burrows, abundance, dispersal, and
575 reproduction within the population are reduced because the individuals no longer have the
576 resources available to survive and disperse in order to reproduce. Roads represent an additional
577 threat associated with development to the WST. Road construction can result in the direct
578 mortality of toads and can cause loss and fragmentation of habitat that could limit dispersal
579 necessary for reproduction. Mortality of WST from motor vehicle strikes has been observed by
580 multiple researchers throughout the range of both the northern and southern clade (Morey and
581 Guinn 1992, p. 150; CNDDB 2019). Roads can also be a barrier to movement and effectively
582 isolate populations. Development will likely continue to impact both WST clades as California's
583 human population continues to grow (California Department of Finance 2017, entire). The range
584 of predicted population growth into the future, which will likely lead to increased development,
585 varies across the range of WST. Amador County in California is predicted to have a population
586 decrease by about 20 percent by 2050, whereas Kings County is predicted to have a population
587 increase by about 49 percent by 2050 (CalTrans 2016, pp. 10, 62). Of the 37 counties within the
588 WST range, only four are projected to have a decrease in population size and 33 are expected to
589 increase (CalTrans 2016, entire). Within just the southern WST clade, all five counties are
590 expected to increase by 14–42 percent (Caltrans 2016, pp. 74, 118, 130, 146, 222). Overall,
591 development reduces the availability and quality of the individual needs of aquatic breeding
592 pools and underground burrows, which impacts the population needs of abundance, dispersal,
593 and reproduction.

594 **8.2 Overabundance of Vegetation**

595 As stated above, vernal pools make up the majority of aquatic habitat for the WST.
596 Changes in vernal pool hydrology caused by overabundant vegetation may adversely affect WST
597 populations. Overabundant vegetation is caused by both nonnative plant invasion as well as the
598 lack of wild grazers on native vegetation. When there is too much vegetation around aquatic
599 breeding pools, the vegetation absorbs the water and the pools dry more quickly. Grazing of both
600 wild grazers and livestock grazers plays an important role in maintaining a balance of vegetation
601 in areas with aquatic breeding pools. Removal of grazing has been found to reduce the

inundation period of pools below the amount of time required for WST to successfully metamorphose (Marty 2005, p. 1626). An assessment of vernal pool habitats found that regions with no grazing had more invasive weeds that cause pools to dry more quickly (Vollmar *et al*. 2017, p. 2–13). However, livestock may crush or even consume egg clusters while utilizing ponds and cause a minor amount of direct mortality to adult and juvenile toads through trampling. Overabundant vegetation reduces the quality of aquatic breeding pools by causing them to dry more quickly, which then has impacts on reproduction and abundance.

8.3 Nonnative Predators

Western spadefoot toads have several natural predators including water birds, garter snakes, California tiger salamanders, and raccoons (Childs 1953, p. 228; Feaver 1971, pp. 44–45). Natural predation is not known to be out of balance for WST populations. However, there have been nonnative crayfish (*Procambarus clarkia*), mosquitofish (*Gambusia affinis*), and bullfrogs (*Lithobates catesbeianus*) introduced within the range of both WST clades that have been found to be predators to WST (Hayes and Warner 1985, p. 109; Hayes and Jennings 1986, p. 490; Jennings and Hayes 1994, p. 96; Fisher and Shaffer 1996, pp. 1389, 1392). All of the nonnative predators were introduced into California in the late 1800s and early 1900s, and through range expansions, additional introductions, and transplants, these exotics have become established throughout most of the state (Fisher and Shaffer 1996, pp. 1392–1393). An inverse relationship has been observed between the presence of nonnative predators and WST (Fisher and Shaffer 1996, p. 1393). Nonnative predators may have displaced WST at lower elevations, resulting in WST being found primarily at higher elevation sites where predators are less abundant (Fisher and Shaffer 1996, p. 1392–1394). Nonnative predators likely pose a greater threat to WST eggs and larvae given both life history needs and morphological and physiological differences between life stages. Adults and juveniles have an extended dormancy period which reduces interaction time with nonnative predators. Western spadefoot toad adults increase activity in response to moisture and low temperatures following storms, whereas bullfrogs increase activity in response to warmer temperatures prior to storms (Morey and Guinn 1992, p. 156). This may reduce the amount of contact and predation adult WST have with nonnative bullfrogs. In addition, toxic secretions from dermal glands of adult and juvenile toads provide a significant deterrent to predators. However, nonnative species may also compete for resources with WST, thus potentially limiting adult and juvenile foraging success. (Morey and Guinn 1992, p. 153). The extent at which nonnative predators is impacting WST populations is unknown. Nonnative predators are negatively impacting the individual needs of small invertebrate prey, which has impacts on the abundance of WST populations because the number of individuals that can be supported by the food source is compromised. Additionally, WST are prey for nonnative predators further reducing the abundance of populations. Figure 6 displays the known locations of nonnative species that may be impacting both clades of WST populations.

Nonnative Species in Western Spadefoot Range

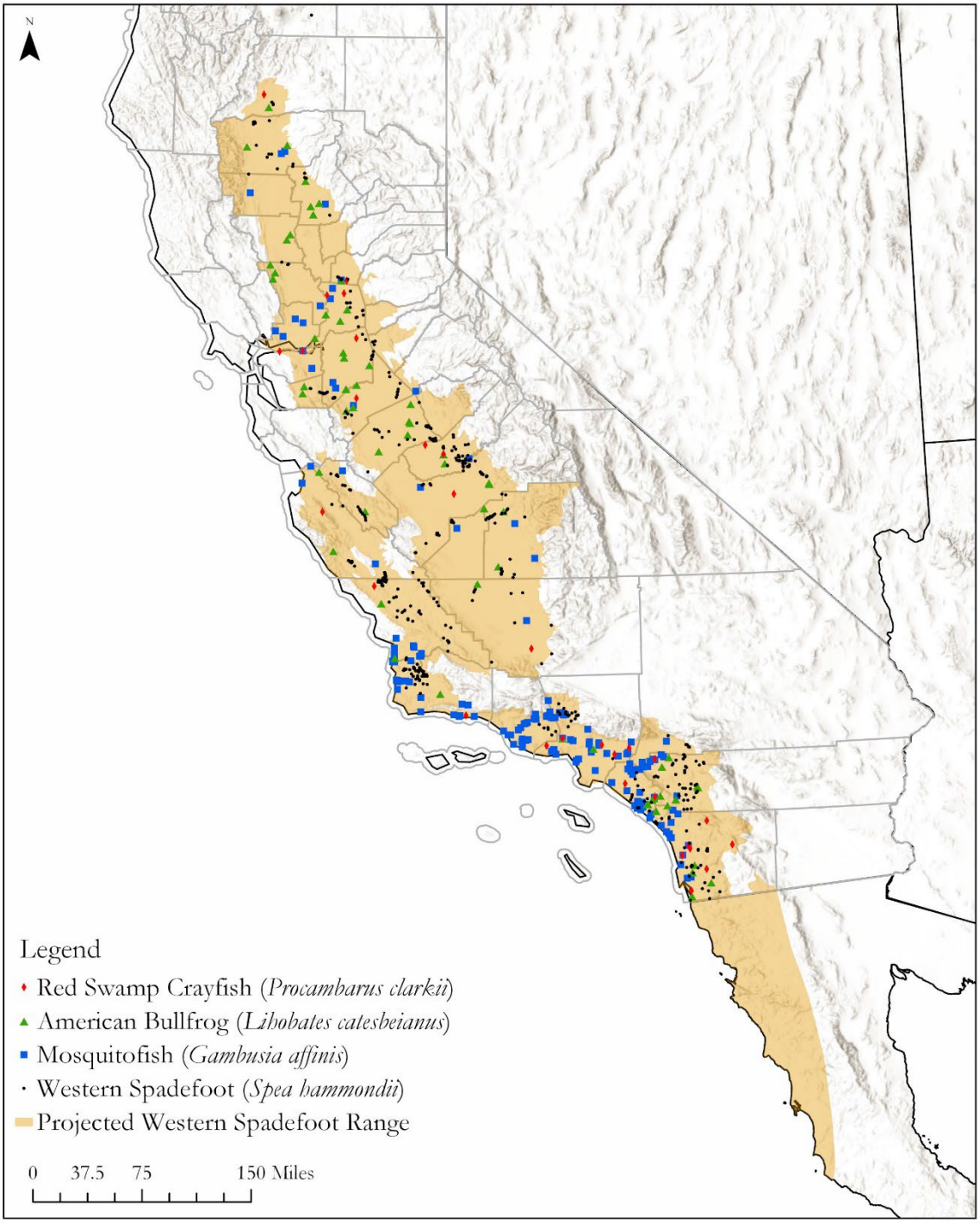

Figure 6: Figure displaying common nonnative species within the projected range of western spadefoot toad. Nonnative species locations are from U.S. Geologic Survey Nonindigenous Aquatic Species Database. Range projections for WST are from IUCN and CWHR.

8.4 Drought

California has recently experienced extreme drought conditions in 2007–2009 and 2012–2014 (Williams *et al*. 2015, pp. 6823–6824). Anthropogenic warming likely contributed to the 2012–2014 drought anomaly (Williams *et al*. 2015, pp. 6819, 6826). It is hypothesized that the recent extended drought periods have led to low effective population size in WST populations (Neal 2019, p. 32). Drought decreases the quality and quantity of aquatic breeding pools available for WST. Without aquatic breeding pools available, dispersal and reproductive opportunities are limited, ultimately reducing the abundance of the population. Small invertebrate prey that also depend on vernal pool ecosystems and the seasonal rains that create them are likely also negatively impacted by drought conditions (Colburn *et al.* 2008, pp. 120–122)). Anthropogenic warming increases the overall likelihood of extreme droughts in California into the future (Williams *et al*. 2015, pp. 6819, 6826). Projected climate change conditions indicate an increased likelihood of more frequent, longer, and intense droughts in the future (Bedsworth *et al*. 2018, p. 57).

8.5 Chemical Contaminants

Western spadefoot toads are exposed to a variety of toxins throughout their range, but the sensitivity and impacts of this species to pesticides, heavy metals, air pollutants, and other contaminants is largely unknown. Each year, millions of kilograms (millions of pounds) of fertilizer, insecticides, herbicides, and fungicides are used on crops, forests, rights of way, and landscape plants in California, including areas within the WST range (DPR 2017, p. 5). Some of these chemicals can be toxic to aquatic organisms such as amphibians and their prey (Davidson 2004, p. 1892; Relyea 2005, p. 1118; Bruhl *et al*. 2013, p. 1). Industrial facilities and motor vehicles also release contaminants. Contaminants from road materials, leaks, and spills could contaminate the water in vernal pools. There is currently no evidence that chemical contaminants are impacting WST. Research looking into proximity of vernal pool habitat that may be impacted by pesticide drift and the presence of WST found no significant correlation between presence or absence of WST and the use of pesticides (Davidson *et al.* 2002, entire). Other than pesticide drift, there has been no research looking into other potential chemical contaminants that could be impacting vernal pool habitat. There is currently no other literature indicating impacts of chemical contamination and we do not consider chemical contamination a threat driving individual, population, or species level concerns.

8.6 Noise Disturbance

Western spadefoot toads are sensitive to noise stimuli and break dormancy and emerge from their burrows in response to noise disturbance (Dimmitt and Ruibal 1980a, p. 26). Activities that produce low frequency noise and vibration, such as grading from construction and development activities, recreational off-road vehicle use, and seismic exploration for natural gas, in or near habitat for WST, may be detrimental to the species (Ouren *et al*. 2007, p. 20; Service

2005, p. II-234). Disturbances that cause WST to emerge at inappropriate times could result in mortality or reduced fitness (Dimmitt and Ruibal 1980a, pp. 27–28). Since WST are dependent on moisture from underground burrows to survive the hot and dry summers (Ruibal *et al.* 1969, p. 571), emerging when rains are not present may cause desiccation of individuals. Once WST break dormancy and emerge, individuals seek out small invertebrate prey to replenish energy stores. If WST individuals use the energy to emerge at inappropriate times, and prey species are not present, they may not have the energy available to return into underground burrows and resurface when conditions are appropriate (Dimmitt and Ruibal 1980a, pp. 27–28; Service 2005, p. II–234).

8.7 Disease

Western spadefoot toads are currently not known to be significantly impacted by any identified diseases. There have been documented cases of WST infected with trematodes and it has been hypothesized that WST eggs may fail to develop potentially due to a fungus that thrives in warmer water temperatures and invades toad eggs (Storer 1925, p. 158; Brown 1967, p. 746; Goldberg and Bursey 2002, pp. 491–492). However, these events have not been documented causing widespread mortality within the species. Ranavirus (Family *Iridoviridae*, Genus *Ranavirus*), a group of emerging pathogens responsible for mass die-offs of amphibians, fish, and reptiles, is known to infect the plains spadefoot toad (*Spea bombifrons*) (Duffus *et al*. 2015, pp. 10–14). In addition, other amphibian species have been infected by numerous diseases contributing to declines including chytrid fungus (*Batrachochytrium dendrobatidis*) and white fungus (*Saprolegnia ferax*), bacterial infections, and trematodes (Daszack *et al*. 1999, entire; Densmore and Green 2007, entire; Wake and Vredenburg 2008, entire). WST does not appear to be significantly impacted by any observed disease.

8.8 Effects of Climate Change

Western spadefoot toads are dependent on environmental conditions and seasonal weather patterns for supplying both feeding and breeding resources. The transition from estivation to emergence from underground burrows is linked to the vibrations from seasonal precipitation felt by WST in the fall and winter (Dimmitt and Ruibal 1980a, p. 26). Both foraging on small invertebrate prey and breeding in aquatic breeding pools occurs after WST emerge from burrows. As stated above, the aquatic pools must be a particular temperature for WST reproduction to be successful (Storer 1925, p. 158; Brown 1967, p. 746), higher ambient temperatures can influence water temperatures. In addition, larval development and metamorphosis must be completed before pools dry (Burgess 1950, p. 49–51; Feaver 1971, p. 53; Morey 1998, p. 86). In California, the annual average temperatures have increased by about 0.8 °C (1.5 °F) since 1895 (Kadir *et al.* 2013, p. 38). Additionally, extreme heating events have increased throughout the state (Kadir *et al.* 2013, p. 48). Furthermore, climate change likely contributed to the 2012–2014 drought anomaly discussed above which may be a contributing factor to low effective population size of WST populations (Williams *et al.* 2015, pp. 6819,

6826; Neal 2019, p. 32). Climate change will likely increase temperatures throughout the range of both WST clades into the future (Bedsworth *et al*. 2018, p. 22). In California, statewide models project warming of 2–4 °C (3.6–7.2 °F) (RCP 4.5, medium emissions scenario) to 4–7 °C (7.2–12.6 °F) (RCP 8.5, business as usual scenario) by the end of the century depending on future greenhouse gas emissions (Pierce *et al*. 2018, pp. iv, 17–18). Although the mean annual changes in temperature will likely have impacts, in many ways the effects of climate change will be felt most strongly as extreme temperature events are predicted to increase (Pierce *et al*. 2018, p. 18–19). Modeled changes in precipitation are more complex and projections are less clear than for temperature. The effects of climate change have significantly increased drought risk in the state (Diffenbaugh *et al*. 2015, p. 3931), leading to increased concern over the reliability of ephemeral vernal pool breeding habitat. In the Baja Peninsula of Mexico, a significant reduction of precipitation is expected and temperature changes larger than 2 °C (3.6 °F) warming by 2050 using downscaled regional climate modeling (Cavazos and Arriaga-Ramirez 2012, p. 5904). Climate change has and will likely continue to alter the temperature and precipitation regimes, generally making the environment warmer and dryer, having impacts on the individual needs of seasonal rains and aquatic breeding pools that will likely cause population impacts to reproduction, dispersal, and abundance. Effects of climate change in the future will be further discussed in chapter 10.0, Future Conditions.

8.9 Cumulative Impacts of Threats

The threats discussed above not only act independently, but also interact with each other. It is important to assess the impacts of combined threats, because there may be new or exacerbated impacts that are not considered when a threat is assessed alone. There are a vast number of ways the combined threats may be interacting with each other, but the SSA will only focus on what is currently most relevant to the viability of the species. Figure 7 shows the relationships between threats, WST individual needs, WST population needs, and ultimately WST viability.

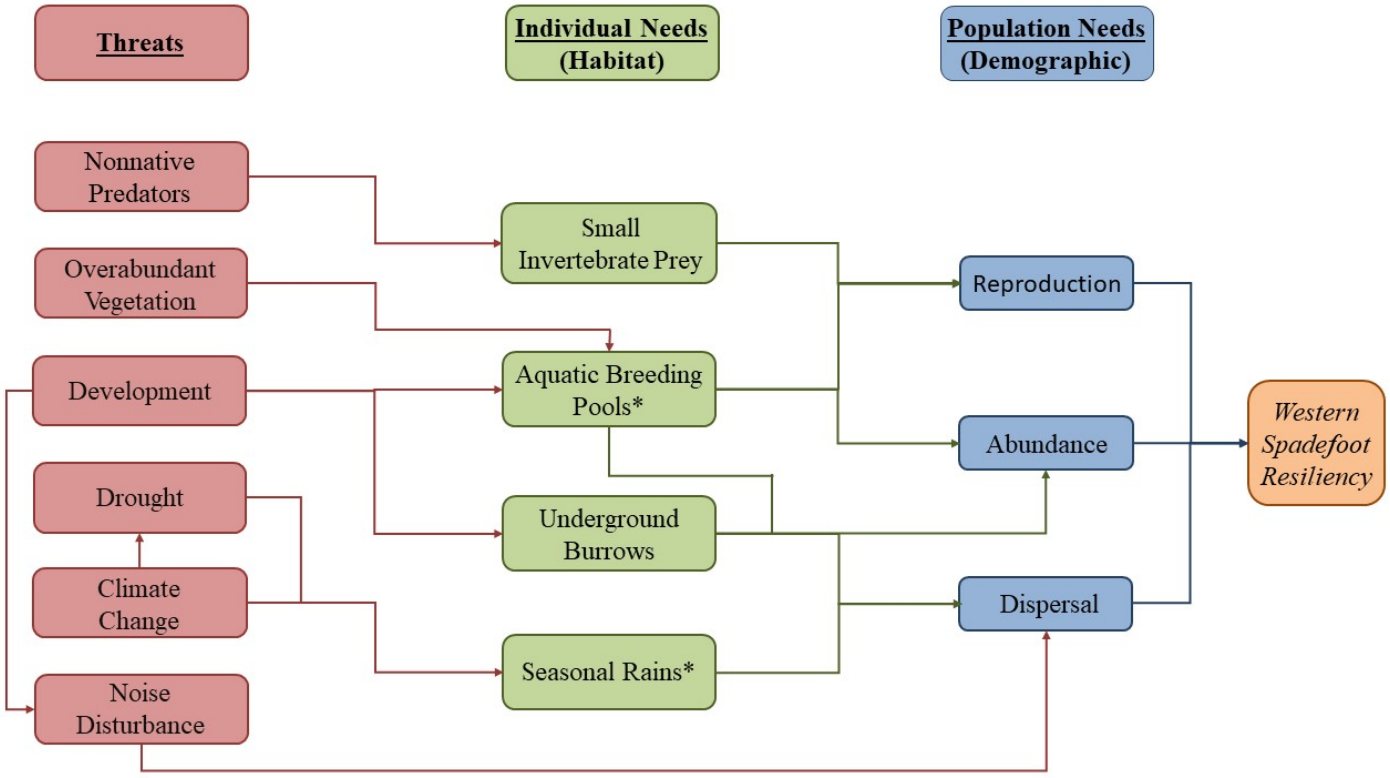

Figure 7: Conceptual model showing the interactions among threats/stressors, individual needs, and population needs, and how they interact to impact resiliency of WST. The green asterisk in the aquatic breeding pools and seasonal rains boxes indicate that these individual needs are connected to each other.

8.10 Conservation

There are several vernal pool species within both the range of the northern WST clade and the southern WST clade that are listed as threatened or endangered under the Act (Service 1998, p. 3; Service 2005, pp. I-4–I-7). A number of conservation efforts have been carried out for the purpose of recovering listed vernal pool species. Some of those conservation actions have included land acquisition and restoration for the purpose of protecting vernal pool habitat, which is also beneficial for the WST. A study of extant vernal pool habitat preserved within regions of the northern WST clade has found the 270,329 acres (109,398 ha) of habitat have been preserved out of 764,862 acres (309,529 ha) of extant habitat (Vollmar *et al*. 2017, p. 1-14). Some land acquisition and restoration activities have been as a result of Habitat Conservation Plans. Habitat Conservation Plans (HCP's) provide a pathway forward to balance wildlife conservation with development or other activities that may negatively impact species. The primary objective of the HCP program is to conserve species and the ecosystems they depend on while streamlining permitting for economic development. Being included as a covered species under an HCP can result in habitat being set aside and managed for the species as compensation for covered activities, such as planned urban development or business operation activities, within the area the

HCP covers. In addition, within the permitted area, avoidance, minimization, and other conservation measures (e.g. monitoring, seasonal work windows, habitat management, etc.) are put into place. There are currently 15 HCP's that include WST as a covered species, five within the range of the northern WST clades and ten within the range of the southern WST clade. conservation activities that have been included in HCP's for WST include habitat protection, light pollution minimization, erosion control of vernal pool habitat, work windows that avoid reproductive season when WST are dispersing, exclusion fencing, entrapment avoidance, and monitoring. The full list of HCP's for WST can be found at the Service website: https://ecos.fws.gov/ecp0/profile/speciesProfile.action?spcode=D02Z.

9.0 CURRENT CONDITION

To assess the current condition of WST for the SSA, the species' range was divided into multiple regions within both northern and southern WST clades shown in Figure 8. The regions were chosen to align with the recovery units in the Service's Recovery Plan for Vernal Pool Ecosystems of California and Oregon (Service 2005, entire). The recovery units were based on CDFW, California Vernal Pool Assessment Preliminary Report defining the vernal pool regions as discrete geographic regions identified largely on the basis of endemic species, with soils and geomorphology as secondary elements, but with some overlap of these features among vernal pool regions (Keeler-Wolf *et al*. 1998, entire). Overall, the vernal pool recovery units are representative of the range of biotic and abiotic features of the vernal pool ecosystem. Although these regions do not encompass all WST occurrences, they capture a majority of the vernal pool habitat that is considered ideal for WST and are representative of the range of both the northern and southern clade. The Santa Barbara Recovery unit was split into two separate regions, the Santa Barbara region and the Ventura region, given the known genetic differences in WST separating the northern and southern species. In addition, a region was added to be representative of the populations in Mexico. The Mexico region is based on the IUCN range map projection into Mexico and not vernal pool habitat. In total, 14 WST regions were identified, 10 northern WST regions and 4 southern WST regions.

For each individual and population need identified earlier in the SSA, a low, moderate, and high condition was defined in Table 2, the Conditions Category Table. In instances where not enough information was available to assign a condition to a category within a region, the condition was labeled as unknown. Table 3 represents the current conditions of individual and population needs assigned to the northern WST regions and Table 4 represents the current conditions of individual and population needs assigned to the southern WST regions. An overall low current condition means that the region has low resiliency and therefore a low probability of persistence under current conditions. A moderate overall condition score means that the region has moderate resiliency and a moderate probability of persistence under current conditions. A high overall condition score means that the region has high resiliency and therefore a high probability of persistence under current conditions.

9.1 Current Condition Summary of Methods

In order to compile condition category definitions for the Conditions Category Table (Table 2), the best available scientific information was used, including peer-reviewed studies, surveys, and reports from U.S. Fish and Wildlife Service and California Department of Fish and Wildlife. Limited information is available to determine quantitative values for the WST individual and population needs. Using best available information, quantitative conditions categories were defined for aquatic breeding pools, underground burrows, seasonal rains, reproduction, dispersal, and abundance. There is currently no quantitative information available for small invertebrate prey, so qualitative condition categories were defined for this individual need. Our understanding of the individual and population needs is currently the same for the northern and southern WST clades. Table 2 below, identifies the definitions of high, medium, and low conditions and was used to define the condition categories for both clades.

To assign the current condition of aquatic breeding pools, we compared extant vernal pool habitat from 2005 and again in 2012. An effort was undertaken to better understand vernal pool habitat extant in 2005 and 2012 to better plan for recovery efforts of vernal pool species (Witham *et al*. 2014, entire; Vollmar *et al*. 2017, p. 1–14). This is the most recent mapping effort undertaken for vernal pool habitats. The study only includes eight of the vernal pool regions in the northern WST clade range. A high condition was determined to be a region that has increased vernal pool habitat. Historic habitat loss in the northern WST range was estimated to be approximately 30 percent in 1994 (Jennings and Hayes 1994, p. 96), so efforts to increase habitat availability from historical losses would result in a high condition. A moderate condition was given to regions with extant habitat loss less than 20 percent from 2005 to 2012. A low condition was given to regions with extant habitat loss greater than 20 percent from 2005 to 2012. Loss in habitat reduces the availability and distribution of vernal pools available for WST. Information was not available to assess aquatic breeding pools for all of the WST regions including some of the northern WST regions and all of the southern WST regions. Table 3 provides a summary of the extant vernal pool habitat loss from 2005 to 2012 (Witham *et al*. 2014, entire; Vollmar *et al*. 2017, p. 1–14). PLACEHOLDER for southern California analysis.

To assign a current condition to underground burrows, the size of preserved vernal pool habitats was considered. Underground burrows must be available upland from the aquatic breeding pools; therefore, a vernal pool habitat must be large enough to support both the pools and the upland habitat. The maximum dispersal distance measured for WST is approximately 262 m (860 ft). Using the dispersal distance as a radius, a buffer distance of 53 acres should provide sufficient upland habitat to support WST underground burrows. A report examining preserved vernal pool habitat in the Central Valley classified blocks of vernal pool habitat by several size classes including less than 10 acres, 10–40 acres, 40–100 acres 100–400 acres, 400–1,000 acres, 1,000–2,000 acres, 2,000–4,000 acres, 4,000–10,000 acres and greater than 10,000 acres (Vollmar *et al*. 2017, p. 1–14). For areas outside of the report, HCP's were used to determine preserved habitat blocks. We looked at the number of preserves with greater than 40 acres of preserved habitat likely sufficient to support both the aquatic and upland habitat for WST given the known dispersal distances from breeding pools. Vernal pool regions with more

than 50 preserved habitat blocks greater than 40 acres provided a high condition for underground burrows. Information is not available to determine the exact number of habitat blocks necessary to sustain a resilient population, so 50 habitat blocks was used as an estimate until more detailed information is available. Regions with 15 to 49 preserved habitat blocks were considered moderate condition for underground burrows, and regions with less than 15 habitat blocks were considered low condition. This analysis only considers size of preserved habitat, and not potentially large areas of extant vernal pool habitats that are not preserved. As science becomes available with more precise habitat use for WST, the condition category definitions should be updated to better reflect the needs of the species.

For the individual need of seasonal rain, we examined the percent of average precipitation over the past 60 months to determine the condition (HPRCC 2020). Regions with less than 80 percent of the average rainfall were considered low condition, regions with 80–100 percent average rainfall were considered moderate condition, and regions with greater than 100 percent were considered high condition. This condition definition addresses the amount of rain, but it may not address the seasonality of the rain that is necessary for successful breeding. The current condition assessment assumes that the rainfall that has fallen within the past 60 months has fallen at the appropriate time of year for WST. As science becomes available with more precise estimates of rainfall necessary to sustain vernal pools, the condition category definition should be updated to better reflect the needs of the species.

For the population needs of reproduction, dispersal, and abundance, a dissertation examining population genetics and habitat resistance models was used to create condition category definitions (Neal 2019, entire). To examine reproduction, the inbreeding coefficient (F_{IS}) was used to evaluate the potential of inbreeding affecting the fitness of individuals within populations. The effects of inbreeding on individual performance can strongly affect population persistence (Keller *et al*. 2002, p. 238). For example, an increase in inbreeding by 10 percent generally leads to a reduction in fitness components of ~5–10 percent (Keller *et al*. 2002, p. 238). Low condition for reproduction was defined as a F_{IS} greater than 10 percent since this is the general threshold where genetic integrity begins to be compromised. Moderate condition for reproduction was defined as an F_{IS} between 5 and 10 percent. A high condition of reproduction was defined as a F_{IS} value less than 5 percent indicating that the population has sufficient genetic diversity for avoiding fitness consequences in offspring.

Habitat resistance models and the maximum percent impervious surface, or areas where WST are unable to disperse, within a 2 km buffer of each pond were used to evaluate dispersal of WST. The maximum impervious surface ranged from zero to 79 percent for measured WST populations. To determine high, moderate, and low conditions, Jenks Natural Breaks Optimization was used to group the values into three categories. The Jenks Natural Breaks Optimization is a statistical formula that groups values with the least variation within each category. A high condition of dispersal was determined to be zero to 10 percent maximum impervious surface. A moderate category 10 to 60 percent, and a low category above 60 percent.

Finally, to examine abundance, the effective number of breeders was used to determine high, moderate, and low conditions for abundance. Measured effective number of breeders in

886 WST populations varied from 1.4 to 20.7 individuals (Neal 2019, p. 113). The minimum number
887 of effective breeders necessary to maintain a stable population is currently unknown for WST. In
888 comparison to other similar species that use the same habitat or have similar life history (black
889 toad *(Bufo exsul*), California tiger salamander (*Ambystoma californiense*), Yosemite toad
890 (*Anaxyrus canorus*) and California red-legged frog (*Rana draytonii*), these values are relatively
891 low. The effective population sizefor these species ranged from 9 to 649 (Wang 2009, pp. 3852–
892 3853; Wang *et al*. 2011, p. 914–915, 918; Wang 2012, p. 1033–1034; Richmond *et al*. 2013, p.
893 815). Based on comparison to other similar species, low condition was determined to be less than
894 20 breeders in a population, moderate condition 20 to 50 breeders in a population, and high
895 condition more than 50 breeders in a population. The high condition falls within the measure of
896 effective population size for other pond-breeding amphibians including black toad, *(Bufo exsul*),
897 California tiger salamander, Yosemite toad, and California red-legged frog (Wang 2009, pp.
898 3852–3853; Wang *et al*. 2011, p. 914–915, 918; Wang 2012, pp. 1033–1034; Richmond *et al*.
899 2013, p. 815).

900 For each individual and population need identified earlier in the SSA, a low, moderate,
901 and high condition was defined in Table 2, the Conditions Category Table. A low condition was
902 given a score of 1, a moderate condition was given a score of 2, and a high condition was given a
903 score of 3. For categories that may fall in between conditions, a low-moderate condition was
904 given a score of 1.5 and a moderate-high condition was given a score of 2.5. Each region was
905 then assessed to determine the condition of the individual and population needs and an overall
906 condition score, which was the average across the individual and population needs, was
907 calculated. Regions with conditions with an overall average ≥2.5 received an overall high
908 condition, regions with an average score between 2.25–2.5 received an overall condition of
909 moderate-high, regions with an overall score between 1.75–2.25 received an overall condition of
910 moderate, regions with a score between 1.5–1.75 received an overall condition of low-moderate
911 and regions between 1–1.5 received an overall low condition. No one individual or population
912 need was considered to have a higher weight in considering overall condition. An overall high
913 condition for a region is an indicator of high probability of persistence of individuals in the
914 region, an overall moderate condition is an indicator that probability of persistence in that region
915 may be compromised by the lack of one or more need, and a low overall condition indicates low
916 probability of persistence of individuals in the region.

Western Spadefoot Regions

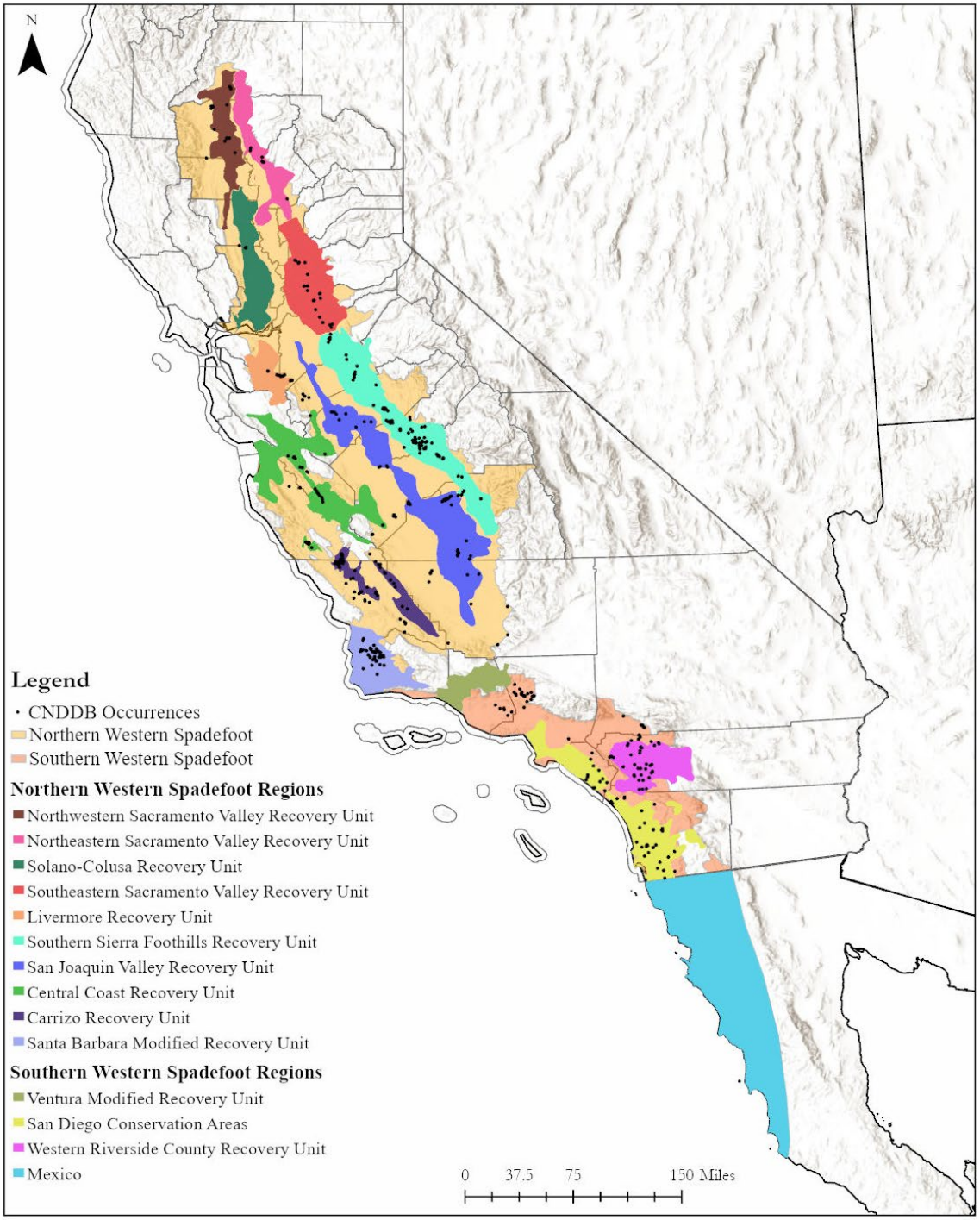

Figure 8: Map of western spadefoot toad regions. Regions are based on vernal pool mapping and align with the Service's Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon with a few species specific modifications for western spadefoot toads (Keeler-Wolfe et al. 1998, entire; Service 2005, p. III18–III87; Neal 2019, p. 1, 14–15, 21, 108).

Table 2: Condition Category Table for Western Spadefoot Individual and Population Needs

Condition	Individual Needs (Habitat)				Population Needs (Demography)		
	Aquatic Breeding Pools	Underground Burrows	Seasonal Rains	Small Invertebrate Prey	Reproduction	Dispersal	Abundance
Low	Low availability and distribution of pools; loss of extant vernal pool habitat by >20 percent since 2005	Low availability and distribution of burrows; <15 preserved habitat blocks	Low seasonal rain such that depth and duration of vernal pools is not sustained for breeding; below average seasonal rain; <80 percent departure from average	Prey not readily available or of low quality	Limited reproductive success by few individuals compromising the fitness of offspring; an inbreeding coefficient of greater than 10 percent	Low dispersal potential indicated by connectivity resistance models; impervious surface max >60 percent	Low abundance that would not withstand a stochastic event; effective number of breeders <20
Moderate	Pools available but not well distributed; loss of extant vernal pool habitat between 0 and 20 percent	Burrows available but not well distributed; 15–49 preserved habitat blocks	Seasonal rains that allow for but limit reproduction because of limited depth or duration of vernal pools; average seasonal rain; 80–100 percent departure from average	Prey available but not well distributed	An inbreeding coefficient of 5–10 percent	Limited dispersal potential indicated by resistance models; impervious surface max 10–60 percent	Abundance is stable but may not be sufficient to withstand a stochastic event; an effective number of breeders from 20 to 50 individuals
High	Pools available and well distributed; increase of extant vernal pool habitat	Burrows available and well distributed; > 50 preserved habitat blocks	Seasonal rains that provide abundant pools of sufficient duration and depth; Above average seasonal rain; >100 percent departure from average	Prey available, high quality, and well distributed	Sufficient number of individuals reproducing to maintain genetic integrity; an inbreeding coefficient less than 5 percent	Sufficient connectivity corridors available in resistance models; impervious surface max 0–10 percent	Abundance is stable or increasing and sufficient to withstand a stochastic event; effective number of breeders of >50 individuals

924 *Table 3: Comparison of Extant Vernal Pool Habitat from 2005 to 2012*

Vernal Pool Region	2005 Extant Habitat (acres)	2012 Extant Habitat (acres)	Percent Loss from 2005 to 2012
Central Coast	3,094	956	69%
Livermore	5,647	5,431	3.8%
Northeastern Sacramento Valley	160,010	133,477	17%
Northwestern Sacramento Valley	76,267	46,015	40%
San Joaquin Valley	237,231	212,524	10%
Solano Colusa	49,100	45,274	7.8%
Southeastern Sacramento Valley	144,147	130,331	9.6%
Southern Sierra Foothills	353,544	190,853	46%

925

926

927 **9.2 Regional Current Condition for Northern WST**

928 ***9.2.1 Northwestern Sacramento Valley***

929 The Northwestern Sacramento Valley vernal pool region extends from the Redding area
930 of Shasta County south to the Williams area of Colusa County, also including parts of Glenn and
931 Tehama counties. A full description of the Northwestern Sacramento Valley vernal pool region
932 can be found in the Recovery Plan for Vernal Pool Ecosystems of California and Southern
933 Oregon (Service 2005, pp. III-82–III-83). For individual needs, the entire Northwestern
934 Sacramento Valley vernal pool region was included in the reports measuring the status of the
935 vernal pool regions in the northern WST range (Witham *et al*. 2014, entire; Vollmar *et al*. 2017,
936 entire). There was a 40 percent loss of extant vernal pool habitat from 76,267 ac (30,864 ha) in

2005 to 46,015 ac (18,621 ha) in 2012, resulting in a low condition for aquatic breeding pools. There is only 16 preserve block >40 acres within the study area of the Northwestern Sacramento Valley vernal pool region, giving the region a low condition for underground burrows. The individual need of seasonal rains was given a moderate condition because a majority of the region had between 80 and100 percent of the average rainfall over the past 60 months (HPRCC 2020). The moderate condition for seasonal rains is likely due to recent droughts that have impacted California.

For population needs, no WST samples were taken from populations within the Northwestern Sacramento Valley vernal pool region in the dissertation assessing population genetics and habitat resistance modeling, therefore the conditions of reproduction, dispersal, and abundance are unknown for this region. In addition, no information was available to assess the individual need of small invertebrate prey. With the available information for individual needs, the overall WST condition for the Northwestern Sacramento Valley vernal pool region was determined to be low. The threats that are likely impacting this region reducing the condition of individual and population needs include a combination of development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and the effects of climate change.

9.2.2 Northeastern Sacramento Valley

The Northeastern Sacramento Valley vernal pool region extends from the Millville Plains to the Sutter Buttes, including parts of Butte, Shasta, Sutter, Tehama, and Yuba counties. It is adjacent to the Northwestern Sacramento Valley vernal pool region, but the two regions differ in soil type. A full description of the Northeastern Sacramento Valley vernal pool region can be found in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, p. III-82). For individual needs, the entire Northeastern Sacramento Valley vernal pool region was included in the reports measuring the status of the vernal pool regions in the northern WST range (Witham *et al*. 2014, entire; Vollmar *et al*. 2017, entire). There was a loss of 17 percent of vernal pool habitat with 160,010 ac (64,754 ha) in 2005 and 133,477 ac (54,016 ha) in 2012, resulting in a moderate condition for aquatic breeding pools. There are 52 preserve blocks >40 acres within the study area of the Northeastern Sacramento Valley vernal pool region, giving the region a high condition for underground burrows. The individual need of seasonal rains was given a moderate-high condition because the region had some areas that received only 80 to 90 percent of average precipitation, while other areas within the region experienced above average precipitation over the last 60 months (HPRCC 2020). The moderate-high condition for seasonal rains is likely due to recent droughts that have impacted California.

For population needs, no WST samples were taken from populations within the Northeastern Sacramento Valley vernal pool region in the dissertation assessing population genetics and habitat resistance modeling, therefore the conditions of reproduction, dispersal, and abundance are unknown for this region. In addition, no information was available to assess the individual need of small invertebrate prey. With the available information for individual needs, the overall WST condition for the Northeastern Sacramento Valley vernal pool region was determined to be high. The threats that are likely impacting this region reducing the condition of

individual and population needs include a combination of development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and the effects of climate change.

9.2.3 Solano-Colusa

The Solano-Colusa vernal pool region includes substantial areas of Solano, Colusa, and Yolo counties, as well as small parts of Glenn, Butte, Sutter, and Contra Costa counties. A full description of the Solano-Colusa vernal pool region can be found in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, p. III-84). The entire Solano-Colusa vernal pool region was included in the reports measuring the status of the vernal pool regions in the northern WST range (Vollmar *et al*. 2017, entire). There was a 7.8 percent loss of vernal pool habitat with 49,100 ac (19,870 ha) in 2005 and 45,274 ac (18,321 ha) in 2012, resulting in a moderate condition for aquatic breeding pools. There are 26 preserve blocks >40 acres within the Solano-Colusa vernal pool region, giving the region a moderate condition for underground burrows. The individual need of seasonal rains was given a moderate-high condition because the region had some areas that received only 80 to 90 percent of average precipitation, while other areas within the region experienced above average precipitation over the last 60 months (HPRCC 2019). The moderate-high condition for seasonal rains is likely due to recent droughts that have impacted California.

For population needs, one population within the Solano-Colusa vernal pool region was sampled as part of the Neal 2019 dissertation that examined population genetics and habitat resistance models of WST (Neal 2019, entire). The sampled population had an inbreeding coefficient of 5.636 percent, giving the region a moderate condition for reproduction (Neal 2019, p. 135). The same population was measured for percent impervious surface within two kilometers of the breeding pool and had no impervious surface, giving the region an overall high condition for dispersal (Neal 2019, pp. 137–138). To determine the condition of abundance for the Solano-Colusa region, measured effective number of breeders was 3.7 individuals giving the region a low condition for abundance (Neal 2019, p. 135). For this region, we were unable to determine the condition of small invertebrate prey. With the available information for individual and population needs, the overall WST condition for the Solano-Colusa vernal pool region was determined to be moderate. The threats that are likely impacting this region reducing the condition of individual and population needs include a combination of development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and the effects of climate change

9.2.4 Southeastern Sacramento Valley

The Southeastern Sacramento Valley vernal pool region extends from southern Yolo County south to San Joaquin and Calaveras counties, incorporating most of Sacramento county and smaller areas of Amador, El Dorado, Nevada, Placer, and Sutter counties. A full description of the Southeastern Sacramento Valley vernal pool region can be found in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, p. III-85). For individual needs, he entire Southeastern Sacramento Valley vernal pool region was included in

the reports measuring the status of the vernal pool regions in the northern WST range (Witham *et al*. 2014, entire; Vollmar *et al*. 2017, entire). There was a loss of 9.6 percent of extant vernal pool habitat with 144,147 ac (58,334 ha) in 2005 and 130,331 ac (52,743 ha) in 2012, resulting in a moderate condition for aquatic breeding pools. There are 83 preserve blocks >40 acres within the Southeastern Sacramento Valley vernal pool region, giving the region a high condition for underground burrows. The individual need of seasonal rains was given a high condition because the region received above average precipitation over the last 36 months (HPRCC 2019).

For population needs, one population within the Southeastern Sacramento Valley vernal pool region was sampled as part of the Neal 2019 dissertation that examined population genetics and habitat resistance models of WST (Neal 2019, entire). The one population had a negative inbreeding coefficient indicating that inbreeding occurred less often than would be expected at random, giving the region a high condition for reproduction (Neal 2019, p. 135). The same population was measured for percent impervious surface within two kilometers of the breeding pool and had only one percent impervious surface, giving the region an overall high condition for dispersal (Neal 2019, pp. 137–138). To determine the condition of abundance for the Southeastern Sacramento Valley vernal pool region, measured effective number of breeders was12.7, giving the region a low condition for abundance (Neal 2019, p. 135). For this region, we were unable to determine the condition of small invertebrate prey. With the available information for individual and population needs, the overall WST condition for the Southeastern Sacramento Valley vernal pool region was determined to be high. The threats that are likely impacting this region reducing the condition of individual and population needs include a combination of development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and the effects of climate change.

9.2.5 Livermore

The Livermore vernal pool region straddles Alameda, Contra Costa, and Santa Clara counties. A full description of the Livermore vernal pool region can be found in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, pp. III-80–III-81). For individual needs, a large portion of the Livermore vernal pool region was included in the reports measuring the status of the vernal pool regions in the northern WST range (Witham *et al*. 2014, entire; Vollmar *et al*. 2017, entire). There was a 3.8 percent loss in vernal pool habitat with 5,647 ac (2,285 ha) in 2005 and 5,431 ac (2,198 ha) in 2012, resulting in a moderate condition for aquatic breeding pools. There are only nine preserve blocks >40 acres within the study area of the Livermore vernal pool region, giving the region a low condition for underground burrows. The individual need of seasonal rains was given a moderate-high condition because the region had some areas that received only 80 to 90 percent of average precipitation, while other areas within the region experienced above average precipitation over the last 60 months (HPRCC 2020). The moderate-high condition for seasonal rains is likely due to recent droughts that have impacted California.

For population needs, one population within the Livermore vernal pool region was sampled as part of the Neal 2019 dissertation that examined population genetics and habitat resistance models of WST (Neal 2019, entire). The one population had a negative inbreeding

coefficient indicating that inbreeding occurred less often than would be expected at random, giving the region a high condition for reproduction (Neal 2019, p. 135). The same population was measured for percent impervious surface within two kilometers of the breeding pool and had less than 10 percent impervious surface, giving the region an overall high condition for dispersal (Neal 2019, pp. 137–138). To determine the condition of abundance for the Livermore region, effective number of breeders was7.9, giving the region a low condition for abundance (Neal 2019, p. 135). For this region, we were unable to determine the condition of small invertebrate prey. With the available information for individual and population needs, the overall WST condition for the Livermore vernal pool region was determined to be moderate. The threats that are likely impacting this region reducing the condition of individual and population needs include a combination of development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and the effects of climate change.

9.2.6 Southern Sierra Foothills

The Southern Sierra Foothills vernal pool region occupies high and low terrace landforms ranging from the junction of San Joaquin, Stanislaus, and Calaveras counties south to Tulare County. Portions of Fresno, Madera, Mariposa, Merced, and Tuolumne counties also in included in the region. A full description of the Southern Sierra Foothills vernal pool region can be found in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, pp. III-85–III-86). For individual needs, the entire Southern Sierra Foothills vernal pool region was included in the reports measuring the status of the vernal pool regions in the northern WST range (Witham *et al*. 2014, entire; Vollmar *et al*. 2017, entire). There was a loss of 46 percent of extant vernal pool habitat with 353,544 ac (143,074 ha) in 2005 and 190,853 ac (77,235 ha) in 2012, resulting in a low condition for aquatic breeding pools. There were 46 preserved blocks >40 acres within the study area of the Southern Sierra Foothills vernal pool region, giving the region a moderate condition for underground burrows. The individual need of seasonal rains was given a moderate-high condition because the region had some areas that received only 80 to 90 percent of average precipitation, while other areas within the region experienced above average precipitation over the last 60 months (HPRCC 2019). The moderate-high condition for seasonal rains is likely due to recent droughts that have impacted California.

For population needs, three populations within the Southern Sierra Foothills vernal pool region were sampled as part of the Neal 2019 dissertation that examined population genetics and habitat resistance models of WST (Neal 2019, entire). Two populations had a negative inbreeding coefficient indicating that inbreeding occurred less often than would be expected at random, which would be considered high condition (Neal 2019, p. 135). However, one population had inbreeding coefficient of 8.883 percent resulting in a moderate condition for one of the three sampled populations within the region (Neal 2019, p. 135). Looking at the three measured populations, the overall condition of reproduction within the region is high. The same three populations were measured for percent impervious surface within two kilometers of the breeding pool. Two of the three populations within the region had less than 10 percent impervious surface, and one population was found to have 19 percent impervious surface. With two of the three populations having less than 10 percent impervious surface, the region has an

overall high condition for dispersal (Neal 2019, pp. 137–138). To determine the condition of abundance for the Southern Sierra Foothills region, effective number of breeders was measured for the same three populations. The number of breeders were found to be 2.3, 2.5, and 8.8 for the three populations (Neal 2019, p. 135), so the region was determined to have a low condition for abundance. For this region, we were unable to determine the condition of small invertebrate prey. With the available information for individual and population needs, the overall WST condition for the Southern Sierra Foothills vernal pool region was determined to be moderate. The threats that are likely impacting this region reducing the condition of individual and population needs include a combination of development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and the effects of climate change.

9.2.7 San Joaquin Valley

The San Joaquin Valley vernal pool region occupies the trough that runs southward from San Joaquin County to Kern County, including parts of Fresno, Kings, Madera, Merced, Stanislaus, and Tulare counties. A full description of the San Joaquin Valley vernal pool region can be found in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, p. III-83). For individual needs, the entire San Joaquin Valley vernal pool region was included in the reports measuring the status of the vernal pool regions in the northern WST range (Witham *et al*. 2014, entire; Vollmar *et al*. 2017, entire). There was a loss of 10 percent of extant vernal pool habitat with 237,231 ac (96,004 ha) in 2005 and 212,524 ac (86,005 ha) in 2012, resulting in a moderate condition for aquatic breeding pools. There are 43 preserve blocks >40 acres within the study area of the San Joaquin Valley vernal pool region, giving the region a moderate condition for underground burrows. The individual need of seasonal rains was given a moderate condition because a majority of the region had between 80 and100 percent of the average rainfall over the past 60 months (HPRCC 2020). The moderate condition for seasonal rains is likely due to recent droughts that have impacted California.

For population needs, six populations within the San Joaquin vernal pool region were sampled as part of the Neal 2019 dissertation that examined population genetics and habitat resistance models of WST (Neal 2019, entire). Two populations had inbreeding coefficients of less than five percent which would be considered high condition (Neal 2019, pp. 135–136). Three populations sampled had an inbreeding coefficients that ranged from 5 to 10 percent indicating a moderate condition for reproduction (Neal 2019, pp. 135–136). One population had an inbreeding coefficient of 13.414 percent indicating inbreeding and a low condition for reproduction (Neal 2019, p. 135–136). Overall, with two populations sampled indicating high reproduction, three indicating moderate, and one indicating low, the vernal pool region is in moderate condition for reproduction. The same six populations were measured for percent impervious surface within two kilometers of the breeding pool and ranged from zero to 71 percent (Neal 2019, pp. 137–140). Of the six populations analyzed in the habitat resistance modeling in the region, two had 60 percent or higher percent impervious surface, two had between 10 and 60 percent impervious surface, and two had less than 10 percent impervious surface (Neal 2019, pp. 137–139). The region was given an overall condition of moderate for dispersal. To determine the condition of abundance for the San Joaquin Valley region, effective

number of breeders was measured for four of the six populations sampled within the region. The number of breeders was found to range from 3.4 to 18.3 individuals. All populations had less than 20 breeders resulting in a low condition for abundance. We were unable to determine the condition small invertebrate prey for this region. With the available information for individual and population needs, the overall WST condition for the San Joaquin Valley vernal pool region was determined to be moderate. The threats that are likely impacting this region reducing the condition of individual and population needs include a combination of development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and the effects of climate change.

9.2.8 Central Coast

The Central Coast vernal pool region includes several polygons distributed over portions of nine counties including Alameda, Fresno, Merced, Monterey, San Benito, San Mateo, Santa Clara, Santa Cruz, and Stanislaus. A full description of the Central Coast vernal pool region can be found in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, pp. III-78–III-79). For individual needs, a small portion of the Central Coast vernal pool region was included in the reports measuring the status of the vernal pool regions in the northern WST range (Witham *et al*. 2014, entire; Vollmar *et al*. 2017, entire). There was a loss of vernal pool habitat by 69 percent from 3,094 ac (1,252 ha) in 2005 to 956 ac (387 ha) in 2012 (Witham *et al*. 2014, data; Vollmar *et al*. 2017, p. 1–14), resulting in a low condition for aquatic breeding pools. There is one preserved block >40 acres within the study area of the Central Coast vernal pool region, giving the region a low condition for underground burrows. The individual need of seasonal rains was given a moderate-high condition because the region had some areas that received 80 to 90 percent of average precipitation, while other areas within the region experienced above average precipitation over the last 60 months (HPRCC 2020). The moderate-high condition for seasonal rains is likely due to recent droughts that have impacted California.

For population needs, three populations within the Central Coast vernal pool region were sampled as part of the Neal 2019 dissertation that examined population genetics and habitat resistance models of WST (Neal 2019, entire). One population had a negative inbreeding coefficient indicating that inbreeding occurred less often than would be expected at random, which would be considered high condition (Neal 2019, p. 135). However, two populations had inbreeding coefficients greater than 10 percent (11.908percent and 12.534 percent) resulting in a low condition for two of the three sampled populations within the region (Neal 2019, p. 135). Looking at the three measured populations, the overall condition of reproduction within the region is low. The same three populations were measured for percent impervious surface within two kilometers of the breeding pool. All three populations within the region had less than 10 percent impervious surface, giving the region an overall high condition for dispersal (Neal 2019, pp. 137–138). To determine the condition of abundance for the Central Coast region, effective number of breeders was measured for the same three populations. The number of breeders was found to be 4.9, 7.7, and 9 for the three populations (Neal 2019, p. 135), putting all three populations in low condition. Therefore, the region was determined to have a low condition for

abundance. For this region, we were unable to determine the condition of small invertebrate prey. With the available information for individual and population needs, the overall WST condition for the Central Coast vernal pool region was determined to be low-moderate. The threats that are likely impacting this region reducing the condition of individual and population needs include a combination of development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and the effects of climate change.

9.2.9 Carrizo

The Carrizo vernal pool region is almost entirely in San Luis Obispo County, but does incorporate small areas of adjacent Kern and Monterey Counties. A full description of the Carrizo vernal pool region can be found in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, p. III–78). For individual needs, the Carrizo vernal pool region was not included in the reports assessing the status of vernal pools in the northern WST range, therefore the conditions of aquatic breeding pools and underground burrows are unknown for this region. The individual need of seasonal rains was given a moderate condition because a majority of the region had between 80 and100 percent of the average rainfall over the past 60 months (HPRCC 2020). The moderate condition for seasonal rains is likely due to recent droughts that have impacted California.

For population needs, three populations within the Carrizo vernal pool region were sampled as part of the Neal 2019 dissertation that examined population genetics and habitat resistance models of WST (Neal 2019, entire). One population examined had an inbreeding coefficient of 8.56 percent, which is considered a moderate condition (Neal 2019, pp. 135). The two other populations have a high condition of reproduction because samples had negative inbreeding coefficients which indicates that inbreeding occurred less often than would be expected at random (Neal 2019, pp. 135–136; Keller *et al*. 2002, p. 231). Overall the region was given a high condition for reproduction, with two populations in high condition and one in moderate. The same three populations were measured for percent impervious surface within two kilometers of the breeding pool. One population had only 6 percent impervious surface classifying it within a high condition, but two populations had 19 and 20 percent impervious surface classifying them as moderate condition (Neal 2019, pp. 137–139). The overall dispersal condition for the Carrizo region is moderate condition, with two populations measured in moderate and only one in high. To determine the condition of abundance for the Carrizo region, effective number of breeders was measured for only one of the three populations and was determined to be 6.1 giving the region a low condition for abundance. For this region, we were unable to determine the condition of aquatic breeding pools, underground burrows, or small invertebrate prey. With the available information for individual and population needs, the overall WST condition for the Carrizo vernal pool region was determined to be moderate. The threats that are likely impacting this region reducing the condition of individual and population needs include a combination of development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and the effects of climate change.

9.2.10 Santa Barbara

The Santa Barbara modified vernal pool region includes the coastal plains of San Luis Obispo and Santa Barbara counties. This unit is modified from the original vernal pool region in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon due to known significant genetic differences between WST populations north and south of the transverse mountains. A description of the Santa Barbara vernal pool region, prior to the modification for WST, can be found in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, pp. III-83–III-84). For individual needs, the Santa Barbara modified vernal pool region was not included in the reports assessing the status of vernal pools in the northern WST range, therefore the conditions of aquatic breeding pools and underground burrows are unknown for this region. The individual need of seasonal rains was given a moderate condition because a majority of the region had between 80 and 100 percent of the average rainfall over the past 60 months (HPRCC 2020). The moderate condition for seasonal rains is likely due to recent droughts that have impacted California.

For population needs, two populations within the Santa Barbara modified vernal pool region were sampled as part of the Neal 2019 dissertation that examined population genetics and habitat resistance models of WST (Neal 2019, entire). One population examined had an inbreeding coefficient of 5.523 percent, which is considered a moderate condition (Neal 2019, pp. 135–136). The other population had a high condition of reproduction because samples had negative inbreeding coefficients which indicates that inbreeding occurred less often than would be expected at random (Neal 2019, pp. 135–136; Keller *et al*. 2002, p. 231). Overall the region was given a moderate-high condition for reproduction, with one population in high condition and one in moderate. The same two populations were measured for percent impervious surface within two kilometers of the breeding pool. One population had no impervious surface classifying it within a high condition, but the other population had 12 percent impervious surface classifying it as moderate condition (Neal 2019, pp. 137–139). The overall dispersal condition for the Santa Barbara modified region is moderate-high condition, with one population measured in moderate and one in high. To determine the condition of abundance for the Santa Barbara region, effective number of breeders was measured for both populations that were sampled. The number of breeders were found to be 3.9 and 3.2, giving the region a low condition for abundance. For this region, we were unable to determine the condition of aquatic breeding pools, underground burrows, or small invertebrate prey. With the available information for individual and population needs, the overall WST condition for the Santa Barbara modified vernal pool region was determined to be moderate. The threats that are likely impacting this region reducing the condition of individual and population needs include a combination of development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and effects of climate change.

Table 4: Current Condition Table for Northern Western Spadefoot Regions

Population	Aquatic Breeding Pools	Underground Burrows	Seasonal Rains	Small Invertebrate Prey	Reproduction	Dispersal	Abundance	Overall Condition
Northwestern Sacramento Valley	Low (1)	Low (1)	Moderate (2)	Unknown	Unknown	Unknown	Unknown	Low (1.33)
Northeastern Sacramento Valley	Moderate (2)	High (3)	Moderate-High (2.5)	Unknown	Unknown	Unknown	Unknown	High (2.50)
Solano-Colusa	Moderate (2)	Moderate (2)	Moderate-High (2.5)	Unknown	Moderate (2)	High (3)	Low (1)	Moderate (2.08)
Southeastern Sacramento Valley	Moderate (2)	High (3)	High (3)	Unknown	High (3)	High (3)	Low (1)	High (2.50)
Livermore	Moderate (2)	Low (1)	Moderate-High (2.5)	Unknown	High (3)	High (3)	Low (1)	Moderate (2.08)
Southern Sierra Foothills	Low (1)	Moderate (2)	Moderate-High (2.5)	Unknown	High (3)	High (3)	Low (1)	Moderate (2.08)
San Joaquin Valley	Moderate (2)	Moderate (2)	Moderate (2)	Unknown	Moderate (2)	Moderate (2)	Low (1)	Moderate (1.83)
Central Coast	Low (1)	Low (1)	Moderate-High (2.5)	Unknown	Low (1)	High (3)	Low (1)	Low-Moderate (1.58)
Carrizo	Unknown	Unknown	Moderate (2)	Unknown	High (3)	Moderate (2)	Low (1)	Moderate (2.00)
Santa Barbara	Unknown	Unknown	Moderate (2)	Unknown	Moderate-High (2.5)	Moderate-High (2.5)	Low (1)	Moderate (2.00)

9.3 Northern WST Clade Redundancy

To assess the current condition of redundancy, the species' current ability to withstand catastrophic events, this SSA considers the number of resilient regions in the northern WST range. Resiliency is evaluated by assessing the condition of the individual and population needs for each region. There is a total of 10 regions in the northern WST range. Currently, two of the 10 regions are considered in high condition, and six are in moderate condition. One region is in low-moderate condition and one is in low condition. A majority of the regions are in moderate condition, which indicates a majority of the regions have one or more individual or population need that may be compromised. Of particular concern is that all the regions within the northern WST clade have a low condition for abundance. The one region within the northern WST clade with low resiliency would likely not withstand a catastrophic event However, there are few regions that have low resiliency, increasing the likelihood that the northern WST clade would withstand a catastrophic event. An example of a catastrophic event that may impact the northern WST clade would be an extended period of drought that reduced the ability of WST population to breed for multiple years.

9.4 Northern WST Clade Representation

As described in the Methodology section, above, representation is the ability of a species to adapt to changing environmental conditions. This factor is assessed at the species level. The WST occurs across a wide physical range that have different environmental conditions and as a result, WST could be considered to have a high level of environmental adaptability. For example, as discussed above WST and other spadefoot species can shorten their metamorphosis timeframe in response to quickly drying aquatic habitat conditions (Gomez-Mestre and Buchholtz 2006, pp. 19024–19026). However, individual adaptability is not necessarily equivalent to evolutionary adaptability of a species, which is what representation attempts to characterize. We typically use the breadth of genetic or environmental diversity within and among populations as a surrogate for evolutionary adaptability. As noted in the Genetics section and Species Needs section above, there is some degree of genetic differences between regions within the northern WST range (Neal 2019, p. 115). However, the low effective number of breeders in all regions of the northern WST clade suggests that there is low genetic variability, which may reduce the representation. The northern WST clade still occupies all known regions, with only two of the ten region in low condition. Currently the species still has some degree of representation since it occupies all its historic unique ecological settings. However, with six of the ten regions with moderate resiliency, the probability of persistence in those region may be compromised by the lack of one or more need. Habitat loss in the range has likely reduced the species representation from historic level (Jennings and Hayes 1994, p. 96; Witham *et al*. 2014, entire; Vollmar *et al*. 2017, entire).

9.5 Regional Current Condition for Southern WST

9.5.1 Ventura

The Ventura modified vernal pool region is the southern portion of the original Santa Barbara vernal pool region that includes the coastal plains of Ventura County south of the Transverse Mountains. This unit is modified from the original vernal pool region in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon due to known significant genetic differences at the species-level between WST populations north and south of the Transverse Range. A description of the Santa Barbara vernal pool region, prior to the modification for WST that includes the new modified Ventura region, can be found in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, pp. III-83–III-84). The Ventura modified vernal pool region was not included in the report assessing the status of vernal pools in the northern WST range, therefore the conditions of aquatic breeding pools and underground burrows are unknown for this region. The individual need of seasonal rains was given a moderate condition because the majority of the region had received only 80 to 90 percent of average precipitation over the last 60 months (HPRCC 2019). The moderate condition for seasonal rains is likely due to recent droughts that have impacted California.

For population needs, two populations within the Ventura modified vernal pool region were sampled as part of the Neal 2019 dissertation that examined population genetics and habitat resistance models of WST (Neal 2019, entire). Both sampled populations had a high condition of reproduction because samples had negative inbreeding coefficients which indicates that inbreeding occurred less often than would be expected at random (Neal 2019, pp. 135–136; Keller *et al*. 2002, p. 231). The same two populations were measured for percent impervious surface within two kilometers of the breeding pool. Both populations had less than 10 percent impervious surface giving the region an overall high condition for dispersal (Neal 2019, pp. 137–139). To determine the condition of abundance for the Ventura region, effective number of breeders was measured for both populations that were sampled. The number of breeders were found to be 4 and 12.1, giving the region a low condition for abundance. For this region, we were unable to determine the condition of aquatic breeding pools, underground burrows, or small invertebrate prey. With the available information for individual and population needs, the overall WST condition for the Ventura modified vernal pool region was determined to be moderate-high. The threats that are likely impacting this region reducing the condition of individual and population needs include a combination of development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and the effects of climate change.

9.5.2 San Diego

The San Diego vernal pool region extends from Los Angeles County to San Diego County, also incorporating parts of Orange County. A full description of the San Diego vernal pool region can be found in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, pp. III-86–III-87). The San Diego vernal pool region was not included in the report assessing the status of vernal pools in the northern WST range.

Information available from HCP's within the San Diego vernal pool region identified 112 preserved habitat blocks >40 acres within the region, giving the region a high condition for underground burrows. The individual need of seasonal rains was given a moderate condition because the majority of the region had received only 80 to 90 percent of average precipitation over the last 60 months (HPRCC 2019). The moderate condition for seasonal rains is likely due to recent droughts that have impacted California.

For population needs, sixteen populations within the San Diego vernal pool region were sampled as part of the Neal 2019 dissertation that examined population genetics and habitat resistance models of WST (Neal 2019, entire). All 16 populations had inbreeding coefficients of less than five percent, so the overall condition of reproduction for the region is high (Neal 2019, pp. 135–137). The same 16 populations were measured for percent impervious surface within two kilometers of the breeding pool and ranged from zero to 79 percent (Neal 2019, pp. 137–140). Of the 16 populations analyzed in the habitat resistance modeling in the region, eight had 60 percent or higher percent impervious surface, two had between 10 and 60 percent impervious surface, and six had less than 10 percent impervious surface (Neal 2019, pp. 137–139). The region was given an overall condition of low-moderate for dispersal. To determine the condition of abundance for the San Diego region, effective number of breeders was measured for all 16 populations sampled within the region. The number of breeders was found to range from 1.4 to 20.7 individuals. There was one population with greater than 20 breeding individuals measured, and the remaining populations measured less than 20 breeding individuals. Overall, the region was given a low condition for abundance. For this region, we were unable to determine the condition of aquatic breeding pools, underground burrows, or small invertebrate prey. With the available information for individual and population needs, the overall WST condition for the San Diego vernal pool region was determined to be moderate. The threats that are likely impacting this region reducing the condition of individual and population needs include a combination of development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and the effects of climate change.

9.5.3 Western Riverside

The Western Riverside vernal pool region is mostly in Riverside County but includes a small portion of adjacent San Diego County. A full description of the Western Riverside vernal pool region can be found in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Service 2005, p. III-86). The Western Riverside vernal pool region was not included in the report assessing the status of vernal pools in the northern WST range. Information available from HCP's within the Western Riverside vernal pool region has identified 43 preserved habitat blocks >40 acres within the region, giving the region a moderate condition for underground burrows. The individual need of seasonal rains was given a moderate condition because the majority of the region had received only 80 to 90 percent of average precipitation over the last 60 months (HPRCC 2019). The moderate condition for seasonal rains is likely due to recent droughts that have impacted California.

For population needs, one population within the Western Riverside vernal pool region was sampled as part of the Neal 2019 dissertation that examined population genetics and habitat

resistance models of WST (Neal 2019, entire). The one population had an inbreeding coefficient of 2.212 percent, giving the region a high condition for reproduction (Neal 2019, p. 135). The same population was measured for percent impervious surface within two kilometers of the breeding pool and had 75 percent impervious surface, giving the region an overall low condition for dispersal (Neal 2019, pp. 137–138). To determine the condition of abundance for the Western Riverside vernal pool region, effective number of breeders was measured, and the number of breeders was found to be found 4.2, giving the region a low condition for abundance (Neal 2019, p. 135). For this region, we were unable to determine the condition of aquatic breeding pools, underground burrows, or small invertebrate prey. With the available information for individual and population needs, the overall WST condition for the Western Riverside vernal pool region was determined to be moderate. The threats that are likely impacting this region reducing the condition of individual and population needs include a combination of development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and the effects of climate change.

9.5.4 Mexico

The Mexico region is the furthest south and extends from the U.S. border south to the end of the range in northwest Baja California (Figure 8). In Mexico WST occurs in the foothills of Sierra San Pedro Martir and in Mesa of San Carlos (Grismer 2002, pp. 84–85). No habitat or demographic analyses were able to be completed for the Mexico region because the data do not exist. Occurrence data from Baja Mexico collected as recently at 2019 indicates that WST are present in Mexico (Peralta and Valdez 2020, pers. comm.). The overall current condition for the Mexico region is unknown. There is a small amount of protected habitat at the southern tip of the WST range in Mexico, but it is unknown how much of this habitat is vernal pool habitat (UNEP-WCMC 2019). The threats that are likely impacting this region include development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and the effects of climate change.

Table 5: Current Condition Table for Western Spadefoot Regions

Population	Aquatic Breeding Pools	Underground Burrows	Seasonal Rains	Small Invertebrate Prey	Reproduction	Dispersal	Abundance	Overall Condition
Ventura	Unknown	Unknown	Moderate (2)	Unknown	High (3)	High (3)	Low (1)	Moderate-High (2.25)
San Diego	Unknown	High (3)	Moderate (2)	Unknown	High (3)	Low-Moderate (1.5)	Low (1)	Moderate (2.10)
Western Riverside	Unknown	Moderate (2)	Moderate (2)	Unknown	High (3)	Low (1)	Low (1)	Moderate (1.80)
Mexico	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

9.6 Southern WST Clade Redundancy

To assess the current condition of redundancy, the species' current ability to withstand catastrophic events, this SSA considers the number of resilient regions in the southern WST range. Resiliency is evaluated by assessing the condition of the individual and population needs for each region. There is a total of four regions in the southern WST range. Currently, one of the regions is in moderate-high condition, and two of the regions are in moderate condition. Half of the southern WST clade regions are in moderate condition, which indicates a half of the regions have one or more individual or population need that may be compromised. The condition of the Mexico region is unknown. None of the known regions in the southern WST range are currently in low condition, increasing the likelihood to withstand a catastrophic event. An example of a catastrophic event that may impact the southern WST clade would be an extended period of drought that reduced the ability of WST population to breed for multiple years.

9.7 Southern WST Clade Representation

As described in the Methodology section, above, representation is the ability of a species to adapt to changing environmental conditions. This factor is assessed at the species level. The WST occurs across a wide physical range that have different environmental conditions and as a result, WST could be considered to have a high level of environmental adaptability. For example, as discussed above WST and other spadefoot species can shorten their metamorphosis timeframe in response to quickly drying aquatic habitat conditions (Gomez-Mestre and Buchholtz 2006, pp. 19024–19026). However, individual adaptability is not necessarily equivalent to evolutionary adaptability of a species, which is what representation attempts to characterize. We typically use the breadth of genetic or environmental diversity within and among populations as a surrogate for evolutionary adaptability. As noted in the Genetics section and Species Needs section above, there is some degree of genetic differences between regions within the southern WST clade (Neal 2019, p. 115). However, the low effective number of breeders in all regions of the southern WST clade suggests that there is low genetic variability, which may reduce representation. The southern WST clade still occupies all known regions, with no regions currently known to be in low condition. Currently the species still has some degree of representation since it occupies all its historic unique ecological settings. However, with known habitat loss in the range, it has likely reduced the species representation from historic level (Jennings and Hayes 1994, p. 96; Witham *et al*. 2014, entire; Vollmar *et al*. 2017, entire).

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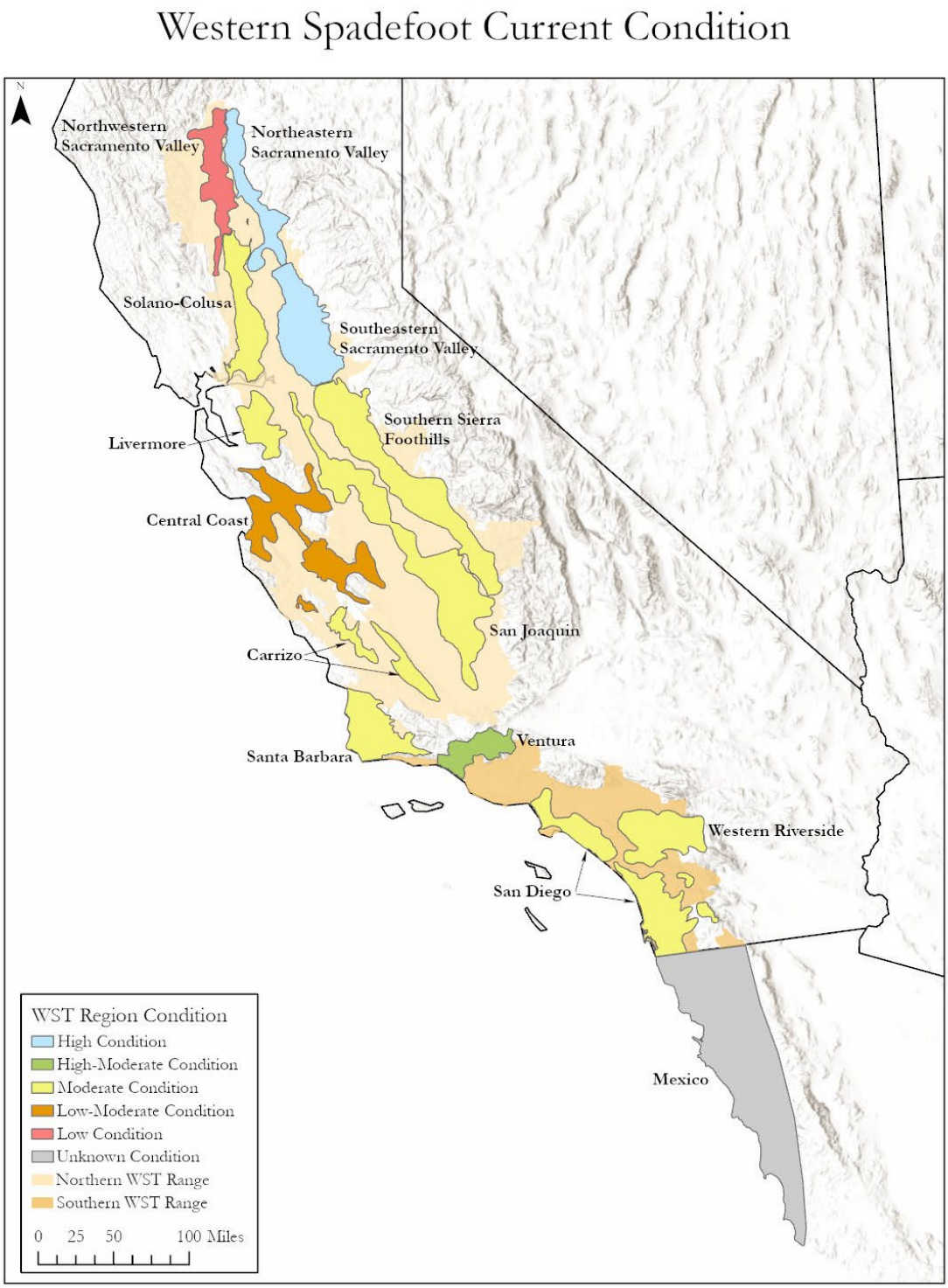

Figure 9: Western spadefoot regions displaying the current condition.

10.0 FUTURE CONDITIONS

In order to provide some insight into the future conditions for a particular species, we construct several plausible scenarios to assist in articulating how the species needs, threats, and habitat conditions may change in the future.

10.1 Scenario Planning and its Application

Scenario planning is a comprehensive exercise that involves the development of scenarios that capture a range of plausible future conditions. That development is then followed by an assessment of the potential effects of those scenarios on a given species. Scenarios are not predictions or forecasts of what will happen in the future for a species, but are projections or explorations into the range of conditions that may exist based on current information (Figure 10). The scenarios are intended to provide the "upper" and "lower" bounds of plausible conditions (Figure 11), outline uncertainties, and provide decision makers with a means for managing risk and maintaining flexibility in current and future decisions.

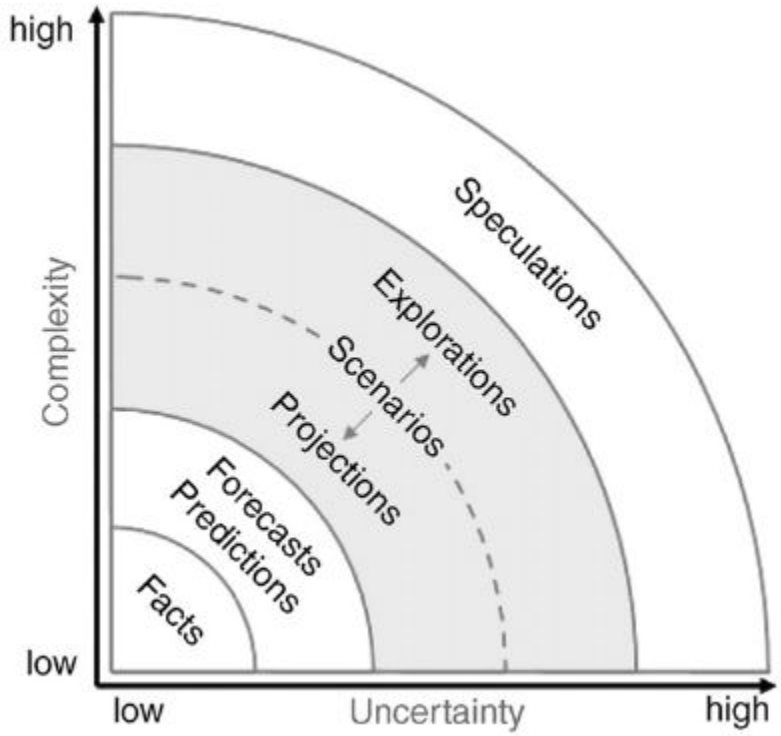

Figure 10. The levels of uncertainty and complexity in situations for which scenarios can be useful in considering future possibilities (adapted from Roland et al. 2014)

A range of time frames with a multitude of possible scenarios allows us to create a "risk profile" for the northern tidewater goby and its viability into the future. While we do not expect every condition for each scenario to be fully realized, we are using these scenarios as examples for the range of possibilities. For each scenario, we describe the stressors that would occur in each population and how they may change in the future. We used the best available science to predict trends in future threats facing the northern tidewater goby. Data availability varies across the range of the species and or individual populations. Where data on future threats or trends were not available, we looked to past threats and their trends and evaluate if it is reasonable to assume these trends will continue into future and to what degree.

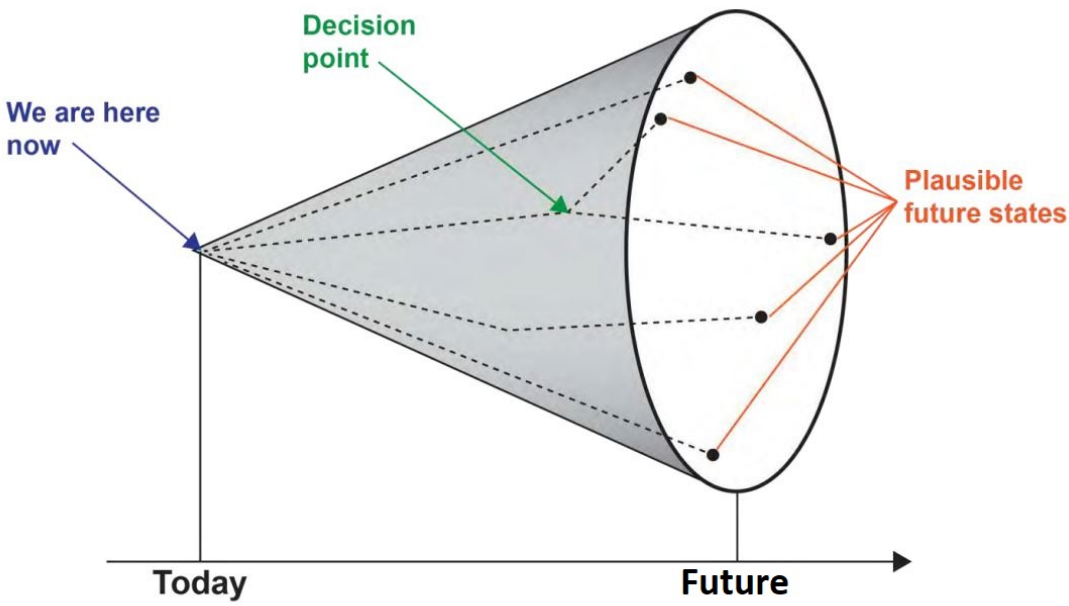

Figure 11. Conceptual diagram of the broadening range of plausible alternative futures as one moves farther away from the present and different events and decision points shift trajectories. (Roland et al. 2012 adapted from Reclamation 2012).

10.2 Future Scenarios for the Western Spadefoot Toad

This section of the SSA forecasts the species' response to a range of plausible future scenarios of environmental conditions and conservation efforts. The future scenarios project the threats discussed earlier in the SSA into the future and consider the impacts those threats would potentially have on WST viability. The concepts of resiliency, redundancy, and representation are applied to the future scenarios to describe the future viability of the northern and southern WST. Three future scenarios are described and future resiliency for each WST region was assessed. Scenario 1 assesses WST viability in a future with increased extreme climate events

and anthropogenic impacts. Scenario 2 assesses the viability of the species under a continuation scenario future, defined as the continuing of the current trajectory of threats and conservation actions into the future. Scenario 3 assesses WST future viability with a lower emission scenario for climate change. Table 4 provides a comparison of the assumptions made for each scenario. By using three scenarios, it allows us to consider a range of future possibilities for predicting the future viability of the species. For this SSA, the future was assessed at approximately 30–40 years. This range represents estimates of mid-century climate projections and human population and development projections for California (The California Economic Forecast 2017, p. 2; Bedsworth *et al*. 2018, p. 23).

An overall high condition for a region is an indicator of high probability of persistence of individuals in the region, an overall moderate condition is an indicator that probability of persistence in that region may be compromised by the lack of one or more need, and a low overall condition indicates low probability of persistence of individuals in the region. Regions in high condition are expected to persist into the future and have the ability to withstand stochastic events that may occur. Regions in moderate condition are less resilient than those in high condition, but the majority of these regions are expected to persist beyond 30–40 years. Regions in moderate condition may have some declines in individual or population needs, but would likely still be able to support a population. Regions in low condition have low resiliency and may not be able to withstand stochastic events because of significant declines in individual or population needs. Regions in low condition are less likely to persist for 30–40 years, but a region in low condition does not automatically mean the region will become extirpated. When assessing the future, viability is not a specific state, but rather a continuous measure of the likelihood that the species will sustain populations over time.

Table 6: Future Scenario Comparison Table

Threats	Scenario 1: Increasing Threats	Scenario 2: Continuation Scenario	Scenario 3: Lower Emissions Scenario
Development	Increase with population growth	Avoid Habitat	Avoid Habitat
Abundance of Vegetation	Increase due to lack of management	Remain the same	Remain the same
Nonnative Predators	Increase due to lack of management	Remain the same	Remain the same
Drought	Increase	Remain the same	Remain the same
Noise Disturbance	Increase with population growth	Remain the same	Remain the same
Climate Change	RCP 8.5, plus increased extreme events such as drought	RCP 8.5	RCP 4.5

10.3 Future Scenario Summary of Methods

Three plausible future scenarios were considered, and the viability of WST was assessed under each scenario using the WST condition category table (Table 2). For each scenario, a description is given of the scenario assumptions, and a table presents predicted changes in stressors/threats, how the threats would impact individual and population needs, the assumed magnitude of the impacts, and the current understanding of the likelihood of the prediction. Table 7 describes the definitions that were used for predicted change, magnitude, and likelihood of threats. The likelihood of the threat refers to the confidence from the scientific literature of how likely the prediction is to occur. The overall condition was determined as described in the current condition section of the SSA (section 11.1). Only categories that were given a condition in the current condition were assigned a condition for the future conditions.

As explained in Section 11.1, data is not available to determine the condition of the individual need of small invertebrate prey for any region. With no current condition basis, a future condition was not predicted for the unknown category. Each scenario only represents one possibility of an infinite number of future scenarios. The threats of chemical contaminants and potential disease were not considered under the future scenarios because there is no evidence that these threats are impacting the species now or will in the future. The same predictions were made for both the northern and southern WST clades. ≤

Table 7: Predicted Magnitude Definitions for Threats

Magnitude Term	Definition
Weak	Threat/stressor may have an impact, but not enough to impact the condition of the individual or population need
Strong	Threat/stressor will impact the condition of the individual or population need

10.4 Future Scenario 1: Increasing Threats Scenario

Scenario 1 considers future WST viability where some threats increase over the next 30–40 years, including extreme weather events of drought. The bounds of the magnitude of each threat are based on the best available science and potential plausible increases in threats. Under this scenario, development increases in California. Of the 37 counties within the WST range, 30 are predicted to have a population increase of at least 10 percent by 2050 (CalTrans 2016, entire). With a majority of counties predicted to have an increase in population, development will likely increase within the range of WST and may occur in vernal pool habitat that is not currently protected. Development would decrease the quality and quantity of aquatic breeding pools and underground burrows leading to declines in abundance, dispersal, and reproduction. The one region that will likely not experience significant impacts from further development is the San Joaquin Valley region, because 59 percent of the extant habitat is already protected (Vollmar *et al*. 2017, p. 1–14). Overabundant vegetation needs to be managed or it can lead to the premature drying of aquatic breeding pools decreasing the ability of WST to disperse and reproduce. Even with protected vernal pool habitat, overabundance of vegetation can occur if the habitat is not

properly managed (Vollmar *et al* 2017, pp. 2-8–2-15). Nonnative predators also have the potential to increase without management actions. The increase of nonnative predators would likely cause declines of abundance and reproduction. Extreme events have the potential to either increase or decrease the number of nonnative predators. Not enough water would likely make the habitat less suitable for nonnative predators considering they prefer more permanent water sources, whereas an increase in storm events may produce aquatic breeding pools that are more hospitable for nonnative predators. An increase of extreme events has been predicted in California including both drought and flooding events (Bedsworth *et al*. 2018, p. 22). Drought would likely have the greatest impact on WST by reducing aquatic breeding pools available and reducing abundance, dispersal, and reproduction. Droughts are likely to be more frequent, longer, and more intense in the future (Bedsworth *et al*. 2018, p. 57). It is hypothesized that current effective population sizes may be low due to recent drought events (Neal 2019, p. 32). Although an extended drought period may minimize the number of nonnative predators, the negative impacts of drought on WST in limiting the number of WST individuals able to breed would likely outweigh benefit of fewer nonnative predators. Noise disturbance would likely increase as the human population and development increases. This disturbance could cause miscues for individuals to come out of burrows and breed when environmental conditions are not appropriate to support breeding. It is possible that individuals could surface at times that may lead to mortality if high temperatures cause desiccation or if energy stores are used up to surface and prey is not available. Lastly, the downscaled climate change projection RCP 8.5, or the business as usual projection, was used as a basis for climate change, but in addition we are considering the impacts of extreme events such as an extended multi-year drought.

Although vernal pool habitat is currently protected, it is possible that under future climate scenarios and with extended drought periods that the protected vernal pool habitat may no longer be suitable for WST. If seasonal rains are compromised, then the aquatic breeding pools may no longer be available for WST. Underground burrows may still be present and protected, but if they are no longer within range of the aquatic breeding pools then they are not sufficient for the needs of WST. Small invertebrate prey would likely also be compromised by climate change and extreme weather conditions. With a decrease of both quality and quantity of all the individual needs, all the population needs would likely also decrease. Looking at the future threats under scenario 1, all the individuals needs will likely decrease in quality or quantity, but they each will only be impacted by some of the threats. The population needs will likely be impacted by all of the future threats. Table 8 provides a summary of the assumptions for Scenario 1, including how each threat is expected to impact the individual and population needs. Table 9 and Figure 12 provide the predicted condition for both northern and southern WST regions under Scenario 1.

Table 8: Future Scenario 1 Threat Projections

Threat	Scenario 1 Prediction	Impacts to Individual and Population Needs	Magnitude of Impact	Regions Impacted
Development		Aquatic Breeding Pools	Weak	All

	Increase with population growth	Underground Burrows	Strong	
		Seasonal Rains	No impact	
		Small Invertebrate Prey	Strong	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	
Overabundant Vegetation	Increase with lack of management	Aquatic Breeding Pools	Strong	All
		Underground Burrows	Weak	
		Seasonal Rains	No Impact	
		Small Invertebrate Prey	Weak	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	
Nonnative Predators	Increase with lack of management	Aquatic Breeding Pools	No Impact	All
		Underground Burrows	No Impact	
		Seasonal Rains	No Impact	
		Small Invertebrate Prey	Weak	
		Reproduction	Strong	
		Dispersal	Weak	
		Abundance	Strong	
Drought	Increase; extended periods	Aquatic Breeding Pools	Strong	All
		Underground Burrows	No Impact	
		Seasonal Rains	Strong	
		Small Invertebrate Prey	Strong	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	
Noise Disturbance		Aquatic Breeding Pools	No Impact	All

	Increase with population growth	Underground Burrows	No Impact	
		Seasonal Rains	No Impact	
		Small Invertebrate Prey	No Impact	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	
Climate Change	RCP 8.5 and extreme events	Aquatic Breeding Pools	Strong	All
		Underground Burrows	Strong	
		Seasonal Rains	Strong	
		Small Invertebrate Prey	Strong	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	

Table 9 Future Condition Scenario 1 Table (Conditions that are bolded indicate a change from the current condition table)

Population	Aquatic Breeding Pools	Underground Burrows	Seasonal Rains	Small Invertebrate Prey	Reproduction	Dispersal	Abundance	Overall Condition
Northern Western Spadefoot Regions								
Northwestern Sacramento Valley	Low (1)	Low (1)	**Low-Moderate (1.5)**	Unknown	Unknown	Unknown	Unknown	Low (1.17)
Northeastern Sacramento Valley	**Low-Moderate (1.5)**	**Moderate-High (2.5)**	**Moderate (2)**	Unknown	Unknown	Unknown	Unknown	**Moderate (2.00)**
Solano-Colusa	**Low-Moderate (1.5)**	**Low-Moderate (1.5)**	**Moderate (2)**	Unknown	**Low (1)**	**Moderate (2)**	Low (1)	**Low-Moderate (1.50)**
Southeastern Sacramento Valley	**Low-Moderate (1.5)**	**Moderate-High (2.5)**	**Moderate-High (2.5)**	Unknown	**Moderate (2)**	**Moderate (2)**	Low (1)	**Moderate (1.92)**
Livermore	**Low-Moderate (1.5)**	Low (1)	**Moderate (2)**	Unknown	**Moderate (2)**	**Moderate (2)**	Low (1)	**Low-Moderate (1.58)**
Southern Sierra Foothills	Low (1)	**Low-Moderate (1.5)**	**Moderate (2)**	Unknown	**Moderate (2)**	**Moderate (2)**	Low (1)	**Low-Moderate (1.58)**
San Joaquin	Moderate (2)	Moderate (2)	**Low-Moderate (1.5)**	Unknown	Low (1)	**Low (1)**	Low (1)	**Low (1.42)**
Central Coast	Low (1)	Low (1)	**Moderate (2)**	Unknown	**Low (1)**	**Moderate (2)**	Low (1)	Low (1.33)
Carrizo	Unknown	Unknown	**Low-Moderate (1.5)**	Unknown	**Moderate (2)**	**Low (1)**	Low (1)	**Low (1.38)**
Santa Barbara	Unknown	Unknown	**Low-Moderate (1.5)**	Unknown	**Low-Moderate (1.5)**	**Low-Moderate (1.5)**	Low (1)	**Low (1.38)**
Southern Western Spadefoot Regions								
Ventura	Unknown	Unknown	**Low-Moderate (1.5)**	Unknown	**Moderate (2)**	**Moderate (2)**	Low (1)	**Low-Moderate (1.63)**
San Diego	Unknown	**Moderate-High (2.5)**	**Low-Moderate (1.5)**	Unknown	**Moderate (2)**	**Low (1)**	Low (1)	**Low-Moderate (1.60)**
Western Riverside	Unknown	**Low-Moderate (1.5)**	**Low-Moderate (1.5)**	Unknown	**Moderate (2)**	Low (1)	Low (1)	**Low (1.40)**
Mexico	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

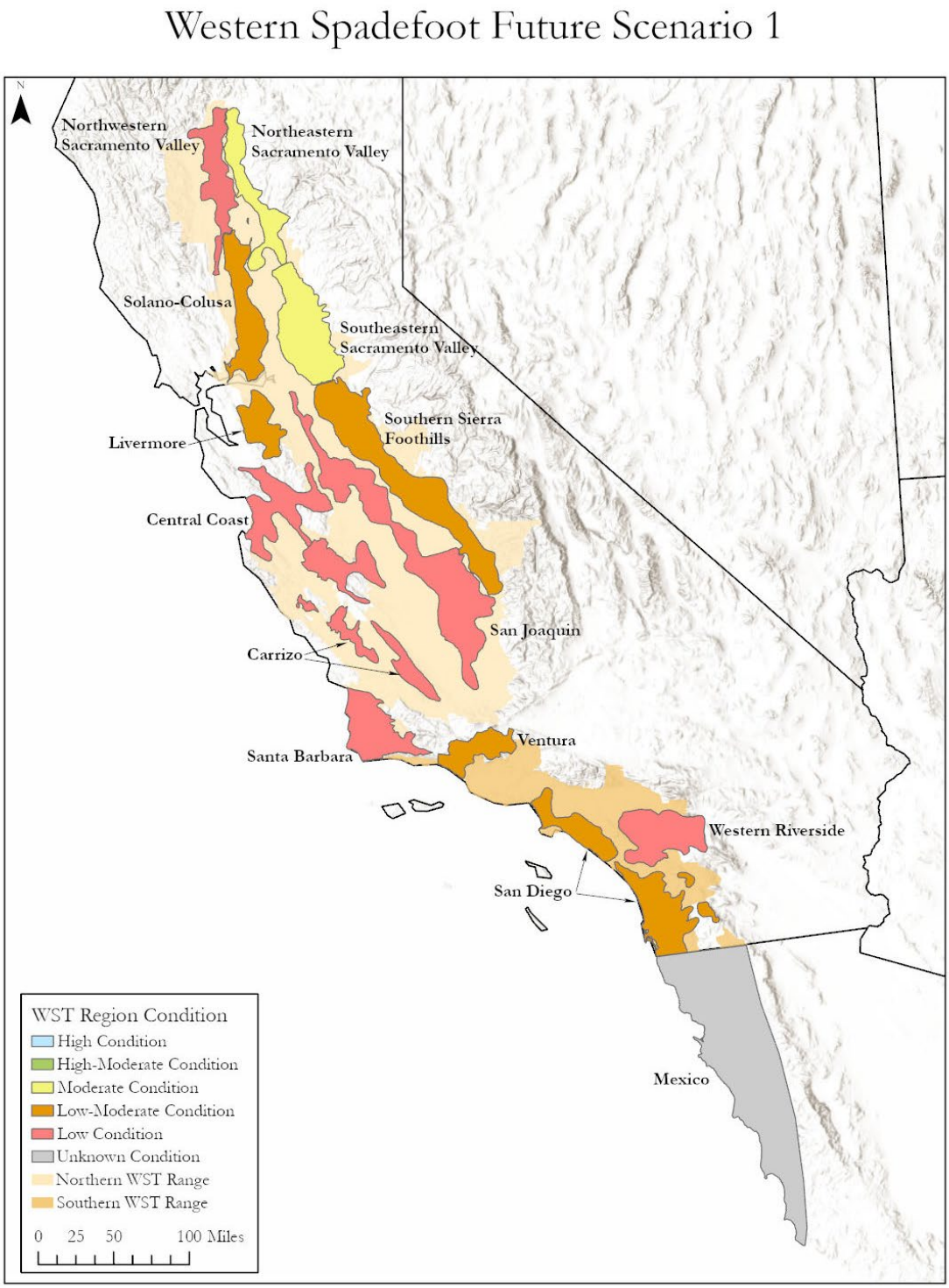

Figure 12: Map of WST regions and the overall viability projection under future Scenario 1.

10.4.1 Future Scenario 1 Northern WST Redundancy

Under Scenario 1, eight of the ten northern WST regions would be less resilient compared to current condition. None of the regions will likely be in high condition, two regions would likely have an overall moderate condition, three would likely have an overall low-moderate condition, and five would likely be in low condition. Regions with a low condition have a low probability of persistence in the future, and would likely not withstand a catastrophic event. Overall, the species would be less likely to withstand catastrophic event than under current condition and would likely have a reduced number of regions in the future. With some regions predicted to be in moderate condition, the species will likely persist, but with reduced redundancy.

10.4.2 Future Scenario 1 Northern WST Representation

As identified above, northern WST has representation in the form of physiological adaptive potential, genetic differences throughout the range, and diversity of ecological settings throughout the range. Predictions for Scenario 1 are that many of the habitat characteristics identified as needs for northern WST will likely have a limited ability to withstand predicted changes and decrease the condition in the future. Under Future Scenario 1, northern WST populations will likely have even lower effective number of breeders than the already low effective number of breeders measured under current conditions. The continued decline in effective number of breeders will result in a loss of genetic diversity for the species, decreasing the representation. With five of the ten regions in low condition, with a low probability of persistence in the future, representation will be decreased under Scenario 1. There will likely be loss in genetic and ecological diversity within the northern WST clade. Although representation will be reduced under Scenario 1, northern WST will likely maintain the multiple regions allowing for some representation into the future.

10.4.3 Future Scenario 1 Southern WST Redundancy

Under Scenario 1, all of the southern WST regions would be less resilient compared to current condition. None of the regions will likely be in high condition, two regions would likely have an overall low-moderate condition, and one region would likely have a low condition. The future condition of the Mexico region is unknown. Regions with a low condition have a low probability of persistence in the future, and would likely not withstand a catastrophic event. Overall, the species would be less likely to withstand catastrophic event than under current condition, and would likely have a reduced number of regions in the future. With two regions in low-moderate condition and one in low condition, it is possible that the southern WST clade could lose redundancy under Scenario 1.

10.4.4 Future Scenario 1 Southern WST Representation

As identified above, southern WST has representation in the form of physiological adaptive potential, genetic differences throughout the range, and diversity of ecological settings throughout the range. Predictions for Scenario 1 are that many of the habitat characteristics identified as needs for southern WST will likely have a limited ability to withstand predicted changes and decrease the condition in the future. Under Future Scenario 1, southern WST populations will likely have even lower effective number of breeders than the already low effective number of breeders measured under current conditions. The continued decline in effective number of breeders will result in a loss of genetic diversity for the species, decreasing the representation. With two regions in low-moderate condition and one in low condition, it is possible that the southern WST clade could lose representation under Scenario 1.

10.5 Future Scenario 2: Continuation Scenario

Scenario 2 considers WST viability under a continuation future where the threats continue at the current levels. The bounds of the magnitude of each threat are based on the best available science and the current trend of the threats. Similar to Scenario 1, under Scenario 2 development increases in California. With projected increases in population in California, development will likely continue within the range of WST (The California Economic Forecast 2016, entire). However, there are several species listed as threatened and endangered under the Endangered Species Act that also occupy vernal pool habitat which may limit development in areas that would impact WST. Some habitat may be lost to development, but if the current protection of vernal pool habitat were to continue into the future, impacts would likely be minimal. Under Scenario 2, development would likely only have a weak impact on the quality and quantity of aquatic breeding pools and underground burrows leading to only minor declines in abundance, dispersal, and reproduction. Overabundant vegetation needs to be managed or it can lead to the premature drying of aquatic breeding pools decreasing the ability of WST to disperse and reproduce. Even with protected vernal pool habitat, overabundance of vegetation can occur if the habitat is not properly managed (Vollmar *et al* 2017, pp. 2-8–2-15). Overall, a majority of vernal pool habitat preserves are being managed adequately in regards to the maintenance of infrastructure (fences, gates, signs, and roads) and protection from nonranching human disturbance; however, looking at all preserves the amount of grazing, residual dry matter, and invasive weed control could be improved (Vollmar *et al*. 2017, p. 2-15). If management were to continue as it is currently into the future, there may be some impacts to WST aquatic breeding pools and population needs, but they would likely not further decrease WST needs from current condition. Under Scenario 2, nonnative predators would likely remain at the current trajectory having some impacts on reproduction and abundance. Extreme events such as drought are likely to increase into the future (Bedsworth *et al*. 2018, p. 22); however, Scenario 2 assumes that there would be adequate time in between drought events for WST populations to recover from the previous drought period. Noise disturbance would likely remain the same given the limited development within vernal pool habitats. Lastly, the downscaled climate change projection RCP 8.5, or the business as usual projection, was used as a basis for climate change.

The projected average annual temperature increase under RCP 8.5 by mid-century (2040–2069) in California is approximately 5.8ºF (Bedsworth *et al*. 2018, p. 23). In addition, precipitation is predicted to increase during winter months, but decrease in spring and fall months (Bedsworth *et al*. 2018, p. iv). Vernal pool habitats will likely be impacted by increased temperatures and precipitation changes in the future. Even without extended periods of drought, pools may dry up faster with warmer average temperatures and decreased precipitation in the spring. Western spadefoot toad physiology allows for some adaptive potential to climate change because tadpoles are able to speed development depending on environmental conditions. Although there may be some decline in reproduction and abundance due to the shorter presence of aquatic breeding pools, given the adaptive potential of the species there will likely be some WST individuals likely to persist even with the shorter duration of seasonal pools.

Looking at the future threats under Scenario 2, aquatic breeding pools, underground burrows, and small invertebrate prey would likely remain the same as current condition. Under Scenario 2, the pattern of seasonal rains may change, but with the adaptive potential of WST it would likely only minorly impact the species. There will likely be some declines in WST population needs in Scenario 2 due to the continuation of threats, however they will be limited due to continuation of current protections of vernal pool habitat and the adaptive potential of the species to withstand shorter vernal pool duration in the spring. Table 10 provides a summary of the assumptions for Scenario 2, including how each threat is expected to impact the individual and population needs. Table 11 and Figure 13 provide the predicted condition for each region under Scenario 2.

Table 10: Future Scenario 2 Threat Projections

Threat	Scenario 2 Prediction	Impacts to Individual and Population Needs	Magnitude of Impact	Regions Impacted
Development	Increase, but avoid vernal pool areas	Aquatic Breeding Pools	Weak	All
		Underground Burrows	Strong	
		Seasonal Rains	No impact	
		Small Invertebrate Prey	Strong	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	
Overabundant Vegetation	Remain the same	Aquatic Breeding Pools	Strong	All
		Underground Burrows	Weak	
		Seasonal Rains	No Impact	

		Small Invertebrate Prey	Weak	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	
Nonnative Predators	Remain the same	Aquatic Breeding Pools	No Impact	All
		Underground Burrows	No Impact	
		Seasonal Rains	No Impact	
		Small Invertebrate Prey	Weak	
		Reproduction	Strong	
		Dispersal	Weak	
		Abundance	Strong	
Drought	Remain the same	Aquatic Breeding Pools	Strong	All
		Underground Burrows	No Impact	
		Seasonal Rains	Strong	
		Small Invertebrate Prey	Strong	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	
Noise Disturbance	Remain the same	Aquatic Breeding Pools	No Impact	All
		Underground Burrows	No Impact	
		Seasonal Rains	No Impact	
		Small Invertebrate Prey	No Impact	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	
Climate Change	RCP 8.5	Aquatic Breeding Pools	Strong	All
		Underground Burrows	Strong	
		Seasonal Rains	Strong	

		Small Invertebrate Prey	Strong	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	

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Table 11: Future Condition Scenario 2 Table (Conditions that are bolded indicate a change from the current condition table)

Population	Aquatic Breeding Pools	Underground Burrows	Seasonal Rains	Small Invertebrate Prey	Reproduction	Dispersal	Abundance	Overall Condition
Northern Western Spadefoot Regions								
Northwestern Sacramento Valley	Low (1)	Low (1)	Moderate (2)	Unknown	Unknown	Unknown	Unknown	Low (1.33)
Northeastern Sacramento Valley	Moderate (2)	High (3)	Moderate-High (2.5)	Unknown	Unknown	Unknown	Unknown	High (2.50)
Solano-Colusa	Moderate (2)	Moderate (2)	Moderate-High (2.5)	Unknown	**Low-Moderate (1.5)**	High (3)	Low (1)	Moderate (2.00)
Southeastern Sacramento Valley	Moderate (2)	High (3)	High (3)	Unknown	**Moderate-High (2.5)**	High (3)	Low (1)	**Moderate-High (2.42)**
Livermore	Moderate (2)	Low (1)	Moderate-High (2.5)	Unknown	**Moderate-High (2.5)**	High (3)	Low (1)	Moderate (2.00)
Southern Sierra Foothills	Low (1)	Moderate (2)	Moderate-High (2.5)	Unknown	**Moderate-High (2.5)**	High (3)	Low (1)	Moderate (2.00)
San Joaquin Valley	Moderate (2)	Moderate (2)	Moderate (2)	Unknown	**Low-Moderate (1.5)**	Moderate (2)	Low (1)	Moderate (1.75)
Central Coast	Low (1)	Low (1)	Moderate-High (2.5)	Unknown	Low (1)	High (3)	Low (1)	Low-Moderate (1.58)
Carrizo	Unknown	Unknown	Moderate (2)	Unknown	**Moderate-High (2.5)**	Moderate (2)	Low (1)	Moderate (1.88)
Santa Barbara	Unknown	Unknown	Moderate (2)	Unknown	**Moderate (2)**	Moderate-High (2.5)	Low (1)	Moderate (1.88)
Southern Western Spadefoot Regions								
Ventura	Unknown	Unknown	Moderate (2)	Unknown	**Moderate-High (2.5)**	High (3)	Low (1)	**Moderate (2.13)**
San Diego	Unknown	High (3)	Moderate (2)	Unknown	**Moderate-High (2.5)**	Low-Moderate (1.5)	Low (1)	Moderate (2.00)
Western Riverside	Unknown	Moderate (2)	Moderate (2)	Unknown	**Moderate-High (2.5)**	Low (1)	Low (1)	**Low-Moderate (1.70)**
Mexico	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

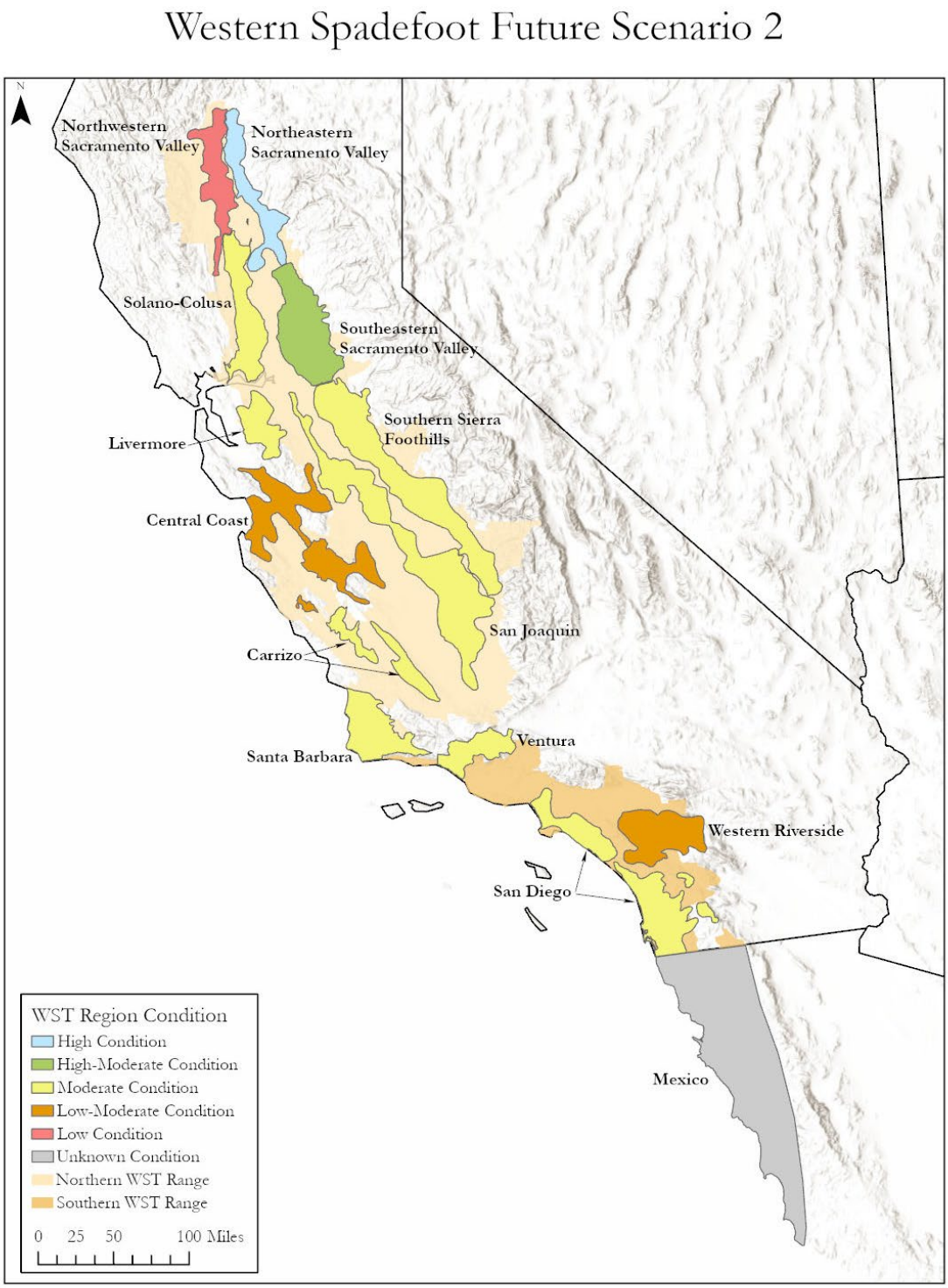

Figure 13: Map of WST regions and the overall viability projection under future Scenario 2.

10.5.1 Future Scenario 2 Northern WST Redundancy

Under Scenario 2, all of the northern WST regions would remain as resilient as they are in the current condition. One region will likely be in high condition, one region will likely have a high-moderate overall condition, six regions would likely have an overall moderate condition, and two regions would likely be in low condition. Overall, a majority of the regions are predicted to have moderate resiliency with a moderate probability of persistence in the future. With a majority of regions more likely than not to persist, the northern WST clade would likely withstand a catastrophic event.

10.5.2 Future Scenario 2 Northern WST Representation

As identified above, northern WST clade has representation in the form of physiological adaptive potential, genetic differences throughout the range, and diversity of ecological settings throughout the range. Predictions for Scenario 2 are that there would be limited change in habitat characteristics and demographics identified as needs for WST. There will likely be a variety of unique vernal pool habitats occupied throughout the northern WST clade into the future. The population need of reproduction will likely be particularly impacted by a generally warmer dryer future, which is a concern due to current low WST effective number of breeders measured in vernal pool regions. Under Future Scenario 2, there will likely continue to be a loss in genetic diversity, reducing representation from the current condition.

10.5.3 Future Scenario 2 Southern WST Redundancy

Under Scenario 2, two of the four southern WST regions would like to be less resilient compared to current condition. Two regions will likely be in moderate condition and one in low-moderate condition. The condition of the Mexico region is unknown. Overall, a majority of the regions predicted to have moderate resiliency, with a moderate probability of persistence in the future. With a majority of regions more likely than not to persist, the southern WST clade would likely withstand a catastrophic event.

10.5.4 Future Scenario 2 Southern WST Representation

As identified above, the southern WST clade has representation in the form of physiological adaptive potential, genetic differences throughout the range, and diversity of ecological settings throughout the range. Predictions for Scenario 2 are that there would be limited change in habitat characteristics and demographics identified as needs for WST. There will likely be a variety of unique vernal pool habitats occupied throughout the southern WST clade into the future. The population need of reproduction will likely be particularly impacted by a generally warmer dryer future, which is a concern due to current low WST effective number of

breeders measured in vernal pool regions. Under Future Scenario 2, there will likely continue to be a loss in genetic diversity, reducing representation from the current condition.

10.6 Future Scenario 3: Lower Emission Scenario

Scenario 3 considers WST viability under a future similar to the continuation scenario but with decreased greenhouse gas emissions (RCP 4.5). The bounds of the magnitude of each threat are based on the best available science and the potential management improvements that could occur for the species within 30–40 years. With projected increases in population in California, development will likely continue within the range of WST (The California Economic Forecast 2016, entire). However, there are several species listed as threatened and endangered under the Endangered Species Act that also occupy vernal pool habitat which may limit development in areas that would impact WST. Under Scenario 3, the assumption is that even with an increase in human population in California, the future development will avoid vernal pool habitat occupied by WST through protection of more vernal pool habitat than what is currently protected. Overabundant vegetation needs to be managed or it can lead to the premature drying of aquatic breeding pools decreasing the ability of WST to disperse and reproduce. Even with protected vernal pool habitat, overabundance of vegetation can occur if the habitat is not properly managed (Vollmar *et al* 2017, pp. 2-8–2-15). Overall, a majority of vernal pool habitat preserves are being managed adequately in regards to the maintenance of infrastructure (fences, gates, signs, and roads) and protection from nonranching human disturbance; however, looking at all preserves the amount of grazing, residual dry matter, and invasive weed control could be improved (Vollmar *et al*. 2017, p. 2-15). If management were to continue as it is currently into the future, there may be some impacts to WST aquatic breeding pools and population needs, but they would likely not further decrease WST needs from current condition. Under Scenario 3, nonnative predators would likely remain at the current trajectory having some impacts on reproduction and abundance. Extreme events such as drought are likely to increase into the future (Bedsworth *et al*. 2018, p. 22); however, Scenario 3 assumes that there would be adequate time in between drought events or active management to ensure presence of pools for WST populations to recover from drought periods. Noise disturbance would likely remain the same given the limited development within vernal pool habitats. Lastly, the downscaled climate change projection RCP 4.5, or the reduced greenhouse gas emission scenario, was used as a basis for climate change in Scenario 3. The projected average annual temperature increase under RCP 4.5 by mid-century (2040–2069) in California is approximately 4.4ºF (Bedsworth *et al*. 2018, p. 23). Vernal pool habitats will likely be impacted by increased temperatures in the future. Even without extended periods of drought, pools may dry up faster with warmer average temperatures. WST physiology allows for some adaptive potential to climate change because tadpoles are able to speed development depending on environmental conditions. Although there may be some decline in reproduction and abundance due to the shorter presence of aquatic breeding pools, given the adaptive potential of the species there will likely be some WST individuals likely to persist even with the shorter duration of seasonal pools.

Under Scenario 3, temperatures will likely increase in the future changing to some extent the time period of available vernal pools, but with the adaptive potential of WST it would likely only minorly impact the species. Under RCP 4.5, abundance and reproduction will likely remain steady under Scenario 3. Table 12 provides a summary of the assumptions for Scenario 3, including how each threat is expected to impact the individual and population needs. Table 13 and Figure 14 provide the predicted condition for each region under Scenario 3.

Table 12: Future Scenario 3 Threat Projections

Threat	Scenario 3 Prediction	Impacts to Individual and Population Needs	Magnitude of Impact	Regions Impacted
Development	Remain the same	Aquatic Breeding Pools	Strong	All
		Underground Burrows	Strong	
		Seasonal Rains	No impact	
		Small Invertebrate Prey	Strong	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	
Overabundant Vegetation	Remain the same	Aquatic Breeding Pools	Strong	All
		Underground Burrows	Weak	
		Seasonal Rains	No Impact	
		Small Invertebrate Prey	Weak	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	
Nonnative Predators	Remain the same	Aquatic Breeding Pools	No Impact	All
		Underground Burrows	No Impact	
		Seasonal Rains	No Impact	
		Small Invertebrate Prey	Weak	
		Reproduction	Strong	
		Dispersal	Weak	
		Abundance	Strong	

Drought	Remain the same	Aquatic Breeding Pools	Strong	All
		Underground Burrows	No Impact	
		Seasonal Rains	Strong	
		Small Invertebrate Prey	Strong	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	
Noise Disturbance	Remain the same	Aquatic Breeding Pools	No Impact	All
		Underground Burrows	No Impact	
		Seasonal Rains	No Impact	
		Small Invertebrate Prey	No Impact	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	
Climate Change	RCP 4.5	Aquatic Breeding Pools	Strong	All
		Underground Burrows	Strong	
		Seasonal Rains	Strong	
		Small Invertebrate Prey	Strong	
		Reproduction	Strong	
		Dispersal	Strong	
		Abundance	Strong	

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Table 13: Future Condition Scenario 3 Table (Conditions that are bolded indicate a change from the current condition table)

Population	Aquatic Breeding Pools	Underground Burrows	Seasonal Rains	Small Invertebrate Prey	Reproduction	Dispersal	Abundance	Overall Condition
Northern Western Spadefoot Regions								
Northwestern Sacramento Valley	Low (1)	Low (1)	Moderate (2)	Unknown	Unknown	Unknown	Unknown	Low (1.33)
Northeastern Sacramento Valley	Moderate (2)	High (3)	Moderate-High (2.5)	Unknown	Unknown	Unknown	Unknown	High (2.50)
Solano-Colusa	Moderate (2)	Moderate (2)	Moderate-High (2.5)	Unknown	Moderate (2)	High (3)	Low (1)	Moderate (2.08)
Southeastern Sacramento Valley	Moderate (2)	High (3)	High (3)	Unknown	High (3)	High (3)	Low (1)	High (2.50)
Livermore	Moderate (2)	Low (1)	Moderate-High (2.5)	Unknown	High (3)	High (3)	Low (1)	Moderate (2.08)
Southern Sierra Foothills	Low (1)	Moderate (2)	Moderate-High (2.5)	Unknown	High (3)	High (3)	Low (1)	Moderate (2.08)
San Joaquin Valley	Moderate (2)	Moderate (2)	Moderate (2)	Unknown	Moderate (2)	Moderate (2)	Low (1)	Moderate (1.83)
Central Coast	Low (1)	Low (1)	Moderate-High (2.5)	Unknown	Low (1)	High (3)	Low (1)	Low-Moderate (1.58)
Carrizo	Unknown	Unknown	Moderate (2)	Unknown	High (3)	Moderate (2)	Low (1)	Moderate (2.00)
Santa Barbara	Unknown	Unknown	Moderate (2)	Unknown	Moderate-High (2.5)	Moderate-High (2.5)	Low (1)	Moderate (2.00)
Southern Western Spadefoot Regions								
Ventura	Unknown	Unknown	Moderate (2)	Unknown	High (3)	High (3)	Low (1)	Moderate-High (2.25)
San Diego	Unknown	High (3)	Moderate (2)	Unknown	High (3)	Low-Moderate (1.5)	Low (1)	Moderate (2.10)
Western Riverside	Unknown	Moderate (2)	Moderate (2)	Unknown	High (3)	Low (1)	Low (1)	Moderate (1.80)
Mexico	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

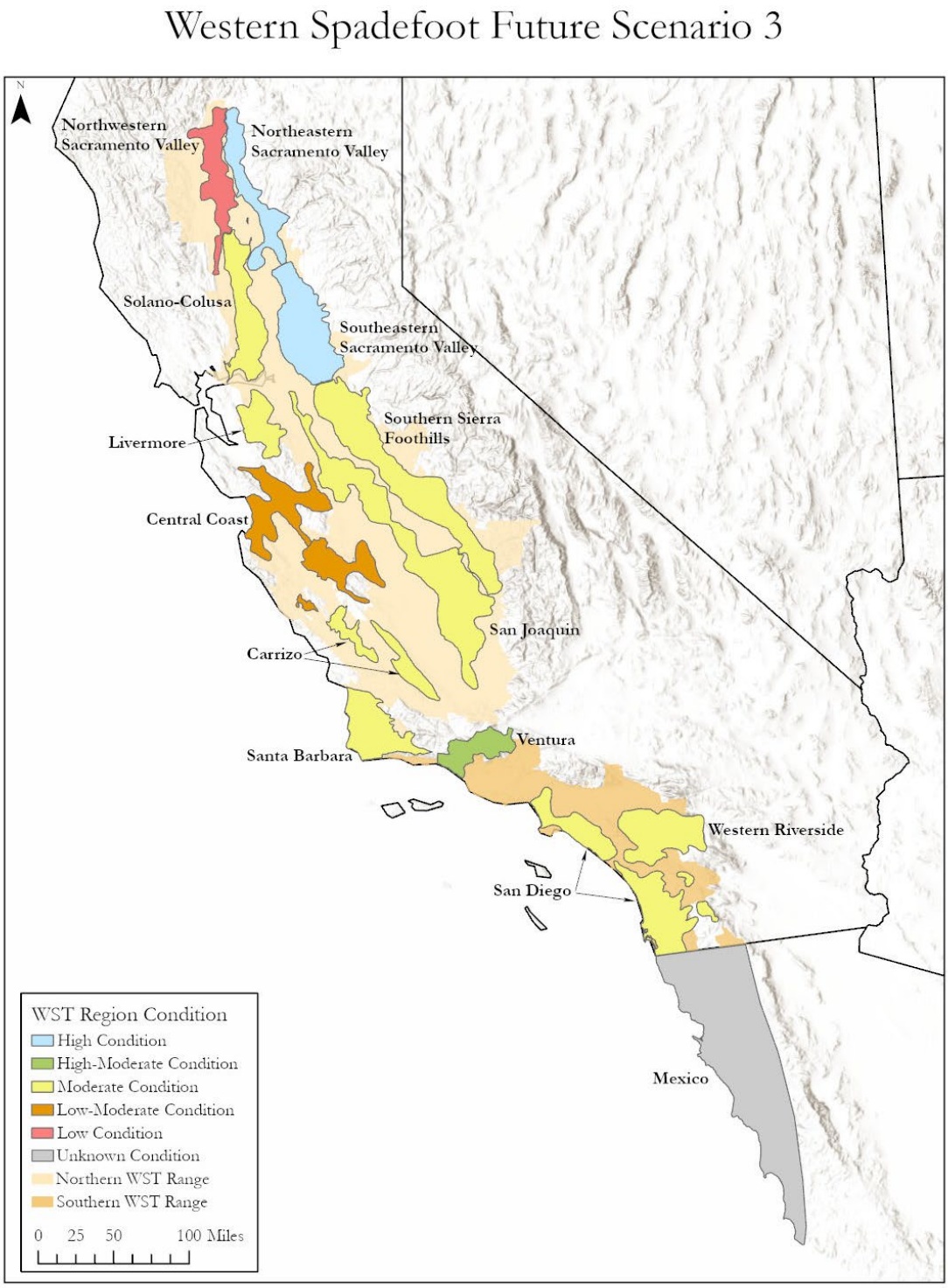

Figure 14: Map of WST regions and the overall viability projection under future Scenario 3.

10.6.1 Future Scenario 3 Northern WST Redundancy

Under Scenario 3, all of the northern WST regions would be similarly resilient compared to current condition. Two regions will likely be in high condition, six regions will likely have an overall moderate condition, one region will likely have a low-moderate overall condition, and one region will likely have a low condition. Overall, the northern WST clade would be likely to withstand catastrophic event similar to the current condition with a majority of the regions likely to persist into the future.

10.6.2 Future Scenario 3 Northern WST Representation

As identified above, northern WST has representation in the form of physiological adaptive potential, genetic differences throughout the range, and diversity of ecological settings throughout the range. Effective number of breeders will likely remain low under Future Scenario 3, which reduces the representation due to lack of genetic diversity. It is possible under Future Scenario 3 there will be minor negative impacts to demography due to predicted changes in climate even under a future with decreased greenhouse gas emissions, but the species physiological adaptive potential will likely allow the species to maintain representation similar to the representation discussed in the current condition.

10.6.3 Future Scenario 3 Southern WST Redundancy

Under Scenario 3, all of the southern WST regions would be similarly resilient compared to current condition. One region will likely be in moderate-high condition and two regions would likely be in moderate condition. Overall, the southern WST clade would be likely to withstand catastrophic event similar to the than under current condition.

10.6.4 Future Scenario 3 Southern WST Representation

As identified above, southern WST has representation in the form of physiological adaptive potential, genetic differences throughout the range, and diversity of ecological settings throughout the range. Effective number of breeders will likely remain low under Future Scenario 3, which reduces the representation due to lack of genetic diversity. It is possible under Future Scenario 3 there will be minor negative impacts to demography due to predicted changes in climate even under a future with decreased greenhouse gas emissions, but the species physiological adaptive potential will likely allow the species to maintain representation similar to the representation discussed in the current condition. .

11.0 OVERALL ASSESSMENT FOR SPECIES VIABILITY

The SSA describes the current condition as well as a range of plausible future scenarios that we considered important influences on the status of both the northern and southern WST clades. The results describe a range of possible conditions of where resilient populations may persist now and in the future. The goal of the SSA is to describe the viability of the species in a manner that will address the individual, population, and species needs in terms of resiliency, redundancy, and representation. Table 14 provides a summary of the overall current condition as well as the predicted future conditions under Scenario 1, 2, and 3 for each region. Figure 15 is a side by side comparison map showing WST regions and the current and predicted future scenario conditions.

11.1 Overall Assessment for Northern WST Clade Viability

WST viability is characterized by summarizing population resiliency and species redundancy and representation. For resiliency, an overall high condition for a region is an indicator of high probability of persistence of individuals in the region, an overall moderate condition is an indicator that probability of persistence in that region may be compromised by the lack of one or more need, and a low overall condition indicates low probability of persistence of individuals in the region. Regions in high condition are expected to persist into the future and have the ability to withstand stochastic events that may occur. Regions in moderate condition are less resilient than those in high condition, but the majority of these regions are expected to persist beyond 30–40 years. Regions in moderate condition may have some declines in individual or population needs, but would likely still be able to support a population. Regions in low condition have low resiliency and may not be able to withstand stochastic events because of significant declines in individual or population needs. Regions in low condition are less likely to persist for 30–40 years, but a region in low condition does not automatically mean the region will become extirpated. We then determine the number and distribution of resilient populations to assess redundancy and representation.

Under the current condition in the northern WST clade range, one of the 10 regions in is in high condition, one region is in moderate-high condition, six regions are in moderate condition, and two regions are in low condition. Therefore, regional resiliency varies from high to low, with a range of conditions represented throughout all three of the genetic clusters within the northern WST range. Currently, there is redundancy in the northern WST clade because even with some regions with low resiliency, many regions exist throughout the northern WST range at moderate to high resiliency, providing a sufficient number of resilient populations across the range to withstand a catastrophic event. The northern WST clade also currently has representation because the species exists throughout its historic range in unique vernal pool regions, providing for some habitat diversity needed to adapt to change. However, low effective number of breeders measured in WST populations throughout the northern WST clades indicates low genetic diversity, reducing the representation of the clade. A combination of threats acting

on the northern WST clade includes development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and climate change.

Under future Scenario 1, where threats increase in the future, including extreme weather events of drought, seven of the 10 northern WST regions would be less resilient compared to current condition and thus the probability of persistence of these regions would be decreased. Of the 10 regions, no regions will likely have high resiliency, two regions would likely have moderate resiliency, three regions would have low-moderate resiliency, and five regions would have low resiliency. With a majority of the regions less resilient and with lower probability of persistence than the current condition, both redundancy and representation would be reduced from current condition. Potential extirpations of regions with low resiliency would result in fewer populations to withstand catastrophic events. The further decrease in effective number of breeders would result in a loss of genetic diversity and presence in ecological settings reducing the representation of the northern WST clade. With three genetic clusters within the northern WST region, the genetic cluster north of the San Joaquin Delta has the highest probability of persistence, with both of the moderately resilient regions. There would likely be a loss of the two other genetic clusters that include south of the San Joaquin Delta and the central coast. The species is likely to continue to persist across the unique vernal pool regions, even within genetic clusters, in the northern WST clade providing for some representation. Threats that will likely increase under Future Scenario 1 include development of unprotected habitat, overabundant vegetation, nonnative predators, drought, noise disturbance, and climate change. The combination of these threats would reduce all the individual and population needs from current condition.

Under future Scenario 2, the continuation scenario, all of the northern WST regions would likely remain in the same condition as the current condition. One of the 10 regions would have high resiliency, one region would have moderate-high resiliency, six regions would have moderate resiliency, one region would have low-moderate resiliency, and one region would have low resiliency. Overall, the northern WST clade would have redundancy because even with one region expected to have low resiliency, many regions would exist throughout the northern WST range with moderate to high resiliency, allowing the species to withstand a catastrophic event. The northern WST clade also would have representation because the species would exist throughout its historic range, within all three genetic clusters, in unique vernal pool regions, providing for some habitat diversity needed to adapt to change. However, low effective number of breeders measured in WST populations throughout the northern WST clade would continue to decline, further reducing the representation of the clade. The threat that will likely have the most significant impact on the northern WST clade in the future under Scenario 2 is climate change. Under warmer and dryer conditions, reproduction will likely be impacted, which could exacerbate the already low effective number of breeders in the future.

Under future Scenario 3, with decreased greenhouse gas emissions under RCP 4.5, the northern WST regions would be as resilient as they are under the current condition. Of the 10 regions, two regions will have high resiliency, six regions will have moderate resiliency, one region will have low-moderate resiliency, and one region would have a low resiliency. Under

Scenario 3, the northern WST clade would likely have similar redundancy as current condition. The northern WST clade also would have representation because the species would exist throughout its historic range, within all three genetic clusters, in unique vernal pool regions, providing for some habitat diversity needed to adapt to change. However, low effective number of breeders measured in WST populations throughout the northern WST clade would remain, reducing the representation of the clade. The threat that will likely have the biggest impact on the species under future Scenario 3 is the climate projection of RCP 4.5.

11.2 Overall Assessment for Southern WST Clade Viability

Under current conditions, in the southern WST range, we found that one region has moderate-high resiliency, and two regions with moderate resiliency. The current condition of the Mexico region is unknown. Currently, the southern WST has less redundancy than the northern WST, simply due to the fact that the range is smaller, with only 3 vernal pool regions. However, no southern WST regions have low resiliency under current conditions, suggesting a sufficient number of resilient populations across the range to withstand catastrophic events. The southern WST clade also currently has representation because the species exists throughout its historic range, within both genetic clusters of the southern WST clade, in unique vernal pool regions, providing for some habitat diversity needed to adapt to change. However, low effective number of breeders measured in WST populations throughout the southern WST clades indicates low genetic diversity, reducing the representation of the clade. A combination of threats acting on the southern WST clade includes development on unprotected areas, overabundant vegetation, nonnative predators, drought, noise disturbance, and climate change.

Under future Scenario 1, where threats increase in the future, including extreme weather events of extreme drought and flooding, three of the four WST regions would be less resilient compared to current condition. Of the three total regions, no regions will likely have high resiliency, two regions would likely have low-moderate resiliency, and one region would likely have low resiliency. The future condition of the region in Mexico is unknown. Overall, redundancy would be moderate-low with a majority of the regions less resilient than the current condition. The further decrease in effective number of breeders would result in a loss of genetic diversity reducing the representation of the southern WST clade from current condition. Threats that will likely increase under Future Scenario 1 include development of unprotected habitat, overabundant vegetation, nonnative predators, drought, noise disturbance, and climate change. The combination of these threats would reduce all the individual and population needs from current condition.

Under future Scenario 2, or the continuation scenario, two of the four southern WST regions would be less resilient than the current condition. Of the four total regions, two would likely have moderate resiliency, one would likely have low-moderate resiliency, and one region is unknown (Mexico). Overall, the southern WST clade would have redundancy because even with reduced resiliency in some regions, the southern WST clade would have a majority moderate resiliency, allowing the species to withstand a catastrophic event. The southern WST clade also would have representation because the species would exist throughout its historic

range in unique vernal pool regions, providing for some habitat diversity needed to adapt to change. However, low effective number of breeders measured in WST populations throughout the southern WST clade would continue to decline, further reducing the representation of the clade. The threat that will likely have the most significant impact on the southern WST clade in the future under Scenario 2 is climate change. Under warmer and dryer conditions, reproduction will likely be impacted, which could exacerbate the already low effective number of breeders in the future.

Under future Scenario 3, with decreased greenhouse gas emissions under RCP 4.5, the southern WST regions would be as resilient as they are under the current condition. One region would likely have moderate-high resiliency, two regions would likely have moderate resiliency, and on region is unknown (Mexico). Under Scenario 3, the southern WST clade would likely have similar redundancy as current condition. The southern WST clade also would have representation because the species would exist throughout its historic range, within both genetic clusters, in unique vernal pool regions, providing for some habitat diversity needed to adapt to change. However, low effective number of breeders measured in WST populations throughout the southern WST clade would remain, reducing the representation of the clade. The threat that will likely have the biggest impact on the species under future Scenario 3 is the climate projection of RCP 4.5.

Table 14: Regional Current and Future Resiliency Comparisons

Region	Current Condition	Future Scenario 1	Future Scenario 2	Future Scenario 3
Northern Western Spadefoot Regions				
Northwestern Sacramento Valley	Low	Low	Low	Low
Northeastern Sacramento Valley	High	Moderate	High	High
Solano-Colusa	Moderate	Low-Moderate	Moderate	Moderate
Southeastern Sacramento Valley	High	Moderate	Moderate-High	High
Livermore	Moderate	Low-Moderate	Moderate	Moderate
Southern Sierra Foothills	Moderate	Low-Moderate	Moderate	Moderate
San Joaquin	Moderate	Low	Moderate	Moderate
Central Coast	Low-Moderate	Low	Low-Moderate	Low-Moderate
Carrizo	Moderate	Low	Moderate	Moderate
Santa Barbara	Moderate	Low	Moderate	Moderate
Southern Western Spadefoot Regions				
Ventura	Moderate-High	Low-Moderate	Moderate	Moderate-High
San Diego	Moderate	Low-Moderate	Moderate	Moderate
Western Riverside	Moderate	Low	Low-Moderate	Moderate
Mexico	Unknown	Unknown	Unknown	Unknown

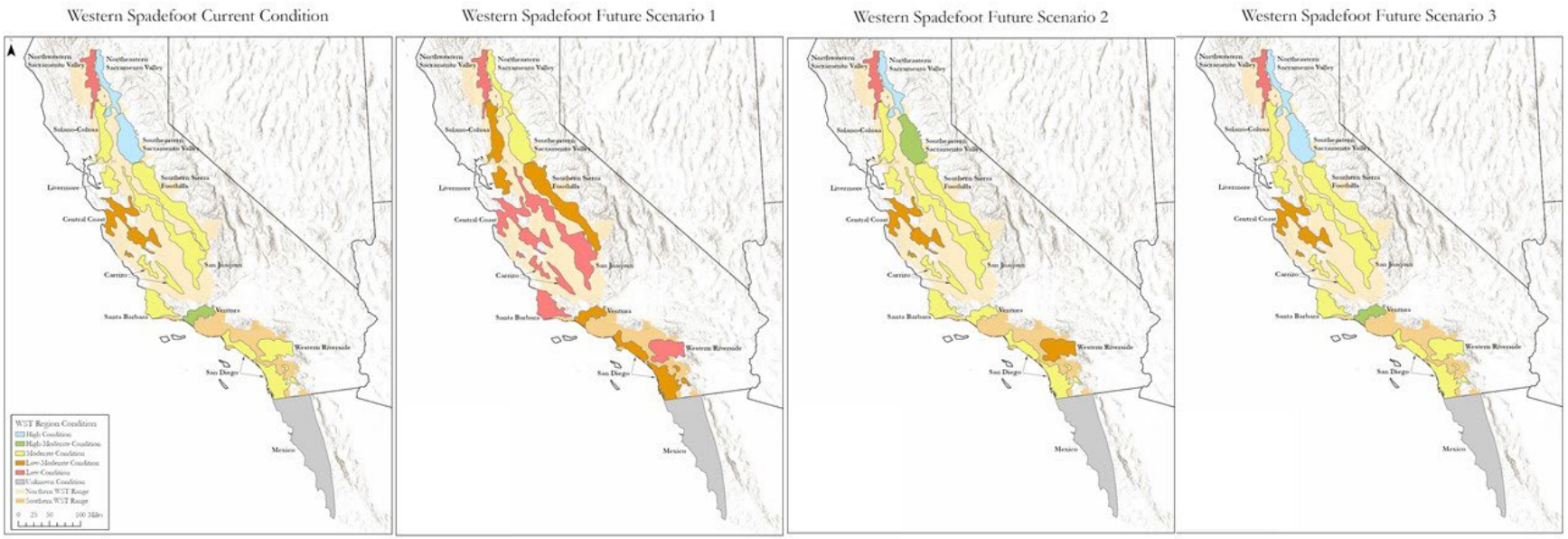

Figure 15: Maps showing the current condition of the WST regions in comparison to projections for WST regions under future Scenarios 1, 2, and 3.

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Reviewer Name	Chapter	Page	Line #	Comment
Jonathan Rose	All			One of my major thoughts about the Western Spadefoot Toad (WST, *Spea hammondii*) SSA is that I wonder if the current or recent occurrence of WST within vernal pool habitats in each region could be incorporated into the analysis. It seems to me that an assumption throughout is that if vernal pools are extant in an area within the historical range of WST, that WST must occupy them. I know WST occurrence data are not so abundant that it would be possible to document presence or non-detection (possibly absence) at each vernal pool complex in each region. However, I would like to know if areas that are classified as having high or moderate-high current condition have not only the appropriate habitat for WST, but recent records of WST presence and reproductive activity.
Jonathan Rose	All			As detailed below, I think the focus on burrows when discussing WST needs beyond their breeding habitat is perhaps too specific. Of course WST spend most of the year in burrows. But the context for those burrows, in the surrounding terrestrial habitat is likely very important for determining whether an area contains suitable habitat for WST. WST require open canopy habitats for example (Stebbins 2003, Western Reptiles and Amphibians). WST in southern California were also found to prefer to burrow in areas of grassland compared shrub cover, and selected areas with less clay and more sand and silt (Baumberger et al. 2019 Plos One 14(10):e0222532). The land cover or land use surrounding spadefoot breeding habitat also likely influences population persistence, with a greater positive relationship between spadefoot occurrence and grassland land cover than agriculture (Rose et al. 2020 Biological Conservation 241:108374). I would like to see the discussion of burrows expanded somewhat to the broader topic of terrestrial habitat surrounding breeding habitat, and its connectivity, which is known to be important for many pond breeding amphibians (Semlitsch and Bodie 2003 Conservation Biology 17(5):1219-1228).
Jonathan Rose	5	8	195-197	Baumberger et al. (2019) Plos One 14(10):e0222532 report burrow depths of Spea hammondii that were radio-tracked in southern California. These burrows averaged 10 cm in depth and ranged from 1 cm to 18 cm. I recommend adding a reference to the findings of Baumberger et al (2019) here to state that WST use shallower burrows as well a other times of the year. Baumberger et al. also report various aspects of where WST chose to burrow within their study sites, selecting grassland land cover at the macro scale and areas of duff cover at the micro scale. WST also avoided soils with high clay content in favor of sand and silt. I see some of this information appears later in section 7.1.2, so it might not be essential to report in the brief summary in section 5.0.
Jonathan Rose	6.1	10	270-276	It is not an evaluation of dispersal through different habitats, but Baumberger et al. (2019) Plos One 14(10):e0222532 report that WST were more likely to move and to move longer distances as the amount of recent rainfall increased.
Jonathan Rose	6.1	10	270-276	I take issue with the characterization of terrestrial habitat as "dispersal habitat." To me, this framing implies that the terrestrial habitat surrounding breeding pools only serves as a movement corridor, and not essential habitat for the life-cycle of WST. As stated in section 5.0, WST spend the majority of the year in terrestrial habitat (largely in burrows), and foraging can take place in terrestrial habitat. The importance of terrestrial habitat surrounding breeding sites for persistence of amphibians with complex life-histories is well established in the literature. For example see Semlitsch and Bodie (2003) Conservation Biology 17(5):1219-1228.
Jonathan Rose	7.2.2	18	447-463	Related to my previous comment, I agree that suitable habitat for dispersal between upland and aquatic habitats, and dispersal between aquatic breeding habitats, is vital for population persistence. But I feel the terrestrial habitat used by adults to forage is a missing piece here. Granted, we do not know as much as we might like about when and where WST adults forage for prey, but it is an essential part of their life cycle and I think it needs to be acknowledged as distinct from strictly dispersing from breeding sites to burrows.
Jonathan Rose	7.2.3	18	478-480	It would be helpful to list some of the estimates of the effective population size for other pond-breeding amphbians here for comparison to the estimate for WST.
Jonathan Rose	8.1	21	576-581	Brehme et al. (2018) Landscape Ecology 33(6):911-935 assessed the risk posed by roads to reptiles and amphibians in southern California based on life-history characteristics and terrestrial movement patterns. Breheme et al. characterized Spea hammondii as being at "High Risk" of extirpation from road impacts. This recent study would be a good reference to add here to support the (justified) assertion that roads pose a threat to WST through direct mortality as well as through reduced population connectivity due to habitat fragmentation.
Jonathan Rose	8.3	23	Figure 6	The distribution of American Bullfrogs in the Central Valley looks to be an underestimate and I wonder if the issue is that the Nonindigenous Aquatic Species Database is not a comprehensive resource for records of this species? I recommend also looking for occurrences of American bullfrogs from the Global Biodiversity Information Facility (www.gbif.org).

Jonathan Rose	9	28	776-803	Why is there not an attempt to look at where there are recent spadefoot occurrence records (say in the last 20 years) within the different vernal pool regions? I know that records for spadefoots can be spotty, but the method for evaluating current conditions has the potential to classify regions as having "high" condition that have vernal pool habitat but from which spadefoots have been extirpated, or have declined, because of other factors (land use change around the vernal pools, introduced predators, noise pollution, etc.)
Jonathan Rose	9.1		824-825	A loss of up to 20 percent of available vernal pool habitat over a period of just 7 years from 2005 to 2012 sounds like a very large amount of habitat loss over a short time period to me. If a 20% loss per 7 years trend continued in the future, little habitat (under 30%) would be left after 40 years. Also, I think the amount of vernal pool habitat available, relative to the total area of the region, at the beginning of the 2005-2012 period should be considered. A 20% loss could be very important for a region with a small total area of vernal pool habitat available, but it could be less damaging for a region with a large area of vernal pool habitat available.
Jonathan Rose	9.1	30	854-863	The rainfall in the last 60 months was compared to the average rainfall of what time period? I assume the rainfall in the past 5 years was compared to the average over some longer time period, but this is not clear from the description provided.
Jonathan Rose	9.1	30-31	884-887	I think the scope of the Neal (2019) study that estimated the effective number of breeders in a WST population should be explained here. Some parts of Neal (2019) looked at a narrow area (western Orange County) and in other sections Neal used data with representation from a larger proportion of the WST range. I believe the effective number of breeders referenced here refers to data collected from many sites throughout the species' range, and it would be helpful to mention that so readers can evaluate the quality and generality of these estimates.
Jonathan Rose	9.1	32	918-921	What is the time period for the CNDDB occurrences of WST displayed on this map? It would be good to know if these represent recent documentation of spadefoot presence, or both historical and recent spadefoot records. For example, based on the current conditions classification, the Northwestern Sacramento Valley region is low condition, but it has many more spadefoot records plotted than the Solano-Colusa region, which is moderate condition. I wonder if this is a historical artifact or if it represents differences in sampling for spadefoots.
Jonathan Rose	9.1	33	Table 2	Under the Moderate condition entry for Aquatic Breeding Pools, I think it should specify that the loss of 0 to 20 percent of vernal pool habitat is since 2005 (or between 2005-2012). The same applies to the entry for High condition.
Jonathan Rose	9.1	33	Table 2	The term "well distributed" shows up in several places in this table, but it is not defined in the description for the different needs categories. What does it mean for prey to be well distributed? I can imagine what it means for vernal pools to not be well distributed (presumably clustered within one or a few areas within a region) but I would like to see the qualitative explanation, if this criterion is being used to differentiate moderate condition from high condition.
Jonathan Rose	9.2.4	37	1023-1024	Why is the precipitation in the past 36 months referenced for determining the individual need of seasonal rains within this region, when 60 months is referenced for the other regions?
Jonathan Rose	10.1	52	1460-1468	The text here regarding the scenario analysis refers to the northern tidewater goby, should be corrected to western spadefoot toad.
Jonathan Rose	10.2	53	1486	Instead of Table 4, this sentence should refer to Table 6.
Jonathan Rose	10.4	55	Table 8	Should the Magnitude of Impact for Development on Aquatic Breeding Pools be strong instead of weak in Scenario 1? I think one of the major contrasts between Scenario 1 and Scenario 2 is the level of protection from development afforded to vernal pool habitats, and in Scenario 2 the impact of development on Aquatic Breeding Pools is weak.
Jonathan Rose	10.5	62	1663-1664	Is this increase in temperature of 5.8 degrees F relative to current temperatures (in 2020) or relative to average 20th century temperatures? What is the reference point?
Jonathan Rose	10.5	62	1670-1673	Although spadefoot tadpoles can exhibit a plastic response to pool drying and increase their rate of metamorphosis, this would likely result in recently metamorphosed spadefoot juveniles having a smaller body size on average. There is an extensive literature on the reproductive and survival effects of having a smaller size at metamorphosis in amphibians (see for example Earl and Whiteman 2015 Copeia 103(2):297-309 for a recent review and meta-analysis). I think this potential sub-lethal effect of rapid metamorphosis should be mentioned.
Jonathan Rose	10.5	62	1677-1678	I find the phrase "There will likely be some declines in WST population needs in Scenario 2 due to the continuation of threats" confusing, because it sounds like a decrease in what WST populations need, rather than a decrease in the essential components needed to support a viable WST population.

Jonathan Rose	10.6	68	1732-1733	I would rephrase this sentence to clarify the relationship between RCP 4.5 (future scenario 3) and RCP 8.5 (future scenarios 1 and 2), because calling RCP 4.5 a scenario with decreased greenhouse gas emissions could be misleading. I think the intention is that RCP 4.5 is a scenario with decreased greenhouse gas emissions compared to the business as usual RCP 8.5, which is true. But RCP 4.5 itself is a scenario where greenhouse gas emissions peak around 2040.
Jonathan Rose	10.6	69	Table 12	I believe the magnitude of impact of Development on Aquatic Breeding Pools should be weak for scenario 3, as scenario 3 is supposed to match scenario 2 in this regard (Table 10). Scenario 3 assumes that future development would not heavily affect vernal pools because vernal pools would be adequately protected. At least that is my understanding based on Table 6 and the text describing each scenario.
Jonathan Rose	10.6.4	73	1811-1813	Again, under decreased greenhouse gas emissions compared to what? If compared to RCP 8.5, state that clearly. If it is compared to current greenhouse gas emissions, I do not think the RCP 4.5 scenario would represent decreased greenhouse gas emissions in the near future. Perhaps a slight decline by 2060 relative to 2020, if one looks at the 40 year horizon.
Jonathan Rose	11.1	75	1891	Same comment as the previous about characterizing RCP 4.5 as a decreasing greenhouse gas emissions scenario.
Jonathan Rose	11.2	77	1950-1952	The threat that would have the biggest impact on WST in Scenario 3 is not the climate projection of RCP 4.5, but the climate change (increased temperatures, higher variability in precipitation) predicted by that climate projection. I suggest rephrasing this sentence for clarity. Something closer to the statements on lines 1938-1941 would work better here.
Jonathan Rose	12	78	Table 14	The color for the San Diego region in Scenario 2 should be changed from pink to light brown to match the other entries for Low-Moderate condition in this table.