Reviewer Name	Chapter	Page	Line #	Comment
Fong	1	17	NA	Figure 4- I like the graphic. Can you add on major roads and dense urban areas to the map (or maybe have a separate graphic) so we get a sense of the connectivity issues associated with each population complex?
Fong	1	30	5	Second paragraph under Representation. The paragraph makes a blanket statement that restoring connectivity across the peninsula is not feasible due to urbanization. I think it is helpful for the reviewer to come to that conclusion if there was a graphic. There may be adjacent population complexes that could have likelihood of movement and connectivity and protection of those linkages would seem to be important. The Conservation Lands network 2.0 had a regional connectivity GIS map that might be interesting to overlay over distribution of snake population complexes too (https://www.bayarealands.org/wp-content/uploads/2019/11/Connectivity.pdf) Critical linkages GIS layer--https://www.bayarealands.org/maps-data/#data)
Fong	4	36		Half Moon Bay. There is more recent data than Sean Barry's 1980s era observations in Denniston Reserv. We had contracted with Swaim Biological for habitat assessment and trapping surveys at Rancho Corral de Tierra, one of our newly acquired parcels which includes the area noted here. Swaim's report noted that suitable habitat and CRLF forage base present. Have attached the 2 Swaim reports for your records. Also, here's a link to information and maps about the portion of the Half Moon Bay site that we manage. https://www.nps.gov/goga/rcdt.htm
Fong	4	56		Table 9. Half Moon Bay has several artificial impounded freshwater ponds, several that are known to support CRLF. Similar to prior comment, additional information are provided in the attached Swaim reports.
Fong	5	61		Climate change. It's difficult to predict changes to habitat conditions assoc. with climate change. While your document covers potential increase in saltwater inundation, another possible change with rising sea level could be higher groundwater conditions. This could be result in seasonal wetlands persisting longer. Also, there is a good synopsis by Pat Kleeman, USGS and Sarah Allen, NPS on climate changes to prey base (CRLF)-- see baylands ecosystem habitat goals-climate change. https://baylandsgoals.org/wp-content/uploads/2015/10/BEHGU_5.1_CaseStudy_RedLeggedFrog.pdf. It also might be helpful to have one of the NPS scientists you cite (Patrick Gonzalez) review your Climate Change section.

Fong	5	62-65	Fragmentation and urbanization. It might be helpful to look at the Conservation lands Network proposed conservation lands to see whether they add any value to increasing or maintaining connectivity for any of the snake populations.
Fong	5	66	Captive propagation. It seems captive propagation might be one tool, but perhaps 'Headstarting' might be a better umbrella term if release of gravid females or other non-propagation options are possible.
Fong	5		Future Condition. I wonder if a section on Restoration/Conservation would be warranted here. There could be positive recovery actions taken in the future by landowners both private and public. The San Mateo RCD recently reached out to us and others to see what collaborative actions are possible. In the past, USGS (Brian Halstead) and I have discussed headstart actions in the Half Moon Bay area and the interest in testing the waters with our adjacent private ag landowners and water district about Safe Harbor agreements with the FWS. We'd be interested in pursuing this again.
Fong	5	69-70	Scenario 1. I don't know the elevations of the facilities, but there is a seawall between the Ocean and Laguna Salada and a discharge pipe. Unless sea level rise will result in storms or king tides overtopping the seawall, it doesn't seem like that waves would lead to saltwater inundation of Laguna Salada as the doc notes. However, there is a strong likelihood of higher salinities due to landward seepage of ocean water through the porous seawall.
Fong	5	73	Tables 9, 12-14. For sites like Half Moon Bay that show absence of data (Half Moon Bay, No. Santa Cruz Co.), it seems weird to come up with ranking for overall habitat and demographic conditions. Maybe more appropriate to note that as important data gap to fill. We can provide some insights on Half Moon Bay habitat-- just let us know how we can help.

Species Status Assessment for the San Francisco gartersnake (*Thamnophis sirtalis tetrataenia*) Version 1.0

Month YEAR
U.S. Fish and Wildlife Service
Region 10
Sacramento, California

EXECUTIVE SUMMARY

This report summarizes a Species Status Assessment (SSA) completed for the San Francisco gartersnake (*Thamnophis sirtalis tetrataenia*). 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 San Francisco gartersnake occurs throughout much of its known historical range in populations largely fragmented by urbanization. For the purposes of this SSA, we grouped populations into complexes to analyze the condition across the species range. Resiliency of population complexes was measured by assessing the habitat needs of impounded freshwater habitat, aquatic vegetation, upland habitat, and amphibian prey, and the demographic factors abundance and age class structure. We identified 13 population complexes, and analyzed 12 of these for current and future condition (the additional complex is extirpated and we do not expect that habitat factors in this area will ever be sufficient to support a resilient San Francisco gartersnake population in the future).

Our analysis of the past, current, and future factors influencing viability of the San Francisco gartersnake revealed that there are several factors that contribute to the current condition and pose a risk to future viability of the species. Alteration and isolation of habitats resulting from urbanization was identified as the primary reason for decline of San Francisco gartersnakes at the time of listing. Current threats include fragmentation and urbanization, changes to aquatic habitat, seral succession, illegal collection, predation from non-native species, and small population sizes. Snake Fungal Disease, recently confirmed to be present in wild snakes in California, is an emerging threat but is not known to impact the species at this time. Ongoing management actions or other factors positively influencing resiliency include habitat restoration, invasive species control, grassland management, educational displays, and Habitat Conservation Plans. We analyzed the current condition of San Francisco gartersnake population complexes relative to overall habitat condition and overall demographic condition. Under current conditions, we determined that the San Francisco gartersnake has eight population complexes in high habitat condition and four in low condition. Regarding demographic condition, the species currently has one population complex in high condition, five in moderate condition, and six in low condition. Those complexes with low habitat and demographic condition were historically surveyed in the 1970s and 1980s but have few recent observations.

The influences to viability described above play a large role in the future resiliency, redundancy, and representation of the San Francisco gartersnake. If complexes lose resiliency (i.e., the ability to support self-sustaining populations of San Francisco gartersnake), they are more vulnerable to extirpation, with resulting losses in representation and redundancy. The rates at which future threats may act on specific complexes and the long-term efficacy of current conservation actions (i.e., conservation strategies) are unknown. We used the best available science to predict how future conditions could influence the resiliency, redundancy, representation, and overall condition of the San Francisco gartersnake. In order to assess future condition, we developed three plausible future scenarios. The future scenarios use different combinations of climate change impacts and conservation efforts, and are evaluated on a time frame of approximately 80 years (through 2100) to align with climate projections for the area. The following is a description of the three future scenarios, the status of the species when analyzed under each scenario, and a summary of the assumptions made under each scenario:

Scenario 1: We assume under a low emission scenario that sea level rise and drought have impacts to impounded freshwater habitat and amphibian prey populations in some areas. We assumed an interaction between amphibian prey population limitation caused by drought and the presence of bullfrogs, an invasive predator that competes with the San Francisco gartersnake for amphibian prey. Scenario 1 also assumes that ongoing management actions continue, and that a new captive breeding program is successfully implemented such that demographic conditions are maintained or increased for some populations. Fragmentation leads to potential extirpation of two population complexes, but habitat and demographic conditions are otherwise the same as in current condition.

Scenario 2: In this scenario, we assume that high emissions lead to sea level rise likely to impact several populations; drought conditions that may make amphibian populations decline (?) across the range in a least some years; and fragmentation continues on unprotected lands. We assumed that current protections from sea level rise were maintained but not increased, which led to reductions in habitat condition for some coastal and bay population complexes. We assumed that a planned captive propagation program was not successful. Under this scenario, fragmentation and sea level rise leads to potential extirpation of three population complexes.

Scenario 3: In this scenario, we assume the same climate impacts as Scenario 2: high emissions, sea level rise with impacts to two population complexes, drought that lowers habitat condition across the range of the species, and fragmentation of unprotected land. However, we assumed better protection from sea level rise than in Scenario 2, and high success of the captive breeding program. In addition to maintaining population abundance and age class structure, we assume the captive breeding program leads to population augmentation in areas with high quality habitat such that abundance increases to high condition. Under this scenario we still predict potential extirpation of two population complexes from fragmentation, and lowered resiliency in habitat conditions for two populations. However, potential success of the captive breeding program leads to increases in demographic conditions to moderate for two population complexes and high for three population complexes.

The projected conditions under all scenarios rely on the continuation of management actions across the species range. There is uncertainty regarding the impacts of sea level rise in the Bay Area, which could lead to notable decreases in habitat and demographic conditions for at least three population complexes if our assumptions overestimate the regional collaboration response regarding sea level rise planning. The main difference between outcomes of the future scenarios depends on success of the captive breeding program, which could lead to maintenance of existing population levels or increases in demographic conditions. Initial success of the facility will be instrumental in guiding projections regarding potential impacts to species' resiliency, redundancy, and representation. We were unable to forecast condition for those population complexes that currently have unknown condition (unless we expected conditions to decrease), and emphasize that surveys in those areas are important for guiding the recovery vision for the species in the central coastal section of its range.

Table of Contents

List of Tables and Figures

Tables

Figures

Chapter 1. Introduction

This report summarizes the results of a Species Status Assessment (SSA) conducted by the U. S. Fish and Wildlife Service (Service) for the San Francisco gartersnake (*Thamnophis sirtalis tertrataenia*). The San Francisco gartersnake is a brightly colored subspecies of common gartersnake found only in San Mateo County and northwestern Santa Cruz County in California.

We used the SSA framework to present a synthesis of our current understanding of the species' ecology and the factors that influence it; habitat and demographic needs at the individual, population, and species level; current status of the species; and potential future status of the species under potential scenarios. In sum, the framework is used as a means of assessing the species' viability. The SSA framework leads to a report that assesses a species' status such that the analyses and information provided can be used for a multitude of decisions and activities carried out under the authority of the Act (Service 2016, p. 7; Smith et al. 2018, entire). More specifically, this version of the SSA for the San Francisco gartersnake evaluates the condition of the species as part of a status review.

Federal History

The San Francisco gartersnake was listed as endangered under the Endangered Species Preservation Act in 1967, and a *Recovery Plan for the San Francisco Garter Snake Thamnophis sirtalis tetrataenia* (Recovery Plan) was first approved in 1985 (Service 1985). A recovery outline in 1995 presented needs of the species that were not addressed in the Recovery Plan (Service 1985, entire).

The Recovery Plan describes downlisting and delisting criteria for the San Francisco gartersnake (Service 1985, p. 18). The criteria focus on the protection of six significant populations and the creation of four additional populations. The six significant populations and the entities managing the land where those populations occur include: the West-of-Bayshore property (City and County of San Francisco/San Francisco International Airport), San Francisco State Fish and Game Refuge property (San Francisco Public Utilities Commission), Laguna Salada/Mori Point (City and County of San Francisco/National Park Service), Pescadero Marsh and Ano Nuevo State Reserve properties (California State Parks), and the Cascade Ranch property (private land owner). The recovery criteria state that the species could be considered for downlisting to threatened if 200 or more individuals are maintained at a 1:1 sex ratio at the six significant population sites for 5 consecutive years. The criteria further suggest that the species may be eligible for delisting if the same abundance and sex ratios are maintained at all 10 locations for 15 consecutive years.

There has been one previous status review for the species (Service 2006).

The Species Status Assessment Framework

This report is a summary of the SSA analysis, which entails three iterative assessment stages (Figure 1):

1. **Species Ecology.** An SSA begins with a compilation of the best available biological information on the species (taxonomy, life history, and habitat) and its ecological needs at the individual, population, and species levels based on how environmental factors are understood to act on the species and its habitat.

2. **Current Species Condition.** An SSA describes the current condition of the species habitat and demographics and the probable explanations for past and ongoing changes in abundance and distribution within the species ecological settings (i.e. areas representative of the geographic, genetic, or life history variation across the species range).

3. **Future Species Condition.** An SSA forecasts the species response to probable future scenarios of environmental conditions and conservation efforts. As a result, the SSA characterizes species ability to sustain populations in the wild over time (viability) based on the best scientific understanding of current and future abundance and distribution within the species ecological settings.

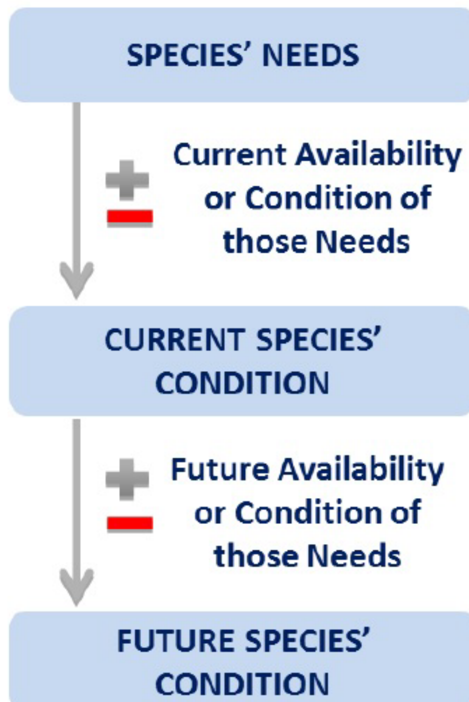

Figure 1. The Species Status Assessment framework

Throughout the assessment, the SSA uses the conservation biology principles of resiliency, redundancy, and representation (collectively known as the "3Rs") as a lens to evaluate the current and future condition of the species. Resiliency describes the ability of the species to withstand stochastic disturbance events, an ability that is associated with population size, growth rate, and habitat quality. Redundancy describes the ability of a species to withstand catastrophic events, an ability that is related to the number, distribution, and resilience of populations. Representation describes the ability of a species to adapt to changing environmental conditions. Measured by the breadth of genetic or environmental diversity within and among populations, representation gauges the probability that a species is capable of adapting to environmental changes. Together, the 3Rs—and their core autecological parameters of abundance, distribution, and diversity—comprise the key characteristics that contribute to a species ability to sustain populations in the wild over time. When combined across populations, they measure the viability of the species as a whole.

Viability is not a static state, and thus we do not attempt to define the species as viable or not viable. In general, species with higher resiliency, redundancy, and representation, are better protected from stochastic and catastrophic impacts to the environment, can better tolerate threats and adapt to changing conditions, and are thus more viable than those with lower levels of the 3Rs. We assessed San Francisco gartersnake viability using the best available science to analyze the species' ecology, current condition, and potential future condition under a number of future scenarios, all in the context of the 3Rs.

Summary of New Information

Since our 2006 review of the San Francisco gartersnake status, we collected newly published peer-reviewed literature and unpublished reports, solicited information from partners and land managers, and reviewed information in our files. We also conducted a search of the California Natural Diversity Database (CNDDB) maintained by the California Department of Fish and Wildlife.

Our literature review and data solicitation resulted in new information on population abundance, including updated information on survival and population sex ratios. Ongoing studies related to initiation of a captive breeding facility, including abundance estimations and evaluation of genetic diversity and population structure, were instrumental in our evaluation of current condition and understanding of resiliency and representation. We also obtained new information about the species' response to wildfires. New information is incorporated into *Chapter 3. Species Ecology and Needs* and *Chapter 4. Historical and Current Condition*.

Uncertainties and Assumptions

This report incorporates the best available information through reports, peer-reviewed literature, and communication with species experts. When information is not available at the species level, we sometimes use surrogate species (generally other common gartersnake subspecies), but are always careful to make this clear throughout the report. In general, we lack information about movement and dispersal of the species, which makes defining a "population" difficult, therefore we emphasize that the way that we currently define population may change as more information becomes available. Many of the historical population occurrences have not been re-surveyed since the 1970s or 1980s, so we emphasize that this report uses the best available information including these historical records, more recent reports, and conversations with species experts.

Chapter 2. Background

In this section, we provide background about the San Francisco gartersnake, including taxonomic history and genetic information, a description of the species and how to distinguish it from similar species, and the historical and current range. The references cited within this section provide additional information pertaining to these topics.

Taxonomy

The San Francisco gartersnake is a subspecies of the common gartersnake (*Thamnophis sirtalis*), and is taxonomically defined as *T. s. tetrataenia* (Table 1).

Table 1. Taxonomic status of the San Francisco gartersnake

Class	Order	Suborder	Family	Genus	Species	Subspecies
Reptilia	Squamata	Serpentes	Colubridae	Thamnophis	sirtalis	tetrataenia

It was originally described and named as *Eutaenia sirtalis tetrataenia* (by Cope in Yarrow 1875, p. 546) based on a lectotype (name-bearing type specimen) that was likely from the San Francisco area but erroneously labeled as being from Pit River, California (Fox 1951, pp. 258-260). Fitch's (1940, p. 114; 1941, p. 570) studies of western gartersnakes changed the genus to *Thamnophis*, but added some confusion to the nomenclature/range because of the erroneously labeled lectotype discussed above (1941, pp. 581-589). The taxonomic history is reviewed in detail and clarified by Fox (1951, pp. 257-260). A subsequent change in the classification of the San Francisco gartersnake to *Thamnophis sirtalis infernalis* was published by Rossman *et al.* (1996, pp. 264-265; see also Boundy and Rossman 1995, pp. 236-239). Rossman *et al.* (1996, pp. 264-265) changed the subspecific name because of similarity between the holotype *T. s. infernalis* with specimens from within the range of *T. s. tetrataenia,* and because the name *T. s. infernalis* is considered the senior synonym. Barry and Jennings (1998, entire) submitted a proposal to the International Commission on Zoological Nomenclature to retain the name *T. s. tetrataenia*, which was accepted (ICZN 2000, p. 191).

Genetics

Multiple studies investigating San Francisco gartersnake genetic diversity and population structure have been undertaken or are currently underway. Janzen et al. (2002) and Lim et al. (2009) offer older analyses relating to species' phylogeography of the common gartersnake and San Francisco gartersnake, respectively. Ongoing analysis (Bauer *in litt*. 2019) on the phylogeography of common gartersnake subspecies in the North Bay, Central Valley, Peninsula, and South Bay, will use updated molecular techniques to address similar themes to Janzen et al. (2002).

The most comprehensive genetic work to date is a draft report that used genome-wide single nucleotide polymorphism (SNP) data to evaluate genetic diversity at seven sites throughout the range of the species and five additional "satellite" sites with smaller sample sizes (Wood *et al*. 2019, entire). Genetic diversity estimates were similar across six of the seven sites, with the Pacifica region being lower than the other sites. Analysis of a temporal dataset indicated an increase in differentiation, especially for the more isolated sites. Differentiation into northern and southern regional clusters was supported by phylogenetic, clustering, and genetic differentiation analyses. The northern cluster extends from Pacifica and San Bruno southward along the San Andreas rift valley, while the southern cluster includes sites from Mindego west and south to the coastal sites (Wood *et al*. 2019, pp. 18, 45). Additional substructure within these two regional groups was consistent with geographic features (e.g., the Santa Cruz Mountains) and fragmentation that left some populations more isolated than others. A site in the putative hybrid zone (see *Historical and Current Range* below) had membership coefficients with roughly equal proportions to both the northern and southern clusters, and was grouped in a phylogenetic clade that is sister to a northern clade corresponding to the northern cluster (Wood *et al*. 2019, pp. 18, 20). There was also evidence of increasing genetic isolation with geographic distance (Wood *et al*. 2019, p. 19).

Further information included in this draft report are included elsewhere in the SSA, including a discussion of effective population sizes in relative to abundance estimates (*Chapter 4. Current Condition*) and discussion of possible genetic management (*Captive Propagation in Chapter 5: Future Condition*). Genetic diversity within and among populations is also discussed in the context of Representation (in *Chapter 3. Species Ecology and Needs*).

Species Description

The San Francisco gartersnake is considered one of the most beautiful snakes in North America, with a greenish-blue or blue belly and red on the top of the head (Stebbins 1985, p. 200). Dorsal background color varies from dark brown to black with a wide cream, yellow, blue, or pale green dorsal stripe bordered on each side by uninterrupted red or brownish-orange stripes between black lateral stripes (Stebbins 1985, p. 200; Fox 1951, p. 260; Figure 2). Ventral color and width of dorsal stripe are individually and geographically variable. Neonates are duller in color than adults (Cover and Boyer 1988). Detailed descriptions, including scale counts, can be found in Fox (1951, pp. 260-261), Stebbins (1985, pp. 199-200), and Fitch (1980, pp. 1, 3).

In some populations, San Francisco gartersnakes have color patterns that are similar to a neighboring subspecies, the California red-sided gartersnake (*Thamnophis sirtalis infernalis*) (Figure 2). In the California red-sided gartersnake the lower black stripe is absent and a series of regularly spaced black blotches are contiguous with the upper black stripe, interrupting the red coloration (Service 1985, p. 4). Intergrades between the two subspecies may have a combination of characteristics associated with each (Barry 1996, p. 4). The San Francisco gartersnake can be distinguished from other syntopic (occurring in the same habitat at the same time) gartersnakes, including the Santa Cruz gartersnake (*T. atratus atratus*) and coast gartersnake (*T. elegans terestris*), based on color patterns including the red head and blue ventral color (Barry 1994, p. 10). Barry (1996, pp. 24-25) provides a key to distinguish gartersnakes found on the San Francisco peninsula.

Figure 2. San Francisco gartersnake (left) and California red-sided gartersnake (right). In the San Francisco gartersnake, note the uninterrupted red stripe between black lateral stripes. The California red-sided gartersnake lacks the lower black stripe and has a series of regularly spaced black blotches that are contiguous with the upper black stripe, interrupting the red coloration. Photo credits: USFWS and Will Bauer.

The San Francisco gartersnake reaches a maximum total length of at least 120 cm (47 inches) for females, although the length more commonly reached is around 100 cm (Barry 1994, pp. 59-60). Male gartersnakes are smaller than females, attaining about 83 percent of female length and 55 percent of female weight (Fitch 1980, p. 1). Female common gartersnakes have shorter tails, relative to overall body length, than males (Rossman 1996, p. 262). Additionally, male common gartersnakes have knobbed keels on the scales above the vent (Stebbins 1995, p. 199).

Range and Distribution

Historical and Current Range

The San Francisco gartersnake is endemic to the San Francisco peninsula. The historical range extended from approximately the San Francisco-San Mateo County line south along the base of the Santa Cruz Mountains into northern Santa Cruz County (Fox 1951, p. 260; Service 1985, p. 9; Service 2006, pp. 4, 43-44). Within this area, populations may have principally occupied the Buri Buri Ridge along the San Andres Rift and south in an arc from the San Gregorio-Pescadero highlands west to Tunitas Creek. From here, San Francisco gartersnake populations extended along the west coastline of the Peninsula. A potential intergrade zone comprised of San Francisco gartersnake and California red-sided gartersnake hybrids stretches from Palo Alto north to the Pulgas region near Upper Crystal Springs Reservoir (Barry 1994, p. 55; Fox 1951, pp. 262-263; but see Barry 1978, p. 14). A draft genetics report suggested evidence of gene exchange within this region, but additional sampling and analyses are necessary to further clarify taxonomic relationships and limits in this group (Wood et al. 2019, pp. 23-24).

A now likely extirpated population at San Bruno Mountain may have once represented the northeastern portion of the range, though this record may have been the result of the translocation of individuals from other locations to San Bruno Mountain by amateur herpetologists in order to protect them from development at their original location (Barry 1994, pp. 27-28). The lack of aquatic habitat at San Bruno Mountain (currently or in early maps) supports the idea that the individuals seen here may have been translocated (Barry 1994, p. 27).

A comprehensive survey has not been conducted recently, but the last significant survey efforts are detailed here. Populations as identified by Barry (1978), the Recovery Plan (Service 1985), and McGinnis (1987) are presented in Figure 3. Because illegal collection is a historical and current threat to the species, we denote population occurrences on the map using general waypoints, but do not provide exact locations. Fox (1951, pp. 261, 264) recorded the species in approximately 11 locations throughout San Mateo County, which were mapped by Barry (1994, pp. 83-84). Extensive surveying across the known range of the species, including many of the sites listed by Fox as well as other potential habitat, occurred in the 1970s. From this effort, Barry (1978, pp. 5-9) identified 28 distinct colonies representing 12 populations. This survey defined a population as a group of snakes occupying a discrete creek or drainage (Barry 1978, p. 4). In the Recovery Plan, six significant populations were noted (Año Nuevo State Reserve, Pescadero Marsh Natural Area, San Francisco State Fish and Game Refuge, Sharp Park Golf Course, Cascade Ranch, and Millbrae); many of the colonies identified by Barry (1978) were not confirmed to be extant (nor were they confirmed to be extirpated, or not occupied) (Service 1985, pp. 15-16). Approximately one decade after Barry's (1978) survey, McGinnis (1987, pp. 1; 17-32) surveyed 52 distinct sites, finding the San Francisco gartersnake at 26 of them (note that these numbers are approximate—the report says both 52 and 53 sites, with the snake found at 24 or 26). Of these, 12 were previously unreported, while two of the populations described by Barry had been lost in that time (McGinnis 1987, p. 1). McGinnis (1987, pp. 17-32) grouped these occurrences into seven habitat complexes. At around the same time, thesis work by Barry documented the San Francisco gartersnake distribution from 1971 to 1983 throughout the San Francisco Bay area, including breeding localities in 59 locations in San Mateo County and individuals at an additional 19 sites (Barry 1994, pp. 15, 28-35). He considered a site to have a breeding population if gravid females and/or all age/size groups were represented (Barry 1994, p. 15).

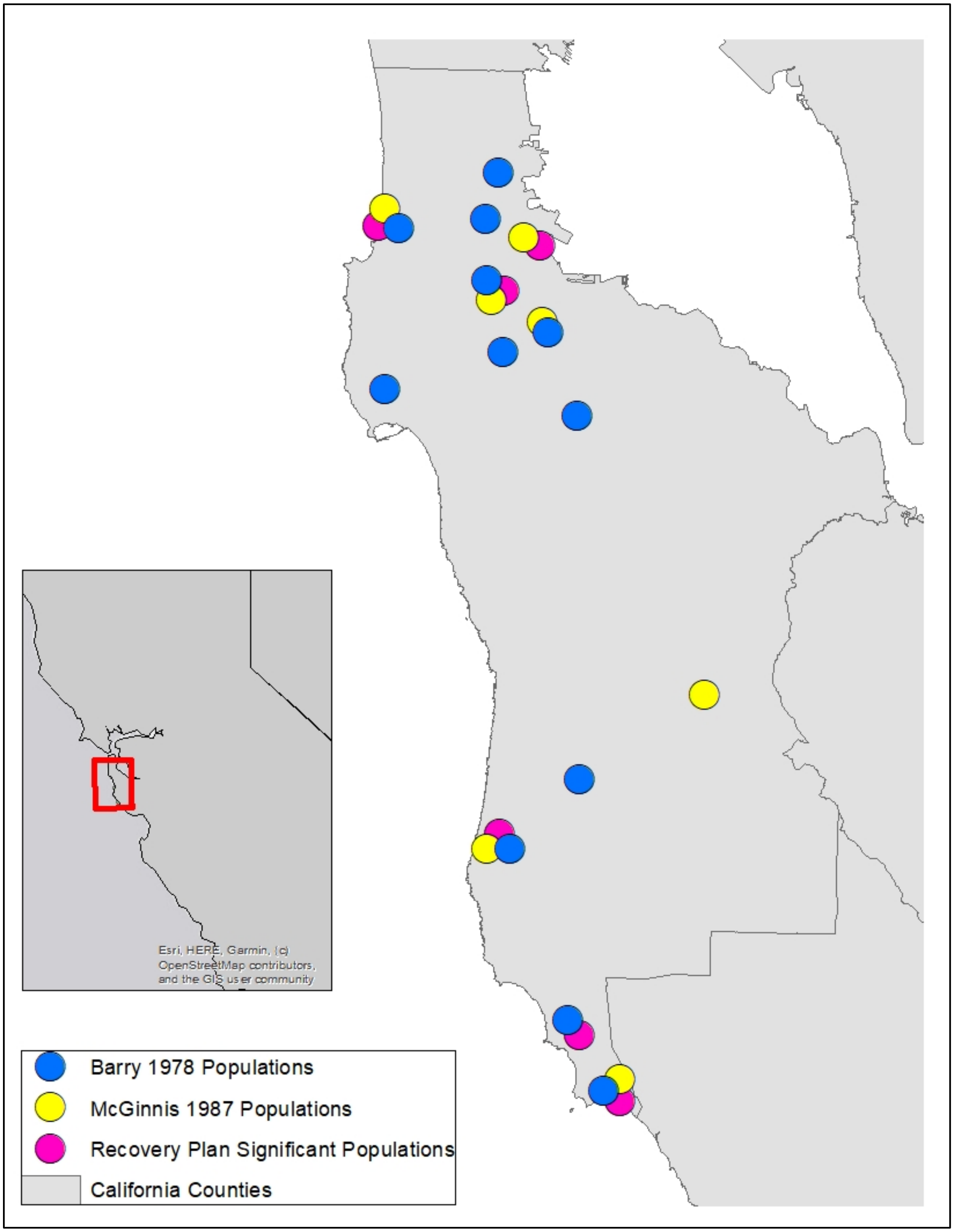

Figure 3. Populations of San Francisco gartersnake according to surveys by Barry (1978) and McGinnis (1987), as well as the six significant populations from the Recovery Plan. Locations are approximate.

Current San Francisco gartersnake populations are found on the San Francisco peninsula from San Mateo County to northwestern Santa Cruz County (Service 2006, pp. 43-44). The California Natural Diversity Database (CNDDB) includes 63 element occurrences that are presumed extant and four element occurrences that are extirpated (CNDDB 2018). Individual observations, populations, or colonies located within one-quarter mile of each other constitute a single occurrence, with some grouping multiple observations based on proximity. Less than one third of the CNDDB occurrences have updated information in the database since the last status review for the species. In addition to the historical records and known CNDDB occurrences, a coastal property on the west side of the Santa Cruz Mountains may be inhabited by San Francisco gartersnake (Service 2006, p. 5). However, because much of this property is privately owned, surveys are not available. Although the species is still distributed across most of its historical range (Barry 1978, pp. 1, 5-9; CNDDB 2018), much of the range has been fragmented or degraded by urbanization.

Population Complexes Used in the SSA

For the purposes of this SSA, we grouped populations into complexes. We do so in order to break the analysis into more manageable units for assessing condition, and because we have little information on movement and dispersal between sites. We use a combination of USGS subwatersheds (HUC 12; USGS *et al.* 2013), proximity, and ecoregions to delineate 13 population complexes (Figure 4). Some of these complexes likely contain populations that may have limited gene flow between them due to urbanization or habitat fragmentation.

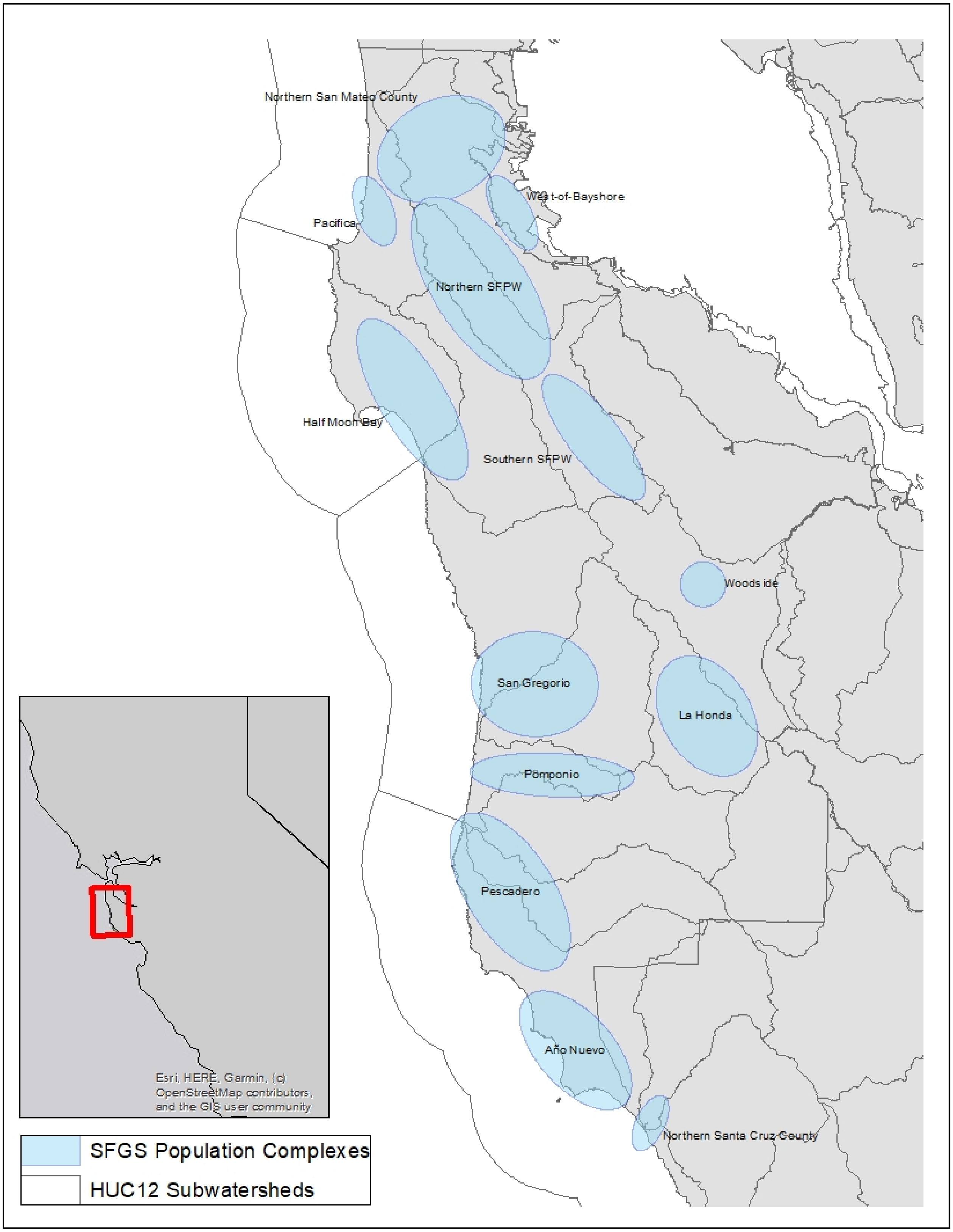

Figure 4. Population complexes used to assess population condition in San Francisco gartersnake resiliency analysis.

Although USGS subwatersheds form the main division defining our population complexes, we do vary from this categorization at times. Using USGS subwatersheds roughly aligns with previous descriptions of populations. For example, in one of the most extensive surveys of the species, Barry (1978, p. 4) described a population as all San Francisco gartersnakes inhabiting a discrete creek system or drainage. The Northern SFPW, Año Nuevo, and Pescadero population complexes include overlap of subwatersheds because of proximity between known occurrences, and communication with species experts regarding likely movement within these areas. We also grouped occurrences across watersheds for the Half Moon Bay and San Gregorio population complexes because of limited recent observations in these areas.

A description of each population complex, including known populations within each complex along with abundances and population trends, is included in *Current Condition*.

Chapter 3. Species Ecology and Needs

In this chapter, we provide biological information about the San Francisco gartersnake, including life history traits such as habitat needs, foraging ecology, and reproductive and demographic parameters. The references cited within this section provide additional information pertaining to the species.

Life History

Life Cycle

Life stages of the San Francisco gartersnake include neonates, juveniles, and sexually mature adults (Figure 5). Neonates are also referred to as newborns (e.g., Larsen 1994, p. 4), or young of the year (e.g.,(McGinnis 1988a), and juveniles as sub-adults (e.g., McGinnis 1988a, p. 15) or yearlings (e.g., Larsen 1994, p. 4). The general activity of these life stages is shown in Figure 6.

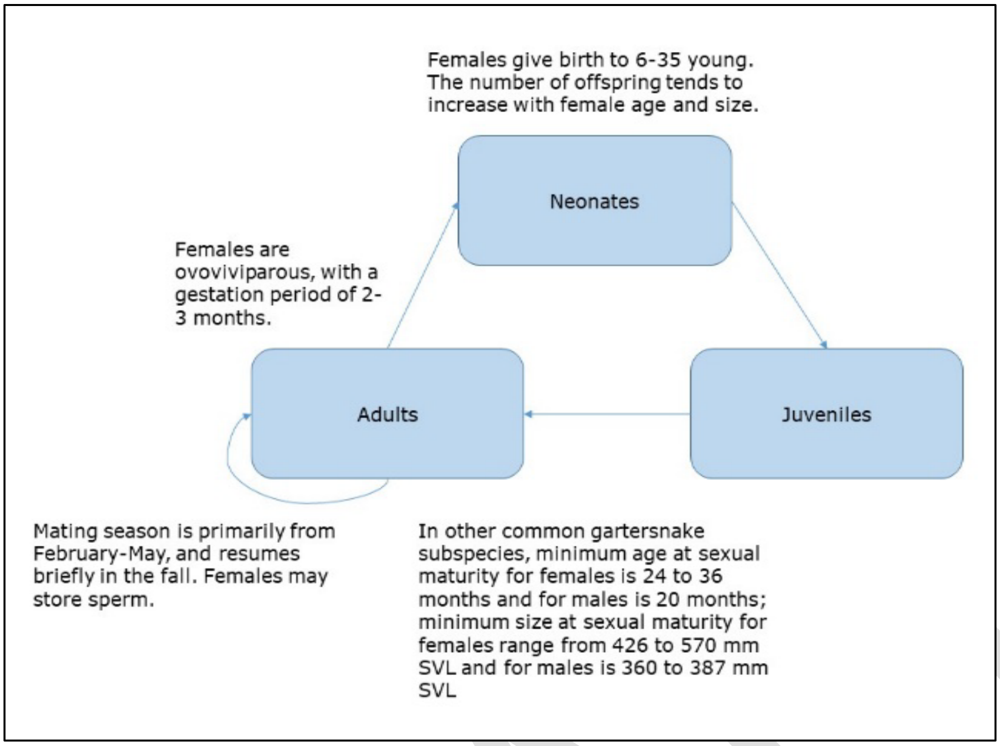

Figure 5. San Francisco gartersnake life cycle.

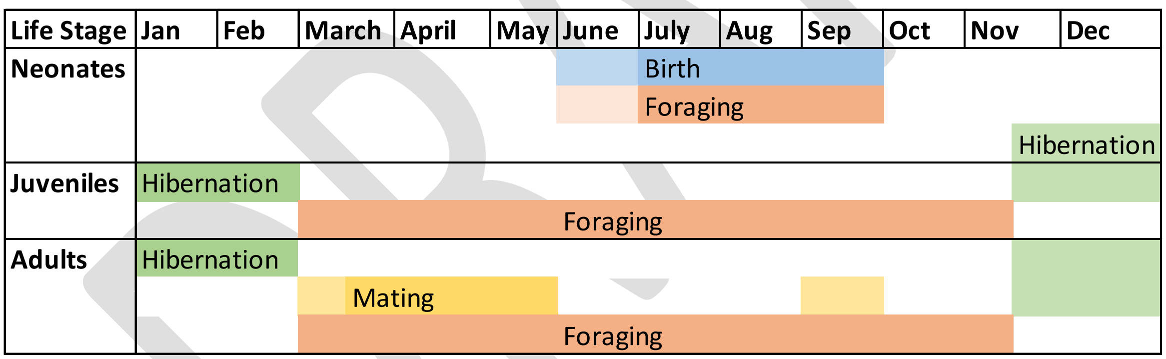

Figure 6. Gantt chart describing general activity of neonates, juvenile, and adult San Francisco gartersnakes throughout the calendar year. Paler colors indicate the limited observations of a given activity, while darker colors indicate the core months that the activities occur.

San Francisco gartersnakes are ovoviviparous (fertilized eggs develop within the female and the embryo gains no nutritional substances from the female). We do not consider eggs as a life stage because they are retained within the females when the neonates emerge. We consider neonates to transition to juveniles after emerging from their first hibernation, and juveniles to transition to adults based on sexual maturity.

Barry (1996, p. 14) further grouped San Francisco gartersnake age according to size following guidelines based on Fitch's (1965) common gartersnake data (Table 2).

Table 2. Age classification of San Francisco gartersnake based on size.

Sex	Snout-vent length (SVL)	Age
Males and females	< 300 mm	1 year or less
Males	301-400 mm	1-2 years
Males	401-500 mm	2-3 years
Males	>500 mm	More than 3 years
Females	301-500 mm	1-2 years
Females	500-600 mm	2-3 years
Females	601-650 mm	3-4 years
Females	>650 mm	More than 4 years

In other common gartersnake subspecies, minimum age at sexual maturity for females is 24 to 36 months and for males is 20 months; minimum size at sexual maturity for females range from 426 to 570 mm SVL and for males is 360 to 387 mm SVL (summarized in Rossman *et al.* 1996, pp. 77-78). In the San Francisco gartersnake, the minimum size at sexual maturity for females is 368 mm (Reeder *et al.* 2015, p. 83). Barry (1996, p. 58) observed all gravid (carrying eggs) females to be at least 2 years old, with older females having higher incidence of gravidity. Although there is little information on reproductive frequency of the San Francisco gartersnake, data on other common gartersnake subspecies suggest that most females probably reproduce each year (Rossman *et al.* 1996, pp. 58-59, 65).

The mating season for the San Francisco gartersnake extends from February into May, and resumes briefly in the fall (Barry 1996, pp. 56-57). Most, but not all, gartersnake species males are ready to mate immediately upon emergence from the hibernacula (Rossman *et al.* 1996, p. 60), and male common gartersnakes probably use pheromone trails to find females (reviewed in Ford 1986, pp. 262-265). Mating aggregations with multiple San Francisco gartersnake males attending a single female have been observed, mainly during the fall (Fox 1955, p. 176; Barry 1996, pp. 56-57). Presence of sperm in cloacal smears within days of emerging from hibernacula indicates that females are mated quickly (Barry 1996, p. 56). The San Francisco gartersnake is likely similar to other subspecies of common gartersnake in the ability to store sperm, which can lead to multiple paternity clutches (Friesen *et al.* 2014, pp. 36-37).

Females give birth in the summer (Barry 1996, p. 96) after a gestation period of 2 to 3 months (Halstead *et al.* 2011, p. 43). When San Francisco gartersnake neonates are born, the shell structure has been reduced to a thin mucous membrane or in some cases has broken through so that it appears that they are born live. Brood size is variable, ranging from six to 35 young (Barry

1996, p. 2; Cover and Boyer 1988). The number of offspring generally increases with female age and size (Barry 1996, p. 59).

Habitat and Activity Patterns

San Francisco gartersnakes are often found in or adjacent to aquatic habitats in association with a terrestrial niche, requiring both shallow freshwater habitat and contiguous uplands, meadows, or riparian habitat (McGinnis 1987, pp. 7-8; McGinnis *et al.* 1987, pp. 8-10, Barry 1996, p. 19). San Francisco gartersnakes have been found in meadowlands up to 2 km (6562 feet) from marshland (Barry 1996, p. 30). Habitat diversity has been positively correlated with occupancy across multiple years at trap arrays, particularly for those located near water (Kim *et al.* 2018, pp. 50-54).

Aquatic habitat, including sag ponds, creeks, marshes, canals, and other water sources, is used for foraging and basking, with requirements related to water depth, inundation period, salinity, and associated vegetation. Water was the primary factor correlated with San Francisco gartersnake presence at a site, with optimal aquatic habitat having a shallow inshore zone and maintaining an average depth of 0.5 m (1.5 feet) throughout the year (McGinnis 1987, pp. 7, 16). The species tends to avoid aquatic habitat with steeply sloped banks (Barry 1996, p. 40). Even artificial aquatic habitats (e.g., reservoirs) can attract San Francisco gartersnakes within a year of development of the habitat (Barry 1996, p. 42), and they are also thought to use less ideal waterbodies, such as irrigation ditches, for foraging (McGinnis pers comm. 2007). Freshwater is important, as salinity can limit presence of the snake's amphibian prey and can influence the growth and/or composition of aquatic vegetation (McGinnis 1987, p. 7; Larsen 1994, pp. 56, 81-83). Vegetative cover, including emergent vegetation and floating aquatic vegetation, is important for feeding and basking (Barry 1994, pp. 40-42, 50; McGinnis 1987, p. 8). Dense cover around or within the freshwater site is also essential for snakes to retreat to when disturbed (McGinnis 1987, p. 8; Fox 1951, p. 264). Aquatic vegetation often consists of a wide band around a pond edge or dense reed-shrub cover throughout a marsh (McGinnis 1987, p. 16; Figure 7), but the species will also use aquatic habitat with sparser emergent vegetation if sufficient cover occurs adjacent to the water (Halstead *in litt.* 2019). Along streams, riparian vegetation often overhangs the edge of habitat including extending upland away from the stream edge, with snakes selecting areas with no clearance between the water and overhanging vegetation (Barry 1996, pp. 26-27). Movements between aquatic habitats (McGinnis 1988a, pp. 24-25) sometimes involve a shift between ephemeral and permanent water sources, with San Francisco gartersnakes shifting resource use to ephemeral marshes during the spring (e.g., Wharton *et al.* 1987, p. 9; McGinnis 1987, p. 23). Aquatic habitat features are discussed further in McGinnis (1987, pp. 7-17) and Barry 1996 (pp. 25-28).

Figure 7. The Visitor Center Pond at Año Nuevo State Park has a wide band of emergent aquatic vegetation as well as thick vegetative cover adjacent to the pond.

The San Francisco gartersnake uses terrestrial habitat that is contiguous to aquatic habitat to regulate its body temperature (thermoregulate), estivate, find cover, forage, mate, and hibernate. San Francisco gartersnakes bask in grasslands, at rodent burrow entrances, on trails, in and under vegetation, in or adjacent to water, and on pond banks (McGinnis 1987, pp. 8-10, 13; Larsen 1994, pp. 69, 98). Grasslands with scattered shrubs provide the best terrestrial habitat (Barry 1994, pp. 42-43, 102), and habitat complexity or heterogeneity is associated with San Francisco gartersnake habitat use (Kim *et al.* 2018, pp. 39, 48). Fox (1955) observed mating aggregations of San Francisco gartersnakes on open grassy slopes in the fall, but only observed mating pairs in spring. San Francisco gartersnakes avoid potentially lethal cold autumn and winter temperatures by moving underground into hibernacula (a place where an animal seeks refuge, or shelter during dormancy) including mammal burrows, crevices, or other voids in the earth. Hibernacula sites are typically open meadowlands with rodent burrows within 1.2 km (3937 feet) of aquatic foraging habitat (Barry 1996, p. 41). The snakes typically select burrows on gentle slopes (Barry 1996, p. 41). Barry (1996, p. 41) suggested that western or southern exposures are preferred. However, San Francisco gartersnakes tracked in a radio telemetry study were found on both northern and southern slopes (McGinnis 1988a, pp. 21-22). Slopes with eastern exposure were avoided (McGinnis 1991, p. 5).

San Francisco gartersnakes begin seeking winter retreats in mid to late November, (Barry 1996, p. 54), and there is some evidence for communal hibernacula (McGinnis *et al.* 1987, p. 10; Wharton *et al.* 1987, p. 9). Foraging and other activities are sporadic at this time and dependent upon weather conditions. However, some individuals emerge from hibernacula to bask, or move short distances, on warmer winter days (Barry 1996, p. 54). San Francisco gartersnakes typically begin emerging from winter retreats in late winter or early spring and are most active from early spring through mid-fall. They appear to move from hibernacula sites to marshlands relatively quickly upon emerging (Barry 1996, pp. 50-54).

Activity and habitat use vary based on season and individual characteristics including sex and age. Most activity occurs during daylight hours (Barry 1996, p. 54), although nocturnal activity has been observed in this subspecies (Biosearch Associates 2005, p. 6) and in at least one other subspecies of common gartersnake (Hansen and Tremper in prep in Rossman *et al.* 1996, p. 267). In summer, snakes are active throughout the day, while in fall and spring the snakes are most active in the early morning and late afternoon (Barry 1996, p. 54). Barry (1996, p. 56) reported a relative scarcity of male San Francisco gartersnakes near foraging habitat in the spring. Females are often found close to water towards the end of gestation even though gartersnakes stop feeding in the latter half of this period (Fitch 1965 in Barry 1996, p. 52). Barry (1996, p. 52) suggests that this habitat use may be adaptive because neonate snakes rely on newly-transformed amphibian food sources near water and are most commonly found close to the water's edge (Barry 1996, pp. 52, 59). Males tend to emerge from hibernacula about two weeks earlier than females (Barry 1996, p. 50). They also tend to emerge downslope from females, suggesting that hibernacula site choice may vary based on sex or other factors (Barry 1996, p. 50).

Diet

San Francisco gartersnakes use both visual and chemical cues to forage, feeding primarily on California red-legged frogs (*Rana draytonii*) and Sierran treefrogs (*Pseudacris sierra*; also Sierran chorus frog) (Larsen 1994, pp. 71-80; McGinnis 1987, p. 11). Note that the California red-legged frog was formerly considered a subspecies of *R. aurora* (Shaffer *et al.* 2004, pp. 4-6), and that Sierran treefrogs were formerly lumped with Pacific treefrogs (*P. regilla*; Recuero *et al.* 2006a, p. 296; Recuero *et al.* 2006b, p. 511; formerly *Hyla regilla*). Both prey types are commonly referred to by their former nomenclature in the San Francisco gartersnake literature, but hereafter we will refer to them as red-legged frogs and treefrogs, respectively. Barry 1996 (pp. 36-38) argues that American bullfrogs (*Lithobates catesbeianus*) may adequately replace red-legged frogs in the San Francisco gartersnake diet at some sites. However, the benefit of bullfrogs is debated by other researchers that argue that the presence of bullfrogs is negative because of their complicated role as prey, predator, and competitor (Larsen 1994, pp. 88-89; Kim 2017, pp. 28, 37; see *Predation* below). San Francisco gartersnake density is loosely correlated with ranid frog density: sites with higher frog densities often have higher snake densities, with the caveat that some sites may have frogs present but not snakes (Barry 1996, pp. 45-49). Other prey taken to a lesser degree include western/California toad (*Anaxyrus boreas halophilus*) (Service 1985, p. 7), slender salamander (*Batrachoseps attenuatus*) (McGinnis 1987, p. 27), small fish (Wharton *et al.* 1987, p. 16; Larsen 1994, p. 78), newts, annelids, and even rodents (Barry 1996, pp. 2, 31, 34). San Francisco gartersnakes are able to eat newts because they are highly resistant to the effects of the neurotoxin (tetrodotoxin) that newt skin contains (Brodie, Jr. *et al.* 2002, p. 2071).

As in other species of gartersnakes (Lind and Welsh 1994, pp. 1266-1267), diet varies based on snake age and size and on prey availability (Kim 2017, pp. 28-29, 38-39). Neonate and juvenile

San Francisco gartersnakes depend heavily upon juvenile treefrogs as prey because of their small size, and newly metamorphosed treefrogs are especially important for newborn snakes (Larsen 1994, p. 73; Barry 1996, p. 34). Tadpoles trapped in seasonally drying pools can be especially abundant and are readily consumed (Wharton *et al.* 1987, p. 18). Treefrogs are of primary importance to snakes up to 500 mm (19.7 inches) snout-vent length (SVL), while adults greater than 500 mm SVL forage mainly on tadpole and adult red-legged frogs (Barry 1996, p. 34). Only large adults are capable of eating adult American bullfrogs (Barry 1996, p. 34). As with other gartersnake species (Seigel 1984 in Rossman 1996, p. 70), the San Francisco gartersnake diet and foraging habitat varies seasonally based on the life cycle of its amphibian prey (Barry 1996, pp. 51-54, 129). Foraging on other species is likely largely related to availability. Snakes will readily take fish in shallow water but may have difficulty catching fish in water deep enough for them to swim (Larsen 1994, p. 78). Newts comprise about half of the diet of neonate San Francisco gartersnakes from at least one site, while at other sites this prey item is completely absent (Barry 1996, pp. 34-35).

Natal food tests demonstrated that juveniles have innate preferences for amphibians and fish, with treefrogs eliciting the highest response (Larsen 1994, p, 52). In contrast, they showed no feeding response when presented with the scent of slugs, mice, or insects (Larsen 1994, p. 72). Although the juveniles had a strong positive response to the scent of earthworms, when presented with them as potential prey some snakes refused to eat them (Larsen 1994, p. 77).

Movement and Dispersal

To our knowledge there are no data on connectivity or dispersal between population sites despite trapping studies and application of radio tags at several sites. Movement and dispersal uncertainty is highlighted by studies at some sites that model population dynamics using both open and closed population assumptions (e.g., Kim *et al.* 2018, p. 9). Within sites, low numbers of recaptures and/or captures at ponds separated by hundreds of meters suggest that the snakes can be relatively transient (McGinnis 1988, pp. 17-18). The use of drift fences to capture individuals moving between habitat patches revealed movement in both directions (Wharton *et al.* 1987, p. 14), but it is not known if this pattern persists between populations. Although little data exists on home range size of San Francisco gartersnakes, Barry (1996, p. 23) suggests that home ranges may average several hectares.

Data from telemetry and mark-recapture studies indicate that San Francisco gartersnakes may be highly mobile during the spring but then stay in the same area for the rest of the year (Larsen 1994, pp. 67-68). A male recaptured in both 2013 and 2017 in the same trap line demonstrates this tendency to stay in the same area (Swain Biological, Incorporated 2018, p. 29). Most recaptures occurred within 167 m (550 feet) of each other (Larsen 1994, p. 40), with one female moving up to 671 m (2200 feet) and a male moving 632 m (2075 feet) (Larsen 1994, p. 38). Recaptures of females at the West-of-Bayshore (WOB) site showed a 1606 m movement over 22 days by an adult and of 1061 m over 3 days by a juvenile (Swaim Biological, Incorporated 2018, p. 21). In contrast, a closely related subspecies, the red-sided gartersnake (*Thamnophis sirtalis parietalis*), dispersed up to 17.7 km (11.0 mi) when going to or from hibernacula (Gregory and Stewart 1975, p. 240). Genetic data indicates male-biased dispersal, based on variation between populations supported by haplotypes (mitochondrial DNA representing females) verses variation within populations supported by microsatellite DNA (representing both males and females) (Lim *et al.* 2009, pp. 5-8; Lim *in litt.* 2019).

Survival

There is little information about survival in San Francisco gartersnakes, and the available information suggests that survival rates vary across populations or years. Trapping data indicates that, in at least some populations, survival is high, with annual survival of 0.88 and 0.82 across two years in one population (Halstead *et al.* 2011, p. 44). However, survival appears to vary across years, ranging from 0.29 to 0.64 across a four-year study in another population (Kim *et al.* 2018, pp. 33-34). Trapping in 2007, 2013, and 2017 at the WOB site yielded 0 recaptures between the first two sampling years and 4 recaptures between the latter, suggesting that survival at the site may be low in comparison to the survival found in Halstead *et al.* 2011 (Swaim Biological, Incorporated 2018, pp. 46-47). Similarly, there were no recaptures in re-trapping across two year surveys at Mori Point in 2004, 2006, and 2008, again potentially suggesting low survival rates (Swaim Biological, Incorporated 2009, pp. 13-14). Barry 1996 (pp. 61, 114) found that under ideal conditions about 27 percent of neonate females survive to reproduce once, and only 2 percent survive to age 5, assuming about 50 percent survival after 2 years of age. In other gartersnake species, survival varied with age class. Survival of *Thamnophis sirtalis fitchi* neonates across two years was 29 and 43 percent, survival of yearlings was about 50 percent, and survival of individuals greater than 2 years old was 33 percent (Jayne and Bennett 1990, pp. 1209-1217).

Sex ratios

The Recovery Plan calls for populations with a 1:1 sex ratio (Service 1985, p. 18). The 2006 status review for the species questioned the appropriateness of that criterion because, although San Francisco gartersnake sex ratios were unknown at the time, available information for the red-sided gartersnake (*Thamnophis sirtalis parietalis*) indicated strongly male-biased sex ratios (Service 2006, p. 4; Shine *et al.* 2001, p. 84). Additional information on the relative numbers of male and female San Francisco gartersnakes since the status review indicate that populations have approximately equal numbers of males and females (e.g., Rose *et al.* 2018, p. 4), although sex ratios varied somewhat across sites. Although sex ratios did not significantly differ from 1:1 at any site, populations in northern regional sites were more female-biased while populations in southern regional sites were more male-biased (Wood *et al*. 2019, p. 17). Comparing sex ratios to census sizes instead of region, lower abundances may be associated with more females (Wood *et al*. 2019, pp. 26-27). The authors' postulate that this might be due to lower survival in males due to time spent in mate-searching and courtship, or to other factors such as potential habitat vs. survey area.

Seasonal activity may vary by sex, age class, season, or trapping method, which all have the potential to influence observed sex ratios (Reeder *et al.* 2015, p. 84). Recent studies use models that include the effect of sex on capture probability to predict population sex ratios more accurately (e.g., Reeder *et al.* 2015, p. 80). For example, although observed sex ratios (males: females) were 0.81 and 1.33 males to females in two years of trapping in one population, the modeled sex ratios in those same years were skewed towards females at 0.76 and 0.77 males to females, respectively (Reeder *et al.* 2015, pp. 80-81). Overall, available data from trapping studies show that sex ratios may fluctuate in some locations or years but do not appear to be significantly different from 1:1 (Table 3). In a recent demographic study, the overall sex ratio was not significantly different from 1:1, although more females were captured (Rose *et al.* 2018, p. 4). As a result, the 1:1 sex ratio is still considered appropriate in this SSA.

Table 3. Observed proportion of male San Francisco gartersnakes in various populations. Observed proportions are based on the proportion of males to females captured, with 0.5 being an equal proportion of males and females. This measure differs from the male:female sex ratio, another demographic measurement used in some studies, where 1:1 would represent an equal number of males to females.

Population	Observed proportion of males	Years	Source
Mindego Ranch	0.41-0.66	2014-2017	Kim et al. 2018, p. 25
West-of-Bayshore[1]	0.45, 0.57, 0.53	2007, 2013, 2017	Swaim Biological, Inc. 2018 pp. 29, 37
Cloverdale	0.43-0.62	2008-2010, 2014-2018	Halstead et al. 2011, p. 44; Kim et al. 2017, p. 4; Rose et al. 2018, p. 10
Pearson Ranch[2]	0.59, 0.77	1987, 1988	McGinnis 1988, p. 19
Ano Nuevo Visitor Center Pond	0.53	2018	Rose et al 2018, p. 10
Ano Nuevo BART	0.50	2018	Rose et al 2018, p. 10
Mori Point/Sharp Park	0.36	2018	Rose et al 2018, p. 10
Skyline Wetlands	0.27	2018	Rose et al 2018, p. 10
Tracy Lake	0.33	2018	Rose et al 2018, p. 10

[1]2007 and 2013 numbers reflect adults only, 2017 reflects adults and juveniles

[2]proportions reflect adults captured; also captured 4 juvenile males each year

San Francisco Gartersnake Needs

In this section, we summarize the life history information available for the species and translate these data into needs at the individual, population, and species levels. For individual San Francisco gartersnakes, we summarize the general habitat resources or conditions that adults, juveniles, and neonates need to complete each stage of their life cycle. Next, we describe the habitat and demographic conditions that resilient populations require. Finally, we describe what the species needs for viability in the context of the 3Rs.

Individual Needs

Individual San Francisco gartersnake needs vary by life stage (Table 4). San Francisco gartersnakes need permanent freshwater habitat with dense aquatic vegetation and adjacent upland habitat with rodent burrows for estivation. Amphibian prey support their caloric needs throughout the active season. Because males tend to emerge from estivation earlier in the year than females, they may need amphibian prey earlier in the year than females. Males may forage further from aquatic habitat, often traveling into marshlands to pursue treefrogs, while gravid females tend to stay close to water. Gravid common gartersnakes typically do not feed during the latter half of gestation (Fitch 1965 in Barry 1996, p. 52), which may also be the case for San Francisco gartersnakes. Barry (1996, p. 52) suggests that gravid females are found in dense vegetation near water because neonates rely on newly metamorphosed treefrogs upon parturition (when females give birth to offspring). Adults over 500 mm SVL are particularly reliant on red-legged frogs to sustain their caloric needs (Barry 1996, p. 28), while individuals in smaller size classes primarily forage on treefrogs. Adults also need to be able to find mates to complete their life cycle (although females can store sperm, so mating every year may not be a requirement). Neonate and juvenile needs are largely the same as adults (but note differences in prey based on size), with the exception that they do not need to find mates.

Table 4. Resource needs for individual San Francisco gartersnakes. Resource functions include feeding (F), sheltering (S), breeding (B), and dispersal (D).

Resource	Life Stage	Resource Function
California red-legged frogs	Adults	F
Pacific tree frogs	Adults, Juveniles, Neonates	F
Tertiary prey sources (e.g., newts)	Adults, Juveniles, Neonates	F
Shallow freshwater habitat with emergent vegetation	Adults, Juveniles, Neonates	F, S, D
Open grassy uplands	Adults, Juveniles, Neonates	F, B, D
Hibernacula (e.g., rodent burrows)	Adults, Juveniles	S

Individual San Francisco gartersnakes must be able to move freely between aquatic habitat and upland habitat. In areas with both permanent and ephemeral water sources, movement corridors between these habitat patches are essential for the snake.

Population Needs

For the purposes of this SSA, we define a population of San Francisco gartersnake as spatially connected colonies that have breeding male and female snakes. In previous surveys of the species, a population was typically described as all San Francisco gartersnakes inhabiting a discrete creek system or drainage, with colonies making up specific habitats in a certain area within the population (Barry 1978, p.4). This definition assumed that there is more interchange within waterbodies than between. Because we have little information on movement and dispersal between populations, we group San Francisco gartersnake populations into population complexes (as described in *Historical and Current Range and Distribution* above). For simplicity, we describe needs at the population level rather than the complex level, with the understanding that complexes have the same needs as those described for populations below, but on a larger spatial scale.

Population Resiliency

Resiliency describes the ability of the species to withstand stochastic disturbance events, an ability that is associated with habitat quality to support particular demographic characteristics. Populations rely on the same habitat resources as individuals (Table 4), but in such a quantity and configuration to support demographic characteristics associated with resilient populations (Figure 8). For example, because females >500 mm SVL are the most productive reproductive cohort (Barry 1996, p. 29), the presence of red-legged frogs (the preferred food for females of this size) is important for population resiliency. Treefrogs are important prey sources for neonates and juveniles, thus are important for recruitment into the population. Although freshwater habitat used by San Francisco gartersnakes can include a variety of waterbodies including sag ponds, creeks, marshes, canals, and other water sources, resilient populations require impounded freshwater with appropriate aquatic vegetation. For example, the use of creek habitats by San Francisco gartersnake is less understood, and those creek systems that do support the species all contain naturally or artificially impounded water (McGinnis 1988b, p. 1). Demographic characteristics of resilient populations are related to abundance, fecundity, and survival. Resilient populations should have at least 200 adults with an approximately 1:1 sex ratio of males:females, a number that was identified as being sufficient for a resilient population in the Recovery Plan (Service 1985, p. 18). High levels of fecundity can drive population growth, which also benefits from survival across age classes. Survival of neonates is important for recruitment into the population, and survival of juvenile females into breeding adults is important in maintaining reproductive individuals in the population. High levels of fecundity and survival can also allow populations to recover from stochastic events such as drought that can temporarily reduce amphibian prey. Because of associations between age class structure and the demographic needs of fecundity and survival, age class structure can be used as a proxy to assess fecundity and survival in the population. Presence of gravid females, and of neonates, are both signs of a healthy breeding population. Survival of neonates, juveniles, and adults, is important in maintaining a diverse age class structure of the population. Large females are necessary for breeding in the population, and small individuals demonstrate recruitment into the population.

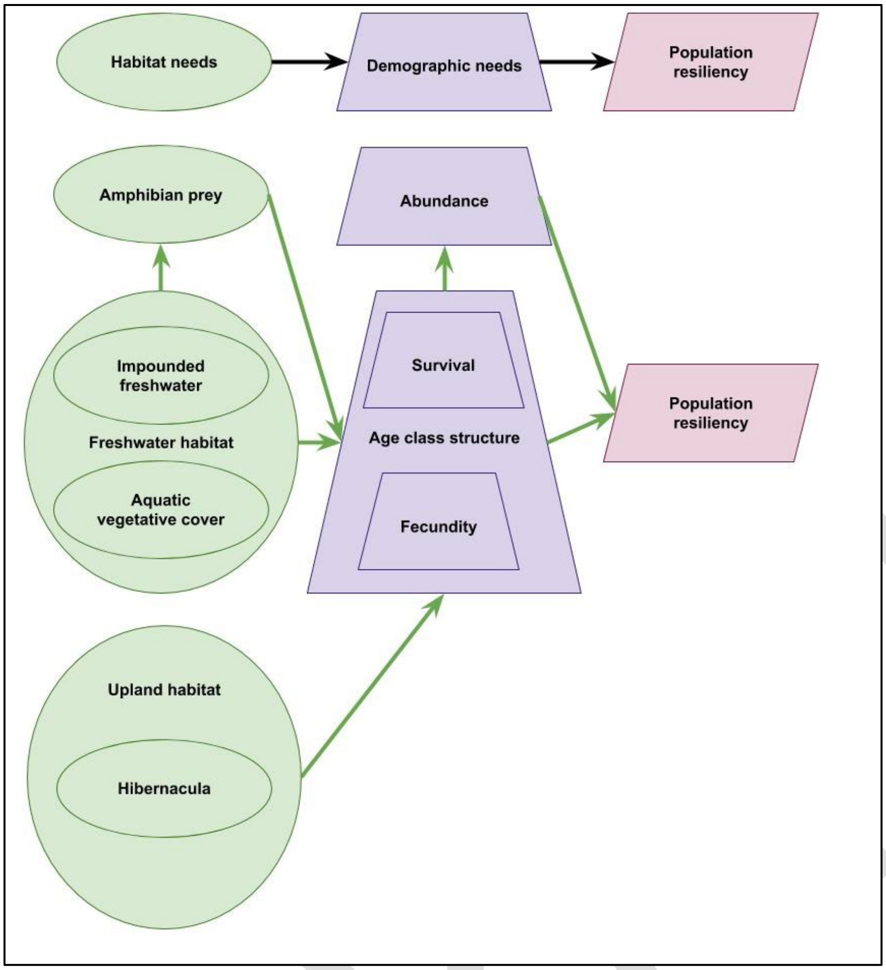

Figure 8. Influence diagram modeling population habitat and demographic needs that promote resiliency for the San Francisco gartersnake.

Species Needs

Maintaining ecological and genetic diversity (representation) by having resilient populations distributed throughout the species' range (representation and redundancy) facilitates adaptation to changing environmental conditions and the ability to withstand catastrophic events.

Redundancy

Redundancy describes the ability of a species to withstand catastrophic events, a measure that is related to the number, distribution, and resilience of populations. Potential catastrophic events that might affect the San Francisco gartersnake include earthquakes (if they led to destruction of dams on the San Francisco peninsula), saltwater inundation into freshwater habitat, long-term drought, or other large-scale losses of amphibian prey for the species.

The Recovery Plan states that the San Francisco gartersnake needs 10 resilient populations that display a breadth of genetic diversity across its range for delisting to be considered (Service 1985, p. 18). These populations should be distributed throughout the species range to maximize genetic and ecological representation of the species.

Representation

Representation describes the ability of a species to adapt to changing environmental conditions, which is related to the breadth of genetic and ecological diversity within and among populations. A species with more representation, or diversity, is more likely to adapt to and persist with natural or human-caused changes to its environment.

Historically, the species' range likely consisted of interconnected populations throughout the San Francisco peninsula that would have been resilient to stochastic events such as drought. Even if some populations were extirpated by such events, they could be recolonized over time by dispersal from nearby surviving populations. This connectivity would have contributed to species' representation. However, under current conditions, restoring that connectivity across the peninsula is not feasible due to extensive urbanization. Instead, it is important to have highly resilient populations distributed throughout the species range, and to preserve the genetic and ecological diversity present in extant populations in order for the species to adapt to stochastic changes in the environment.

Across the species range, there is genetic variation separating northern San Francisco gartersnake populations from more southern populations, and ecological variation moving inland from the coast and upward in elevation. Recent genetic analyses show that the species largely clusters into two groups throughout its range, a northern and a southern cluster. Reduction in gene flow between these clusters as a result of both isolation and geographic or habitat limitations suggests managing these regional groups as separate genetic units (Wood *et al*. 2019, p. 23), and maintaining resilient populations across these clusters is important for species representation. Only one population in the genetic analyses occurred at high elevation, and this site is genetically differentiated from other populations in the southern cluster (Wood *et al*. 2019, p. 19). Other than this site, there is limited information about the species' potential distribution at higher elevations, although it has the potential to be an important example of ecological diversity within the species. Other ecological settings vary somewhat as the populations move further from the coast, and there may be ecological adaptations to this variation. Temperature may vary between inland and coastal sites, and may covary with fog levels. Temperature can influence growth rate of ectotherms (animals that depend on external temperatures for body heat) such as the San Francisco gartersnake. For example, in experimental enclosures in two different habitat types, gravid female common gartersnakes grew faster when they had warmer body temperatures (Halliday and Blouin-Demers 2018, p. 26). Growth rate is an important consideration because snakes that grow faster may reach reproductive status more quickly or grow into size classes that are less vulnerable to predation. Anecdotally, the San Francisco gartersnake has a higher mean body size at an inland ranch compared to a coastal ranch (Kim *in litt.* 2019), which could be related to temperature or other differences between the sites. At the WOB site, biologists noted that size distribution of individuals seems to have downshifted compared to capture records from the 1980s (Swaim Biological, Incorporated 2018, pp. 26-27). However, this downshift could be related to habitat conditions, habitat quality, interspecific competition, or other unknown factors rather than temperature. Other variation in climatic conditions throughout the species range includes variation in precipitation, which can influence aquatic features and amphibian prey. Treefrog seasonal activity can vary based on temperature, availability of water, and elevation

(Brattstrom and Warren 1955, p. 188). If some sites support multiple clutches of treefrogs per year (see Perrill and Daniel 1983, entire), this could increase prey availability and subsequent recruitment in San Francisco gartersnake populations. Maintaining resilient populations across the north-south and east-west distribution of the species range would conserve the relevant genetic and ecological diversity within the species, thus maintaining current levels of representation.

Additionally, behavioral variation between populations may be important. Although red-legged frogs and treefrogs are the primary food sources for the species, for at least some sites, newts make up a significant proportion of the diet (Halstead *in litt*. 2019). This variation and flexibility in diet is important to maintain. Although there is morphological variation in appearance within and between populations, it is unclear at this time if morphological variation adds to species representation.

Summary of Species Ecology and Needs

Individual San Francisco gartersnakes need access to sufficient food and habitat in order to maintain resilient populations. Populations need to be resilient to be able to withstand periodic natural disturbances, such as drought. At the population level, survival of juveniles to the minimum size for reproduction is essential to drive population growth, as is survival of reproductive females. Distribution of resilient populations throughout the range enables the species to be able to withstand catastrophic events (redundancy) and adapt to changing environmental conditions (representation) to sustain populations in the wild over time (viability) (Table 5).

Table 5. Summary of individual, population, and species' needs for the San Francisco gartersnake in terms of the 3Rs.

Level	Need	Function of Need	Association with 3 Rs
Individual and Population Habitat Needs	Amphibian prey (red-legged frogs, treefrogs, and other tertiary prey items)	Provides caloric needs for hatchlings, juveniles, and adults	Resiliency
	Freshwater habitat with dense aquatic vegetation	Provides sites for foraging; refugia	Resiliency
	Upland habitat	Provides sites for thermoregulation, estivation, and hibernation	Resiliency
	Hibernacula	Provides sites for refugia, thermoregulation, and hibernation	Resiliency
Population Demographic Needs	Abundance	Prevents inbreeding depression	Resiliency

	Survival	Promotes abundance; allows adults to become reproductively capable	Resiliency
	Fecundity/recruitment	Drives population growth	Resiliency
Species Needs	Resilient populations across the species' range	Improves species viability by spreading risk associated with catastrophic events	Representation, Redundancy
	Maintenance of multiple resilient populations within both genetic clusters in the species range	Maintains adaptive capacity of the species	Representation

Chapter 4. Current Condition

Historical and Current Abundance and Trends within Population Complexes

Little is known about historical abundances of the San Francisco gartersnake. The species was listed as endangered prior to any systematic range-wide survey effort or population studies, and extensive urbanization led to the extirpation of some populations prior to this effort (Barry 1978, p. 6).

Below, we summarize available data on San Francisco gartersnake population complexes, including abundance and population trends for those areas for which we have information. Note that some figures or numbers are the actual number of individuals that were observed or trapped, while other figures or numbers denote modeled abundance estimates. Population complexes are roughly organized from north to south. Those that are previously reported in Service publications (the Recovery Plan and Status Reviews) or the literature are identified in the report by their proper geographic name (e.g., the Año Nuevo State Park Visitor Center pond). However, those occurring on private land or in previously undisclosed locations are referenced vaguely (e.g., two ponds on a private ranch) because of the ongoing threat of illegal collection.

Northern San Mateo County

This complex includes the sag ponds along Skyline Boulevard where Fox sampled extensively, and were the most abundant population on record (Fox 1951, p. 264; Barry 1994, p. 26). In two years of sampling beginning in 1947, Fox collected at least 230 individuals in just 25 visits, leading Barry (1994, p. 26) to estimate that the population must have contained over 1000 individuals in a small geographic area. This complex is now considered extirpated. We include this population complex to include the complete historical range, but do not expect that habitat factors in this area will ever be sufficient to support resilient San Francisco gartersnake populations in the future.

Pacifica

Within Pacifica, San Francisco gartersnake population records exist for Laguna Salada and Mori Point. Although the historical records for Laguna Salada and Mori Point treat these areas as two separate populations, the only feature that distinguishes them is a property line. Laguna Salada is a managed waterbody within the Sharp Park Golf Course, owned by the City of San Francisco. Translation of Laguna Salada as "Salty Lake" suggests that the area historically consisted of a coastal lagoon with seasonal freshwater accumulation (Philip Williams & Associates, Ltd. *et al.* 1992, p. 2). Mori Point is a 32-hectare undeveloped coastal bluff that is part of the Golden Gate National Recreation Area. Additional history of the sites is detailed by Phillip Williams & Associates, Ltd. *et al. et al.* (1992, entire) and Swaim Biological, Incorporated (2009, pp. 1-4).

Most San Francisco gartersnake survey estimates at Laguna Salada and Mori Point are reported in raw observations numbers, but do not attempt to estimate actual population abundance at the site. The population at Laguna Salada was first documented in 1946 by Fox (1951, p. 264), who collected 44 specimens in 1946 and 1947 (CNDDB 2018). A subsequent population decline was associated in part with illegal collection (Barry 1978, pp. 12-13). Laguna Salada was subject to saltwater intrusion in the 1980s, reducing habitat for amphibian prey of the snake and corresponding to a further decline in population abundance (McGinnis 1986, pp 4-5; Phillip Williams & Associates, Ltd. *et al.* 1992, p. 3). Trapping and observations in 1986 failed to detect San Francisco gartersnakes or its aquatic prey despite 2000 trap-hours and 84 visual survey hours (McGinnis 1986, pp. 2, 4). In contrast, the congeneric coast and Santa Cruz gartersnakes were both detected, and habitat seemed suitable for these species based on their preferred prey (rodents and fish, respectively) (McGinnis 1986, pp. 3-4). However, San Francisco gartersnakes were observed at a junk pile adjacent to the site later in the same year, demonstrating ongoing occurrence at the site (McGinnis 1987, pp. 26-27). Trapping surveys at Mori Point from 2004 to 2008, initiated because of pond construction and other site improvements, yielded low but positive occurrence results. There were no recaptures of individuals between 2004 to 2006 or 2006 to 2008 (Swain 2009, pp. 13-14). Visual encounter surveys at Mori Point from 2013-2018 also resulted in low encounter rates that failed to elucidate a trend in population abundance (Fong and Kindall 2019, pp. 5, 11). However, trapping in 2018 yielded captures of 25 individuals and a population estimate of 38 to 104 individuals (Rose *et al.* 2018, p. 9).

To the south of Mori Point, Calera Creek and several ponds near the creek used to support San Francisco gartersnakes, and the species frequently moved back and forth over the hill between the properties, thus we also consider the Calera Creek area (when it has appropriate habitat) to be part of this population. The upland coast grassland-scrub area referred to as the "Mori Bowl" (Fong and Kindall 2019, p. 4) was considered an important area for the species and a potential migratory corridor (Phillip Williams & Associates 1992, p. 20). The creek was realigned and vegetated as part of mitigation for a wastewater treatment plant on the property, which also included the construction of two new ponds to replace old ponds that were filled in. However, the current status of the San Francisco gartersnake on the Claera Creek ponds is unknown, and lack of management has led to extremely dense vegetation in the creek and loss of the ponds.

West-of-Bayshore

This complex contains only the WOB population, which is surrounded by housing and urban development on all sides. The WOB property, located near and owned by the San Francisco International Airport (SFO), is a 73-hectare (180 acres) site that historically consisted of tidal marsh (LSA Associates 2008, p. 7). Construction of highways and installation of tidal gates effectively eliminated tidal influence, and the site now consists of seasonally inundated wetlands interspersed with upland habitat and drainages that provide permanent stream habitat (LSA Associates 2008, pp. 7-8). The site is thought to have supported a resident population of San Francisco gartersnakes since at least the late 1960s (based on a museum specimen collected in 1968, reported in Barry 1994, p. 68). Seasonal activity and an associated shift in distribution between ephemeral marsh habitat and canals at the site is described in Wharton *et al.* (1987, pp. 9-14). The site is situated in an urban matrix isolated from other San Francisco gartersnake locations (Barry 1994, p. 68; Reeder *et al.* 2015, p. 78).

WOB is one of the largest populations of San Francisco gartersnakes (McGinnis 1987, p. 7; Swaim Biological, Incorporated 2018, p. 11). Trapping results from three time points across recent years indicate a high-density population at the site, with the most current population estimate also thought to be the most reliable because of the high number of recaptures (Swaim Biological, Incorporated 2018, p. 11). Population estimates in 2007, 2013, and 2017 were 1520, 1284, and 1316 snakes, respectively (Swaim Biological, Incorporated 2018 pp. 1-2). Trapping in the 1980s and 1990s yielded 695 individuals across 3 years in the former decade but only 179 individuals in the latter (Wharton *et al.* 1986, p. 8; Larsen 1994, p. 38). Trapping surveys within a limited area prior to the construction of a Bay Area Regional Transport station in 1997 resulted in the capture of only 25 individuals (Larsen pers. com. in Service 2006, p. 5). This opportunistic sampling in the 1990s indicated a potential population decline in the 1990s, suggested to relate to declines in habitat quality, reduction in prey, drought conditions, and/or illegal collection (Larsen 1994, pp. 98-99; LSA Associates 2008, p. 1). Although available data suggest a potential population decline during the 1990s, we stress that population estimates are not directly comparable across years because of differences in sampling area, monitoring efforts, capture techniques, and analytical methods. Moreover, opportunistic trapping in the 1990's as opposed to the more structured approach taken in the last decade may exaggerate population differences over time.

Much of the population at the WOB site consists of snakes intermediate in appearance between the San Francisco gartersnakes and other gartersnake subspecies (Figure 9). Barry (1994, pp. 68-69) estimated that 80 percent of the population did not have a phenotype entirely consistent with the San Francisco gartersnake, and that 20 percent of the population showed extensive melanic suffusion (Barry 1994, p. 68). Anecdotally, were any hybridization to have occurred in the WOB population, it may be in part due to rumored release of California red-sided gartersnakes in an effort to boost the population (Barry 1994, p. 69). Speculation over genetic relationships of this population has likely led to a decrease in illegal collection (Barry *in litt.* 2006). However, results from genetic analyses are consistent with individuals from WOB grouping with other San Francisco gartersnake populations (Wood et al. 2019).

Figure 9. San Francisco gartersnakes at WOB. Photo credits: left, Sheila Larson, USFWS. Right: unknown.

Northern San Francisco Peninsula Watershed

We refer to the "San Francisco State Fish and Game Refuge" population from the Recovery Plan as the San Francisco Peninsula Watershed (SFPW), which we have broken into two population complexes, Northern and Southern, based on genetic differences identified in Lim *et al*. (2009, p. 7). Although this property is designated as a California Department of Fish and Wildlife (CDFW) refuge, the San Francisco Public Utilities Commission (SFPUC) has ownership and management responsibility for the area (Stoltz, pers. comm. in Service 2006, p. 7). Several extant populations exist within the SFPW, with individuals found along all major reservoirs, in ponds, and in creeks (BioMaAS and AECOM 2016, p. 3). BioMaAS and AECOM (2016, p. 6) includes a summary of all known trapping and surveys from 1998 through 2016. The Nroterhn SFPW population complex includes all habitat in the SFPW north of Highway 92.

Trapping at Skyline Wetlands and at another lake in 2018 yielded 27 individuals at each site, with median population estimates of 68 (45-104) and 65 (41-101), respectively (Rose *et al.* 2018, pp. 7, 9). Surveys as part of ongoing management along the Fifield-Cahill Ridge Trail (targeting snakes from Mud Dam and Pilarcitos Reservoir) documented the presence of the species but did not attempt to quantify abundance (BioMaAS and AECOM 2016, p. 3). Trapping along the Fifield-Cahill Ridge Trail caught individuals of different life stages and sexes, indicating recruitment in the area (BioMaAS and AECOM 2016, p. 4).

Half Moon Bay

This population was documented in the 1980s (Barry 1996). The complex includes Denniston Creek and Denniston Reservoir, as well as the mouth of Pilarcitos Creek to the south. Although we consider this population to be extant, McGinnis (1988b, p. 1) notes that surveys in 1987 failed to produce any observations and suggested that dredging and other habitat destruction of impounded water in the area reduced habitat quality for the species.

Southern San Francisco Peninsula Watershed

The Southern SFPW includes all habitat in the SFPW that are south of Highway 92. San Francisco gartersnakes were observed in this complex in recent surveys (CNDDB 2018), but we are not aware of recent trapping surveys or population estimates. Barry (1994, p. 55) described the Pulgas region near Upper Crystal Springs Reservoir as a potential intergrade zone with California red-sided gartersnake.

Woodside

This complex is in an area described as an intergrade zone ((Barry 1994, p. 55; Fox 1951, pp. 262-263; but see Barry 1978, p. 14). Habitat in this area is included in the Stanford Habitat Conservation Plan, and there is at least one known occurrence on private property in this vicinity.

San Gregorio

This population complex was documented in the 1980s (Barry 1996). Current status of the species is not known in this area. It includes habitat along Tunitas and San Gregorio Creeks, as well as several ponds.

La Honda

Populations near La Honda that have trapping surveys or abundances are found on ranches on two private properties.

One of the ranches includes two sag ponds separated from one another by a ridge and a linear distance of 280 m (919 ft), and from other aquatic features by 1.6 km (1 mile) (McGinnis 1988a, p. 4). The two ponds are at 369 m and 435 m elevation. Trapping at the Upper Pond resulted in 32 individuals in 1987 and an additional 31 new captures in 1988 (McGinnis 1988a, pp. 16-19). McGinnis (1988a) speculated that the population was highly transient in nature based on the male:female sex ratio (p. 19), low numbers of juveniles and neonates (p. 20), and evidence of movement between the Upper Pond and Lower Pond (p. 24).

The other ranch, part of the Russian Ridge Open Space Preserve owned and managed by the Midpeninsula Regional Open Space District, is a 424-hectare (1,047-acre) former cattle operation. This is the highest elevation San Francisco gartersnake population that we are aware of, at approximately 550 m elevation (Wood *et al*. 2019, p. 23). The species was first detected on the ranch in 1986, and reproductive colonies are present at two lakes on the property; San Francisco gartersnakes have been observed at all four water bodies. A habitat management plan for the site promotes improving aquatic and upland habitat on the property. The management plan specifically promotes the long-term resilience of the snake through restoration activities including targeted removal of non-native aquatic species and maintenance of upland habitat through grazing (Biosearch Associates 2012, pp. 25-52). From 2014-2017, mark-recapture population estimates indicated a stable population fluctuating from 97-195 individuals, with additional variation based on modelling methods (open verses closed models) (Figure 10; Kim *et al.* 2018, pp. 30-34, 76). Male and female gartersnakes of varying sizes were captured in all four years (Kim *et al.* 2018, pp. 14-20).

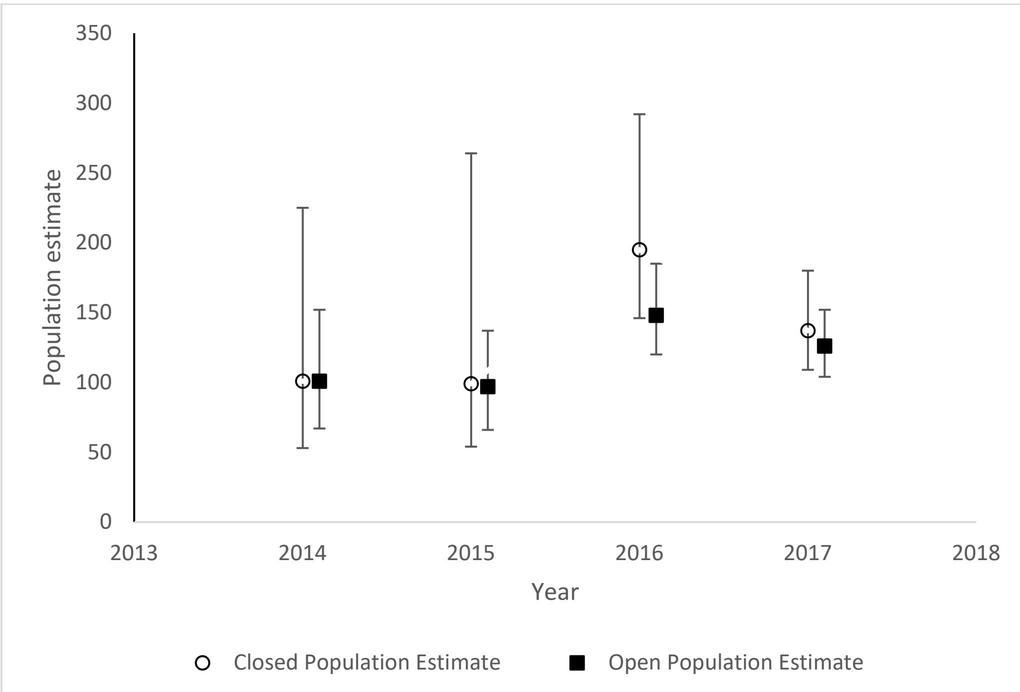

Figure 10. Population estimates at a private ranch in the La Honda complex. Model-averaged abundances with 95% posterior probabilities are shown. Because of uncertainty in connectivity between the trapping location and other habitat, the authors calculated both open and closed population estimates.

Pomponio

This population complex was documented in the 1980s (Barry 1996), and includes habitat along Pomponio Creek and Pomponio Reservoir. Current status of the species is not known in this area.

Pescadero

Although Pescadero Marsh Natural Preserve (hereafter Pescadero) is listed as a significant population in the Recovery Plan, it is likely that the largest contributions to the population complex in this area are on ponds on private properties. Several kilometers south of Pescadero, a private ranch on protected property owned by the Peninsula Open Space Trust (POST) occupies 213 hectares (526 acres) of former pasture, including several wetlands and ponds as well as grasslands (Halstead *et al.* 2011, p. 42). Trapping from 2008 through 2018, except in 2011, indicates some fluctuations in population abundance (Figure 11; Kim *et al.* 2017, p. 5; Rose *et al.* 2018, p. 9). From 2015 through 2017, population abundance exceeded 200 individuals and included individuals of varying sizes, characteristics of a resilient population (Kim *et al.* 2017, pp. 5-6). However, the population estimate from trapping in 2018, although one of the highest among the six sites trapped in this study, was below 100 individuals (Rose *et al.* 2018, p. 9).

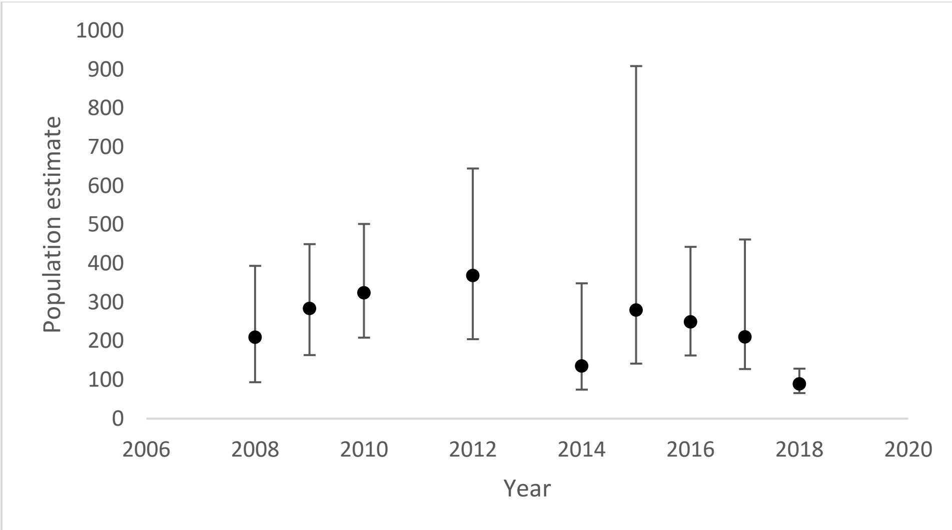

Figure 11. Population estimates (model-averaged abundance and 95% posterior density interval) at a private ranch near Pescadero. Source: Halstead et al. 2011, Sweeney et al. 2012, Kim et al. 2017.

Año Nuevo

This complex includes two significant populations from the Recovery Plan: Año Nuevo State Reserve properties (California State Parks), and the Cascade Ranch property (private). It includes occurrences on both sides of Highway 1, including the Año Nuevo Visitor Center Pond, BART mitigation site, and Lake Elizabeth.

Año Nuevo State Reserve, which merged into Año Nuevo State Park in 2008 (California State Park and Recreation Commission Resolution 27-2008), is the site where upland use by the species was first explored (Barry 1978, p. 9; McGinnis *et al.* 1987, entire). Population estimates based on a 1988 trapping study suggested that, at the time, this might have been one of the most concentrated San Francisco gartersnake populations (McGinnis 1991, p. 6). Studies at the Año Nuevo State Park headquarters pond indicated low prey abundance but the authors suggest that high snake densities may be supported by other nearby habitat (McGinnis *et al.* 1987, pp. 10-12; McGinnis 1991, p. 6).

Mark/recapture analysis of the 1988 trapping data resulted in an estimated 135 (SE=29) individuals in the greater headquarters pond area (McGinnis 1991, pp. 5-6). Trapping in 2006 resulted in a similar number of captures (57 individuals captured in 1988, 53 in 2006) in only a 30 day period (compared to almost 9 months in McGinnis 1991, p. 3) (Swaim Biological Consulting 2006, p. 4). However, trapping in 2007 resulted in only 13 San Francisco gartersnakes (Swaim Biological Consulting 2007, p. 3). Trapping in 2018 occurred at two distinct sites: the visitor center pond and the BART mitigation site (Rose *et al.* 2018, p. 2). Population estimates for the two sites were 96 (62 to 153) and 60 (34 to 95) gartersnakes, respectively (Rose *et al.* 2018, p. 9).

Northern Santa Cruz County

This is the only population complex in Santa Cruz County. There are several seasonal ponds and at least one permanent pond near the coast in the northern part of the county that have had reported San Francisco gartersnakes (CNDDB 2018). We do not have information on trends or abundances in this complex.

Factors Influencing Viability

Here, we consider the historical and current anthropogenic and environmental factors influencing San Francisco gartersnake population resiliency, which in turn contribute to the overall viability of the species. We acknowledge that there are other factors that influence the San Francisco gartersnake, but for the purposes of this SSA we focus on those factors that are generally thought to have population or species-level effects. Additional stressors to the San Francisco gartersnake, including parasitism, and human interface activities (e.g., recreation), are summarized in the five-factor analysis of the 2006 status review (Service 2006, pp. 15-28) but are largely excluded from the analysis in this report because we deemed them more likely to affect individual snakes and not have population-level effects. Additionally, the threat of the chytrid fungus *(Batrachochytrium dendrobatidis)*, a parasite that is widespread in amphibians, is mentioned in the status review (Service 2006, p. 21). We do not include a discussion of chytrid here because evidence suggests that neither treefrogs nor California red-legged frogs are thought to have high mortality from the fungus (Reeder *et al.* 2012, pp. 2-4; Tatarian and Tatarian 2010, pp. 326-327). However, any future widespread threats to amphibian prey for the San Francisco gartersnake, including chytrid, could have significant affects to populations. The threat of chytrid or other amphibian diseases could be elevated if new evidence suggests population-level effects to the amphibian prey of the San Francisco gartersnake.

In this section, we first discuss factors that are limiting San Francisco gartersnake populations, including a description of the factor, the path through which it is thought to influence population resiliency, and the magnitude of its impact (if known). We then discuss management actions that are currently underway, or are in consideration, and how these actions stem from, or may alleviate, limiting factors. Figure 12 is an influence diagram summarizing the pathways through which management actions and anthropogenic or environmental factors can influence San Francisco gartersnake resiliency through their effects on habitat or demographic parameters.

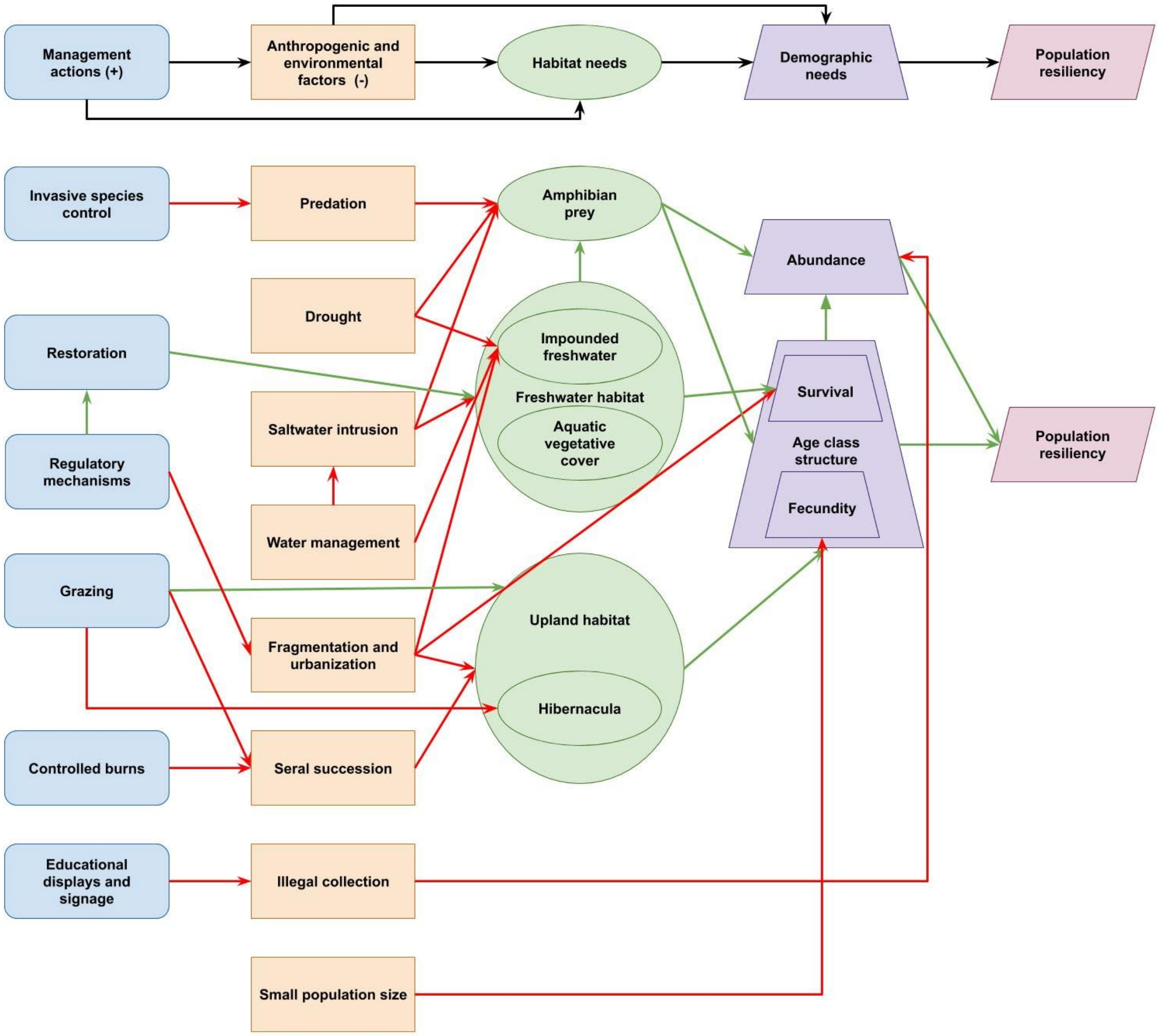

Figure 12. Influence diagram illustrating pathways between management actions and anthropogenic or environmental factors that can influence San Francisco gartersnake habitat needs or demographic parameters. Red lines represent negative relationships and green lines represent positive relationships.

Habitat Modification and Destruction

Alteration and isolation of habitats resulting from urbanization was identified as the primary reason for decline of San Francisco gartersnakes in the Recovery Plan (Service 1985, p. 13). Habitat loss and the degradation of remaining habitat continue to be the primary threats to the species' recovery. Contributing factors include urbanization and associated habitat fragmentation, seral succession, and hydrologic changes, including drought.

Habitat modification can also take place on a smaller scale. Barry (1978, p. 12) stated that San Francisco gartersnakes will not recolonize an area with cut emergent vegetation until at least one new generation of new plant growth has died back to form mats around living emergent plants. However, as mentioned in Individual and Population Habitat Needs (Chapter 3), he also stated that artificial aquatic habitats could attract the species within a year of development (Barry 1996, p. 42).

Fragmentation and Urbanization

Urbanization was historically a direct threat to the San Francisco gartersnake through development resulting in destruction of its habitat (Service 1985, p. 13). Known population extirpations linked to development included the once numerous population in the sag ponds near Skyline Boulevard (Banta and Morafka 1966, p. 233) and several other nearby occurrences (CNDDB 2018). Modification in habitat quality (not leading to extirpations) from urbanization through 2006 is detailed in the status review (Service 2006, pp. 15-17). Risks from urbanization include direct morality, habitat loss, fragmentation, and habitat isolation.

Although not as pressing of a threat as it was historically, today loss and the degradation of San Francisco gartersnake habitat continues to threaten the species. Mortality on roads and bike trails can be a risk in urbanized areas, and are even a threat in protected areas with limited traffic (Terry *in litt*. 2020). Brehme *et al.* (2018, pp. 928-929) rated the San Francisco gartersnake as being at "very high risk" from roads at the population- and species-levels. Even if not directly causing San Francisco gartersnake mortality, fragmentation by the expansion of infrastructure supporting increasing residential and commercial developments, including new roads, improved utilities matrices, and recreational facilities (Service 2006, p. 15), can limit connectivity within and between populations. Limiting movements between populations can reduce dispersal and corresponding gene flow, reducing population resiliency. Populations left isolated can be particularly vulnerable to environmental or anthropogenic stochastic and/or catastrophic events. In fragmented habitat, when occurrences become extirpated the chance of recolonization from any remaining populations is reduced.

Agricultural conversion of San Francisco gartersnake habitat on private lands is a potential threat, particularly to upland habitat for the species. From 2009 to 2018, over 340 acres (138 hectares) of grassland within the San Francisco gartersnake historical range have been converted to crops or other habitat types that would not be suitable for the species (USDA National Agricultural Statistics Service Cropland Data Layer 2019)). However, this habitat change analysis was done using a polygon encompassing all occurrences of San Francisco gartersnakes and the land in between those occurrences, so it is unclear how much of this land conversion would have actually impacted the species. An additional 669 acres (271 hectares) of grassland changed to shrubland in the same time period (see *Seral Succession* below).

Changes to Aquatic Habitat

In addition to modifying or altering San Francisco gartersnake habitat, changes in water depth, inundation period, salinity, waterbody structure, and/or associated vegetation, can have negative consequences for the species by reducing its available amphibian prey and/or facilitating invasive species populations that can further reduce prey. In this section we talk about a variety of changes to aquatic habitat, of which saltwater intrusion and drought are the most likely to have population-level effects on the species. Various threats associated with changes to aquatic habitat are also discussed in the status review (Service 2006, pp. 15-20).

Saltwater Intrusion

Intrusion of ocean water into San Francisco gartersnake habitat can affect the species indirectly by reducing amphibian prey. Treefrogs and California red-legged frogs can both survive without apparent harm at salinity levels of 5 parts per thousand (ppt), but both frog species showed reduction in growth or health at 6 or 7 ppt, tadpole mortality starting at 8 ppt, and adult mortality starting at 9 ppt (McGinnis 1986, p. 5). Egg masses are more vulnerable than adults, with some red-legged frog embryos experiencing deformities or mortality when exposed to salinity levels as low as 4.4 ppt (Jennings and Hayes 1990, pp. 17-18, 40-41). Salinization has had negative effects on San Francisco gartersnake populations at Laguna Salada/Mori Point, WOB, and Pescadero Marsh (Service 2006, pp. 19-20).

Drought

Drought reduces available food because early drying of marshes can kill amphibian prey (Larsen 1994, p. 74). Reduced availability of prey following drought, particularly if drought reduces reproduction in tree frogs, can be especially difficult for neonates that rely on the availability of newly metamorphosed treefrogs for successful recruitment into the population. Reduced prey was suggested as a potential correlate to the lowest abundance of San Francisco gartersnakes across 4 years of sampling at a well-studied population on a private ranch (Kim *et al.* 2017, p. 5). Drought could also have negative impacts on habitat vegetative features, although to our knowledge the impacts to prey are of more concern. If water recedes such that there is no longer emergent vegetation along the edge of the aquatic feature, this can increase predation risk for foraging San Francisco gartersnakes, and/or decrease foraging opportunities.

Water Management

Water management activities, including fluctuations in water levels at reservoirs, flood control, and channelization, can all impact habitat quality. Siltation is also of concern at some sites, including within habitat for the Pescadero population complex. Some water management activities, such as dredging, could be either a threat or a positive management activity depending on the implementation. Dredging and silt dumping at Denniston Reservoir decreased habitat quality at that site, potentially making it unusable by San Francisco gartersnakes (McGinnis 1988b, p 2; Barry in litt. 2003). However, dredging in the canals at WOB is an important part of the restoration work at that site (San Francisco Airport and LSA 2017, p. 4). Many of the reservoirs that support San Francisco gartersnakes are managed waterbodies with water regimes that could affect water depth or period of inundation. Dropping water levels quickly during the San Francisco gartersnake breeding season could limit food availability for females and neonates following parturition near the water edge (Barry pers. com. 2019). In contrast, maintaining deep water levels can support habitat for invasive carnivorous fish or bullfrogs, which can reduce amphibian prey for the San Francisco gartersnake.

Seral Succession

Upland habitat used by the San Francisco gartersnake was historically maintained by periodic disturbance. Elimination of disturbance to these habitats, including fire control and elimination of grazing, has led to the persistence and expansion of seral ecosystems that alter upland grassland habitat used by the San Francisco gartersnake. Note that grazing and controlled burns are still practiced in some population localities, as discussed in *Grassland Management* below. Seral succession is included here as a potential threat to populations, although the severity of this threat is unknown. We note that habitat structural complexity is an important aspect of high-quality habitat for the species, and discuss the potential impacts of extensive seral succession with this caveat in mind. Although the species probably uses areas with extensive seral succession, the upper limit of habitat that the species can use is not known.

Domination of woody species across the coastal landscape limits the extent of grasslands, which were likely important movement corridors for populations of San Francisco gartersnake in their migrations between aquatic habitats (Hankins in litt 2006; McGinnis *et al.* 1987, pp. 14-16). However, the actual threshold limit of scrub in areas that San Francisco gartersnakes use is unclear. Despite extensive scrub encroachment throughout the area surrounding the Año Nuevo visitor center pond, current population estimates are almost as high as those in the 1980s when the site was thought to have one of the healthiest populations (McGinnis 1991, p. 5; Rose *et al.* 2018, p. 9). Succession of grasslands can also reduce rodent populations, which in turn influences San Francisco gartersnakes because 1) rodent burrowing activities help to maintain grasslands, and 2) San Francisco gartersnakes use rodent burrows for hibernacula (discussed in *Habitat and Activity Patterns* above). Continuous soil disturbance by gophers living in grass-dominated uplands can help to inhibit successional processes by bringing nitrogen-poor soil to the surface (Stromberg and Griffin 1996, pp. 1204-1206). However, when brush species begin to dominate former grasslands despite this soil disturbance, it can potentially preclude burrowing animals (Service 2006, p. 25).

Illegal Collection

The Recovery Plan lists illegal collection as one of the primary threats to the species (Service 1985, pp. 1, 13-14). The snake is targeted largely because of its beauty, its rarity, and its ability to be kept in captivity (Barry 1978, p. 12). Illegal collection is of particular concern in easily accessible populations, and historically contributed to population declines at WOB (Larsen 1994, p. 99), Laguna Salada, and Lower Crystal Springs Reservoir (Barry 1978, p. 12). Collection at WOB has subsided, likely because hybridized appearance of the individuals at this location makes them less desirable to collectors (S. Barry *in litt.* 2006). Although current amounts of illegal collection and its effect on the species is not clear (Service 2006, pp. 20-21), it is still likely a threat that could have population-level affects without enforced regulations.

Predation

San Francisco gartersnakes have a diverse group of potential predators, including mammalian, reptilian, amphibian, avian, and predatory fish species. Many San Francisco gartersnakes have scars or signs of injuries, such as missing tail tips, presumably acquired during attacks by predators (Barry 1996, p. 62). Predation by two invasive species and feral cats is described below. Other known or potential predators are summarized in Barry 1996 (pp. 2, 62-64) and Larsen 1994 (p. 64).

Of particular concern is depredation by invasive species. Non-native American bullfrogs (*Lithobates catesbeianus*) and largemouth bass (*Micropterus salmoides*) both have a similar role of preying on both the snake and its prey (Barry 1996, pp. 36, 63), and there is the possibility that habitats with both species present could have an increased impact (i.e., Invasional Meltdown Hypothesis, Simberloff and Von Holle 1999, p. 22). The relative impact of predation by the American bullfrog on San Francisco gartersnake populations and its amphibian prey are debated (discussed in Service 2006, p. 22), although bullfrogs are generally argued to have a negative impact on the species. Bullfrogs do prey on San Francisco gartersnake (Kim 2017, p. 33), although the extent of predation is not known. Bullfrog predation on congeners can be significant, with estimates that bullfrogs prey upon about 22 percent of neonatal giant gartersnakes (*Thamnophis gigas*) (Wylie *et al.* 2003, pp.141-144). Perhaps more importantly, the bullfrog likely has a strong impact on San Francisco gartersnake populations as a competitor for amphibian prey. The introduction of bullfrogs has negative impacts on native amphibian species (Kupferberg 1997, pp. 1741-1746; Boone *et al.* 2004, pp. 686-687), including red-legged frogs (Service 2002, p. 24) and treefrogs (Kim 2017, p. 34). However, bullfrog introductions are usually concurrent with changes to waterbodies or water management, making it difficult to pinpoint bullfrogs as the cause of associated reductions in San Francisco gartersnakes or their prey (Barry 1996, pp. 30-31). The status of bullfrogs in waterbodies with San Francisco gartersnake complexes is summarized in Table 6.

Table 6. Status of bullfrogs within San Francisco gartersnake population complexes.

	Bullfrogs	**Source**
Northern San Mateo County	NA	
Pacifica	Yes	Fong and Kindall 2019
West-of-Bayshore	No	Reeder pers. comm. 2019
Northern SFPW	Yes	CNDDB 2018
Southern SFPW	Yes	Lim pers. comm. 2019
Half Moon Bay	Unknown	
Woodside	Unknown	
San Gregorio	Unknown	
La Honda	Yes	Kim et al. 2018
Pomponio	Yes	CNDDB 2018
Pescadero	Yes	Olson and Dexter 2008
Año Nuevo	Yes	Service 2006
Northern Santa Cruz County	No	SBI 2006

Feral cats also pose a potential threat that may or may not have population-level effects. Researchers documented five presumed cases of feral cat injury or predation on San Francisco gartersnakes within the WOB population in three months (Swaim 2018, pp. 11-12), suggesting that the impact of feral cats could be significant in some populations. A large number of feral cats was also noted at WOB in the 1990s and several deceased San Francisco gartersnakes were recovered at that location that showed injuries consistent with cat kills (Larsen 1994, p. 88). A trap-neuter-release program at WOB was recently started in an attempt to better understand feral cat dynamics at the site (Reeder pers. com. 2019; but see Longcore *et al.* 2009, pp. 890-891). Feral cats have also been noted near other San Francisco gartersnake habitat at Mori Point, another population that is adjacent to residential communities (Swaim Biological, Inc. 2009, p. 24).

Small Population Sizes

Low population abundances in small or fragmented habitat patches have the potential to lead to inbreeding depression and loss of genetic diversity. Both of these genetic factors can contribute to extinction risk (reviewed in Frankham 2005, entire). Effective population sizes (N_e) for six of seven sampled San Francisco gartersnake populations were below the short-term threshold recommendation of $N_e \geq 100$ for inbreeding depression in Frankham *et al*. (2014, p. 58); the only population with an effective population size greater than this threshold was WOB (Wood et al. 2019, pp. 21, 40). Effective population size, the size of an idealized population that would give rise to the same variance of gene frequency, or rate of inbreeding, as the actual population under consideration, is often much lower than census population size (Frankham 1995, entire; Frankham 2005, p. 95). The ratio between effective population size and census population size varies based on factors such as unequal sex ratios, variance in family size, and population fluctuations. Comparison of effective population size from genetic analyses with census size from mark-recapture studies offer the first values of the ratio of effective population size to census population size in San Francisco gartersnakes (Wood et al. 2019, pp. 20-21, 25-27, 40). The ratio at sampled San Francisco gartersnake sites varied considerably, from 0.16 to 0.78 (Wood et al. 2019, p. 40). The highest ratio at Pescadero could indicate additional suitable habitat outside of the area surveyed in the census (Wood et al. 2019, p. 26).

Wood *et al*. (2019, pp. 16, 21) also used estimates of inbreeding coefficients to evaluate the possibility that genetic erosion had occurred across the seven sites in their genetic analysis. In the northern regional cluster, their data suggested that Pacifica is suffering from genetic erosion, and in the southern cluster, Mindego (in the population complex we refer to as La Honda in this SSA) showed evidence of genetic erosion. Both of these sites are isolated from other San Francisco gartersnake populations.

Other evidence exists that isolation may limit gene flow between populations. For example, within the northern genetic cluster, both the Pacifica and WOB subgroups are isolated from the other northern populations by habitat fragmentation (Wood et al. 2019, p. 18). The effects of this isolation are most pronounced at the Pacifica site, where there is some evidence that the population may have experienced a population bottleneck. A decline in population abundance related to saltwater inundation that affected amphibian prey for the Pacifica population (discussed above in *Historical and Current Abundance and Population Trends*) is likely reflected in genetic analyses that show low N_e and low heterozygosity for San Francisco gartersnakes at that site.

Evaluation of a temporal dataset (sampled in two time periods approximately a decade apart) indicated an increase in pairwise estimates of genetic differentiation over time, especially for the sites that are the most geographically isolated due to fragmentation (Wood et al. 2019, pp. 20-21, 39). Increasing or introducing genetic diversity in the absence of natural gene flow is a possible avenue that could be explored in development of the captive breeding and population augmentation program discussed below.

Disease

Snake Fungal Disease (SFD) is an emerging threat to wild snakes caused by *Ophidiomyces ophiodiicola* (Lorch *et al.* 2016). The infection has been documented throughout the eastern United States, with clinical signs including skin lesions, thickened skin, and facial swelling (Lorch *et al.* 2015). In a field study across 15 species, SFD was more prevalent in snakes with aquatic habitat affiliations than terrestrial (McKenzie *et al.* 2019). Cases of SFD range from mild to life-threatening. In late 2019, SFD was confirmed in a California kingsnake (*Lampropeltis californiae*) in Amador County and a deceased Florida watersnake (*Nerodia fasciata pictiventris*) in Sacramento County (CDFW 2019). At this time, we are not aware of any cases of SFD in San Francisco gartersnakes. It is unknown how SFD may affect the species, but CDFW plans increased surveillance and implementation of precautions to minimize risk of human-caused spread (CDFW 2019).

Management Activities and Conservation

Management activities that can positively influence the San Francisco gartersnake include restoration, invasive species control, grassland management, educational displays and research, and habitat conservation plans. Water management, described above, can also have positive influences in San Francisco gartersnake habitat, including limiting saltwater intrusion.

Invasive Species Control

Management in some habitats includes control of invasive species such as bullfrogs. Bullfrog control in 2014 and 2015 at the permanent waterbody on a private ranch, combined with a drought in 2014, likely extirpated bullfrogs from the site (Kim *et al.* 2018, pp. 4, 62). This reduction in the invasive species correlated with increased recruitment in the San Francisco gartersnake population (Kim *et al.* 2018, pp. 62, 72). Kim (2017, p. 37) suggested that the mechanism for this increased recruitment was reduction in competition for treefrogs, particularly for smaller San Francisco gartersnakes that rely more strongly on treefrogs compared to red-legged frogs. The eradication of bullfrogs at WOB has been correlated with increases in the San Francisco gartersnake population (Larsen pers. com. 2019).

Restoration

Habitat restoration activities in areas occupied by San Francisco gartersnakes include creation and restoration of aquatic and upland habitat, with a focus on the creation of habitat for the amphibian prey of the species.

Restoration activities for the Laguna Salada/Mori Point population have occurred in habitats on both properties supporting the species. Creation of a seawall along the Sharp Park golf course beachfront was intended to eliminate seawater intrusion into Laguna Salada (as recommended in McGinnis 1986, p. 7). Habitat creation and enhancement at Mori Point specifically aimed to increase foraging habitat for the San Francisco gartersnake (Fong *et al.* 2004, p. 2). Prior to habitat creation beginning in 2004, the area contained seasonal wetlands but did not have permanent water sources that would provide a consistent prey source. Restoration consisted of construction of two ponds and modification of two others (Swaim Biological, Incorporated 2009, pp. 3-4). Verification of breeding by treefrogs and red-legged frogs, in combination with San

Francisco gartersnakes, indicates that the species is capable of finding and using newly created habitat (Swaim Biological, Incorporated 2009, pp. 23-24).

At the WOB site, declines in San Francisco gartersnake observations in the 1990s led to the creation of a recovery action plan (RAP), with the goals of increasing breeding habitat for amphibian prey and supporting a stable or increasing population of San Francisco gartersnakes (LSA Associates 2008, p. 40). The original RAP was renewed in 2019 to address future habitat enhancement and management actions (Dudek 2019, entire). These RAPs are specific to the WOB site and represent a cooperative effort between the San Francisco International Airport, the Service, and the California Department of Fish and Wildlife to manage and protect the San Francisco gartersnake at the site (LSA Associates 2008, entire; Dudek 2019, entire). The RAPs are separate documents from the Recovery Plan for the species (Service 1985). Implementation of the RAP included restoring canals, pond construction, removal of overgrown and non-native vegetation, increased site security, and monitoring San Francisco gartersnake and prey populations (Reeder *et al.* 2015, p. 79; Dudek 2019, p. 2). Between 2008 and 2013, this resulted in the creation of approximately 0.6 acres of open water habitat and restoration of an additional 1 acre of open water, upland habitat enhancement on 0.4 acres, and additional activities related to security and road infrastructure (Dudek 2019, p. 3). The renewed RAP aims to: increase aquatic prey availability through habitat restoration and enhancement, reduce sediment input into the canals, and continue to enhance upland habitat. Descriptions of proposed actions, including continuation of prior RAP activities and new operations or maintenance activities is provided in Dudek (2019, pp. 21-32).

Near Pescadero, restoration activities in 2006 included efforts to restore connectivity between Pescadero Creek and adjacent floodplain outside of the Pescadero Marsh Natural Area. Restoration activities in 2006 included removal of a levee to restore connectivity between the creek and floodplain, and the creation of new aquatic features that they expected to fill naturally from the creek and rainfall (Olson and Dexter 2008, p. 1). Post-restoration trapping in 2008 failed to detect San Francisco gartersnakes. More recently, restoration of Butano Creek is in progress to restore flow where the creek flows through Pescadero Marsh Natural Preserve. The San Mateo Resource Conservation District is working to re-establish 8,000 feet of the historic creek channel, remove 45,000 cubic yards of sediment, and re-use the dredge material to fill historical human-made pits to restore 28 acres of degraded marsh (CBEC, Inc. 2018). A healthy individual San Francisco gartersnake was found during restoration work in 2019 (Halbert in litt. 2019), demonstrating use of the area by San Francisco gartersnakes and potential for these projects to benefit the species by improving foraging habitat.

Regulatory Mechanisms that Provide Conservation Benefits

There are several State and Federal laws and regulations that are pertinent to listed species, each of which may contribute in varying degrees to the conservation of listed and non-listed species. In addition to being listed as a federally endangered species, the San Francisco gartersnake was listed as endangered (and fully protected) species by the State of California in 1971. Below we provide details on protection of San Francisco gartersnake through the Endangered Species Act

(ESA); additional information relating to state and federal protections is included in the status review (Service 2006, pp. 23-25).

The Endangered Species Act of 1973, as amended, is the primary Federal law providing protection for the San Francisco gartersnake. The Service has responsibility for administering the Act, including sections 7, 9, and 10 that address take. Section 9 prohibits the taking of any federally listed endangered or threatened species. Take is defined in Section 3 as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harass is defined by Service regulations at 50 CFR 17.3 as an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering. Harm is defined by the same regulations as an act which actually kills or injures wildlife. Harm is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering. The Act provides for civil and criminal penalties for the unlawful taking of listed species.

Since listing, the Service has analyzed the potential effects of Federal projects under section 7(a)(2), which requires Federal agencies to consult with the Service prior to authorizing, funding, or carrying out activities that may affect listed species. For projects without a Federal nexus that would likely result in incidental take of listed species, the Service may issue incidental take permits to non-Federal applicants pursuant to section 10(a)(1)(B). Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity (50 CFR 402.02). To qualify for an incidental take permit, applicants must develop, fund, and implement a Service-approved Habitat Conservation Plan that details measures to minimize and mitigate the project's adverse impacts to listed species. Many of these Habitat Conservation Plans are coordinated with the State of California's related Natural Community Conservation Planning program.

The status of the San Francisco gartersnake as a species listed under the ESA can reduce the severity of the effects of habitat loss due to fragmentation and urban development, which continues to be a threat to the San Francisco gartersnake throughout its range (see Habitat Modification and Destruction above). Development projects that are subject to section 7 consultation or result in the issuance of an incidental take permit under section 10 typically include habitat compensation, which can reduce the severity of overall habitat loss typically associated with these projects. Habitat compensation can occur via a variety of mechanisms, including the purchase of credits at approved conservation banks, through permittee responsible mitigation, and through the development of habitat conservation plans (HCPs) and Safe Harbor Agreements. Additional information about these mechanisms of habitat compensation can be found at: https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=C002; note that at this time there are no approved conservation banks or Safe Harbor Agreements for the San Francisco gartersnake. In addition to reducing the amount of overall habitat loss for the species, Section 10(a)(1)(A) of the Act allows for permits to be issued for recovery activities that result in take. Recovery activities are those activities that are specifically implemented for scientific purposes or to enhance the propagation or survival of the affected species, including interstate commerce activities.

Permittee-Responsible Mitigation

Permittee-responsible mitigation includes activities or projects undertaken by a permittee (or authorized agent) to provide compensatory mitigation for which the permittee retains full responsibility. Permittee-responsible mitigation projects are typically not established in advance of the impacts they are offsetting and they do not have credits that can be used at a later time to offset different impacts, like conservation banks.

Habitat compensation through permittee-responsible mitigation for the San Francisco gartersnake has occurred throughout the subspecies range for a number of projects. For example, there have been a number of restoration actions implemented by the San Francisco Public Utilities Commission in the Crystal Springs Reservoir watershed as mitigation for the effects of the Lower Crystal Springs Dam Improvement Project and other Water Storage Investment Program (WSIP) projects. Additionally, mitigation for PG&E projects has resulted in aquatic and upland habitat enhancement and preservation near the WOB and Pescadero population complexes (various Service biological opinions; Terry *in litt*. 2020)

Habitat Conservation Plans

Habitat Conservation Plans provide a pathway forward to balance wildlife conservation with development. 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 means that measures will be implemented to avoid or minimize take of the covered species within the area the HCP covers, as agreed upon and permitted by the Service. Specifics for each HCP are included within each agreement, including habitat will be set aside and managed for the species as compensation for covered activities, such as planned urban development, within the area the HCP covers; avoidance and minimization measures; and other conservation measures (e.g. monitoring, seasonal work windows, habitat management, etc.). Currently, there are three HCPs that include the San Francisco gartersnake as a covered species (Table 7), including the San Bruno HCP under its fifth amendment.

The PG&E Bay Area Operations and Maintenance HCP includes avoidance and minimization measures to be implemented during activities that could affect the San Francisco gartersnake (ICF 2017, pp. 5.9-5.16). Although the HCP covers almost the entire range for the San Francisco gartersnake (with the exception of Santa Cruz County), impacts to the species are anticipated to be limited. In developing the HCP, core and dispersal San Francisco gartersnake habitat within the HCP area was modeled. PG&E anticipates that covered activities in the Plan Area could: permanently remove 0.04 acre of core habitat (a 59-ft. × 59-ft. area) and 0.04 acre of dispersal habitat for San Francisco gartersnake annually, and no more than 2 acres of core habitat and 2 acres of dispersal habitat over 30 years; and temporarily disturb 0.3 acre of core habitat and 0.2 acre of dispersal habitat annually, and no more than 16 acres of core habitat and 10 acres of dispersal habitat over 30 years (ICF 2017, p. 4.54). The plan calls for mitigation of temporary impacts at a 1:1 ratio and of permanent impacts at a 3:1 ratio (ICF 2017, p. 5.38).

The San Bruno Mountain HCP included the San Francisco gartersnake because of uncertainty regarding the species' presence at the site. However, the species has not been seen over the entire monitoring period of the HCP, and is unlikely to be present (Ormshaw 2018, p. 44).

The Stanford HCP includes monitoring, management, and enhancement activities (Stanford University HCP 2013, pp. 3-22), including pond construction and trapping non-native species. A permanent conservation easement set aside 90 acres of high-quality habitat to be used by covered species, including the San Francisco gartersnake.

Table 7. HCPs that include the San Francisco gartersnake as a covered species.

Plan Name	Permit Period
PG&E Bay Area Operations and Maintenance HCP	2017-2047
San Bruno Mountain Amendment #5 (North East Ridge revision)	2009-2039
Stanford University HCP	2013-2063

Recovery Permits

Recovery permits, also referred to as 10(a)1(A) permits, allow scientists to take listed species as a means to ultimately contribute to the recovery of the listed species. The data acquired from some actions covered under recovery permits (e.g., occurrence, abundance, distribution, etc.) allow the Service to make informed decisions for the species that will enhance their survival and recovery. Recovery permits can be issued for activities that directly aid the recovery of a species, such as captive breeding, reintroductions, habitat restoration, removal or reduction of threats, and educational programs. The Service's recovery permitting program aids in the conservation of listed species by ensuring permittees have adequate field experience and qualifications for conducting activities with the target listed species and, for most species, ensures that permittees are following standardized protocols while surveying. The recovery permitting application process ensures that scientific proposals are crafted using the recommended actions laid out in the Recovery Plan for the target species. There is currently no protocol survey guidance for the San Francisco gartersnake; however, there are minimum qualifications to obtain a recovery permit for the species. Minimum qualifications and species specific protocols can be found at: https://www.fws.gov/sacramento/es/Permits/.

Research and surveys performed by biologists with recovery permits has resulted in a number of peer-reviewed papers, and has contributed to our knowledge of San Francisco gartersnake ecology, population dynamics, and genetics incorporated throughout this document.

Grazing

Both grazing and controlled burns (discussed below) are grassland management techniques that are recommended in the previous status review for the species (Service 2006, pp. 26, 31). Recent publications highlight the need for additional studies on these techniques (e.g., Kim *et al.* 2017, p. 5; Halstead *et al.* 2019, p. 238).

Private ranches that have San Francisco gartersnake populations are often grazed. Although we discuss grazing in the context of management, cattle can also threaten aquatic resources or amphibian prey (if grazing occurs near ponds during amphibian breeding), thus the relationship between grazing and San Francisco gartersnakes is not clear. Although grazing can help to reduce the spread of woody brush and increase grassland diversity, it can also reduce burrowing rodents (e.g. gophers) that create burrows used by San Francisco gartersnakes for hibernacula (Stromberg and Griffin 1996, p. 1205, and references discussed within). Grazing also significantly lowers grass heights in meadows, which could potentially lead to upland habitat that is more open than that typically used by the species. Ideal habitat can be described as early successional, with adequate grass and other heterogeneous vegetation to provide dappled sunlight that allows both basking for thermoregulation and cover for predator protection. Kim *et al.* (2017, p. 5) discusses how additional monitoring or studies looking at grazed verses ungrazed areas might help elucidate the use of grazing as a management tool for San Francisco gartersnake habitat. Although population monitoring at one of these ranches specifically lists evaluating the effects of grazing on San Francisco gartersnake demography (Kim *et al.* 2018, p. 3), the authors note that the effects of grazing on distribution or demography could not be quantified in their study to date (Kim *et al.* 2018, p. 73). However, they suggest that the species might benefit from low-intensity grazing if it promotes habitat heterogeneity in or near aquatic habitat (Kim *et al.* 2018, p. 73).

Controlled Burns

Controlled burns have also been used at several sites occupied by San Francisco gartersnakes. Prescribed burns on the west side of the Visitor Center at Año Nuevo State Reserve (now Año Nuevo State Park) were conducted in 2004 and 2005 to maintain a more open shrub community in upland habitat for the species (Swaim Biological Consulting 2007, p. 1). Larsen (*in litt.* 2019) hypothesized that the 2004 burn may have supported a temporary boost in snake abundance (see Swaim Biological Consulting 2006, pp. 4-5) because associated vegetation changes made prey more available to foraging snakes. Trapping in 2007 resulted in fewer captures than in previous years, but lack of a thorough baseline study or control plot makes it difficult to link trapping data to the controlled burns or to offer specific fire-related management recommendations (Swaim Biological Consulting 2007, pp. 4-5). Indeed, Halstead *et al.* (2019, p. 232) mention the lack of specific studies on the effects of prescribed fire on San Francisco gartersnake populations despite a call for their use in habitat management in a status review for the species. Prescribed fires at a private ranch (Swaim Biological, Inc. 2006 and 2007, entire) did not appear to have population-level effects on San Francisco gartersnakes at the site. Because the study found that prescribed fire had relatively small effects on San Francisco survival and movements, the authors concluded that prescribed fire in areas with robust populations are a useful management tool to maintain grasslands. However, the authors include the caveat that their recommendations are specific to the conditions of their study and "perhaps other conditions" (Halstead *et al.* 2019, pp. 234-238), thus further studies on the specific effects and mechanisms through which fire can influence San Francisco gartersnake populations may be useful.

Educational Displays and Signage

Educational displays are present at a number of public lands that support the San Francisco gartersnake. These signs facilitate public awareness of the threatened and endangered species that occur at the parks, as well as including information about the ecology of the species and/or habitat restoration activities to support these species. Additionally, signs identifying areas with restricted access for endangered species are often located outside of fenced areas. These restrictions may have helped with reduction in illegal take. In addition to signage, cover boards in areas with higher public presence are camouflaged, located out of public view in fenced areas, and secured to the ground to deter poaching (Fong and Townsend 2018, pp. 4-5).

Current Condition of Population Complexes (Resiliency)

For a San Francisco gartersnake population complex to be considered in high condition, it needs to meet the needs identified in Chapter 3 of this SSA as being important for resiliency. At the population level, we identified habitat needs as amphibian prey, freshwater habitat (including impounded freshwater and aquatic vegetation), and upland habitat (including hibernacula) (Figure 8). We included all of these factors in our analysis of current condition. However, after consulting with experts and taking into account data availability, we split important components of freshwater habitat into two categories (impounded freshwater and aquatic vegetative cover), but included hibernacula as part of upland habitat in one category (upland habitat). Although it is clear that hibernacula (e.g., rodent burrows) are important for resilient San Francisco gartersnake populations, little data exists on what would distinguish high verses low conditions, and it is unlikely that hibernacula availability is currently limiting the species. We identified the following demographic needs as being useful for assessing the current condition of population complexes: abundance and age class structure (which incorporates fecundity and survival). Because no current, range-wide, demographic data measuring fecundity and/or survival rates have been collected, we assessed condition using categories to assess only abundance and age class structure. For both categories, we focus on the core population within each complex because it aligns these categories with available trapping data, population estimates, and observations.

We measured four factors that influence habitat (Impounded Freshwater, Aquatic Vegetative Cover, Upland Habitat, and Amphibian Prey) and two factors based on demographics (Abundance and Age Class Structure). We used the habitat evaluation system developed by McGinnis (1987, pp. 15-17) as a framework for the impounded freshwater, vegetative cover, and amphibian prey categories in our condition category table, with some modifications based on consultation with species experts. We did not include the competitive gartersnake category from McGinnis (1987, p. 16), but included a category assessing upland habitat and the two demographic needs categories as discussed above.

We classified each of our 12 extant population complexes as being in “high,” “moderate,” or “low” condition for each of the six factors (Table 8). Population complexes that are in high condition are healthier and have higher resilience than those in lower condition, meaning they are less vulnerable to stochastic events. Having multiple, high condition population complexes spread throughout the range of the species is associated with higher species viability.

Table 8. Condition category table for San Francisco gartersnake.

	Habitat features				**Demographic parameters**	
Condition	**Impounded Freshwater**	**Aquatic Vegetative Cover**	**Upland Habitat**	**Amphibian Prey**	**Abundance**	**Age Class Structure**
High	Multiple freshwater features of various sizes present all year; large shallow inshore zone	Intermediate density reed-shrub cover throughout marsh or in a wide band around the entire edge of impounded waterbodies	Early successional grassland habitat adjacent to aquatic habitat with heterogeneous shrub cover and abundant rodent burrows available	Red-legged frogs and treefrogs readily available	Core population has greater than 200 adults with an approximately 1:1 male:female sex ratio	Lots of adults, lots of neonates, and evidence of size classes in between
Moderate	Multiple freshwater features present all year	Cover patchy throughout or in a narrow band around entire edge of impounded waterbodies, or patchy aquatic vegetation but abundant cover in immediately adjacent habitat	Upland habitat adjacent to aquatic habitat with relatively heterogeneous habitat complexity and rodent burrows available	Treefrogs and red-legged frogs present but may be limiting	Core population has a minimum of 50 adult SFGS	Adults and neonates (unknown numbers)
Low	Ephemeral pools dry completely by late summer, or saltwater inundation in some years	Reed-shrub cover in small clumps along one half or less of water edges	Upland habitat adjacent to aquatic habitat with extensive scrub succession, low vegetative diversity, or few rodent burrows available	Amphibian prey available (treefrogs OR red-legged frogs, might also include other prey e.g. newts)	Present, but unknown numbers or fewer than 50 adults	Adults only

We assessed condition in habitat factors through consultation with species experts and land managers of properties within the different population complex areas. Although McGinnis (1987, pp. 24, 31) assessed habitat conditions for some population complexes (e.g., Half Moon Bay and La Honda) in the 1980s, we left habitat condition as unknown if complexes had not had relatively current surveys. We used population monitoring reports and consultations with species experts to assess demographic condition. We pulled out 'core' populations when assessing the abundance and age class structure of San Francisco gartersnakes within each complex because of limited trapping data, using each of these core populations as a surrogate to assess the condition of the complex as a whole. This also allows us to align the current condition analysis with abundance targets identified in the Recovery Plan, which calls for resilient populations containing at least 200 adults.

Each population complex was given a numeric score relative to each factor: 1 for low condition, 2 for moderate condition, and 3 for high condition. We conservatively scored unknown rankings as if the population complex was in low condition for that category. We next translated the overall condition score into an overall habitat condition and overall demographic condition ratings of high, moderate, or low. We separate overall habitat condition from overall demographic condition because oftentimes habitat condition was higher than demographic condition for the species. For example, historical saltwater inundation in the Pacifica population complex likely drastically reduced prey populations for the San Francisco gartersnake, and the population demographics may be lagging behind habitat conditions in responding to habitat restoration. We did not evaluate overall habitat or demographic condition for the Northern San Mateo County population complex, instead giving it an overall condition of extirpated.

For habitat condition, a complex with all low, all moderate, or all high ratings for the factors would have overall habitat conditions scores of 4, 8, or 12, respectively. We took the difference between the lowest and highest possible overall condition scores and divided this into three equal intervals representing the breadth of possible scores. A score of less than 6.7 means the complex is in overall low condition, a score greater than 9.3 means the complex is in overall high condition, and scores between 6.7 and 9.3 mean that the complex is in moderate condition.

When assessing overall demographic condition, we doubled the weight of abundance relative to age class structure. Although both categories are important towards identifying resilient populations, those with higher abundances are more likely to be able to withstand stochastic disturbances that could have temporary effects on survival or reproduction. A complex with all low, all moderate, or all high ratings would have overall demographic condition scores of 3, 6, or 9, respectively. We took the difference between the lowest and highest possible overall condition scores and divided this into three equal intervals representing the breadth of possible scores. A score of 5 or less means the complex is in overall low condition, a score greater than 7 means the complex is in overall high condition, and scores between 5 and 7 mean that the complex is in moderate condition. To be conservative, we considered scores that were on the cusp between condition categories (i.e. 5 or 7) to be in the lower category.

The results of our current condition analysis are presented in Table 9. There are 12 extant population complexes and one extirpated population complex (Northern San Mateo County). Of the 12 extant population complexes, there are currently eight population complexes with high overall habitat condition and four in low condition. For overall demographic condition, there are currently one population complex in high condition, five population complexes in moderate condition, and six population complexes in overall low condition.

Table 9. Current condition of San Francisco gartersnake populations in habitat complexes.

	Habitat features					Demographic parameters		
Population complex	**Impounded Fresh Water**	**Aquatic Vegetative Cover**	**Upland habitat**	**Prey**	**Overall Habitat Condition**	**Abundance**	**Age Class Structure**	**Overall Demographic Condition**
Northern San Mateo County	N/A	N/A	N/A	N/A	Extirpated	Extirpated	Extirpated	Extirpated
Pacifica	High[1]	High[1]	High[1]	High[1]	High	Moderate[6]	Moderate[2]	Moderate
West-of-Bayshore	Moderate[2]	High[2]	High[2]	High[2]	High	High[7]	High[7]	High
Northern SFPW	High[2]	High[2]	High[2]	High[2]	High	Moderate[6]	Moderate[2]	Moderate
Southern SFPW	High[2]	High[2]	High[2]	High[2]	High	Low[7]	Unknown	Low (Unknown
Half Moon Bay	Unknown[3]	Unknown[3]	Unknown	Unknown	Low (Unknown)	Unknown	Unknown	Low (Unknown
Woodside	High[4]	High[4]	High[4]	High[4]	High	Low[4]	Unknown	Low (Unknown
San Gregorio	Unknown	Unknown	Unknown	Unknown	Low (Unknown	Unknown	Unknown	Low (Unknown
La Honda	High[5]	High[5]	High[5]	High[5]	High	Moderate[5]	High[5]	Moderate
Pomponio	Unknown	Unknown	Unknown	Unknown	Low (Unknown	Unknown	Unknown	Low (Unknown
Pescadero	High[2]	High[2]	High[2]	High[2]	High	Moderate[6]	High[2]	Moderate
Año Nuevo	High[2]	High[2]	Moderate[2]	High[2]	High	Moderate[6]	High[2]	Moderate
Northern Santa Cruz County	Unknown	Unknown	Unknown	Unknown	Low (Unknown	Low[2]	Unknown	Low (Unknown

[1]Fong and Kindall 2019 (including photos of habitat)
[2]Expert elicitation
[3]McGinnis 1987, pp. 23-24 describes low condition of these site, but we are unaware of more recent surveys.
[4]Stanford HCP Annual Report 2019
[5]Kim *et al.* 2018
[6]Rose *et al.* 2018
[7]Swaim 2018
[8]CNDDB 2018

Current Condition in Relation to Recovery Criteria

Recovery criteria for downlisting of the San Francisco gartersnake focuses on abundance estimates at six significant populations defined in the Recovery Plan. Specifically, the criteria call for 200 or more individuals at a 1:1 sex ratio at each of the sites for five consecutive years. Our analysis of demographic condition categorized population complexes as being in high condition for abundance if they had a core population with greater than 200 adults, thus all complexes in high condition for that category would count towards achieving this recovery criterion. The only complex that meets this abundance criterion is WOB. Thus, the downlisting criteria for this species are not met.

Synopsis of Current Condition

The San Francisco gartersnake tends to have higher overall condition related to habitat factors than demographic factors. According to our basic analysis of relevant habitat factors, the San Francisco gartersnake currently has eight population complexes in overall high condition and four population complexes in overall low condition. With regard to demographic condition, the species has one population complex in overall high condition, five population complexes in moderate condition, and six population complexes in low condition (Figure 13). It is important to note that the population complexes with high habitat conditions tended to be those with management activities, including habitat restoration, invasive species control, grassland management, and educational signs. The continuation of these management activities is important to maintain these resilient populations. All of the populations with high or moderate overall demographic condition had high habitat conditions.

Habitat and demographic condition were unknown across many of the population complexes, especially in the center of the range. Because of our conservative approach to assume that categories with unknown conditions were in low condition, this may have biased our analysis towards suggesting that these populations have low resiliency. However, we also note the lack of recent observations for many of these locations. Populations that had recent trapping surveys tended to have habitat features in higher condition. However, this is not surprising given that these populations were subjectively chosen to assess possible source locations for a captive breeding program (see Captive Propagation section below).

Redundancy for the species hinges on having multiple resilient population complexes distributed throughout the species range. There is only one population with both high habitat and demographic resiliency, but the distribution of population complexes with high habitat condition and moderate demographic condition across the species range makes it likely that the species could withstand any catastrophic events that may occur. For example, the presence of population complexes with high habitat condition and moderate demographic condition in both coastal and inland locations means that some population complexes would be protected from a catastrophic tsunami or earthquake impacting waterways. However, because population complexes exist in a fragmented landscape that likely has limited connectivity, recolonization of some areas following local extirpations may be unlikely.

The presence of population complexes with high habitat condition and high or moderate demographic condition at both the northern and southern edge of the species' range, in combination with the distribution of populations, indicates that the species exhibits moderate representation. The population complexes with high habitat condition are distributed throughout the species range and relatively evenly mixed between the northern and southern genetic clusters. Both clusters have multiple populations with either high or moderate demographic condition. There are also population complexes with high or moderate resiliency along the coast and more inland. Together, this indicates that the species may have the ability to adapt to changing environmental and biological conditions. However, we note that results from the draft genetic study found that the northern genetic cluster tended to have greater population structure, lower effective population sizes, and lower genetic diversity. Improving habitat and demographic condition in those populations with low resiliency, in particular in the northern regional cluster and along the central coastal portion of the species range, will improve representation for the species.

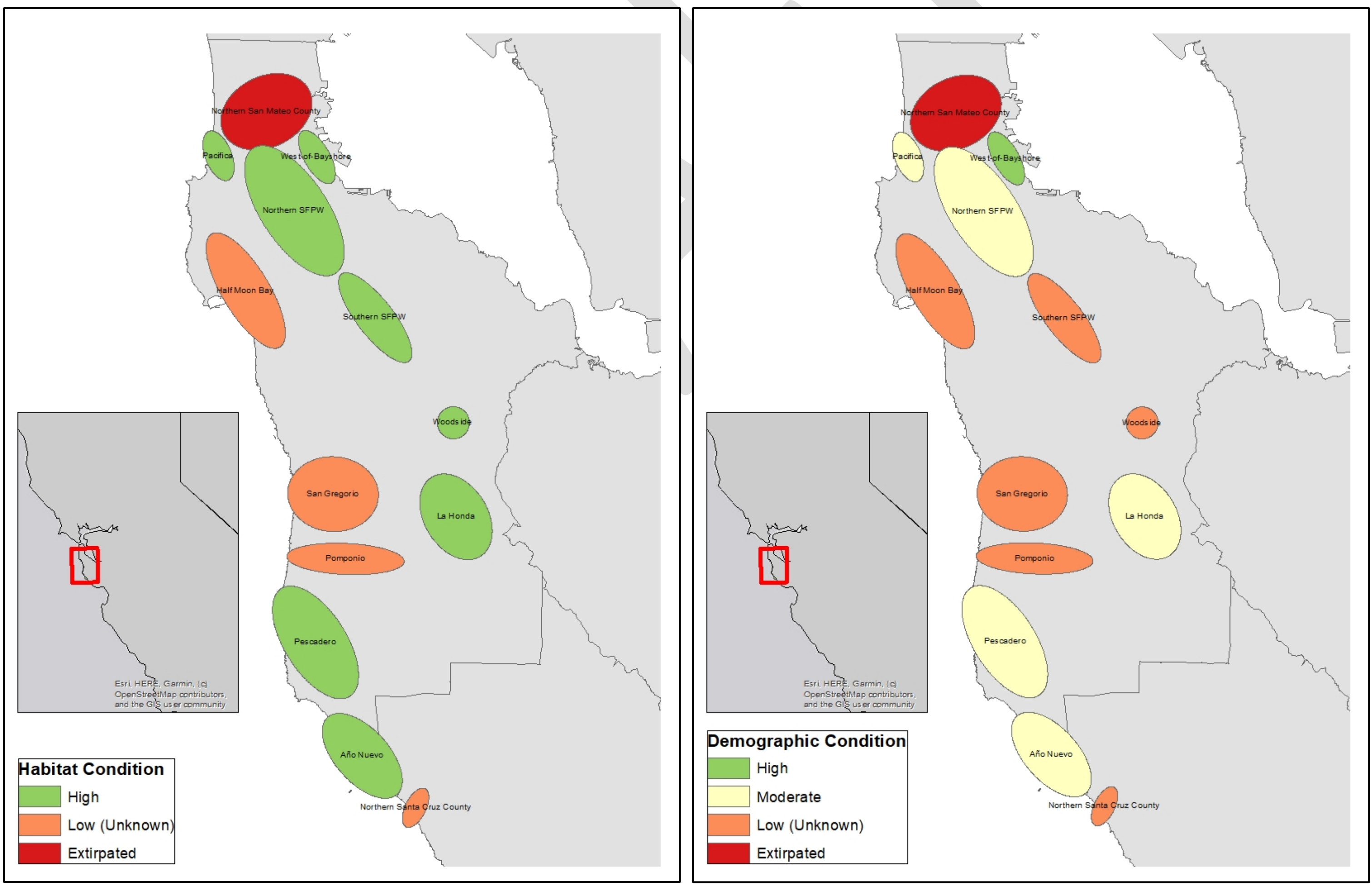

Figure 13. Overall habitat and demographic condition for San Francisco gartersnake population complexes.

Chapter 5. Future Condition

In this chapter, we predict the future viability of 12 San Francisco gartersnake population complexes under three plausible scenarios. We did not include the extirpated Northern San Mateo County complex in this analysis. The future scenarios use different combinations of climate change impacts and conservation efforts, and are evaluated on a time frame of approximately 80 years (through 2100) to align with climate projections for the area. This analysis will help us predict how viability of the San Francisco gartersnake may change in the future. We discuss San Francisco gartersnake resiliency, representation, and redundancy in the context of these scenarios.

Before discussing the scenarios and analysis results, we first describe how conditions are expected to change in the future. Factors influencing viability of the San Francisco gartersnake are assessed in the context of climate change. We also discuss captive propagation as a potential future management action for the species. Figure 14 updates the influence diagram presented in Chapter 4 with the addition of climate change and captive propagation, with expected changes through their effects on habitat or demographic parameters.

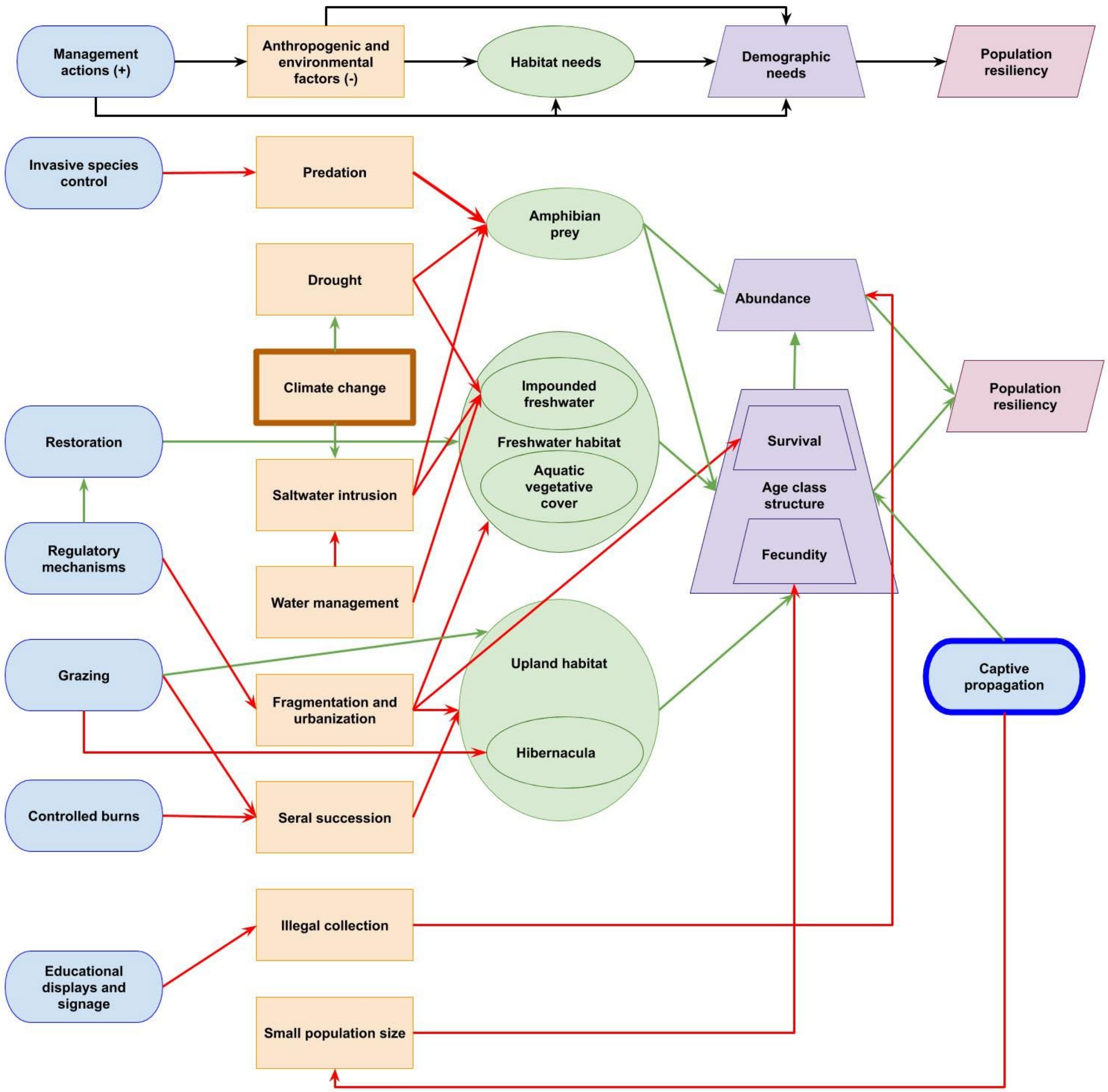

Figure 14. Updated influence diagram including climate change and captive propagation with expected influence on habitat and demographic needs. These new factors are outlined in bold in the diagram.

Potential future changes to factors influencing viability such as illegal collection or predation are unclear and are not discussed in this section. Additionally, although development or agricultural conversion of undeveloped private property remains a potential threat that is expected to continue or increase in the future, we do not have enough information about San Francisco gartersnake populations on private land to attempt to estimate effects of future development on the species. The potential impacts of small population size are unclear and largely depend on the future condition of populations or complexes.

Climate Change

Climate change impacts in national parks in the San Francisco Bay Area are summarized, including original analyses, in Gonzalez 2016 (entire). This report focuses on national parks in Marin, San Francisco, and northern San Mateo Counties, but for the purposes of this document, we assume that the data and trends presented in Gonzalez (2016) are representative of expected impacts throughout the San Francisco gartersnake range. Direct effects of climate change on San Francisco gartersnakes are difficult to assess. Increased temperature may increase growth rates for individual San Francisco gartersnakes, which may allow females to reach reproductive status more quickly, increase reproductive output of females (based on a correlation between female size and number of offspring), or allow individuals to reach size classes that are less vulnerable to predation. However, the magnitude of these potential changes for individuals, and the population-level effects of these potential morphological or demographic changes, are unclear, thus we do not make assumptions about direct effects of climate change on San Francisco gartersnakes. Instead, climate change is expected to have mainly indirect effects on the San Francisco gartersnake. In this section, we discuss anticipated indirect impacts to San Francisco gartersnake from sea level rise, precipitation, temperature, and drought. We also briefly discuss changes to fog, although we don't have enough information to expect impacts from these possible changes.

Climate change-induced sea level rise risks saltwater inundation of San Francisco gartersnake habitat. This threat is greatest in habitat along the coast. Historically, sea level rise of 22 cm (9 in) from 1854 to 2016 is attributed to human-mediated climate change (Gonzalez 2016, p. 5). Sea level is expected to continue to increase globally through both expansion of ocean water when it warms and increased volume of water in oceans from melting glaciers and ice (Gonzalez 2016, p. 12). The Intergovernmental Panel on Climate Change projects global sea level rise of 26-55 cm (10-22 in) under the lowest emissions scenario and 52-98 cm (20-39 in) under the highest emissions scenario by 2100, and it is expected that the San Francisco Bay Area will be similar to the global average. Saltwater inundation can make habitat unsuitable for amphibian prey, which in turn is expected to negatively influence San Francisco gartersnake survival and reproduction. Further, observations of bullfrogs in brackish water in North Carolina suggests that this species may be more tolerant of saltwater intrusion than treefrogs and red-legged frogs, which could lead to further reductions in prey species for the San Francisco gartersnake.

Total annual precipitation did not significantly change from 1950 to 2010, but models in general show an increase in precipitation under various emissions scenarios. Precipitation extremes are expected to increase, as evidenced by a prediction for higher frequency of both extremely wet and extremely dry years (Swain *et al.* 2018, pp. 427-433). Average annual temperatures within the boundaries of San Francisco Bay Area National Parks significantly increased from 1950 to 2010, and are expected to increase by 3.8 degrees Celsius (6.8 degrees Fahrenheit) on average from 2000 to 2100. Temperature changes are expected to increase further from the coast (Gonzalez 2016, p. 7). Anticipated changes to precipitation and temperature have the potential to impact amphibian populations with indirect effects on San Francisco gartersnake populations. However, the distribution of red-legged frogs and treefrogs in areas throughout California that are highly variable in precipitation and temperature measures suggests flexibility of amphibians to persist given the projected changes. Precipitation increases are expected to decrease with distance from the Pacific, while temperature increases are projected to be higher further from the coast (Gonzalez 2016, p. 7). Taken together, this means that inland populations could see less change in precipitation combined with higher temperatures, which is discussed in the context of drought below. Changes in precipitation and temperature have the potential to impact upland habitat for the San Francisco gartersnake, but specific ways in which these variables may influence the threat of seral succession are unclear.

Despite overall predictions of increased precipitation, hotter temperatures are expected to increase the probability and frequency of droughts (Diffenbaugh *et al.* 2015, pp. 3932-3933). San Francisco gartersnake and its prey, red-legged frogs, are both listed as highly vulnerable to drought in an assessment of vertebrate taxa in Golden Gate National Recreation Area (CDFW 2016, p. 14). Drought-related changes to impounded freshwater habitat can reduce reproduction of amphibians in these habitats, which will in turn reduce prey availability for San Francisco gartersnakes. In the interior coast range, increased temperatures combined with decreased precipitation may lead to shortened hydroperiods which can reduce amphibian reproduction. This may disproportionately affect neonate and juvenile San Francisco gartersnakes that rely on small amphibian prey as food sources. Monitoring of San Francisco gartersnake populations spread throughout the range of the species (e.g., the Pescadero, WOB, and Pacifica complexes) all suggest that amphibian prey may be limiting during drought years (Kim *et al.* 2017, Larsen 1994).

Potential changes to coastal fog could impact basking conditions in upland habitat. Studies demonstrate that Pacific coast and Bay Area fog has decreased in recent years relative to the beginning of the century (Johnstone and Dawson 2010, p. 4534), potentially associated with urbanization and pollution (summarized in Ackerly *et al.* 2018, pp. 25-27). Future changes in the fog belt related to climate change are possible, but there is a lot of uncertainty because of the interplay between heat and humidity across various sources (i.e., land, ocean, air). Although significant increases in fog could alter the thermal environment in upland habitat, we don't take this into consideration in this SSA.

Fragmentation and Urbanization

Protected areas relative to San Francisco gartersnake population complexes are shown in Figure 15. Although fragmentation and urbanization may increase throughout the range of the species, all of the population complexes that have rankings for habitat and demographic condition (i.e., not categorized as "unknown") have protected habitat within the complex that supports the species, so we did not anticipate large-scale effects from this threat for these populations. Of the population complexes that have unknown habitat conditions, the San Gregorio and Pomponio population complexes both occur in areas that are on largely unprotected lands, and we expect that continued urban development and fragmentation could occur which could directly or indirectly influence San Francisco gartersnakes in these areas. Populations within these complexes occur primarily in areas that the San Mateo County General Plan classifies as having land use of "Agriculture" (Figure 16). We note that the Half Moon Bay population complex as mapped also has the majority of the polygon within area that is marked as "Agriculture".

However, inspection of population occurrences from CNDDB reveals that the actual occurrences within this polygon are on protected land.

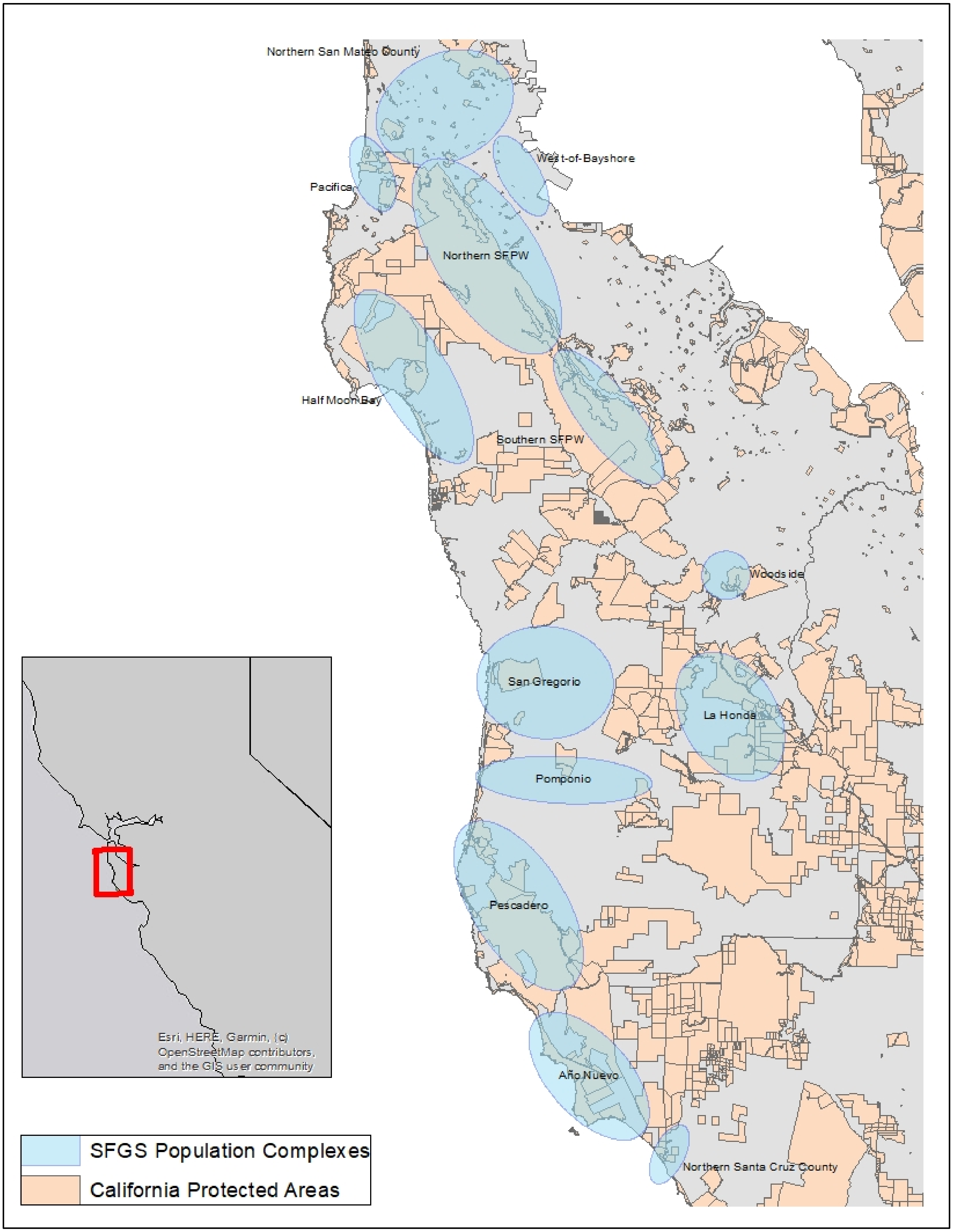

Figure 15. Protected lands within the range of the San Francisco gartersnake. Protected areas are from the California Protected Areas Database.

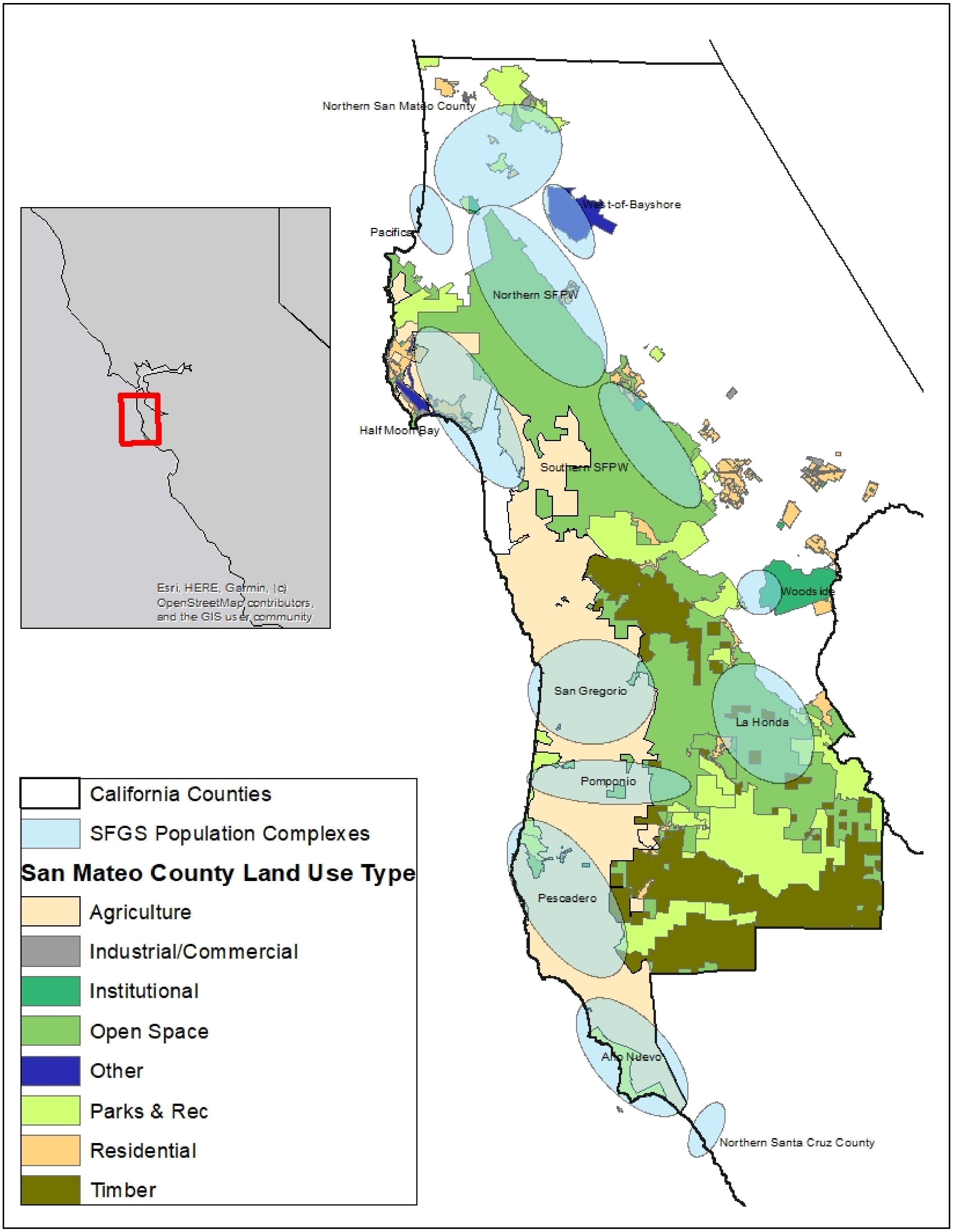

Figure 16. Land use in San Mateo County, using available data from the San Mateo County General Plan Land Use from areas within the County's planning jurisdiction.

Captive Propagation

Planning and permitting is currently underway for a captive breeding and/or headstarting facility that is intended to contribute to the conservation and recovery of imperiled California species, including the San Francisco gartersnake. Captive breeding or headstarting will be carefully integrated with the recovery strategy for this species. As part of an agreement with the Service, the Western Ecological Research Center of the U.S. Geological Survey (USGS) sampled for San Francisco Gartersnakes at six sites from April–June 2018 and 2019 to identify potential donor populations for captive breeding and translocation/reintroduction efforts (Rose *et al.* 2019, entire). The sampling included sites within the Pacifica, Northern SFPW, and Año Nuevo population complexes. In a concurrent study, USGS is evaluating the population structure and genetic diversity of the species (Wood *et al*. 2019), which could be integrated into a genetic management strategy for the captive facility. Captive breeding or headstarting through this facility is expected to lead to population augmentation at sites with suitable habitat but low abundance of San Francisco gartersnakes. Population augmentation may also be used to increase population abundance and/or genetic diversity in areas threatened by small population size. However, there is some uncertainty regarding the projected success of this facility, as many details of the proposed actions here still need to be determined.

Future Scenarios

We assess the condition of the San Francisco gartersnake in three potential scenarios using predicted changes in threats to the species (Table 10).

Table 10. Predicted future change to threats influencing viability of the San Francisco gartersnake.

Threat	Predicted Change
Fragmentation and Urbanization	May increase
Changes to Aquatic Habitat: Saltwater Intrusion	May increase
Changes to Aquatic Habitat: Drought	May increase
Changes to Aquatic Habitat: Water Management	Unknown
Seral Succession	Unknown
Illegal collection	Unknown
Predation	Unknown
Small Population Size	May decrease

In Scenario 1 we assume a sea level rise of 55 cm (22 in). This amount is the greatest projected sea level increase under low emissions, and has the potential to increase the threat of saltwater inundation. We also assume that there will be increased drought years, even with low emissions. Rather than influencing the condition of impounded freshwater habitat, we anticipate that drought may reduce prey availability to San Francisco gartersnakes such that it may become limiting in some population complexes and years. Reductions in availability of amphibian prey may be exacerbated by the presence of bullfrogs, thus we expected changes to amphibian prey under this scenario only for those population complexes known to have bullfrogs present. We assume that the captive breeding program is successful in rearing San Francisco gartersnakes and releasing them back into the populations where they originated. Because of the projected success of this program, we do not anticipate population declines within the population complexes currently included in the study assessing captive breeding.

In Scenario 2 we assume a sea level rise of 98 cm (39 in). This amount is the greatest projected sea level increase under high emissions, and is likely to increase the threat of saltwater inundation. We analyzed the condition of the population complexes assuming that there would be some infrastructure failures (e.g., sea wall failure) and that saltwater intrusion protections near the San Francisco airport remain at current levels. Under the high emissions scenario we assume that there will be increased drought years, with potential to decrease amphibian prey availability. We assume that the captive propagation program is not successful for various potential reasons including, but not limited to, funding issues, difficulty rearing in captivity, or problems related to translocations.

In Scenario 3, we again use a high emissions scenario with sea level rise of 98 cm (39 in), which is likely to increase the threat of saltwater inundation. However, in this scenario we assumed that additional infrastructure designed to protect the Bay Area from saltwater intrusion also lessons the potential impacts from sea water for San Francisco gartersnakes and its habitat. We also assumed there would be increased drought years and potential reductions in amphibian prey. Reductions in availability of amphibian prey may be exacerbated by the presence of bullfrogs. We assume that the captive breeding and translocation program is highly successful. In addition to limiting population declines in those areas being evaluated in the captive breeding study, we also anticipate translocations into other population complexes with suitable habitat but low abundance. We assume that range-wide surveys are used to estimate population abundances prior to translocations, such that individuals can be used to augment those populations with the lowest numbers.

In all scenarios, we assume that habitat fragmentation continues to occur on unprotected lands, and that conservation efforts and management activities on public lands continue at their current levels. Current management activities occur on public lands that have management plans in place that promote recovery of the San Francisco gartersnake, or on state or federal lands in areas where we expect continued restoration for the species. Scenarios are summarized in Table 11.

Table 11. Scenarios used to analyze future condition of San Francisco gartersnake population complexes.

Scenario 1	**Scenario 2**	**Scenario 3**
Low emissions	High emissions	High emissions
Sea level rise of 22 in	Sea level rise of 39 inches	Sea level rise of 39 inches

Potential to increase threat of saltwater inundation	Increased threat of saltwater inundation, with infrastructure failures	Likely to increase threat of saltwater inundation, but infrastructure somewhat protects key areas
Interaction between drought and predation reduces prey availability at sites with bullfrogs	Increases in drought frequency reduces prey availability such that it may be limiting	Increases in drought frequency reduces prey availability such that it may be limiting
Captive breeding maintains abundance and age class structure at select sites	Captive breeding program not implemented or has low success	Captive breeding and translocations maintain or increase abundance and age class structure
Continued habitat fragmentation occurs on unprotected lands	Continued habitat fragmentation occurs on unprotected lands	Continued habitat fragmentation occurs on unprotected lands
Management and restoration continues at current levels	Management and restoration continues at current levels	Management and restoration continues at current levels

Analysis of Future Condition

We predicted the future conditions of each population complex based on the variations of saltwater inundation, drought, fragmentation, and success of the captive breeding program. Predicted changes to habitat and demographic conditions are provided for each scenario. Specifically, we predicted changes to the same habitat and demographic needs measured in our current condition analysis. Continuation of management and restoration activities is expected in all scenarios. For population complexes with unknown condition for any habitat condition categories, we did not change future habitat except in those situations where we expected condition to be low in the future. In these cases, we changed “unknown” to “low”, which did not actually change the calculation for overall habitat quality, but provides more certainty. For example, the San Gregorio population complex has the potential to be impacted by saltwater inundation, which could change habitat quality in multiple categories and make the species less likely to persist in this area. For populations that currently have unknown demographic conditions, we changed abundance to low/extirpated in populations where we expected pressures that could challenge the persistence of the population. For example, on unprotected habitat in areas where we determined that fragmentation may increase as a threat, we changed abundance to low/extirpated.

We calculated overall habitat and demographic conditions for each population complex in our future condition analysis in the same way as in our current condition analysis (see explanation in

Current Condition of Population Complexes (Resiliency). For those populations with an abundance condition of low/extirpated, we assumed that the overall demographic condition would also be low/extirpated.

Scenario 1

We assessed changes relative to drought based on suggestions that drought may lead to reductions in amphibian prey. Because we do not have specific information about amphibian populations within each complex, we assumed that condition in that category would be decreased under a low emissions scenario only for population complexes known to have bullfrogs. The presence of bullfrogs can also reduce availability of amphibian prey, and we assumed a potential synergistic reaction between these two factors both associated with decline of amphibian prey. This method has the potential to overestimate or underestimate the potential for drought to affect future conditions for the species. We assumed that habitat fragmentation could reduce abundance of San Francisco gartersnakes in population complexes predominantly on unprotected lands to low/extirpated. Accordingly, we reduced the abundance for the San Gregorio and Pomponio population complexes to low/extirpated.

We assessed future changes in saltwater inundation by mapping sea level rise using the Our Coast Our Future online mapping tool (http://data.pointblue.org/apps/ocof/cms/). We used the tool to project flooding under 50 cm of sea level rise and with an annual storm scenario. We assume that 50 cm of sea level rise is roughly equivalent to the 55 cm projected sea level rise we used in this scenario. Under these parameters, the population complexes that would potentially be affected include Pacifica, WOB, and San Gregorio. In the Pacifica population complex, waves could lead to saltwater inundation of Laguna Salada, but not the ponds at Mori Point (Figure 17). We therefore decreased the condition for freshwater condition to moderate condition, because the available freshwater habitat would be limited to the ponds at Mori Point which are relatively similar in size and are smaller than Laguna Salada. We assumed that WOB would be somewhat protected from saltwater inundation under the low emissions scenario because of protections put in place by the San Francisco Airport, such that condition of impounded freshwater habitat would be reduced to moderate (Figure 18). We also assumed that saltwater seepage could reduce availability of amphibian prey to moderate condition, changing that category condition to moderate as well. For San Gregorio we reduced the condition for impounded freshwater habitat and aquatic vegetation to low condition (Figure 19). Although the Pescadero population complex has some populations that could likely be inundated with saltwater under this flooding scenario (Figure 20), the most resilient populations within this complex are inland and unlikely to be affected by saltwater. The Año Nuevo population complex shows saltwater inundation that will approach, but not reach, the Visitor Center Pond, thus we did not think it was likely that saltwater inundation would impact this population complex (Figure 21).

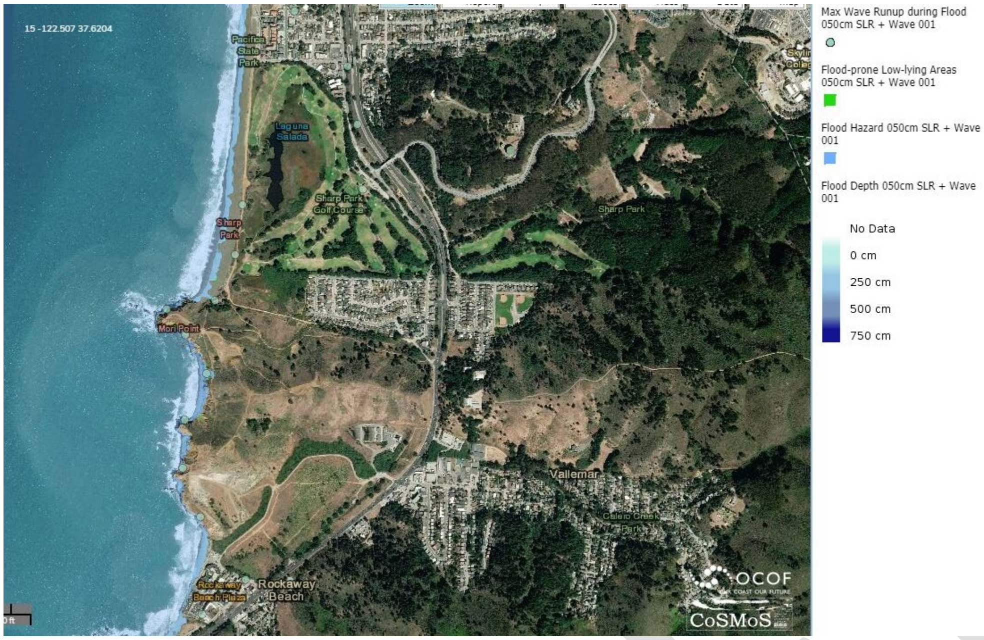

Figure 17. Habitat near the Pacifica San Francisco gartersnake population complex showing predicted flooding under 50 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

Figure 18. Habitat near the WOB San Francisco gartersnake population complex showing predicted flooding under 50 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

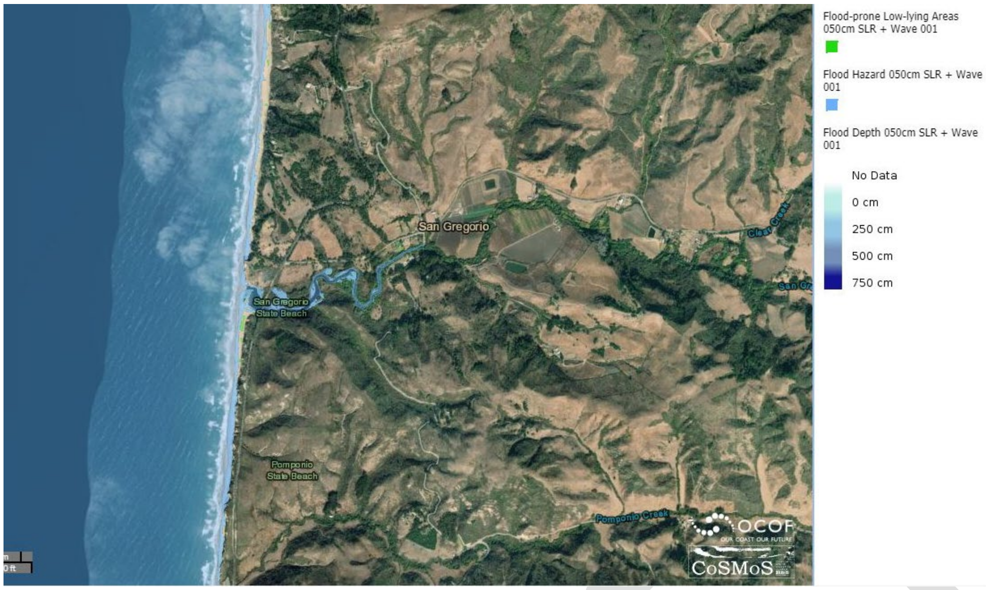

Figure 19. Habitat near the San Gregorio San Francisco gartersnake population complex showing predicted flooding under 50 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

Figure 20. Habitat near the Pescadero San Francisco gartersnake population complex showing predicted flooding under 50 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

Figure 21. Habitat near the Año Nuevo San Francisco gartersnake population complex showing predicted flooding under 50 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/). The Visitor Center Pond is visible near the center of the image.

We assessed future changes based on population augmentation under moderate success of the captive breeding facility. Under moderate success, we assumed that population complexes with moderate abundance of San Francisco gartersnake would have captive breeding and reintroductions into those populations that would maintain abundance. We assumed that this would increase the condition for age class structure for those populations currently in moderate condition.

Conditions under Scenario 1 are presented in Table 12.

Table 12. Population complex conditions under Scenario 1.

	Habitat features					Demographic parameters		
Population complex	**Impounded Fresh Water**	**Aquatic Vegetative Cover**	**Upland habitat**	**Prey**	**Overall Habitat Condition**	**Abundance**	**Age Class Structure**	**Overall Demographic Condition**
Northern San Mateo County	N/A	N/A	N/A	N/A	Extirpated	Extirpated	Extirpated	Extirpated
Pacifica	Moderate	High	High	Moderate	High	Moderate	High	Moderate
West-of-Bayshore	Moderate	High	High	Moderate	High	High	High	High
Northern SFPW	High	High	High	Moderate	High	Moderate	High	Moderate
Southern SFPW	High	High	High	Moderate	High	Low	Unknown	Low
Half Moon Bay	Unknown	Unknown	Unknown	Unknown	Low	Unknown	Unknown	Low
Woodside	High	High	High	High	High	Low	Unknown	Low
San Gregorio	Low/Extirpated	Unknown	Unknown	Unknown	Low/Extirpated	Low/Extirpated	Unknown	Low/Extirpated
La Honda	High	High	High	Moderate	High	Moderate	High	Moderate
Pomponio	Unknown	Unknown	Unknown	Unknown	Low	Low/Extirpated	Unknown	Low/Extirpated
Pescadero	High	High	High	Moderate	High	Moderate	High	Moderate
Año Nuevo	High	High	Moderate	Moderate	High	Moderate	High	Moderate
Northern Santa Cruz County	Unknown	Unknown	Unknown	Unknown	Low	Low	Unknown	Low

Scenario 2

We assessed changes relative to drought based on suggestions that drought may lead to reductions in amphibian prey. Under a high emissions scenario, we assumed that availability of amphibian prey could become a limiting factor for all population complexes in some years. We therefore reduced prey availability to moderate for all populations that are in high condition currently. We assumed that habitat fragmentation could reduce abundance of San Francisco gartersnakes in population complexes predominantly on unprotected lands to low/extirpated. Accordingly, we reduced the abundance for the San Gregorio and Pomponio population complexes to low/extirpated.

We assessed future changes in saltwater inundation by mapping sea level rise using the Our Coast Our Future online mapping tool (http://data.pointblue.org/apps/ocof/cms/). We used the tool to project flooding under 100 cm of sea level rise and with an annual storm scenario. We assume that 100 cm of sea level rise is roughly equivalent to the 98 cm projected sea level rise we used in this scenario. Under these parameters, the population complexes that would potentially be affected include Pacifica, WOB, and San Gregorio. For Pacifica, we assumed that waves and saltwater inundation at Laguna Salada would change condition of impounded freshwater habitat to low (Figure 22). We also changed aquatic habitat to moderate, assuming some vegetative changes, and upland habitat to moderate assuming that there might be fewer burrows available. At WOB, we assumed that saltwater inundation would be more extensive (Figure 23). Because we assumed that saltwater intrusion protections near the San Francisco airport would remain at current levels, we decreased most habitat conditions to low; we decreased impounded freshwater to low/extirpated, and correspondingly changed demographic conditions to low/extirpated. For San Gregorio we reduced the condition for impounded freshwater habitat to low condition (Figure 24). Although the Pescadero population complex has some populations that could likely be inundated with saltwater under this flooding scenario (Figure 25), the most resilient populations within this complex are inland and unlikely to be affected by saltwater. Accordingly, we did not change habitat conditions despite likely impacts from saltwater inundation. The Año Nuevo population complex shows saltwater inundation that will approach, but not reach, the Visitor Center Pond, thus we did not think it was likely that saltwater inundation would impact this population complex (Figure 26).

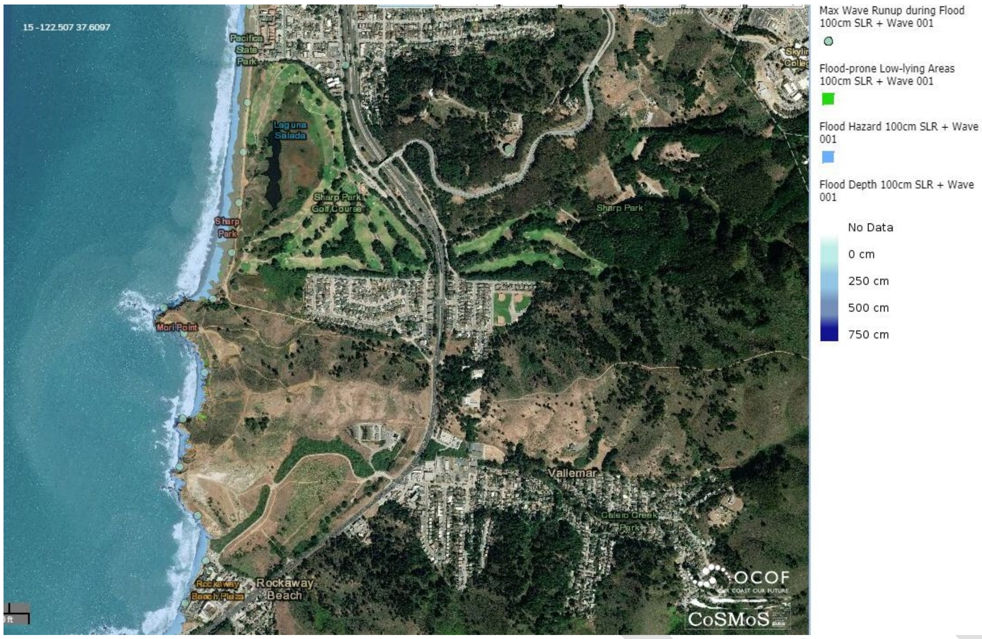

Figure 22. Habitat near the Pacifica San Francisco gartersnake population complex showing predicted flooding under 100 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

Figure 23. Habitat near the WOB San Francisco gartersnake population complex showing predicted flooding under 100 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

Figure 24. Habitat near the San Gregorio San Francisco gartersnake population complex showing predicted flooding under 100 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

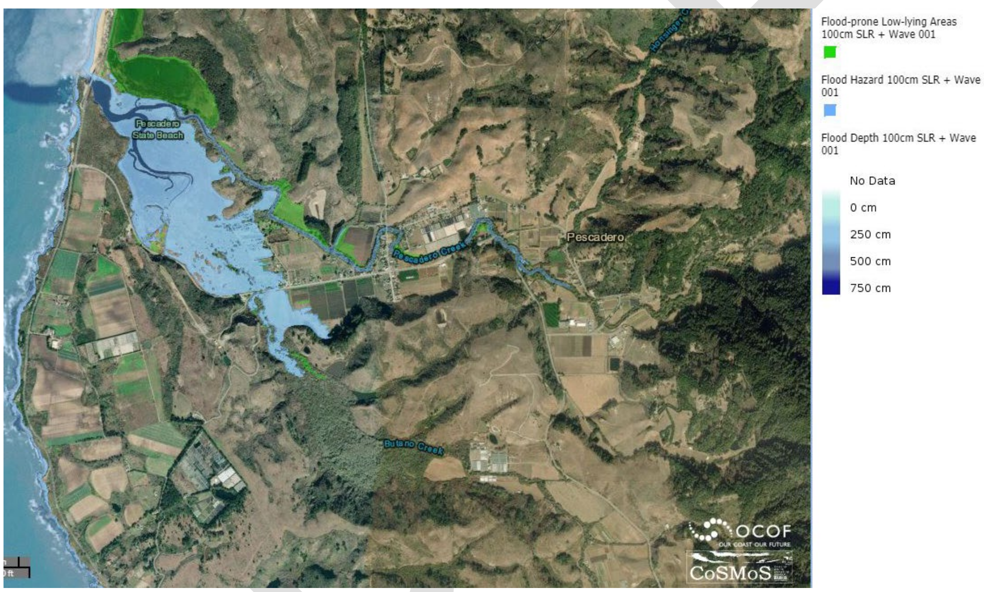

Figure 25. Habitat near the Pescadero San Francisco gartersnake population complex showing predicted flooding under 100 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

Figure 26. Habitat near the Año Nuevo San Francisco gartersnake population complex showing predicted flooding under 100 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

We did not make changes to demographic conditions related to captive propagation because we assumed the program would not be successful.

Conditions under Scenario 2 are presented in Table 13.

Table 13. Population complex conditions under Scenario 2.

	Habitat features					Demographic parameters		
Population complex	**Impounded Fresh Water**	**Aquatic Vegetative Cover**	**Upland habitat**	**Prey**	**Overall Habitat Condition**	**Abundance**	**Age Class Structure**	**Overall Demographic Condition**
Northern San Mateo County	N/A	N/A	N/A	N/A	Extirpated	Extirpated	Extirpated	Extirpated
Pacifica	Low	Moderate	Moderate	Moderate	Moderate	Moderate	High	Moderate
West-of-Bayshore	Low/Extirpated	Low	Low	Low	Low/Extirpated	Low/Extirpated	Low	Low/Extirpated
Northern SFPW	High	High	High	Moderate	High	Moderate	High	Moderate
Southern SFPW	High	High	High	Moderate	High	Low	Unknown	Low
Half Moon Bay	Unknown	Unknown	Unknown	Unknown	Low	Unknown	Unknown	Low
Woodside	High	High	High	Moderate	High	Low	Unknown	Low
San Gregorio	Low/Extirpated	Unknown	Unknown	Unknown	Low/Extirpated	Low/Extirpated	Unknown	Low/Extirpated
La Honda	High	High	High	Moderate	High	Moderate	High	Moderate
Pomponio	Unknown	Unknown	Unknown	Unknown	Low	Low/Extirpated	Unknown	Low/Extirpated
Pescadero	High	High	High	Moderate	High	Moderate	High	Moderate
Año Nuevo	High	High	Moderate	Moderate	High	Moderate	High	Moderate
Northern Santa Cruz County	Unknown	Unknown	Unknown	Unknown	Low	Low	Unknown	Low

Scenario 3

As in the other high emissions scenario, we assumed that availability of amphibian prey could become a limiting factor for all population complexes in some years. We therefore reduced prey availability to moderate for all populations that have high condition currently. We assumed that habitat fragmentation could reduce abundance of San Francisco gartersnakes in population complexes predominantly on unprotected lands to low/extirpated. Accordingly, we reduced the abundance for the San Gregorio and Pomponio population complexes to low/extirpated.

We assessed future changes in saltwater inundation by mapping sea level rise using the Our Coast Our Future online mapping tool (http://data.pointblue.org/apps/ocof/cms/). As in Scenario 2, we used the tool to project flooding under 100 cm of sea level rise and with an annual storm scenario. Figures presented under Scenario 2 are also applicable to this scenario. However, we made some modifications to our analysis in this scenario because we assumed that additional infrastructure designed to protect the Bay Area from saltwater intrusion lessens the potential impacts from sea water for San Francisco gartersnakes and its habitat. We still expected the population complexes that would potentially be affected to include Pacifica, WOB, and San Gregorio. For Pacifica, we assumed that waves and saltwater inundation would be limited to Laguna Salada, changing the condition of impounded freshwater habitat to moderate. We also changed aquatic habitat to moderate, assuming some vegetative changes, and upland habitat to moderate assuming that there might be less burrows available. At WOB, we assumed that saltwater inundation would be more extensive than that under 50 cm of sea level rise, although we did still assume in this scenario that protections put in place by the airport would maintain some habitat at the site. Consistent seepage of saltwater would change impounded freshwater habitat condition to low and could change aquatic vegetation, so we also reduced condition in that category to moderate. We further assumed that reduction in habitat quality and prey would increase competition for the species, which could result in a significant reduction in abundance at that site and decreases in reproduction or survival (assessed in our analysis as age class structure). Because the current abundance is over five-fold of our minimum target for high condition in abundance, it is likely that the population will maintain high condition for this category, but we decreased the age structure condition to moderate because breeding may not be as consistently successful. For San Gregorio we reduced the condition for impounded freshwater habitat and aquatic vegetation to low condition. Although the Pescadero population complex has some populations that could likely be inundated with saltwater under this flooding scenario, the most resilient populations within this complex are inland and unlikely to be affected by saltwater. Thus, some Pescadero complex populations could be extirpated in this scenario, but overall the complex is not. The Año Nuevo population complex shows saltwater inundation that will approach, but not reach, the Visitor Center Pond, thus we did not think it was likely that saltwater inundation would impact this population complex.

We assessed future changes based on population augmentation under high success of the captive breeding facility, assuming both captive propagation and population augmentations. We assumed that population complexes with moderate abundance of San Francisco gartersnake would have captive breeding and reintroductions into those populations that would maintain abundance, and that this would increase the condition for age class structure for those populations currently in moderate condition. We also assumed that complexes with high quality habitat and moderate abundance would be augmented such that abundance changes to high, and those with high quality habitat condition but low abundance would be augmented such that abundance and age class structure are both moderate.

Conditions under Scenario 3 are presented in Table 14.

Table 14. Population complex conditions under Scenario 3.

	Habitat features					Demographic parameters		
Population complex	**Impounded Fresh Water**	**Aquatic Vegetative Cover**	**Upland habitat**	**Prey**	**Overall Habitat Condition**	**Abundance**	**Age Class Structure**	**Overall Demographic Condition**
Northern San Mateo County	N/A	N/A	N/A	N/A	Extirpated	Extirpated	Extirpated	Extirpated
Pacifica	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	High	Moderate
West-of-Bayshore	Low	Moderate	Moderate	Moderate	Moderate	High	Moderate	High
Northern SFPW	High	High	High	Moderate	High	Moderate	High	Moderate
Southern SFPW	High	High	High	Moderate	High	Moderate	Moderate	Moderate
Half Moon Bay	Unknown	Unknown	Unknown	Unknown	Low	Unknown	Unknown	Low
Woodside	High	High	High	Moderate	High	Moderate	Moderate	Moderate
San Gregorio	Low/Extirpated	Unknown	Unknown	Unknown	Low/Extirpated	Low/Extirpated	Unknown	Low/Extirpated
La Honda	High	High	High	Moderate	High	High	High	High
Pomponio	Unknown	Unknown	Unknown	Unknown	Low	Low/Extirpated	Unknown	Low/Extirpated
Pescadero	High	High	High	Moderate	High	High	High	High
Año Nuevo	High	High	Moderate	Moderate	High	High	High	High
Northern Santa Cruz County	Unknown	Unknown	Unknown	Unknown	Low	Low	Unknown	Low

Synopsis of Future Condition Analysis

The results of the future condition analysis show differences based on variation mainly due to potential negative impacts from saltwater inundation related to sea level rise, and increases in demographic condition due to captive propagation. For demographic condition, there were reductions across all scenarios for the San Gregorio and Pomponio populations to low/extirpated, and additional decreases in condition for other population complexes based on expected impacts from sea level rise. However, in Scenarios 1 and 3 we also predicted varying success in the proposed captive propagation program would lead to increases to demographic conditions in some population complexes. Continued occurrence of the most resilient population currently, the WOB population, relies on protections put in place by the San Francisco airport to combat sea level rise that may also protect habitat for the San Francisco gartersnake at that site.

Under Scenario 1, there are no changes to overall habitat or demographic condition for most population complexes, but there were potential extirpations of population complexes at San Gregorio and Pomponio. Changes to individual habitat factors could slightly lower the resiliency of some population complexes, but these subtle changes were not large enough to change the overall conditions scores in our analysis. Scenario 2 had the most pessimistic outlook for the species, assuming extensive saltwater inundation and no success of the captive propagation program. Under this scenario, one population complex would be potentially extirpated because of habitat conditions and that population complex and one additional would be potentially extirpated because of demographic conditions. Populations along the coast and bay are most at risk in this scenario, whereas inland populations had relatively consistent habitat conditions. Scenario 3 was the most optimistic, with both increases and decreases in demographic condition for several population complexes. Both Pacifica and WOB had decreases in habitat condition, but remained in moderate and high demographic condition, respectively. Populations along the coast and bay are still most at risk, but successful implementation of the captive breeding program, with population augmentation in the La Honda, Año Nuevo, and Pescadero population complexes could bring these population complexes up to high demographic condition, and the Southern SFPW and Woodside population complexes into moderate demographic condition.

Chapter 6. Species Viability

Status Assessment Summary

We used the best available information to evaluate the current condition and forecast the likely future condition of the San Francisco gartersnake (Table 15, Table 16). We have considered what the San Francisco gartersnake needs at the individual, population, and species-level and how they relate to viability (Chapter 3), and we evaluated the species' current condition in relation to those needs (Chapter 4). We also forecast how the species' condition may change in the future under three different scenarios (Chapter 5). In this chapter, we synthesize the results from our historical, current, and future analyses and discuss the potential consequences for the future viability of the San Francisco gartersnake, with emphasis on resiliency, redundancy, and representation.

The San Francisco gartersnake faces a variety of risks from habitat modification and destruction, illegal collection, predation from non-native species, small population size, and climate change. Results of our analysis in various scenarios show variation based on effects from sea level rise and success of a captive propagation program, and rely on continued conservation and management of species' habitat to maintain resilient populations across the species range. Range-wide habitat and population surveys are necessary to fill in data gaps that left current and future condition of some population complexes unclear.

Table 15. Summary of population complex overall habitat condition under current and future conditions using three plausible scenarios.

	Habitat Overall Condition			
Population complex	**Current Condition**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Northern San Mateo County	Extirpated	Extirpated	Extirpated	Extirpated
Pacifica	High	High	Moderate	Moderate
West-of-Bayshore	High	High	Low/Extirpated	Moderate
Northern SFPW	High	High	High	High
Southern SFPW	High	High	High	High
Half Moon Bay	Low	Low	Low	Low
Woodside	High	High	High	High
San Gregorio	Low	Low/Extirpated	Low/Extirpated	Low/Extirpated
La Honda	High	High	High	High
Pomponio	Low	Low	Low	Low
Pescadero	High	High	High	High
Año Nuevo	High	High	High	High
Northern Santa Cruz County	Low	Low	Low	Low

Table 16. Summary of population complex overall demographic condition under current and future conditions using three plausible scenarios.

	Demographic Overall Condition			
Population complex	**Current Condition**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Northern San Mateo County	Extirpated	Extirpated	Extirpated	Extirpated
Pacifica	Moderate	Moderate	Moderate	Moderate
West-of-Bayshore	High	High	Low/Extirpated	High
Northern SFPW	Moderate	Moderate	Moderate	Moderate
Southern SFPW	Low	Low	Low	Moderate
Half Moon Bay	Low	Low	Low	Low
Woodside	Low	Low	Low	Moderate
San Gregorio	Low	Low/Extirpated	Low/Extirpated	Low/Extirpated

La Honda	Moderate	Moderate	Moderate	High
Pomponio	Low	Low/Extirpated	Low/Extirpated	Low/Extirpated
Pescadero	Moderate	Moderate	Moderate	High
Año Nuevo	Moderate	Moderate	Moderate	High
Northern Santa Cruz County	Low	Low	Low	Low

We emphasize that for some of the population complexes where surveys have not been conducted for decades, habitat and demographic conditions are not known. In these cases where current conditions were unknown, we only made projections into the future when we thought conditions would be lowered. Success of the captive breeding facility has the potential to increase demographic conditions for additional populations once we have more information about the habitat and occurrences for those sites where conditions are currently unknown. Although the condition for the species under Scenario 3 is promising, the successful recovery of the San Francisco gartersnake relies on increases in demographic conditions for additional populations than those with assessed changes in this SSA report.

Resiliency

Resiliency describes the ability of the species to withstand stochastic disturbance events, an ability that is associated with population size, growth rate, and habitat quality.

Historically, the San Francisco gartersnake experienced large population losses due to habitat development and urbanization, as well as illegal collection because of the species' beauty and rarity. The largest historical population at the sag ponds along Skyline Boulevard was extirpated prior to federal listing of the species, and it is unclear how abundant the population once was. We used the best available science to assess the resiliency of current populations. To do so, we grouped the populations into 12 extant complexes across the species range. Based on the habitat factors in our analysis, the species has eight complexes with high habitat condition and four complexes with low habitat condition. Regarding demographic condition, the species currently has one population complex in high condition, five in moderate condition, and six in low condition. For the most part, the low habitat and demographic conditions are in population complexes that have not been assessed for a number of years.

Population complex resiliency varied somewhat across three potential future scenarios. For several, there were reductions in habitat condition based on projected impacts from saltwater inundation, which has the potential to affect at least three population complexes. There were also potential extirpations in 2 population complexes in all scenarios, as well as the population complex that is currently the most resilient, in 1 scenario. In the most optimistic scenario there were increases or maintenance of resiliency in some population complexes because of anticipated captive breeding and population augmentation.

Maintenance of resilient population complexes, which in turn contribute to species redundancy and representation, is contingent on continued management and restoration efforts that are currently being undertaken to promote health of the species and its habitat. Although not explicitly factored into our future condition analysis, we assumed that these measures would be continued in all scenarios, and stress that the continued health of the species depends on this assumption.

Redundancy

Redundancy describes the ability of a species to withstand catastrophic events, an ability that is related to the number, distribution, and resilience of populations.

The current distribution of the San Francisco gartersnake is similar to the known historical distribution, with the caveat that range-wide surveys were not conducted until the species had already suffered extensive population declines from habitat urbanization. Although we have identified more population complexes in this SSA than were originally targeted as needing resilient populations in the downlisting criteria for the species, many of these complexes have unknown habitat or demographic conditions, thus are not considered to have resilient populations currently and in most of the future scenarios. However, presence of extant populations in high quality habitat throughout the species range makes it unlikely that a catastrophic event could extirpate all of the analysis units at once.

The continued presence of population complexes at both the northern and southern edge of the species' range with either high or moderate habitat and demographic conditions, in combination with the distribution of these populations, suggest that the species has the potential to retain redundancy. This is particularly true in Scenario 3, where some population complexes increase in resiliency, including those spread throughout the species range. Reduction in the number of population complexes because of the possible extirpations along the central coastal part of the species' range would lower redundancy somewhat, but these complexes are not resilient currently. It is unlikely that a catastrophic event would extirpate the species under any of the scenarios, but potential reductions in condition, particularly in Scenario 2, highlight the potential for redundancy to be lowered.

Representation

Representation describes the ability of a species to adapt to changing environmental conditions, which is related to the breadth of genetic and ecological diversity within and among populations.

The San Francisco gartersnake will likely maintain its current level of genetic diversity into the future since the species is projected to continue to have population complexes distributed across both the northern and southern genetic clusters under all three scenarios, although some of these population complexes may have reduced resiliency. However, potential reductions in habitat conditions for both the Pacifica and WOB population complexes could lower representation for the species because these population complexes are both in the northern genetic cluster (and are two of the more resilient populations currently). Further, if saltwater inundation affects these areas, it could lower the ecological diversity of the species because these are two of the more resilient coastal population complexes. Thus, the species is likely to maintain its genetic diversity but may have reduced ecological diversity in the future.

References

Ackerly, D. D., A. Jones, M. Stacey, B. Riordan. 2018. San Francisco Bay Area Summary Report. California's Fourth Climate Change Assessment. Publication number: CCCA4-SUM-2018-005

Banta, B. H. and D. Morafka. 1966. An annotated check list of the recent amphibians and reptiles inhabiting the city and county of San Francisco, California.

Barry, S. J. 1996. The San Francisco Garter Snake and the San Francisco Watershed. Unpublished technical report of 5 year study.

Barry, S. J. 1978. Status of the San Francisco garter snake. California Department of Fish and Game, Inland Fisheries Endangered Species Program, Special Publication 78-2. October 1978. 21 pp

Barry, S., and M. Jennings. 1998. *Coluber infernalis* Blainville, 1835 and *Eutaenia sirtallis tetrataenia* Cope in Yarrow, 1875 (currently *Thamnopus sirtalis infernalis* and *Ts. tetrataenia;* Reptilia, Squamata): proposed conservation of the subspecific names by the designation of a neotype for *T.s. infernal is.* Bulletin of Zoological Nomenclature 55(4): 224-228.

Barry, S. 1994. The Distribution, Habitat, and Evolution of the San Francisco Garter Snake, Thamnophis sirtalis tetrataenia. Master's thesis, University of California, Davis.

BioMaAS and AECOM. 2016. 2016 San Francisco Garter Snake Trapping Results. Memorandum from Milton Yacego and Bill Stagnaro, BioMaAS, and Tammy Lim, AECOM, to Scott Simono and Ellen Natesan, San Francisco Public Utilities Commission. 21 pp.

Biosearch Associates. 2012. San Francisco Gartersnake Habitat Management Plan, Site A, Russian Ridge Open Space Preserve, San Mateo County, California. Aptos, CA.

Biosearch Associates. 2005. Final Biological monitoring at the Whitehouse Creek Road conservation easement, San Mateo County, California, 2001-2005. Unpublished report prepared for: Steve Gregory, Costanoa Project Manager, San Luis Obispo, California. Dated 28 November 2005.

Boone, M., E. L. Little, and R. D. Semlitsch. 2004. Overwintered bullfrog tadpoles negatively affect salamanders and anurans in native amphibian communities. Copeia 3: 683-690.

Brehme, C. S., S. A. Hathaway, and R. N. Fisher. 2018. An objective road risk assessment method for multiple species: ranking 166 reptiles and amphibians in California. Landscape Ecology 33: 911-935.

Brodie, E. D., B. J. Ridenhour, and E. D. Brodie. 2002. The evolutionary response of predators to dangerous prey: hotspots and coldspots in the geographic mosaic coevolution between garter snakes and newts. Evolution 56:2067-2082.

California State Park and Recreation Commission. 2008. Reclassification and addition of Año Nuevo State Natural Reserve into the existing Año Nuevo State Park. Resolution 27-2008 adopted by the California State Park and Recreation Commission at its regular meeting in Pescadero, CA. October 31, 2008.

CBEC, Inc. 2018. Butano Creek channel reconnection and resilience project. Report prepared for San Mateo Resource Conservation District and California Department of Parks and Recreation. 327 pp.

Cope, E. D. 1875. Check-list of North American Batrachia and Reptilia; with a systematic list of the higher groups, and an essay on geographical distribution based on the specimens contained in the United States National Museum. Bulletin U.S. National Museum 1: 1-104.

(CDFW) California Department of Fish and Wildlife. 2019. Snake Fungal Disease detected in California. Available online at https://cdfgnews.wordpress.com/2019/11/05/snake-fungal-disease-detected-in-california/. Accessed November 6, 2019.

(CDFW) California Department of Fish and Wildlife. 2016. A rapid assessment of the vulnerability of sensitive wildlife to extreme drought. Report by the Wildlife Branch, Nongame Wildlife Program July 15, 2015. Revised January 22, 2016.

Cover J. F., Jr., and D. M. Boyer. 1988. Captive reproduction of the San Francisco garter snake Thamnophis sirtalis tetrataenia. Herpetological review 19: 29-33.

(CNDDB) California Department of Fish and Wildlife, Natural Diversity Database. 2018. Element occurrence reports for San Francisco gartersnake. Unpublished cumulative data current to December 12, 2018.

Diffenbaugh, N. S., D. L. Swain, and D. Touma. 2015. Anthropogenic warming has increased drought risk in California. Proceedings of the National Academy of Sciences of the United States of America, 112: 3931-3936.

Dudek. 2019. San Francisco garter snake recovery actionplan 2019-2029 West-of-Bayshore property, San Francisco International Airport, San Mateo County, California. Prepared for San Francisco International Airport. 96 pp.

Fitch, H. S. 1941. Geographic variation in garter snakes of the species Thamnophis sirtalis in the Pacific Coast region of North America. American Midland Naturalist 26:570-592.

Fitch, H. S. 1940 A biogeographical study of the Ordinoides Artenkreis of garter snakes (Genus *Thamnophis*). University of California Publications in Zoology (J. F. Daniel, H. Kirby, S. F. Light, and A. H. Miller, eds.). Volume 44: 1-150. University of California Press, Berkeley, CA.

Fitch, H. S. 1965. An ecological study of the garter snake, *Thamnophis sirtalis*. University of Kansas Publications Museum of Natural History 15:493-564.

Fitch, H. S. 1980. *Thamnophis sirtalis*. Pages 270.1-270.4 in Catalogue of American Amphibians and Reptiles.

Fong, D., D. Collman, T. Elliot and E. Martin. 2004. Habitat Enhancement for the Endangered San Francisco Garter Snake: Construction Summary Report. Golden Gate National Recreation Area (National Park Service) and Golden Gate National Parks Conservancy. 11 pp.

Fong, D. and K. Kindall 2019. San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) visual encounter and coverboard surveys at Golden Gate National Recreation Area, 2018. Unpublished report prepared for U.S. Fish and Wildlife Office Sacramento Field Office. 23 pp.

Fong, D. and R. Townsend. 2018. San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) visual encounter and coverboard surveys at Golden Gate National Recreation Area, 2017. Unpublished report prepared for U.S. Fish and Wildlife Office Sacramento Field Office. 21 pp.

Ford, N. B. 1986. The Role of Pheromone Trails in the Sociobiology of Snakes. In: Duvall D., Müller-Schwarze D., Silverstein R.M. (eds) Chemical Signals in Vertebrates 4. Springer, Boston, MA.

Fox, W. 1951. The status of the gartersnake, *Thamnophis sirtalis tetrataenia*. Copeia 1951: 257–267

Fox, W. 1955. Mating aggregations of garter snakes. Herpetologica 11:176.

Frankham, R. 1995. Effective population size/adult population size ratios in wildlife: a review. Genetics Research 66: 95-107.

Friesen, C. R., R. T. Mason, S. A. Arnold, and S. Estes. Patterns of sperm use in two populations of red-sided garter snake (Thamnophis sirtalis parietalis) with long-term female sperm storage. Canadian Journal of Zoology 92: 33-40.

Gonzalez, P. 2016. Climate change in the National Parks of the San Francisco Bay Area, California, USA. Report by Natural Resource Stewardship and Science, U. S. National Park Service, Berkeley CA. 54 pp.

Gregory, P. T. and K. W. Stewart. 1975. Long-distance dispersal and feeding strategy of the red-sided garter snake (Thamnophis sirtalis parietalis) in the Interlake of Manitoba. Canadian Journal of Zoology 53: 238-245.

Halstead, B. J., G. D. Wylie, M. Amarello, J. J. Smith, M. E. Thompson, E. J. Routman, and M. L. Casazza. 2011. Demography of the San Francisco gartersnake in coastal San Mateo County, California. Journal of Fish and Wildlife Management 2:41–48.

Halstead, B. J., M. E. Thompson, M. Amarello, J. F. Smith, G. D. Wylie, E. J. Routman, and M. L. Casazza. 2019. Effects of prescribed fire on San Francisco gartersnake survival and movement. The Journal of Wildlife Management 83: 231-240.

ICF. 2017. Bay Area Habitat Conservation Plan operations & maintenance. Final plan prepared for Pacific Gas & Electric Company, Environmental Policy. September 2017. 548 pp.

ICZN. 2000. *Coluber infernalis* Blainville, 1835 and *Eutaenia sirtallis tetrataenia* Cope in Yarrow, 1875 (currently *Thamnopus sirtalis infernalis* and *T.s. tetrataenia;* Reptilia, Serpentes): subspecific names conserved by the designation of a neotype for *T.s. infernalis.* Bulletin of Zoological Nomenclature 57(3): 191-192.

Janzen, F.J., J.G. Krenz, T.S. Haselkom, E.D. Brodie, Jr., and E.D. Brodie, III. 2002. Molecular phylogeography of common garter snakes *(Thamnophis sirtalis)* in western North America: implications for regional historical forces. Molecular Ecology 11: 1739-1751.

Jayne, B. C., and A. F. Bennett. 1990. Selection on locomotor performance capacity in a natural population of garter snakes. Evolution 44: 1204-1229.

Jennings, M.R., and M.P. Hayes. 1990. Final Report of the Status of the California Red-Legged Frog (Rana aurora draytonii) in the Pescadero Marsh Natural Preserve. Prepared for the California Department of Parks and Recreation under Contract No. 4-823-9018 with the California Academy of Sciences.

Johnstone, J. A., and T. E. Dawson. 2010. Climatic context and ecological implications of summer fog decline in the coast redwood region. PNAS 107:4533-4538.

Kim, R., B. J. Halstead, P. Lien, G. D. Wylie, and M. L. Casazza. 2017. Abundance and distribution of San Francisco gartersnakes (Thamnophis sirtalis tetrataenia) at Cloverdale Coastal Ranch, San Mateo County, California. Report prepared by the Western Ecological Research Center, U. S. Geological Survey for the U. S. Fish and Wildlife Service Sacramento Field Office.

Kim, R., B. J. Halstead, G. D. Wylie, and M. L. Casazza. 2018, Distribution and demography of San Francisco gartersnakes (Thamnophis sirtalis tetrataenia) at Mindego Ranch, Russian Ridge Open Space Preserve, San Mateo County, California: U.S. Geological Survey Open-File Report 2018-1063. 80 pp.

Kupferberg, S. J. 1997. Bullfrog (*Rana catesbeiana*) invasion of a California river: the role of larval competition. Ecology 76: 1736-1751.

Larsen, S. S. 1994. Life History Aspects of the San Francisco garter snake at the Millbrae habitat site. M.S. Thesis. California State University, Hayward. 105pp.

Lim, T., K. Swaim, and E. J. Routman. 2009. A phylogeography of the San Francisco garter snake (*Thamnophis sirtalis tetrataenia*). Masters Thesis, San Francisco State University. San Francisco, CA.

Lind, A. J. and H. H. Welsh, Jr. 1994. Ontogenic changes in foraging behavior and habitat use by the Oregon garter snake, *Thamnophis atratus hydrophilus*. Animal Behaviour 48: 1261-1273.

Lorch J. M., S. Knowles, J. S. Lankton, K. Michell, J. L. Edwards, J. M. Kapfer, R. A. Staffen, E. R. Wild, K. Z. Schmidt, A. E. Ballmann, D. Blodgett, T. M. Farrell, B. M. Glorioso, L. A. Last, S. J. Price, K. L. Schuler, C. E. Smith Jr., J. F. X. Wellehan, and D. S. Blehert. 2016. Snake fungal disease: an emerging threat to wild snakes. Philosophical Transactions of the Royal Society B: Biological Sciences 371:20150457

Lorch J. M., J. Lankton, K. Werner, E. A. Falendysz, K. McCurley, and D. S. Blehert. 2015. Experimental infection of snakes with *Ophidiomyces ophiodiicola* causes pathological changes that typify snake fungal disease. mBio 6:1–9

LSA. 2008. *Recovery Action Plan for the San Francisco Garter Snake, West-of-Bayshore Property, San Francisco International Airport*. Prepared for San Francisco International Airport, San Francisco, California. April 24, 2008.

McGinnis, S.M. 1986. The status of the San Francisco garter snake *(Thamnophis sirtalis tetrataenia)* at the Sharp Park Golf Course, Pacifica California. Prepared for Geomatrix Consultants, Inc.

McGinnis, S.M. 1987. The distribution and feeding habitat requirements of the San Francisco garter snake (*Thamnophis sirtalis tetrataenia*). Final report prepared for the California Department of Fish and Game Interagency Agreements C-673 and C-1376.

McGinnis, S. M., P. Keel, and E. Burko. 1987. The use of upland habitats by snake species at Ano Nuevo State Reserve. Report to California Department of Fish and Game. December 30, 1987. 13 pp.

McGinnis, S. 1988a. Life history of the San Francisco garter snake (*Thamnophis sirtalis tetrataenia*). Final Report for the California Department of Fish and Game Interagency Agreement -2045 (FY 87-88). 47 pp.

McGinnis, S. M. 1988b. The status of the San Francisco garter snake *Thamnophis sirtalis tetrataenia* in the Pilarcitos Creek drainage between its mouth and its confluence with Corinda Los Trancos Creek. Submitted to U.S. Fish and Wildlife Service July 7, 1988. 15pp.

McGinnis, S. M. 1991. Habitat requirements and population estimate for the San Francisco garter snake *(Thamnophis sirtalis tetrataenia)* at Ano Nuevo State Reserve, San Mateo, California. Unpublished report, submitted to: The Department of Parks and Recreation. Sacramento, California.

McKenzie, J. M., Price, S. J., Fleckenstein, J. L., Drayer, A. N., Connette, G. M., Bohuski, E., and J. M Lorch. 2019. Field diagnostics and seasonality of *Ophidiomyces ophiodiicola* in wild snake populations. EcoHealth 16: 141-150.

Olson, E. and W. Dexter. 2008. Pescadero Marsh Natural Preserve San Francisco garter snake habitat improvement assessment. Report prepared for California State Parks. 15 pp.

Ormshaw, H. 2018 San Bruno Mountain Habitat Conservation Plan 2017-18 activities report for federally listed species. Prepared by San Mateo County Parks Department for U. S. Fish and Wildlife Sacramento Field Office. 98 pp.

Our Coast Our Future. 2019. Online interactive mapping application. Available online at http://data.pointblue.org/apps/ocof/cms/. Accessed November 6, 2019.

Philip Williams & Associates, Ltd., Wetlands Research Associates, Inc., and Associated Consultants T. Steiner and J. Hafernik. 1992. Laguna Salada resource enhancement plan. Plan submitted to City of San Francisco and the State of California Coastal Conservancy. 173 pp.

Recuero, E., I. Martinez-Solano, G. Parra-Olea, and M. Garcia-Paris. 2006a. Phylogeography of *Pseudacris regilla* (Anura: Hylidae) in western North America, with a proposal for a new taxonomic rearrangement. Molecular Phylogenetics and Evolution 39: 293-304.

Recuero, E., I. Martinez-Solano, G. Parra-Olea, and M. Garcia-Paris. 2006b. Corrigendum to "Phylogeography of *Pseudacris regilla* (Anura: Hylidae) in western North America, with a proposal for a new taxonomic rearrangement" [Mol. Phylogenet. Evol. 39 (2006) 293-304]. Molecular Phylogenetics and Evolution 41: 511.

Reeder, N. M. M., A. P. Pessier, and V. T. Vredenburg. 2012. A reservoir species for the emerging aphbibian pathogen Batrachochytrium dendrobatidis thrives in a landscape decimated by disease. PloS ONE 7: e33567.

Reeder N. M. M., R. M. Byrnes, R. W. Stoelting, and K. E. Swaim. 2015. *An endangered snake thrives in a highly urbanized environment*. Endangered Species Research 28:77-86.

Rose, J. P., J. A. S. Ersan, E. J. Schoenig, D. A. Macias, E. M. Armistead, P. C. Lien, and B. J. Halstead. 2018. Abundance estimation of San Francisco gartersnakes (*Thamnophis sirtalis tetrataenia*) at six sites for evaluation of captive breeding and translocation donor sites. Report prepared by Western Ecological Research Center, U. S. Geological Survey, for U.S. Fish and Wildlife Office Sacramento Field Office.

Rossman, D. A., N. B. Ford, and R. A. Seigel. 1996. The garter snakes: evolution and ecology. University of Oklahoma Press, Norman, Oklahoma.

San Francisco International Airport and LSA Associates, Inc. (SFO and LSA). 2017. Ninth Annual Progress Report for the Recovery Action Plan for the San Francisco Garter Snake, West-of-Bayshore Property, San Francisco International Airport. San Francisco International Airport, San Mateo County, California. February 2, 2018

Seigel, R. A. 1984. The foraging ecology and resource partitioning patterns of two species of garter snake. Ph. D. dissertation, University of Kansas, Lawrence.

(Service) U.S. Fish and Wildlife Service. 2013. Stanford University Habitat Conservation Plan. Revised March 2013. 152 pp.

(Service) U.S. Fish and Wildlife Service. 1985. San Francisco garter snake recovery plan. U. S. Fish and Wildlife Service, Endangered Species Program, Portland, Oregon. 77pp.

(Service) U.S. Fish and Wildlife Service. 2006. *San Francisco Garter Snake (Thamnophis sirtalis tetrataenia) 5-Year Review: Summary and Evaluation*. U.S. Fish and Wildlife Service, Sacramento, California.

(Service) U.S. Fish and Wildlife Service. 2016. USFWS Species Status Assessment Framework: an integrated analytical framework for conservation. Version 3.4 dated August 2016.

(Service) U.S. Fish and Wildlife Service. 2017. Final Environmental Assessment for the Pacific Gas & Electric Company Bay Area Operations and Maintenance Habitat Conservation Plan. September. (NSR No. 26301). Redding, CA. With technical assistance from North State resources, Inc., Redding, CA.

Simberloff, D., and B. Von Holle. 1999. Positive interactions of nonindigenous species: invasional meltdown? Biological Invasions 1:21-32.

Shaffer, H. B., G. M. Fellers, S. R. Voss, J. C. Oliver, and G. B Pauly. 2004. Species boundaries, phylogeography and conservation genetics of the red-legged frog (Rana aurora/draytonii) complex. Molecular Ecology 13: 2667-2677.

Shine, R., M. J. Elphick, P. S. Harlow, T. Moore, P. LeMaster, and R. T. Mason. 2001. Movements, mating, and dispersal of red-sided gartersnakes (Thamnophis sirtalis parietalis) from a communal den in Manitoba. Copeia 2001: 82-91.

Smith, D., N. C. Allan, C. P. McGowan, J. A. Szymanski, S. R. Oetker, and H. M. Bell. 2018. Development of a Species Status Assessment process for decisions under the U.S. Endangered Species Act. Journal of Fish and Wildlife Management 9: 302-320.

Stebbins, R.C. 1985. A field guide to western reptiles and amphibians. Houghton Mifflin Company, Boston, Massachusetts and New York, New York. 335 pp.

Stewart, J. A. E., J. H. Thorne, M. Gogol-Prokurat and S. D. Osborn. 2016. A climate change vulnerability assessment for twenty California mammal taxa. Information Center for the Environment, University of California, Davis, CA.

Stromberg, M., and J. Griffin. 1996. Long-term patterns in coastal California grasslands in relation to cultivation, gophers, and grazing. Ecological Applications 6: 1189-1211.

Swain, D. L., B. Langenbrunner, J. D. Neelin and A. Hall. 2018. Increasing precipitation volatility in twenty-first-century California. Nature Climate Change 8: 427-433.

Swaim Biological Consulting. 2006. Results of 2005 surveys for the San Francisco garter snake *(Thamnophis sirtalis tetrataenia)* at Año Nuevo State Reserve, San Mateo County, California, draft report. 16 pp.

Swaim Biological Consulting. 2007. 2007 spring trapping survey for San Francisco garter snake *(Thamnophis sirtalis tetrataenia)* at Año Nuevo State Reserve, San Mateo County, California. 15 pp.

Swaim Biological, Incorporated. 2009. San Francisco garter snake habitat improvement project at Mori Point, Pacific, California, 2004-2008. Document No. 801818 prepared for U.S. Fish and Wildlife Service, Sacramento, CA. 54 pp.

Swain, K. E. 2018. 2017 summary annual report. Prepared for U.S. Fish and Wildlife Service Sacramento Field Office. 76 pp.

Swaim Biological, Incorporated. 2018. San Francisco garter snake monitoring report 2007-2017 mark-recapture survey results. Unpublished report prepared for San Francisco International Airport Bureau of Planning and Environmental Affairs. 67 pp.

Tatarian, P., and G. Tartarian. 2010. Chytid infection of Rana daytonii in the Sierra Nevada, California, USA. Herpetological Review 41: 325-327.

(USGS) U.S. Geological Survey and U.S. Department of Agriculture, Natural Resources Conservation Service. 2013. Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD) (4th edition): U.S. Geological Survey Techniques and Methods 11–A3. 63 p.

USDA National Agricultural Statistics Service Cropland Data Layer2019

Wharton, J. C., J. M. Brode, and M. Knudsen. 1987. Ecological and life history aspects of the San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) at the San Francisco International Airport study site. Final report for Caltrans Interagency Agreements C-226 and C-975 (FY 82/83-85/86). 21 pp.

Wood, D. A., J. P. Rose, B. J. Halstead, R. E. Stoelting, K. E. Swaim, and A. G. Vandergast. 2019. Combining genetic and demographic monitoring better informs conservation of an endangered urban snake. Draft report submitted to the USFWS.

Wylie, G. D., M. L. Casazza, and M. Carpenter. 2003. Diet of *L. catesbeianus* in relation to predation on giant garter snakes at Colusa National Wildlife Refuge. California Fish and Game 89:139-145.

Yarrow, H. C. 1875. Report upon the collections of batrachians and reptiles made in portions of Nevada, Utah, California, Colorado, New Mexico, and Arizona, during the years 1871, 1872, 1873, 1874. In: Report upon the geographical and geological explorations made west of the 100th meridian. Engineer Dept., U.S. Army. Vol. 5 (Zoology):509-594.

***In litteris* citations**

Barry, S. 2003. Email to Anne Corbett regarding recent San Francisco gartersnake information. August 11, 2003.

Barry, S.J. 2006. Electronic mail to Lucy Triffleman, U.S. Fish and Wildlife Service, Sacramento, of April 10, 2006.

Bauer, W. 2019. Email to Samantha Lantz regarding San Francisco gartersnake genetic work. Received March 12, 2019.

Halbert, P. 2019. Email to Leif Goude regarding San Francisco gartersnake at Pescadero Marsh. Received July 25, 2019.

Halstead, B. Email to Samantha Lantz regarding San Francisco gartersnake condition category table and species needs. Received March 31, 2019.

Hankins, D. 2006. Email to Lucy Triffleman, U.S. Fish and Wildlife Service, Sacramento, on June 26, 2006.

Kim, R. 2019. Email to Samantha Lantz regarding San Francisco gartersnake status. Received March 30, 2019.

Lim, T. 2019. Email to Samantha Lantz regarding San Francisco gartersnake phylogeny. Received March 12, 2019.

Terry, J. 2020. Comments on draft SSA. Received by Samantha Lantz on January 13, 2020.

Personal Communication

Larsen, S. 2006. Personal communication cited in Service 2006.

Larsen, S. 2019. Conversation with Samantha Lantz regarding San Francisco gartersnake status and bullfrogs at WOB. March 16, 2019

McGinnis, S. 2007. Phone call with Lucy Triffleman regarding gartersnake feeding in irrigation ditches in Half Moon Bay. April 23, 2007.

Reeder, N. 2019. Site visit and discussion between Samantha Lantz and Natalie Reeder at WOB site. August 22, 2019.

Stoltz, J. 2006. Personal communication with SFPUC biologist cited in Service 2006.

USGS 2019 (or cite genetics report)

Reviewer Name	Chapter	Page	Line #	Comment
Natalie Reeder	Exec Sun	2		gartersnakes should be gartersnake
Natalie Reeder	Exec Sun	3	2	move plausible before future scenarios
Natalie Reeder	Exec Sun	3	3rd paragraph	Unclear what is meant by "drought conditions may make amphibian populatons…". Perhaps insert "decline" to read "drought conditions may make amphibian populations decline across the range"
Natalie Reeder	Exec Sun	3	4th paragraph	unnecessary comma after …"whith high quality habitat, such that abundance increases to high condition."
Natalie Reeder	1	8	4th paragraph	Because City of SF is named as owner of Laguna Salada, you may consider changing the airport designation to "West-of-Bayshore property (City and County of San Francisco/San Francisco International Airport)." Similary, though perhaps not necessary, consider adding "and County" to City of SF for Laguna Salada
Natalie Reeder	1	9	last sentence	period missing at end of sentence
Natalie Reeder	2	13	1st paragraph	Recommend adding clarification that this is not known to be a common characteristic of SFGS
Natalie Reeder	2	13	3rd paragraph	While it is discussed in the next paragraph that this population is not confirmed to remain extant, here is sounds as though it is. Perhaps add some clarification of the likelihood of extirpation
Natalie Reeder	2	14		Millbrae is mispelled Milbrae in "In the Recover Plan, six significant populations were noted…"
Natalie Reeder	2	16	1st paragraph	change to "In addition to historical records and known CNDDB occurrences, a coastal property on the west side of the Santa Cruz Mountains…"
Natalie Reeder	3	23	3rd paragraph	tetrodotoxin is misspelled as tetrototoxin
Natalie Reeder	3	24	1st paragraph	I would add "Only large adults are capable of eating *adult* American bullfrogs" to clarify that SFGS may take other life stages
Natalie Reeder	3	26	1st paragraph	change …"modeled sex ratios in those same years was…" to …"modeled sex ratios in those same years *were*…"
Natalie Reeder	3	26	1st paragraph	4th line - "study" is repeated
Natalie Reeder	3	27	Table 4 caption	Resource may accidentally be pluralized in the second sentence of the caption
Natalie Reeder	3	30	3rd paragraph	Consider stating the elevation of the "high elevation" population in "Only one population in the genetic analyses occurred at high elevation,…"
Natalie Reeder	4	32	2nd paragraph	Should be "Below, we summarize available *data* on San Francisco gartersnake…"

Natalie Reeder	4	33	3rd paragraph	I would move "However" to the next sentence as it is a bit confusing as written. The first sentence "The creek was realigned and vegetated as part of mitigation…" sounds like a good thing. "However" fits better in "However, the current status of the SFGS on the Calera Creek ponds is unknown..."
Natalie Reeder	4	34	1st paragraph	The WOB property is technically owned by the City and County of San Francisco, that also owns SFO itself. I don't know if that's important to clarify here.
Natalie Reeder	4	35	1st paragraph	I would edit the 3rd sentence to make it more clear that hybridization is not known to occur, and, in fact, the work of Wood et al. 2019 suggests there is no hybridization. Suggest: "Anecdotally, were any hybridization to have occurred in the WOB population, it may be in part due to rumored release of California red-sided gartersnakes in an effot to boost the population..."
Natalie Reeder	4	35	1st paragraph	I think Wood et al. 2019 would be a better citation for for the WOB population grouping with other SFGS populations vs. any other subspecies, which would have suggested hybridization
Natalie Reeder	4	38	2nd paragraph	Keep consistency of Ano Nuevo vs. A~no Nuevo
Natalie Reeder	4	44	2nd paragraph	Might be worth clarifying that the SFGS victims of cat predation were documented at WOB over only a 3-month period while trapping in 2017, rather than over the course of a full year, as implied.
Natalie Reeder	4	46	2nd paragraph	California Department of Fish and Game should be California Department of Fish and Wildlife
Natalie Reeder	4	49	HCP 1st paragraph	Confusing sentence "Specifics for each HCP are included within each agreement, including habitat will be set aside an managed for the species as compensatio for covered activities, such as planned urban development, within the ara the HCP covers…"
Natalie Reeder	4	57	1st paragraph	Should be "Specifically, the criteria call* for 200 or more…"
Natalie Reeder	5	59	1st paragraph	Place holder as this may be discussed later: Is there any discussion about potential re-establishment of a population here? Even just the potential, but also what would be needed to make the habitat suitable (e.g. need ponds, permanent water, etc.)? Would it be appropriate to establish a population here?
Natalie Reeder	5	61	2nd paragraph	Perhaps change "human climate change" to "climate change induced by human activity" or something that makes it more clear
Natalie Reeder	5	61	3rd paragraph	Celsius is mispelled
Natalie Reeder	5	62	4th paragraph	Change "affects" to "effects"

Natalie Reeder	5	68	1st paragraph	"For example, the San Gregorio population complex has the potential to be impacted by saltwater inundation, which could change habitat quality in multiple categories and make* the species less likely..."
Natalie Reeder	5	74	2nd paragraph	Sorry, not substantive, but consider changing "We also changed aquatic habitat to moderate...assuming that there might be fewer* burrows available."
Natalie Reeder	5	74	2nd paragraph	While inundation might increase, it is unlikely to affect a large portion of the freshwater habitat. In fact, it is likely only to affect Cupid Row Canal (the canal on the norther portion of the property that enters at the dead end of 1st Ave and leaves the property at San Bruno Ave. South Lomita Canal (to the south and where CRLF breeding is regularly observed) is protected from salt water intrusion by both tide gates and an elevated pump structure. Cupid Row Canal is only protected by tide gates that are more easily overwhelmed. Many of the central ponds are storm water runoff and should not be inundated by salt water except by sewer backup and it is unclear how much that might occur. Lastly, there are several exclusively rain-fed ponds that are safe. This seems to be reflecte in the model in Fig. 23. In short (long), I doubt that sea level rise would result in extirpation of amphibian prey or the SFGS population, though it may reduce habitat quality, prey availability, and thus SFGS abundance to moderate or low.
Natalie Reeder	5	79	2nd paragraph	"However, we made some modifications....infrastructure designed to protect the Bay Area from saltwater instrusion lessens* the potential impacts..."
Natalie Reeder	6	83	Table 15	Again, would recommend changing to low (or even moderate) rather than extirpated. Extirpation seems unlikely in Scenario 2.
Natalie Reeder	6	83	Table 16	See above comment for Table 15
Natalie Reeder	6	85	3rd paragraph	Possible missing possessive in "Reduction in the number of population complexes...along the central coastal part of the species'* range..."
Natalie Reeder	6	85	5th paragraph	"The San Francisco gartersnake will likely maintain...complexes distributed across *in(delete)* both the northern and southern genetic clusters..."
Natalie Reeder	6	85	end	Thank you so much for this important and quality work. Little had changed for SFGS in quite some time, but this effort has spurred new research and, hopefully, will promote additional recovery actions in the future. Well done!

Species Status Assessment for the San Francisco gartersnake (*Thamnophis sirtalis tetrataenia*) Version 1.0

Month YEAR
U.S. Fish and Wildlife Service
Region 10
Sacramento, California

EXECUTIVE SUMMARY

This report summarizes a Species Status Assessment (SSA) completed for the San Francisco gartersnake (*Thamnophis sirtalis tetrataenia*). 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 San Francisco gartersnake occurs throughout much of its known historical range in populations largely fragmented by urbanization. For the purposes of this SSA, we grouped populations into complexes to analyze the condition across the species range. Resiliency of population complexes was measured by assessing the habitat needs of impounded freshwater habitat, aquatic vegetation, upland habitat, and amphibian prey, and the demographic factors abundance and age class structure. We identified 13 population complexes, and analyzed 12 of these for current and future condition (the additional complex is extirpated and we do not expect that habitat factors in this area will ever be sufficient to support a resilient San Francisco gartersnake population in the future).

Our analysis of the past, current, and future factors influencing viability of the San Francisco gartersnake revealed that there are several factors that contribute to the current condition and pose a risk to future viability of the species. Alteration and isolation of habitats resulting from urbanization was identified as the primary reason for decline of San Francisco gartersnakes at the time of listing. Current threats include fragmentation and urbanization, changes to aquatic habitat, seral succession, illegal collection, predation from non-native species, and small population sizes. Snake Fungal Disease, recently confirmed to be present in wild snakes in California, is an emerging threat but is not known to impact the species at this time. Ongoing management actions or other factors positively influencing resiliency include habitat restoration, invasive species control, grassland management, educational displays, and Habitat Conservation Plans. We analyzed the current condition of San Francisco gartersnakes population complexes relative to overall habitat condition and overall demographic condition. Under current conditions, we determined that the San Francisco gartersnake has eight population complexes in high habitat condition and four in low condition. Regarding demographic condition, the species currently has one population complex in high condition, five in moderate condition, and six in low condition. Those complexes with low habitat and demographic condition were historically surveyed in the 1970s and 1980s but have few recent observations.

The influences to viability described above play a large role in the future resiliency, redundancy, and representation of the San Francisco gartersnake. If complexes lose resiliency (i.e., the ability to support self-sustaining populations of San Francisco gartersnake), they are more vulnerable to extirpation, with resulting losses in representation and redundancy. The rates at which future threats may act on specific complexes and the long-term efficacy of current conservation actions (i.e., conservation strategies) are unknown. We used the best available science to predict how future conditions could influence the resiliency, redundancy, representation, and overall condition of the San Francisco gartersnake. In order to assess future condition, we developed three future plausible scenarios. The future scenarios use different combinations of climate change impacts and conservation efforts and are evaluated on a time frame of approximately 80 years (through 2100) to align with climate projections for the area. The following is a description of the three future scenarios, the status of the species when analyzed under each scenario, and a summary of the assumptions made under each scenario:

Scenario 1: We assume under a low emission scenario that sea level rise and drought have impacts to impounded freshwater habitat and amphibian prey populations in some areas. We assumed an interaction between amphibian prey population limitation caused by drought and the presence of bullfrogs, an invasive predator that competes with the San Francisco gartersnake for amphibian prey. Scenario 1 also assumes that ongoing management actions continue, and that a new captive breeding program is successfully implemented such that demographic conditions are maintained or increased for some populations. Fragmentation leads to potential extirpation of two population complexes, but habitat and demographic conditions are otherwise the same as in current condition.

Scenario 2: In this scenario, we assume that high emissions lead to sea level rise likely to impact several populations; drought conditions that may make amphibian populations across the range in a least some years; and fragmentation continues on unprotected lands. We assumed that current protections from sea level rise were maintained but not increased, which led to reductions in habitat condition for some coastal and bay population complexes. We assumed that a planned captive propagation program was not successful. Under this scenario, fragmentation and sea level rise leads to potential extirpation of three population complexes.

Scenario 3: In this scenario, we assume the same climate impacts as Scenario 2: high emissions, sea level rise with impacts to two population complexes, drought that lowers habitat condition across the range of the species, and fragmentation of unprotected land. However, we assumed better protection from sea level rise than in Scenario 2, and high success of the captive breeding program. In addition to maintaining population abundance and age class structure, we assume the captive breeding program leads to population augmentation in areas with high quality habitat, such that abundance increases to high condition. Under this scenario we still predict potential extirpation of two population complexes from fragmentation, and lowered resiliency in habitat conditions for two populations. However, potential success of the captive breeding program leads to increases in demographic conditions to moderate for two population complexes and high for three population complexes.

The projected conditions under all scenarios rely on the continuation of management actions across the species range. There is uncertainty regarding the impacts of sea level rise in the Bay Area, which could lead to notable decreases in habitat and demographic conditions for at least three population complexes if our assumptions overestimate the regional collaboration response regarding sea level rise planning. The main difference between outcomes of the future scenarios depends on success of the captive breeding program, which could lead to maintenance of existing population levels or increases in demographic conditions. Initial success of the facility will be instrumental in guiding projections regarding potential impacts to species' resiliency, redundancy, and representation. We were unable to forecast condition for those population complexes that currently have unknown condition (unless we expected conditions to decrease), and emphasize that surveys in those areas are important for guiding the recovery vision for the species in the central coastal section of its range.

Table of Contents

List of Tables and Figures

Tables

Figures

Chapter 1. Introduction

This report summarizes the results of a Species Status Assessment (SSA) conducted by the U. S. Fish and Wildlife Service (Service) for the San Francisco gartersnake (*Thamnophis sirtalis tertrataenia*). The San Francisco gartersnake is a brightly colored subspecies of common gartersnake found only in San Mateo County and northwestern Santa Cruz County in California.

We used the SSA framework to present a synthesis of our current understanding of the species' ecology and the factors that influence it; habitat and demographic needs at the individual, population, and species level; current status of the species; and potential future status of the species under potential scenarios. In sum, the framework is used as a means of assessing the species' viability. The SSA framework leads to a report that assesses a species' status such that the analyses and information provided can be used for a multitude of decisions and activities carried out under the authority of the Act (Service 2016, p. 7; Smith et al. 2018, entire). More specifically, this version of the SSA for the San Francisco gartersnake evaluates the condition of the species as part of a status review.

Federal History

The San Francisco gartersnake was listed as endangered under the Endangered Species Preservation Act in 1967, and a *Recovery Plan for the San Francisco Garter Snake Thamnophis sirtalis tetrataenia* (Recovery Plan) was first approved in 1985 (Service 1985). A recovery outline in 1995 presented needs of the species that were not addressed in the Recovery Plan (Service 1985, entire).

The Recovery Plan describes downlisting and delisting criteria for the San Francisco gartersnake (Service 1985, p. 18). The criteria focus on the protection of six significant populations and the creation of four additional populations. The six significant populations and the entities managing the land where those populations occur include: the West-of-Bayshore property (San Francisco International Airport), San Francisco State Fish and Game Refuge property (San Francisco Public Utilities Commission), Laguna Salada/Mori Point (City of San Francisco/National Park Service), Pescadero Marsh and Ano Nuevo State Reserve properties (California State Parks), and the Cascade Ranch property (private land owner). The recovery criteria state that the species could be considered for downlisting to threatened if 200 or more individuals are maintained at a 1:1 sex ratio at the six significant population sites for 5 consecutive years. The criteria further suggest that the species may be eligible for delisting if the same abundance and sex ratios are maintained at all 10 locations for 15 consecutive years.

There has been one previous status review for the species (Service 2006).

The Species Status Assessment Framework

This report is a summary of the SSA analysis, which entails three iterative assessment stages (Figure 1):

1. **Species Ecology.** An SSA begins with a compilation of the best available biological information on the species (taxonomy, life history, and habitat) and its ecological needs at the individual, population, and species levels based on how environmental factors are understood to act on the species and its habitat.

2. **Current Species Condition.** An SSA describes the current condition of the species habitat and demographics and the probable explanations for past and ongoing changes in abundance and distribution within the species ecological settings (i.e. areas representative of the geographic, genetic, or life history variation across the species range).

3. **Future Species Condition.** An SSA forecasts the species response to probable future scenarios of environmental conditions and conservation efforts. As a result, the SSA characterizes species ability to sustain populations in the wild over time (viability) based on the best scientific understanding of current and future abundance and distribution within the species ecological settings.

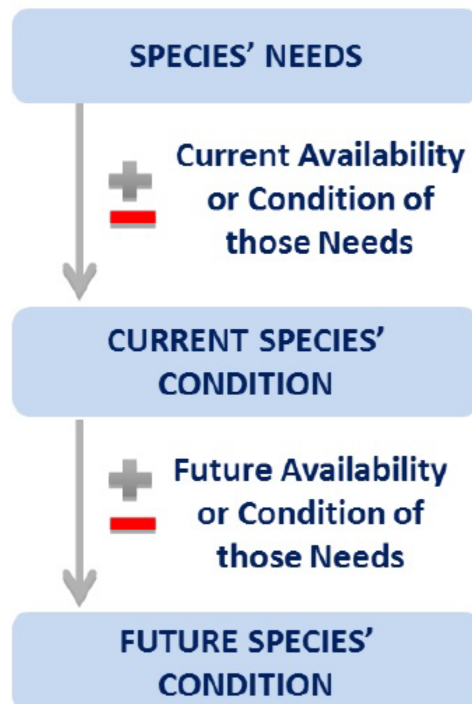

Figure 1. The Species Status Assessment framework

Throughout the assessment, the SSA uses the conservation biology principles of resiliency, redundancy, and representation (collectively known as the "3Rs") as a lens to evaluate the current and future condition of the species. Resiliency describes the ability of the species to withstand stochastic disturbance events, an ability that is associated with population size, growth rate, and habitat quality. Redundancy describes the ability of a species to withstand catastrophic events, an ability that is related to the number, distribution, and resilience of populations. Representation describes the ability of a species to adapt to changing environmental conditions. Measured by the breadth of genetic or environmental diversity within and among populations, representation gauges the probability that a species is capable of adapting to environmental changes. Together, the 3Rs—and their core autecological parameters of abundance, distribution, and diversity—comprise the key characteristics that contribute to a species ability to sustain populations in the wild over time. When combined across populations, they measure the viability of the species as a whole

Viability is not a static state, and thus we do not attempt to define the species as viable or not viable. In general, species with higher resiliency, redundancy, and representation, are better protected from stochastic and catastrophic impacts to the environment, can better tolerate threats and adapt to changing conditions, and are thus more viable than those with lower levels of the 3Rs. We assessed San Francisco gartersnake viability using the best available science to analyze the species' ecology, current condition, and potential future condition under a number of future scenarios, all in the context of the 3Rs.

Summary of New Information

Since our 2006 review of the San Francisco gartersnake status, we collected newly published peer-reviewed literature and unpublished reports, solicited information from partners and land managers, and reviewed information in our files. We also conducted a search of the California Natural Diversity Database (CNDDB) maintained by the California Department of Fish and Wildlife.

Our literature review and data solicitation resulted in new information on population abundance, including updated information on survival and population sex ratios. Ongoing studies related to initiation of a captive breeding facility, including abundance estimations and evaluation of genetic diversity and population structure, were instrumental in our evaluation of current condition and understanding of resiliency and representation. We also obtained new information about the species' response to wildfires. New information is incorporated into *Chapter 3. Species Ecology and Needs* and *Chapter 4. Historical and Current Condition*.

Uncertainties and Assumptions

This report incorporates the best available information through reports, peer-reviewed literature, and communication with species experts. When information is not available at the species level, we sometimes use surrogate species (generally other common gartersnake subspecies), but are always careful to make this clear throughout the report. In general, we lack information about movement and dispersal of the species, which makes defining a "population" difficult, therefore we emphasize that the way that we currently define population may change as more information becomes available. Many of the historical population occurrences have not been re-surveyed since the 1970s or 1980s, so we emphasize that this report uses the best available information including these historical records, more recent reports, and conversations with species experts.

Chapter 2. Background

In this section, we provide background about the San Francisco gartersnake, including taxonomic history and genetic information, a description of the species and how to distinguish it from similar species, and the historical and current range. The references cited within this section provide additional information pertaining to these topics.

Taxonomy

The San Francisco gartersnake is a subspecies of the common gartersnake (*Thamnophis sirtalis*), and is taxonomically defined as *T. s. tetrataenia* (Table 1).

Table 1. Taxonomic status of the San Francisco gartersnake

Class	Order	Suborder	Family	Genus	Species	Subspecies
Reptilia	Squamata	Serpentes	Colubridae	Thamnophis	sirtalis	tetrataenia

It was originally described and named as *Eutaenia sirtalis tetrataenia* (by Cope in Yarrow 1875, p. 546) based on a lectotype (name-bearing type specimen) that was likely from the San Francisco area but erroneously labeled as being from Pit River, California (Fox 1951, pp. 258-260). Fitch's (1940, p. 114; 1941, p. 570) studies of western gartersnakes changed the genus to *Thamnophis*, but added some confusion to the nomenclature/range because of the erroneously labeled lectotype discussed above (1941, pp. 581-589). The taxonomic history is reviewed in detail and clarified by Fox (1951, pp. 257-260). A subsequent change in the classification of the San Francisco gartersnake to *Thamnophis sirtalis infernalis* was published by Rossman *et al.* (1996, pp. 264-265; see also Boundy and Rossman 1995, pp. 236-239). Rossman *et al.* (1996, pp. 264-265) changed the subspecific name because of similarity between the holotype *T. s. infernalis* with specimens from within the range of *T. s. tetrataenia,* and because the name *T. s. infernalis* is considered the senior synonym. Barry and Jennings (1998, entire) submitted a proposal to the International Commission on Zoological Nomenclature to retain the name *T. s. tetrataenia*, which was accepted (ICZN 2000, p. 191).

Genetics

Multiple studies investigating San Francisco gartersnake genetic diversity and population structure have been undertaken or are currently underway. Janzen et al. (2002) and Lim et al. (2009) offer older analyses relating to species' phylogeography of the common gartersnake and San Francisco gartersnake, respectively. Ongoing analysis (Bauer *in litt*. 2019) on the phylogeography of common gartersnake subspecies in the North Bay, Central Valley, Peninsula, and South Bay, will use updated molecular techniques to address similar themes to Janzen et al. (2002).

The most comprehensive genetic work to date is a study that used genome-wide single nucleotide polymorphism (SNP) data to evaluate genetic diversity at seven sites throughout the range of the species and five additional "satellite" sites with smaller sample sizes (Wood *et al*. 2019, entire). Genetic diversity estimates were similar across six of the seven sites, with the Pacifica region being lower than the other sites. Analysis of a temporal dataset indicated an increase in differentiation, especially for the more isolated sites. Differentiation into northern and southern regional clusters was supported by phylogenetic, clustering, and genetic differentiation analyses. The northern cluster extends from Pacifica and San Bruno southward along the San Andreas rift valley, while the southern cluster includes sites from Mindego west and south to the coastal sites (Wood *et al*. 2019, pp. 18, 45). Additional substructure within these two regional groups was consistent with geographic features (e.g., the Santa Cruz Mountains) and fragmentation that left some populations more isolated than others. A site in the putative hybrid zone (see *Historical and Current Range* below) had membership coefficients with roughly equal proportions to both the northern and southern clusters. A phylogenetic analysis grouped this site into a mixed clade with other congeners of T. sirtalis, which was sister to a northern clade of San

Francisco gartersnakes corresponding to the northern cluster (Wood *et al*. 2019, pp. 18, 20). There was also evidence of increasing genetic isolation with geographic distance (Wood *et al*. 2019, p. 19).

Further information included in this draft report are included elsewhere in the SSA, including a discussion of effective population sizes in relative to abundance estimates (*Chapter 4. Current Condition*) and discussion of possible genetic management (*Captive Propagation in Chapter 5: Future Condition*). Genetic diversity within and among populations is also discussed in the context of Representation (in *Chapter 3. Species Ecology and Needs*).

Species Description

The San Francisco gartersnake is considered one of the most beautiful snakes in North America, with a greenish-blue or blue belly and red on the top of the head (Stebbins 1985, p. 200). Dorsal background color varies from dark brown to black with a wide cream, yellow, blue, or pale green dorsal stripe bordered on each side by uninterrupted red or brownish-orange stripes between black lateral stripes (Stebbins 1985, p. 200; Fox 1951, p. 260; Figure 2). Ventral color and width of dorsal stripe are individually and geographically variable. Neonates are duller in color than adults (Cover and Boyer 1988). Detailed descriptions, including scale counts, can be found in Fox (1951, pp. 260-261), Stebbins (1985, pp. 199-200), and Fitch (1980, pp. 1, 3).

In some populations, San Francisco gartersnakes have color patterns that are similar to a neighboring subspecies, the California red-sided gartersnake (*Thamnophis sirtalis infernalis*) (Figure 2). In the California red-sided gartersnake the lower black stripe is absent and a series of regularly spaced black blotches are contiguous with the upper black stripe, interrupting the red coloration (Service 1985, p. 4). Intergrades between the two subspecies may have a combination of characteristics associated with each (Barry 1996, p. 4). The San Francisco gartersnake can be distinguished from other syntopic (occurring in the same habitat at the same time) gartersnakes, including the Santa Cruz gartersnake (*T. atratus atratus*) and coast gartersnake (*T. elegans terestris*), based on color patterns including the red head and blue ventral color (Barry 1994, p. 10). Barry (1996, pp. 24-25) provides a key to distinguish gartersnakes found on the San Francisco Peninsula.


Figure 2. San Francisco gartersnake (left) and California red-sided gartersnake (right). In the San Francisco gartersnake, note the uninterrupted red stripe between black lateral stripes. The California red-sided gartersnake lacks the lower black stripe and has a series of regularly spaced black blotches that are contiguous with the upper black stripe, interrupting the red coloration. Photo credits: USFWS and Will Bauer.

The San Francisco gartersnake reaches a maximum total length of at least 120 cm (47 inches) for females, although the length more commonly reached is around 100 cm (Barry 1994, pp. 59-60). Male gartersnakes are smaller than females, attaining about 83 percent of female length and 55 percent of female weight (Fitch 1980, p. 1). Female common gartersnakes have shorter tails, relative to overall body length, than males (Rossman 1996, p. 262). Additionally, male common gartersnakes have knobbed keels on the scales above the vent (Stebbins 1995, p. 199).

Range and Distribution

Historical and Current Range

The San Francisco gartersnake is endemic to the San Francisco peninsula. The historical range extended from approximately the San Francisco-San Mateo County line south along the base of the Santa Cruz Mountains into northern Santa Cruz County (Fox 1951, p. 260; Service 1985, p. 9; Service 2006, pp. 4, 43-44). Within this area, populations may have principally occupied the Buri Buri Ridge along the San Andres Rift and south in an arc from the San Gregorio-Pescadero highlands west to Tunitas Creek. From here, San Francisco gartersnake populations extended along the west coastline of the Peninsula. A potential intergrade zone comprised of the San Francisco gartersnake and the California red-sided gartersnake stretches from Palo Alto north to the Pulgas region near Upper Crystal Springs Reservoir (Barry 1994, p. 55; Fox 1951, pp. 262-263; but see Barry 1978, p. 14). Genetic analyses suggested evidence of gene exchange within this region consistent with an intergrade zone, but additional sampling and analyses are necessary to further clarify taxonomic relationships and the extent of gene exchange or lack therof in this group (Wood et al. 2019, pp. 23-24).

A population at San Bruno Mountain may have once represented the northeastern portion of the range, though this record may have been the result of the translocation of individuals from other locations to San Bruno Mountain by amateur herpetologists in order to protect them from development at their original location (Barry 1994, pp. 27-28). The lack of aquatic habitat at San Bruno Mountain (currently or in early maps) supports the idea that the individuals seen here may have been translocated (Barry 1994, p. 27).

A comprehensive survey has not been conducted recently, but the last significant survey efforts are detailed here. Populations as identified by Barry (1978), the Recovery Plan (Service 1985), and McGinnis (1987) are presented in Figure 3. Because illegal collection is a historical and current threat to the species, we denote population occurrences on the map using general waypoints, but do not provide exact locations. Fox (1951, pp. 261, 264) recorded the species in approximately 11 locations throughout San Mateo County, which were mapped by Barry (1994, pp. 83-84). Extensive surveying across the known range of the species, including many of the sites listed by Fox as well as other potential habitat, occurred in the 1970s. From this effort, Barry (1978, pp. 5-9) identified 28 distinct colonies representing 12 populations. This survey defined a population as a group of snakes occupying a discrete creek or drainage (Barry 1978, p. 4). In the Recovery Plan, six significant populations were noted (Año Nuevo State Reserve, Pescadero Marsh Natural Area, San Francisco State Fish and Game Refuge, Sharp Park Golf Course, Cascade Ranch, and Milbrae); many of the colonies identified by Barry (1978) were not confirmed to be extant (nor were they confirmed to be extirpated, or not occupied) (Service 1985, pp. 15-16). Approximately one decade after Barry's (1978) survey, McGinnis (1987, pp. 1; 17-32) surveyed 52 distinct sites, finding the San Francisco gartersnake at 26 of them (note that these numbers are approximate—the report says both 52 and 53 sites, with the snake found at 24 or 26). Of these, 12 were previously unreported, while two of the populations described by Barry had been lost in that time (McGinnis 1987, p. 1). McGinnis (1987, pp. 17-32) grouped these occurrences into seven habitat complexes. At around the same time, thesis work by Barry documented the San Francisco gartersnake distribution from 1971 to 1983 throughout the San Francisco Bay area, including breeding localities in 59 locations in San Mateo County and individuals at an additional 19 sites (Barry 1994, pp. 15, 28-35). He considered a site to have a breeding population if gravid females and/or all age/size groups were represented (Barry 1994, p. 15).

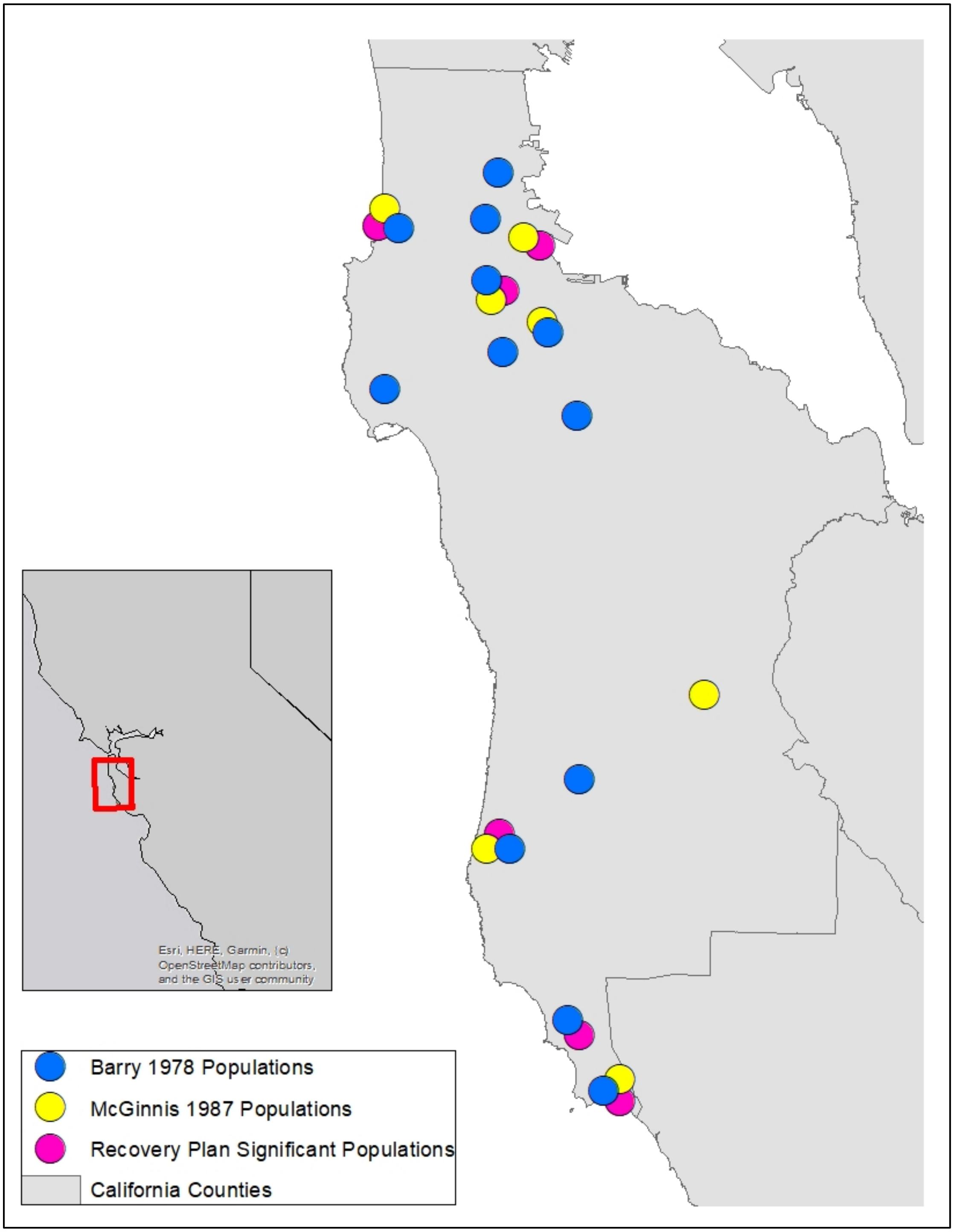

Figure 3. Populations of San Francisco gartersnake according to surveys by Barry (1978) and McGinnis (1987), as well as the six significant populations from the Recovery Plan. Locations are approximate.

Current San Francisco gartersnake populations are found on the San Francisco peninsula from San Mateo County to northwestern Santa Cruz County (Service 2006, pp. 43-44). The California Natural Diversity Database (CNDDB) includes 63 element occurrences that are presumed extant and four element occurrences that are extirpated (CNDDB 2018). Individual observations, populations, or colonies located within one-quarter mile of each other constitute a single occurrence, with some grouping multiple observations based on proximity. Less than one third of the CNDDB occurrences have updated information in the database since the last status review for the species. In addition to the historical records and known CNDDB occurrences, additional coastal property on the west side of the Santa Cruz Mountains may be inhabited by San Francisco gartersnakes (Service 2006, p. 5). However, because much of this property is privately owned, surveys are not available. Although the species is still distributed across most of its historical range (Barry 1978, pp. 1, 5-9; CNDDB 2018), much of the range has been fragmented or degraded by urbanization.

Population Complexes Used in the SSA

For the purposes of this SSA, we grouped populations into complexes. We do so in order to break the analysis into more manageable units for assessing condition, and because we have little information on movement and dispersal between sites. We use a combination of USGS subwatersheds (HUC 12; USGS *et al.* 2013), proximity, and ecoregions to delineate 13 population complexes (Figure 4). Some of these complexes likely contain populations that may have limited gene flow between them due to urbanization or habitat fragmentation.

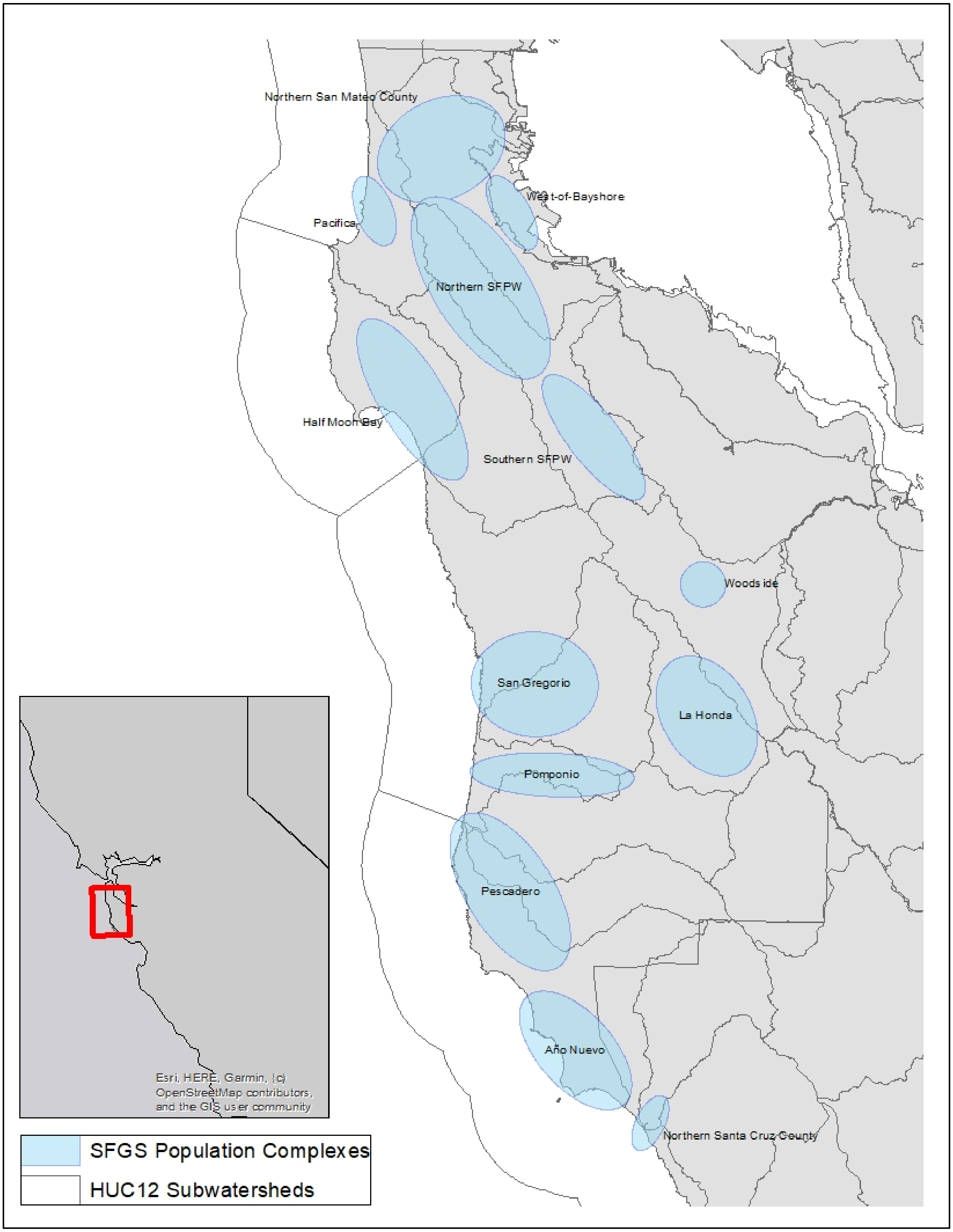

Figure 4. Population complexes used to assess population condition in San Francisco gartersnake resiliency analysis.

Although USGS subwatersheds form the main division defining our population complexes, we do vary from this categorization at times. Using USGS subwatersheds roughly aligns with previous descriptions of populations. For example, in one of the most extensive surveys of the species, Barry (1978, p. 4) described a population as all San Francisco gartersnakes inhabiting a discrete creek system or drainage. The Northern SFPW, Año Nuevo, and Pescadero population complexes include overlap of subwatersheds because of proximity between known occurrences, and communication with species experts regarding likely movement within these areas. We also grouped occurrences across watersheds for the Half Moon Bay and San Gregorio population complexes because of limited recent observations in these areas.

A description of each population complex, including known populations within each complex along with abundances and population trends, is included in *Current Condition*.

Chapter 3. Species Ecology and Needs

In this chapter, we provide biological information about the San Francisco gartersnake, including life history traits such as habitat needs, foraging ecology, and reproductive and demographic parameters. The references cited within this section provide additional information pertaining to the species.

Life History

Life Cycle

Life stages of the San Francisco gartersnake include neonates, juveniles, and sexually mature adults (Figure 5). Neonates are also referred to as newborns (e.g., Larsen 1994, p. 4), or young of the year (e.g.,(McGinnis 1988a), and juveniles as sub-adults (e.g., McGinnis 1988a, p. 15) or yearlings (e.g., Larsen 1994, p. 4). The general activity of these life stages is shown in Figure 6.

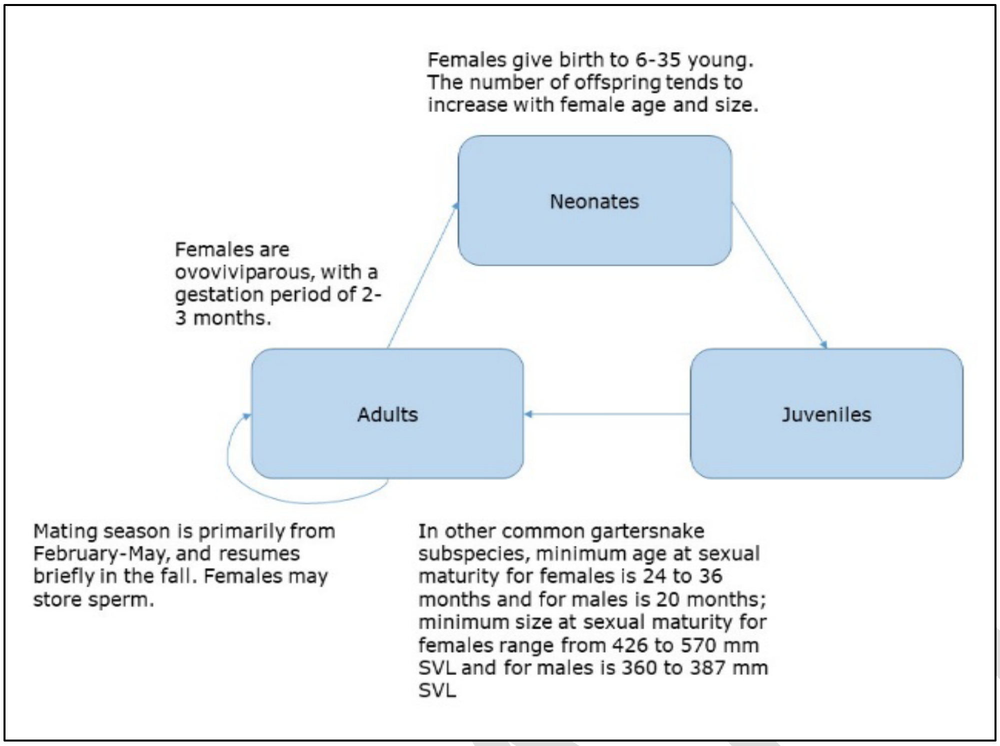

Figure 5. San Francisco gartersnake life cycle.

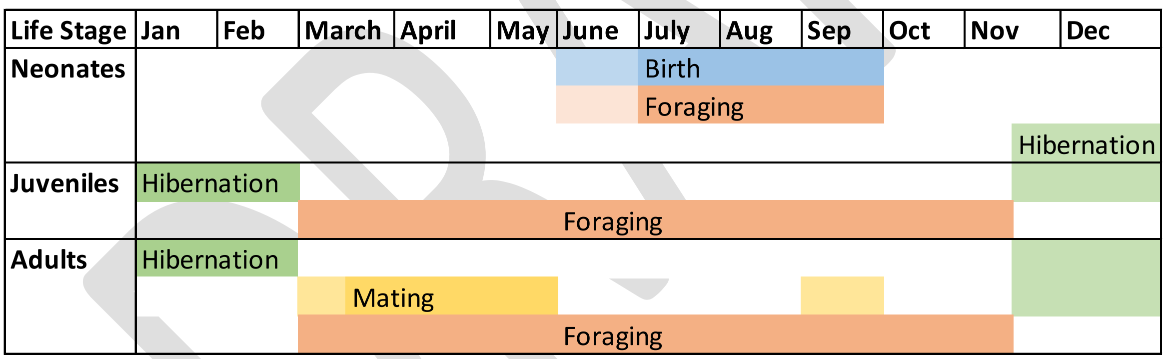

Figure 6. Gantt chart describing general activity of neonates, juvenile, and adult San Francisco gartersnakes throughout the calendar year. Paler colors indicate the limited observations of a given activity, while darker colors indicate the core months that the activities occur.

San Francisco gartersnakes are ovoviviparous (fertilized eggs develop within the female and the embryo gains no nutritional substances from the female). We do not consider eggs as a life stage because they are retained within the females when the neonates emerge. We consider neonates to transition to juveniles after emerging from their first hibernation, and juveniles to transition to adults based on sexual maturity.

Barry (1996, p. 14) further grouped San Francisco gartersnake age according to size following guidelines based on Fitch's (1965) common gartersnake data (Table 2).

Table 2. Age classification of San Francisco gartersnake based on size.

Sex	Snout-vent length (SVL)	Age
Males and females	< 300 mm	1 year or less
Males	301-400 mm	1-2 years
Males	401-500 mm	2-3 years
Males	>500 mm	More than 3 years
Females	301-500 mm	1-2 years
Females	500-600 mm	2-3 years
Females	601-650 mm	3-4 years
Females	>650 mm	More than 4 years

In other common gartersnake subspecies, minimum age at sexual maturity for females is 24 to 36 months and for males is 20 months; minimum size at sexual maturity for females range from 426 to 570 mm SVL and for males is 360 to 387 mm SVL (summarized in Rossman *et al.* 1996, pp. 77-78). In the San Francisco gartersnake, the minimum size at sexual maturity for females is 368 mm (Reeder *et al.* 2015, p. 83). Barry (1996, p. 58) observed all gravid (carrying eggs) females to be at least 2 years old, with older females having higher incidence of gravidity. Although there is little information on reproductive frequency of the San Francisco gartersnake, data on other common gartersnake subspecies suggest that most females probably reproduce each year (Rossman *et al.* 1996, pp. 58-59, 65).

The mating season for the San Francisco gartersnake extends from February into May, and resumes briefly in the fall (Barry 1996, pp. 56-57). Most, but not all, gartersnake species males are ready to mate immediately upon emergence from the hibernacula (Rossman *et al.* 1996, p. 60), and male common gartersnakes probably use pheromone trails to find females (reviewed in Ford 1986, pp. 262-265). Mating aggregations with multiple San Francisco gartersnake males attending a single female have been observed, mainly during the fall (Fox 1955, p. 176; Barry 1996, pp. 56-57). Presence of sperm in cloacal smears within days of emerging from hibernacula indicates that females are mated quickly (Barry 1996, p. 56). The San Francisco gartersnake is likely similar to other subspecies of common gartersnake in the ability to store sperm, which can lead to multiple paternity clutches (Friesen *et al.* 2014, pp. 36-37).

Females give birth in the summer (Barry 1996, p. 96) after a gestation period of 2 to 3 months (Halstead *et al.* 2011, p. 43). When San Francisco gartersnake neonates are born, the shell structure has been reduced to a thin mucous membrane or in some cases has broken through so that it appears that they are born live. Brood size is variable, ranging from six to 35 young (Barry

1996, p. 2; Cover and Boyer 1988). The number of offspring generally increases with female age and size (Barry 1996, p. 59).

Habitat and Activity Patterns

San Francisco gartersnakes are often found in or adjacent to aquatic habitats in association with a terrestrial niche, requiring both shallow freshwater habitat and contiguous uplands, meadows, or riparian habitat (McGinnis 1987, pp. 7-8; McGinnis *et al.* 1987, pp. 8-10, Barry 1996, p. 19). San Francisco gartersnakes have been found in meadowlands up to 2 km (6562 feet) from marshland (Barry 1996, p. 30). Habitat diversity has been positively correlated with occupancy across multiple years at trap arrays, particularly for those located near water (Kim *et al.* 2018, pp. 50-54).

Aquatic habitat, including sag ponds, creeks, marshes, canals, and other water sources, is used for foraging and basking, with requirements related to water depth, inundation period, salinity, and associated vegetation. Water was the primary factor correlated with San Francisco gartersnake presence at a site, with optimal aquatic habitat having a shallow inshore zone and maintaining an average depth of 0.5 m (1.5 feet) throughout the year (McGinnis 1987, pp. 7, 16). The species tends to avoid aquatic habitat with steeply sloped banks (Barry 1996, p. 40). Even artificial aquatic habitats (e.g., reservoirs) can attract San Francisco gartersnakes within a year of development of the habitat (Barry 1996, p. 42), and they are also thought to use less ideal waterbodies, such as irrigation ditches, for foraging (McGinnis pers comm. 2007). Freshwater is important, as salinity can limit presence of the snake's amphibian prey and can influence the growth and/or composition of aquatic vegetation (McGinnis 1987, p. 7; Larsen 1994, pp. 56, 81-83). Vegetative cover, including emergent vegetation and floating aquatic vegetation, is important for feeding and basking (Barry 1994, pp. 40-42, 50; McGinnis 1987, p. 8). Dense cover around or within the freshwater site is also essential for snakes to retreat to when disturbed (McGinnis 1987, p. 8; Fox 1951, p. 264). Aquatic vegetation often consists of a wide band around a pond edge or dense reed-shrub cover throughout a marsh (McGinnis 1987, p. 16; Figure 7), but the species will also use aquatic habitat with sparser emergent vegetation if sufficient cover occurs adjacent to the water (Halstead *in litt.* 2019). Along streams, riparian vegetation often overhangs the edge of habitat including extending upland away from the stream edge, with snakes selecting areas with no clearance between the water and overhanging vegetation (Barry 1996, pp. 26-27). Movements between aquatic habitats (McGinnis 1988a, pp. 24-25) sometimes involve a shift between ephemeral and permanent water sources, with San Francisco gartersnakes shifting resource use to ephemeral marshes during the spring (e.g., Wharton *et al.* 1987, p. 9; McGinnis 1987, p. 23). Aquatic habitat features are discussed further in McGinnis (1987, pp. 7-17) and Barry 1996 (pp. 25-28).

Figure 7. The Visitor Center Pond at Año Nuevo State Park has a wide band of emergent aquatic vegetation as well as thick vegetative cover adjacent to the pond.

The San Francisco gartersnake uses terrestrial habitat that is contiguous to aquatic habitat to regulate its body temperature (thermoregulate), estivate, find cover, forage, mate, and hibernate. San Francisco gartersnakes bask in grasslands, at rodent burrow entrances, on trails, in and under vegetation, in or adjacent to water, and on pond banks (McGinnis 1987, pp. 8-10, 13; Larsen 1994, pp. 69, 98). Grasslands with scattered shrubs provide the best terrestrial habitat (Barry 1994, pp. 42-43, 102), and habitat complexity or heterogeneity is associated with San Francisco gartersnake habitat use (Kim *et al.* 2018, pp. 39, 48). Fox (1955) observed mating aggregations of San Francisco gartersnakes on open grassy slopes in the fall, but only observed mating pairs in spring. San Francisco gartersnakes avoid potentially lethal cold autumn and winter temperatures by moving underground into hibernacula (a place where an animal seeks refuge, or shelter during dormancy) including mammal burrows, crevices, or other voids in the earth. Hibernacula sites are typically open meadowlands with rodent burrows within 1.2 km (3937 feet) of aquatic foraging habitat (Barry 1996, p. 41). The snakes typically select burrows on gentle slopes (Barry 1996, p. 41). Barry (1996, p. 41) suggested that western or southern exposures are preferred. However, San Francisco gartersnakes tracked in a radio telemetry study were found on both northern and southern slopes (McGinnis 1988a, pp. 21-22). Slopes with eastern exposure were avoided (McGinnis 1991, p. 5).

San Francisco gartersnakes begin seeking winter retreats in mid to late November, (Barry 1996, p. 54), and there is some evidence for communal hibernacula (McGinnis *et al.* 1987, p. 10; Wharton *et al.* 1987, p. 9). Foraging and other activities are sporadic at this time and dependent upon weather conditions. However, some individuals emerge from hibernacula to bask, or move short distances, on warmer winter days (Barry 1996, p. 54). San Francisco gartersnakes typically begin emerging from winter retreats in late winter or early spring and are most active from early spring through mid-fall. They appear to move from hibernacula sites to marshlands relatively quickly upon emerging (Barry 1996, pp. 50-54).

Activity and habitat use vary based on season and individual characteristics including sex and age. Most activity occurs during daylight hours (Barry 1996, p. 54), although nocturnal activity has been observed in this subspecies (Biosearch Associates 2005, p. 6) and in at least one other subspecies of common gartersnake (Hansen and Tremper in prep in Rossman *et al.* 1996, p. 267). In summer, snakes are active throughout the day, while in fall and spring the snakes are most active in the early morning and late afternoon (Barry 1996, p. 54). Barry (1996, p. 56) reported a relative scarcity of male San Francisco gartersnakes near foraging habitat in the spring. Females are often found close to water towards the end of gestation even though gartersnakes stop feeding in the latter half of this period (Fitch 1965 in Barry 1996, p. 52). Barry (1996, p. 52) suggests that this habitat use may be adaptive because neonate snakes rely on newly-transformed amphibian food sources near water and are most commonly found close to the water's edge (Barry 1996, pp. 52, 59). Males tend to emerge from hibernacula about two weeks earlier than females (Barry 1996, p. 50). They also tend to emerge downslope from females, suggesting that hibernacula site choice may vary based on sex or other factors (Barry 1996, p. 50).

Diet

San Francisco gartersnakes use both visual and chemical cues to forage, feeding primarily on California red-legged frogs (*Rana draytonii*) and Sierran treefrogs (*Pseudacris sierra*; also Sierran chorus frog) (Larsen 1994, pp. 71-80; McGinnis 1987, p. 11). Note that the California red-legged frog was formerly considered a subspecies of *R. aurora* (Shaffer *et al.* 2004, pp. 4-6), and that Sierran treefrogs were formerly lumped with Pacific treefrogs (*P. regilla*; Recuero *et al.* 2006a, p. 296; Recuero *et al.* 2006b, p. 511; formerly *Hyla regilla*). Both prey types are commonly referred to by their former nomenclature in the San Francisco gartersnake literature, but hereafter we will refer to them as red-legged frogs and treefrogs, respectively. Barry 1996 (pp. 36-38) argues that American bullfrogs (*Lithobates catesbeianus*) may adequately replace red-legged frogs in the San Francisco gartersnake diet at some sites. However, the benefit of bullfrogs is debated by other researchers that argue that the presence of bullfrogs is negative because of their complicated role as prey, predator, and competitor (Larsen 1994, pp. 88-89; Kim 2017, pp. 28, 37; see *Predation* below). San Francisco gartersnake density is loosely correlated with ranid frog density: sites with higher frog densities often have higher snake densities, with the caveat that some sites may have frogs present but not snakes (Barry 1996, pp. 45-49). Other prey taken to a lesser degree include western/California toad (*Anaxyrus boreas halophilus*) (Service 1985, p. 7), slender salamander (*Batrachoseps attenuatus*) (McGinnis 1987, p. 27), small fish (Wharton *et al.* 1987, p. 16; Larsen 1994, p. 78), newts, annelids, and even rodents (Barry 1996, pp. 2, 31, 34). San Francisco gartersnakes are able to eat newts because they are highly resistant to the effects of the neurotoxin (tetrotoxin) that newt skin contains (Brodie, Jr. *et al.* 2002, p. 2071).

As in other species of gartersnakes (Lind and Welsh 1994, pp. 1266-1267), diet varies based on snake age and size and on prey availability (Kim 2017, pp. 28-29, 38-39). Neonate and juvenile

San Francisco gartersnakes depend heavily upon juvenile treefrogs as prey because of their small size, and newly metamorphosed treefrogs are especially important for newborn snakes (Larsen 1994, p. 73; Barry 1996, p. 34). Tadpoles trapped in seasonally drying pools can be especially abundant and are readily consumed (Wharton *et al.* 1987, p. 18). Treefrogs are of primary importance to snakes up to 500 mm (19.7 inches) snout-vent length (SVL), while adults greater than 500 mm SVL forage mainly on tadpole and adult red-legged frogs (Barry 1996, p. 34). Only large adults are capable of eating American bullfrogs (Barry 1996, p. 34). As with other gartersnake species (Seigel 1984 in Rossman 1996, p. 70), the San Francisco gartersnake diet and foraging habitat varies seasonally based on the life cycle of its amphibian prey (Barry 1996, pp. 51-54, 129). Foraging on other species is likely largely related to availability. Snakes will readily take fish in shallow water but may have difficulty catching fish in water deep enough for them to swim (Larsen 1994, p. 78). Newts comprise about half of the diet of neonate San Francisco gartersnakes from at least one site, while at other sites this prey item is completely absent (Barry 1996, pp. 34-35).

Natal food tests demonstrated that juveniles have innate preferences for amphibians and fish, with treefrogs eliciting the highest response (Larsen 1994, p, 52). In contrast, they showed no feeding response when presented with the scent of slugs, mice, or insects (Larsen 1994, p. 72). Although the juveniles had a strong positive response to the scent of earthworms, when presented with them as potential prey some snakes refused to eat them (Larsen 1994, p. 77).

Movement and Dispersal

To our knowledge there are no data on connectivity or dispersal between population sites despite trapping studies and application of radio tags at several sites. Movement and dispersal uncertainty are highlighted by studies at some sites that model population dynamics using both open and closed population assumptions (e.g., Kim *et al.* 2018, p. 9). Within sites, low numbers of recaptures and/or captures at ponds separated by hundreds of meters suggest that the snakes can be relatively transient (McGinnis 1988, pp. 17-18). The use of drift fences to capture individuals moving between habitat patches revealed movement in both directions (Wharton *et al.* 1987, p. 14), but it is not known if this pattern persists between populations. Although little data exists on home range size of San Francisco gartersnakes, Barry (1996, p. 23) suggests that home ranges may average several hectares.

Data from telemetry and mark-recapture studies indicate that San Francisco gartersnakes may be highly mobile during the spring but then stay in the same area for the rest of the year (Larsen 1994, pp. 67-68). A male recaptured in both 2013 and 2017 in the same trap line demonstrates this tendency to stay in the same area (Swain Biological, Incorporated 2018, p. 29). Most recaptures occurred within 167 m (550 feet) of each other (Larsen 1994, p. 40), with one female moving up to 671 m (2200 feet) and a male moving 632 m (2075 feet) (Larsen 1994, p. 38). Recaptures of females at the West-of-Bayshore (WOB) site showed a 1606 m movement over 22 days by an adult and of 1061 m over 3 days by a juvenile (Swaim Biological, Incorporated 2018, p. 21). In contrast, a closely related subspecies, the red-sided gartersnake (*Thamnophis sirtalis parietalis*), dispersed up to 17.7 km (11.0 mi) when going to or from hibernacula (Gregory and Stewart 1975, p. 240). Genetic data indicates male-biased dispersal, based on variation between populations supported by haplotypes (mitochondrial DNA representing females) verses variation within populations supported by microsatellite DNA (representing both males and females) (Lim *et al.* 2009, pp. 5-8; Lim *in litt.* 2019).

Survival

There is little information about survival in San Francisco gartersnakes, and the available information suggests that survival rates vary across populations or years. Trapping data indicates that, in at least some populations, survival is high, with annual survival of 0.88 and 0.82 across two years in one population (Halstead *et al.* 2011, p. 44). However, survival appears to vary across years, ranging from 0.29 to 0.64 across a four-year study in another population (Kim *et al.* 2018, pp. 33-34). Trapping in 2007, 2013, and 2017 at the WOB site yielded 0 recaptures between the first two sampling years and 4 recaptures between the latter, suggesting that survival at the site may be low in comparison to the survival found in Halstead *et al.* 2011 (Swaim Biological, Incorporated 2018, pp. 46-47). Similarly, there were no recaptures in re-trapping across two year surveys at Mori Point in 2004, 2006, and 2008, again potentially suggesting low survival rates (Swaim Biological, Incorporated 2009, pp. 13-14). Barry 1996 (pp. 61, 114) found that under ideal conditions about 27 percent of neonate females survive to reproduce once, and only 2 percent survive to age 5, assuming about 50 percent survival after 2 years of age. In other gartersnake species, survival varied with age class. Survival of *Thamnophis sirtalis fitchi* neonates across two years was 29 and 43 percent, survival of yearlings was about 50 percent, and survival of individuals greater than 2 years old was 33 percent (Jayne and Bennett 1990, pp. 1209-1217).

Sex ratios

The Recovery Plan calls for populations with a 1:1 sex ratio (Service 1985, p. 18). The 2006 status review for the species questioned the appropriateness of that criterion because, although San Francisco gartersnake sex ratios were unknown at the time, available information for the red-sided gartersnake (*Thamnophis sirtalis parietalis*) indicated strongly male-biased sex ratios (Service 2006, p. 4; Shine *et al.* 2001, p. 84). Additional information on the relative numbers of male and female San Francisco gartersnakes since the status review indicate that populations have approximately equal numbers of males and females (e.g., Rose *et al.* 2018, p. 4), although sex ratios varied somewhat across sites. While sex ratios did not significantly differ from 1:1 at any site, populations in northern regional sites were more female-biased while populations in southern regional sites were more male-biased (Wood *et al*. 2019, p. 17). When sex ratios were compared to census sizes instead of region, female-biased populations were also associated with lower abundances (Wood *et al*. 2019, pp. 26-27). The authors' postulate that this might be due to lower survival in males due to time spent in mate-searching and courtship in low density populations, or to other factors such as potential habitat vs. survey area.

Seasonal activity may vary by sex, age class, season, or trapping method, which all have the potential to influence observed sex ratios (Reeder *et al.* 2015, p. 84). Recent studies use models that include the effect of sex on capture probability to predict population sex ratios more accurately (e.g., Reeder *et al.* 2015, p. 80). For example, although observed sex ratios (males: females) were 0.81 and 1.33 males to females in two years of trapping in one population, the modeled sex ratios in those same years was skewed towards females at 0.76 and 0.77 males to females, respectively (Reeder *et al.* 2015, pp. 80-81). Overall, available data from trapping studies show that sex ratios may fluctuate in some locations or years but do not appear to be significantly different from 1:1 (Table 3). In a recent demographic study, the overall sex ratio was not significantly different from 1:1, although more females were captured (Rose *et al.* 2018, p. 4). As a result, the 1:1 sex ratio is still considered appropriate in this SSA.

Table 3. Observed proportion of male San Francisco gartersnakes in various populations. Observed proportions are based on the proportion of males to females captured, with 0.5 being an equal proportion of males and females. This measure differs from the male:female sex ratio, another demographic measurement used in some studies, where 1:1 would represent an equal number of males to females.

Population	**Observed proportion of males**	**Years**	**Source**
Mindego Ranch	0.41-0.66	2014-2017	Kim et al. 2018, p. 25
West-of-Bayshore[1]	0.45, 0.57, 0.53	2007, 2013, 2017	Swaim Biological, Inc. 2018 pp. 29, 37
Cloverdale	0.43-0.62	2008-2010, 2014-2018	Halstead et al. 2011, p. 44; Kim et al. 2017, p. 4; Rose et al. 2018, p. 10
Pearson Ranch[2]	0.59, 0.77	1987, 1988	McGinnis 1988, p. 19
Ano Nuevo Visitor Center Pond	0.53	2018	Rose et al 2018, p. 10
Ano Nuevo BART	0.50	2018	Rose et al 2018, p. 10
Mori Point/Sharp Park	0.36	2018	Rose et al 2018, p. 10
Skyline Wetlands	0.27	2018	Rose et al 2018, p. 10
Tracy Lake	0.33	2018	Rose et al 2018, p. 10

[1]2007 and 2013 numbers reflect adults only, 2017 reflects adults and juveniles

[2]proportions reflect adults captured; also captured 4 juvenile males each year

San Francisco Gartersnake Needs

In this section, we summarize the life history information available for the species and translate these data into needs at the individual, population, and species levels. For individual San Francisco gartersnakes, we summarize the general habitat resources or conditions that adults, juveniles, and neonates need to complete each stage of their life cycle. Next, we describe the habitat and demographic conditions that resilient populations require. Finally, we describe what the species needs for viability in the context of the 3Rs.

Individual Needs

Individual San Francisco gartersnake needs vary by life stage (Table 4). San Francisco gartersnakes need permanent freshwater habitat with dense aquatic vegetation and adjacent upland habitat with rodent burrows for estivation. Amphibian prey support their caloric needs throughout the active season. Because males tend to emerge from estivation earlier in the year than females, they may need amphibian prey earlier in the year than females. Males may forage further from aquatic habitat, often traveling into marshlands to pursue treefrogs, while gravid females tend to stay close to water. Gravid common gartersnakes typically do not feed during the latter half of gestation (Fitch 1965 in Barry 1996, p. 52), which may also be the case for San Francisco gartersnakes. Barry (1996, p. 52) suggests that gravid females are found in dense vegetation near water because neonates rely on newly metamorphosed treefrogs upon parturition (when females give birth to offspring). Adults over 500 mm SVL are particularly reliant on red-legged frogs to sustain their caloric needs (Barry 1996, p. 28), while individuals in smaller size classes primarily forage on treefrogs. Adults also need to be able to find mates to complete their life cycle (although females can store sperm, so mating every year may not be a requirement). Neonate and juvenile needs are largely the same as adults (but note differences in prey based on size), with the exception that they do not need to find mates.

Table 4. Resource needs for individual San Francisco gartersnakes. Resources functions include feeding (F), sheltering (S), breeding (B), and dispersal (D).

Resource	Life Stage	Resource Function
California red-legged frogs	Adults	F
Pacific tree frogs	Adults, Juveniles, Neonates	F
Tertiary prey sources (e.g., newts)	Adults, Juveniles, Neonates	F
Shallow freshwater habitat with emergent vegetation	Adults, Juveniles, Neonates	F, S, D
Open grassy uplands	Adults, Juveniles, Neonates	F, B, D
Hibernacula (e.g., rodent burrows)	Adults, Juveniles	S

Individual San Francisco gartersnakes must be able to move freely between aquatic habitat and upland habitat. In areas with both permanent and ephemeral water sources, movement corridors between these habitat patches are essential for the snake.

Population Needs

For the purposes of this SSA, we define a population of San Francisco gartersnake as spatially connected colonies that have breeding male and female snakes. In previous surveys of the species, a population was typically described as all San Francisco gartersnakes inhabiting a discrete creek system or drainage, with colonies making up specific habitats in a certain area within the population (Barry 1978, p.4). This definition assumed that there is more interchange within waterbodies than between. Because we have little information on movement and dispersal between populations, we group San Francisco gartersnake populations into population complexes (as described in *Historical and Current Range and Distribution* above). For simplicity, we describe needs at the population level rather than the complex level, with the understanding that complexes have the same needs as those described for populations below, but on a larger spatial scale.

Population Resiliency

Resiliency describes the ability of the species to withstand stochastic disturbance events, an ability that is associated with habitat quality to support particular demographic characteristics. Populations rely on the same habitat resources as individuals (Table 4), but in such a quantity and configuration to support demographic characteristics associated with resilient populations (Figure 8). For example, because females >500 mm SVL are the most productive reproductive cohort (Barry 1996, p. 29), the presence of red-legged frogs (the preferred food for females of this size) is important for population resiliency. Treefrogs are important prey sources for neonates and juveniles, thus are important for recruitment into the population. Although freshwater habitat used by San Francisco gartersnakes can include a variety of waterbodies including sag ponds, creeks, marshes, canals, and other water sources, resilient populations require impounded freshwater with appropriate aquatic vegetation. For example, the use of creek habitats by San Francisco gartersnake is less understood, and those creek systems that do support the species all contain naturally or artificially impounded water (McGinnis 1988b, p. 1). Demographic characteristics of resilient populations are related to abundance, fecundity, and survival. Resilient populations should have at least 200 adults with an approximately 1:1 sex ratio of males:females, a number that was identified as being sufficient for a resilient population in the Recovery Plan (Service 1985, p. 18). High levels of fecundity can drive population growth, which also benefits from survival across age classes. Survival of neonates is important for recruitment into the population, and survival of juvenile females into breeding adults is important in maintaining reproductive individuals in the population. High levels of fecundity and survival can also allow populations to recover from stochastic events such as drought that can temporarily reduce amphibian prey. Because of associations between age class structure and the demographic needs of fecundity and survival, age class structure can be used as a proxy to assess fecundity and survival in the population. Presence of gravid females, and of neonates, are both signs of a healthy breeding population. Survival of neonates, juveniles, and adults is important in maintaining a diverse age class structure of the population. Large females are necessary for breeding in the population, and small individuals demonstrate recruitment into the population.

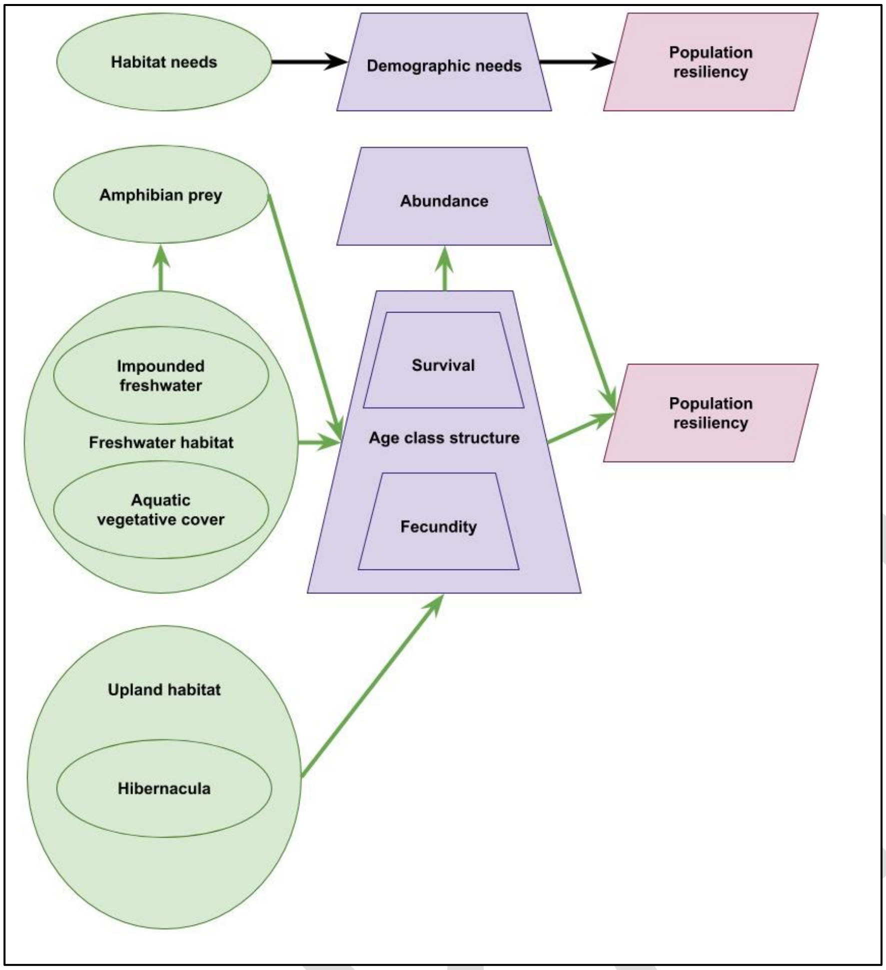

Figure 8. Influence diagram modeling population habitat and demographic needs that promote resiliency for the San Francisco gartersnake.

Species Needs

Maintaining ecological and genetic diversity (representation) by having resilient populations distributed throughout the species' range (representation and redundancy) facilitates adaptation to changing environmental conditions and the ability to withstand catastrophic events.

Redundancy

Redundancy describes the ability of a species to withstand catastrophic events, a measure that is related to the number, distribution, and resilience of populations. Potential catastrophic events that might affect the San Francisco gartersnake include earthquakes (if they led to destruction of dams on the San Francisco peninsula), saltwater inundation into freshwater habitat, long-term drought, or other large-scale losses of amphibian prey for the species.

The Recovery Plan states that the San Francisco gartersnake needs 10 resilient populations that display a breadth of genetic diversity across its range for delisting to be considered (Service 1985, p. 18). These populations should be distributed throughout the species range to maximize genetic and ecological representation of the species.

Representation

Representation describes the ability of a species to adapt to changing environmental conditions, which is related to the breadth of genetic and ecological diversity within and among populations. A species with more representation, or diversity, is more likely to adapt to and persist with natural or human-caused changes to its environment.

Historically, the species' range likely consisted of interconnected populations throughout the San Francisco peninsula that would have been resilient to stochastic events such as drought. Even if some populations were extirpated by such events, they could be recolonized over time by dispersal from nearby surviving populations. This connectivity would have contributed to species' representation. However, under current conditions, restoring that connectivity across the peninsula is not feasible due to extensive urbanization. Instead, it is important to have highly resilient populations distributed throughout the species range, and to preserve the genetic and ecological diversity present in extant populations in order for the species to adapt to stochastic changes in the environment.

Across the species range, there is genetic variation separating northern San Francisco gartersnake populations from more southern populations, and ecological variation moving inland from the coast and upward in elevation. Recent genetic analyses show that the species largely clusters into two groups throughout its range, a northern and a southern cluster. Reduction in gene flow between these clusters as a result of both isolation and geographic or habitat limitations suggests managing these regional groups as separate genetic units (Wood *et al*. 2019, p. 23), and maintaining resilient populations across these clusters is important for species representation. Only one population in the genetic analyses occurred at high elevation, and this site is genetically differentiated from other populations in the southern cluster (Wood *et al*. 2019, p. 19). Other than this site, there is limited information about the species' potential distribution at higher elevations, although it has the potential to be an important example of ecological diversity within the species. Other ecological settings vary somewhat as the populations move further from the coast, and there may be ecological adaptations to this variation. Temperature may vary between inland and coastal sites, and may covary with fog levels. Temperature can influence growth rate of ectotherms (animals that depend on external temperatures for body heat) such as the San Francisco gartersnake. For example, in experimental enclosures in two different habitat types, gravid female common gartersnakes grew faster when they had warmer body temperatures (Halliday and Blouin-Demers 2018, p. 26). Growth rate is an important consideration because snakes that grow faster may reach reproductive status more quickly or grow into size classes that are less vulnerable to predation. Anecdotally, the San Francisco gartersnake has a higher mean body size at an inland ranch compared to a coastal ranch (Kim *in litt.* 2019), which could be related to temperature or other differences between the sites. At the WOB site, biologists noted that size distribution of individuals seems to have downshifted compared to capture records from the 1980s (Swaim Biological, Incorporated 2018, pp. 26-27). However, this downshift could be related to habitat conditions, habitat quality, interspecific competition, or other unknown factors rather than temperature. Other variation in climatic conditions throughout the species range includes variation in precipitation, which can influence aquatic features and amphibian prey. Treefrog seasonal activity can vary based on temperature, availability of water, and elevation

(Brattstrom and Warren 1955, p. 188). If some sites support multiple clutches of treefrogs per year (see Perrill and Daniel 1983, entire), this could increase prey availability and subsequent recruitment in San Francisco gartersnake populations. Maintaining resilient populations across the north-south and east-west distribution of the species range would conserve the relevant genetic and ecological diversity within the species, thus maintaining current levels of representation.

Additionally, behavioral variation between populations may be important. Although red-legged frogs and treefrogs are the primary food sources for the species, for at least some sites, newts make up a significant proportion of the diet (Halstead *in litt*. 2019). This variation and flexibility in diet is important to maintain. Although there is morphological variation in appearance within and between populations, it is unclear at this time if morphological variation adds to species representation.

Summary of Species Ecology and Needs

Individual San Francisco gartersnakes need access to sufficient food and habitat in order to maintain resilient populations. Populations need to be resilient to be able to withstand periodic natural disturbances, such as drought. At the population level, survival of juveniles to the minimum size for reproduction is essential to drive population growth, as is survival of reproductive females. Distribution of resilient populations throughout the range enables the species to be able to withstand catastrophic events (redundancy) and adapt to changing environmental conditions (representation) to sustain populations in the wild over time (viability) (Table 5).

Table 5. Summary of individual, population, and species' needs for the San Francisco gartersnake in terms of the 3Rs.

Level	Need	Function of Need	Association with 3 Rs
Individual and Population Habitat Needs	Amphibian prey (red-legged frogs, treefrogs, and other tertiary prey items)	Provides caloric needs for hatchlings, juveniles, and adults	Resiliency
	Freshwater habitat with dense aquatic vegetation	Provides sites for foraging; refugia	Resiliency
	Upland habitat	Provides sites for thermoregulation, estivation, and hibernation	Resiliency
	Hibernacula	Provides sites for refugia, thermoregulation, and hibernation	Resiliency
Population Demographic Needs	Abundance	Prevents inbreeding depression	Resiliency

	Survival	Promotes abundance; allows adults to become reproductively capable	Resiliency
	Fecundity/recruitment	Drives population growth	Resiliency
Species Needs	Resilient populations across the species' range	Improves species viability by spreading risk associated with catastrophic events	Representation, Redundancy
	Maintenance of multiple resilient populations within both genetic clusters in the species range	Maintains adaptive capacity of the species	Representation

Chapter 4. Current Condition

Historical and Current Abundance and Trends within Population Complexes

Little is known about historical abundances of the San Francisco gartersnake. The species was listed as endangered prior to any systematic range-wide survey effort or population studies, and extensive urbanization led to the extirpation of some populations prior to this effort (Barry 1978, p. 6).

Below, we summarize available data? on San Francisco gartersnake population complexes, including abundance and population trends for those areas for which we have information. Note that some figures or numbers are the actual number of individuals that were observed or trapped, while other figures or numbers denote modeled abundance estimates. Population complexes are roughly organized from north to south. Those that are previously reported in Service publications (the Recovery Plan and Status Reviews) or the literature are identified in the report by their proper geographic name (e.g., the Año Nuevo State Park Visitor Center pond). However, those occurring on private land or in previously undisclosed locations are referenced vaguely (e.g., two ponds on a private ranch) because of the ongoing threat of illegal collection.

Northern San Mateo County

This complex includes the sag ponds along Skyline Boulevard where Fox sampled extensively, which were the most abundant population on record (Fox 1951, p. 264; Barry 1994, p. 26). In two years of sampling beginning in 1947, Fox collected at least 230 individuals in just 25 visits, leading Barry (1994, p. 26) to estimate that the population must have contained over 1000 individuals in a small geographic area. This complex is now considered extirpated. We include this population complex to include the complete historical range, but do not expect that habitat factors in this area will ever be sufficient to support resilient San Francisco gartersnake populations in the future.

Pacifica

Within Pacifica, San Francisco gartersnake population records exist for Laguna Salada and Mori Point. Although the historical records for Laguna Salada and Mori Point treat these areas as two separate populations, the only feature that distinguishes them is a property line. Laguna Salada is a managed waterbody within the Sharp Park Golf Course, owned by the City of San Francisco. Translation of Laguna Salada as "Salty Lake" suggests that the area historically consisted of a coastal lagoon with seasonal freshwater accumulation (Philip Williams & Associates, Ltd. *et al.* 1992, p. 2). Mori Point is a 32-hectare undeveloped coastal bluff that is part of the Golden Gate National Recreation Area. Additional history of the sites is detailed by Phillip Williams & Associates, Ltd. *et al. et al.* (1992, entire) and Swaim Biological, Incorporated (2009, pp. 1-4).

Most San Francisco gartersnake survey estimates at Laguna Salada and Mori Point are reported in raw observation numbers, but do not attempt to estimate actual population abundance at the site. The population at Laguna Salada was first documented in 1946 by Fox (1951, p. 264), who collected 44 specimens in 1946 and 1947 (CNDDB 2018). A subsequent population decline was associated in part with illegal collection (Barry 1978, pp. 12-13). Laguna Salada was subject to saltwater intrusion in the 1980s, reducing habitat for amphibian prey of the snake and corresponding to a further decline in population abundance (McGinnis 1986, pp 4-5; Phillip Williams & Associates, Ltd. *et al.* 1992, p. 3). Trapping and observations in 1986 failed to detect San Francisco gartersnakes or its aquatic prey despite 2000 trap-hours and 84 visual survey hours (McGinnis 1986, pp. 2, 4). In contrast, the congeneric coast gartersnake and Santa Cruz gartersnake were both detected, and habitat seemed suitable for these species based on their preferred prey (rodents and fish, respectively) (McGinnis 1986, pp. 3-4). However, San Francisco gartersnakes were observed at a junk pile adjacent to the site later in the same year, demonstrating ongoing occurrence at the site (McGinnis 1987, pp. 26-27). Trapping surveys at Mori Point from 2004 to 2008, initiated because of pond construction and other site improvements, yielded low but positive occurrence results. There were no recaptures of individuals between 2004 to 2006 or 2006 to 2008 (Swain 2009, pp. 13-14). Visual encounter surveys at Mori Point from 2013-2018 also resulted in low encounter rates that failed to elucidate a trend in population abundance (Fong and Kindall 2019, pp. 5, 11). However, trapping in 2018 yielded captures of 25 individuals and a population estimate of 38 to 104 individuals (Rose *et al.* 2018, p. 9).

To the south of Mori Point, Calera Creek and several ponds near the creek used to support San Francisco gartersnakes, and the species frequently moved back and forth over the hill between the properties, thus we also consider the Calera Creek area (when it has appropriate habitat) to be part of this population. The upland coast grassland-scrub area referred to as the "Mori Bowl" (Fong and Kindall 2019, p. 4) was considered an important area for the species and a potential migratory corridor (Phillip Williams & Associates 1992, p. 20). However, the creek was realigned and vegetated as part of mitigation for a wastewater treatment plant on the property, which also included the construction of two new ponds to replace old ponds that were filled in. The current status of the San Francisco gartersnake on the Claera Creek ponds is unknown, and lack of management has led to extremely dense vegetation in the creek and loss of the ponds.

West-of-Bayshore

This complex contains only the WOB population, which is surrounded by housing and urban development on all sides. The WOB property, located near and owned by the San Francisco International Airport (SFO), is a 73-hectare (180 acres) site that historically consisted of tidal marsh (LSA Associates 2008, p. 7). Construction of highways and installation of tidal gates effectively eliminated tidal influence, and the site now consists of seasonally inundated wetlands interspersed with upland habitat and drainages that provide permanent stream habitat (LSA Associates 2008, pp. 7-8). The site is thought to have supported a resident population of San Francisco gartersnakes since at least the late 1960s (based on a museum specimen collected in 1968, reported in Barry 1994, p. 68). Seasonal activity and an associated shift in distribution between ephemeral marsh habitat and canals at the site is described in Wharton *et al.* (1987, pp. 9-14). The site is situated in an urban matrix isolated from other San Francisco gartersnake locations (Barry 1994, p. 68; Reeder *et al.* 2015, p. 78).

WOB is one of the largest populations of San Francisco gartersnakes (McGinnis 1987, p. 7; Swaim Biological, Incorporated 2018, p. 11). Trapping results from three time points across recent years indicate a high-density population at the site, with the most current population estimate also thought to be the most reliable because of the high number of recaptures (Swaim Biological, Incorporated 2018, p. 11). Population estimates in 2007, 2013, and 2017 were 1520, 1284, and 1316 snakes, respectively (Swaim Biological, Incorporated 2018 pp. 1-2). Trapping in the 1980s and 1990s yielded 695 individuals across 3 years in the former decade but only 179 individuals in the latter (Wharton *et al.* 1986, p. 8; Larsen 1994, p. 38). Trapping surveys within a limited area prior to the construction of a Bay Area Regional Transport station in 1997 resulted in the capture of only 25 individuals (Larsen pers. com. in Service 2006, p. 5). This opportunistic sampling in the 1990s indicated a potential population decline in the 1990s, suggested to relate to declines in habitat quality, reduction in prey, drought conditions, and/or illegal collection (Larsen 1994, pp. 98-99; LSA Associates 2008, p. 1). Although available data suggest a potential population decline during the 1990s, we stress that population estimates are not directly comparable across years because of differences in sampling area, monitoring efforts, capture techniques, and analytical methods. Moreover, opportunistic trapping in the 1990's as opposed to the more structured approach taken in the last decade may exaggerate population differences over time.

Much of the population at the WOB site consists of snakes intermediate in appearance between the San Francisco gartersnakes and other gartersnake subspecies (Figure 9). Barry (1994, pp. 68-69) estimated that 80 percent of the population did not have a phenotype entirely consistent with the San Francisco gartersnake, and that 20 percent of the population showed extensive melanic suffusion (Barry 1994, p. 68). Anecdotally, hybridization in the WOB population may be in part due to release of California red-sided gartersnakes in an effort to boost the population (Barry 1994, p. 69). Speculation over genetic relationships of this population has likely led to a decrease in illegal collection (Barry *in litt.* 2006). However, results from genetic analyses are consistent with individuals from WOB grouping with other San Francisco gartersnake populations (USGS pers. com. 2019).

Figure 9. San Francisco gartersnakes at WOB. Photo credits: left, Sheila Larson, USFWS. Right: unknown.

Northern San Francisco Peninsula Watershed

We refer to the “San Francisco State Fish and Game Refuge” population from the Recovery Plan as the San Francisco Peninsula Watershed (SFPW), which we have broken into two population complexes, Northern and Southern, based on genetic differences identified in Lim *et al*. (2009, p. 7). Although this property is designated as a California Department of Fish and Wildlife (CDFW) refuge, the San Francisco Public Utilities Commission (SFPUC) has ownership and management responsibility for the area (Stoltz, pers. comm. in Service 2006, p. 7). Several extant populations exist within the SFPW, with individuals found along all major reservoirs, in ponds, and in creeks (BioMaAS and AECOM 2016, p. 3). BioMaAS and AECOM (2016, p. 6) includes a summary of all known trapping and surveys from 1998 through 2016. The Northern SFPW population complex includes all habitat in the SFPW north of Highway 92.

Trapping at Skyline Wetlands and at another lake in 2018 yielded 27 individuals at each site, with median population estimates of 68 (45-104) and 65 (41-101), respectively (Rose *et al.* 2018, pp. 7, 9). Surveys as part of ongoing management along the Fifield-Cahill Ridge Trail (targeting snakes from Mud Dam and Pilarcitos Reservoir) documented the presence of the species but did not attempt to quantify abundance (BioMaAS and AECOM 2016, p. 3). Trapping along the Fifield-Cahill Ridge Trail caught individuals of different life stages and sexes, indicating recruitment in the area (BioMaAS and AECOM 2016, p. 4).

Half Moon Bay

This population was documented in the 1980s (Barry 1996). The complex includes Denniston Creek and Denniston Reservoir, as well as the mouth of Pilarcitos Creek to the south. Although we consider this population to be extant, McGinnis (1988b, p. 1) notes that surveys in 1987 failed to produce any observations and suggested that dredging and other habitat destruction of impounded water in the area reduced habitat quality for the species.

Southern San Francisco Peninsula Watershed

The Southern SFPW includes all habitat in the SFPW that are south of Highway 92. San Francisco gartersnakes were observed in this complex in recent surveys (CNDDB 2018), but we are not aware of recent trapping surveys or population estimates. Barry (1994, p. 55) described the Pulgas region near Upper Crystal Springs Reservoir as a potential intergrade zone with California red-sided gartersnake.

Woodside

This complex is in an area described as an intergrade zone (Barry 1994, p. 55; Fox 1951, pp. 262-263; but see Barry 1978, p. 14). Habitat in this area is included in the Stanford Habitat Conservation Plan, and there is at least one known occurrence on private property in this vicinity.

San Gregorio

This population complex was documented in the 1980s (Barry 1996). Current status of the species is not known in this area. It includes habitat along Tunitas and San Gregorio Creeks, as well as several ponds.

La Honda

Populations near La Honda that have trapping surveys or abundances are found on ranches on two private properties.

One of the ranches includes two sag ponds separated from one another by a ridge and a linear distance of 280 m (919 ft), and from other aquatic features by 1.6 km (1 mile) (McGinnis 1988a, p. 4). The two ponds are at 369 m and 435 m elevation. Trapping at the Upper Pond resulted in 32 individuals in 1987 and an additional 31 new captures in 1988 (McGinnis 1988a, pp. 16-19). McGinnis (1988a) speculated that the population was highly transient in nature based on the male:female sex ratio (p. 19), low numbers of juveniles and neonates (p. 20), and evidence of movement between the Upper Pond and Lower Pond (p. 24).

The other ranch, part of the Russian Ridge Open Space Preserve owned and managed by the Midpeninsula Regional Open Space District, is a 424-hectare (1,047-acre) former cattle operation. This is the highest elevation San Francisco gartersnake population that we are aware of, at approximately 550 m elevation (Wood *et al*. 2019, p. 23). The species was first detected on the ranch in 1986, and reproductive colonies are present at two lakes on the property; San Francisco gartersnakes have been observed at all four water bodies. A habitat management plan for the site promotes improving aquatic and upland habitat on the property. The management plan specifically promotes the long-term resilience of the snake through restoration activities including targeted removal of non-native aquatic species and maintenance of upland habitat through grazing (Biosearch Associates 2012, pp. 25-52). From 2014-2017, mark-recapture population estimates indicated a stable population fluctuating from 97-195 individuals, with additional variation based on modelling methods (open verses closed models) (Figure 10; Kim *et al.* 2018, pp. 30-34, 76). Male and female gartersnakes of varying sizes were captured in all four years (Kim *et al.* 2018, pp. 14-20).

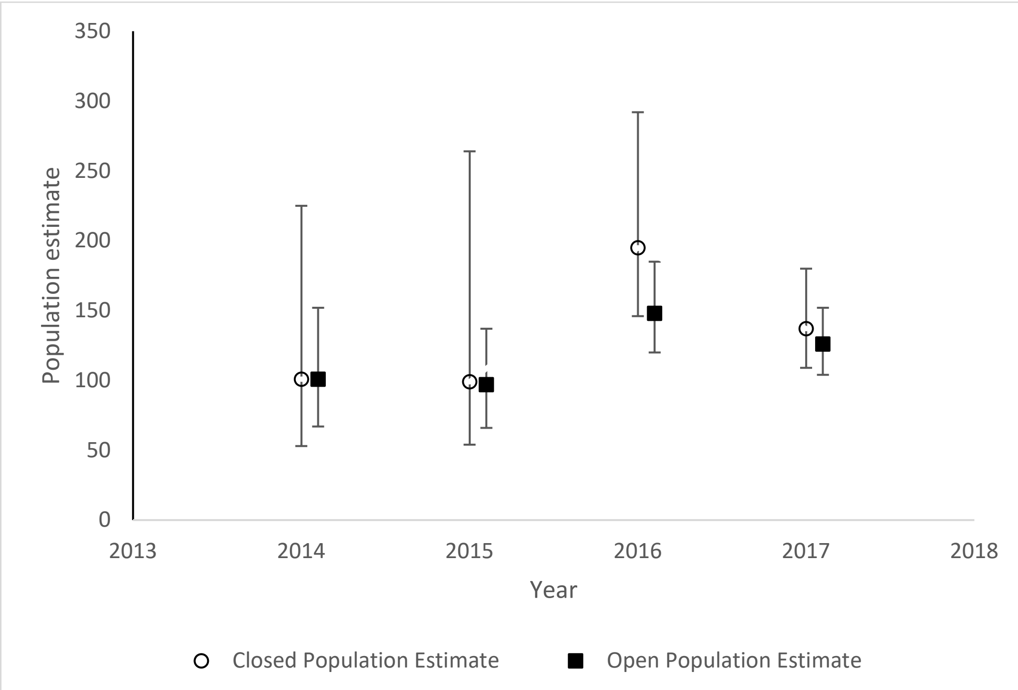

Figure 10. Population estimates at a private ranch in the La Honda complex. Model-averaged abundances with 95% posterior probabilities are shown. Because of uncertainty in connectivity between the trapping location and other habitat, the authors calculated both open and closed population estimates.

Pomponio

This population complex was documented in the 1980s (Barry 1996) and includes habitat along Pomponio Creek and Pomponio Reservoir. Current status of the species is not known in this area.

Pescadero

Although Pescadero Marsh Natural Preserve (hereafter Pescadero) is listed as a significant population in the Recovery Plan, it is likely that the largest contributions to the population complex in this area are on ponds on private properties. Several kilometers south of Pescadero, a private ranch on protected property owned by the Peninsula Open Space Trust (POST) occupies 213 hectares (526 acres) of former pasture, including several wetlands and ponds as well as grasslands (Halstead *et al.* 2011, p. 42). Trapping from 2008 through 2018, except in 2011, indicates some fluctuations in population abundance (Figure 11; Kim *et al.* 2017, p. 5; Rose *et al.* 2018, p. 9). From 2015 through 2017, population abundance exceeded 200 individuals and included individuals of varying sizes, characteristics of a resilient population (Kim *et al.* 2017, pp. 5-6). However, the population estimate from trapping in 2018, although one of the highest among the six sites trapped in this study, was below 100 individuals (Rose *et al.* 2018, p. 9).

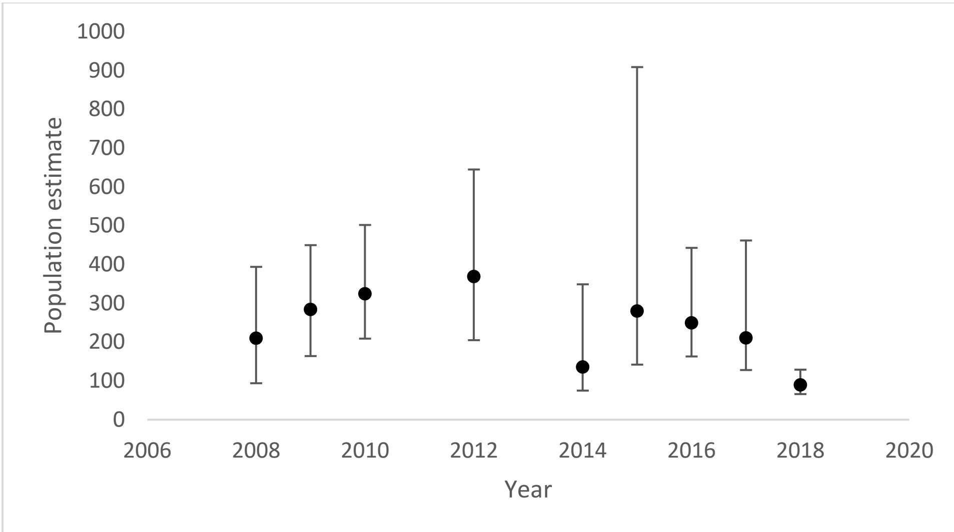

Figure 11. Population estimates (model-averaged abundance and 95% posterior density interval) at a private ranch near Pescadero. Source: Halstead et al. 2011, Sweeney et al. 2012, Kim et al. 2017.

Año Nuevo

This complex includes two significant populations from the Recovery Plan: Ano Nuevo State Reserve properties (California State Parks), and the Cascade Ranch property (private). It includes occurrences on both sides of Highway 1, including the Ano Nuevo Visitor Center Pond, BART mitigation site, and Lake Elizabeth.

Año Nuevo State Reserve, which merged into Año Nuevo State Park in 2008 (California State Park and Recreation Commission Resolution 27-2008), is the site where upland use by the species was first explored (Barry 1978, p. 9; McGinnis *et al.* 1987, entire). Population estimates based on a 1988 trapping study suggested that, at the time, this might have been one of the most concentrated San Francisco gartersnake populations (McGinnis 1991, p. 6). Studies at the Año Nuevo State Park headquarters pond indicated low prey abundance, but the authors suggest that high snake densities may be supported by other nearby habitat (McGinnis *et al.* 1987, pp. 10-12; McGinnis 1991, p. 6).

Mark/recapture analysis of the 1988 trapping data resulted in an estimated 135 (SE=29) individuals in the greater headquarters pond area (McGinnis 1991, pp. 5-6). Trapping in 2006 resulted in a similar number of captures (57 individuals captured in 1988, 53 in 2006) in only a 30 day period (compared to almost 9 months in McGinnis 1991, p. 3) (Swaim Biological Consulting 2006, p. 4). However, trapping in 2007 resulted in only 13 San Francisco gartersnakes (Swaim Biological Consulting 2007, p. 3). Trapping in 2018 occurred at two distinct sites: the visitor center pond and the BART mitigation site (Rose *et al.* 2018, p. 2). Population estimates for the two sites were 96 (62 to 153) and 60 (34 to 95) gartersnakes, respectively (Rose *et al.* 2018, p. 9).

Northern Santa Cruz County

This is the only population complex in Santa Cruz County. There are several seasonal ponds and at least one permanent pond near the coast in the northern part of the county that have had reported San Francisco gartersnakes (CNDDB 2018). We do not have information on trends or abundances in this complex.

Factors Influencing Viability

Here, we consider the historical and current anthropogenic and environmental factors influencing San Francisco gartersnake population resiliency, which in turn contribute to the overall viability of the species. We acknowledge that there are other factors that influence the San Francisco gartersnake, but for the purposes of this SSA we focus on those factors that are generally thought to have population or species-level effects. Additional stressors to the San Francisco gartersnake, including parasitism, and human interface activities (e.g., recreation), are summarized in the five-factor analysis of the 2006 status review (Service 2006, pp. 15-28) but are largely excluded from the analysis in this report because we deemed them more likely to affect individual snakes and not have population-level effects. Additionally, the threat of the chytrid fungus *(Batrachochytrium dendrobatidis)*, a parasite that is widespread in amphibians, is mentioned in the status review (Service 2006, p. 21). We do not include a discussion of chytrid here because evidence suggests that neither treefrogs nor California red-legged frogs are thought to have high mortality from the fungus (Reeder *et al.* 2012, pp. 2-4; Tatarian and Tatarian 2010, pp. 326-327). However, any future widespread threats to amphibian prey for the San Francisco gartersnake, including chytrid, could have significant affects to populations. The threat of chytrid or other amphibian diseases could be elevated if new evidence suggests population-level effects to the amphibian prey of the San Francisco gartersnake.

In this section, we first discuss factors that are limiting San Francisco gartersnake populations, including a description of the factor, the path through which it is thought to influence population resiliency, and the magnitude of its impact (if known). We then discuss management actions that are currently underway, or are in consideration, and how these actions stem from, or may alleviate, limiting factors. Figure 12 is an influence diagram summarizing the pathways through which management actions and anthropogenic or environmental factors can influence San Francisco gartersnake resiliency through their effects on habitat or demographic parameters.

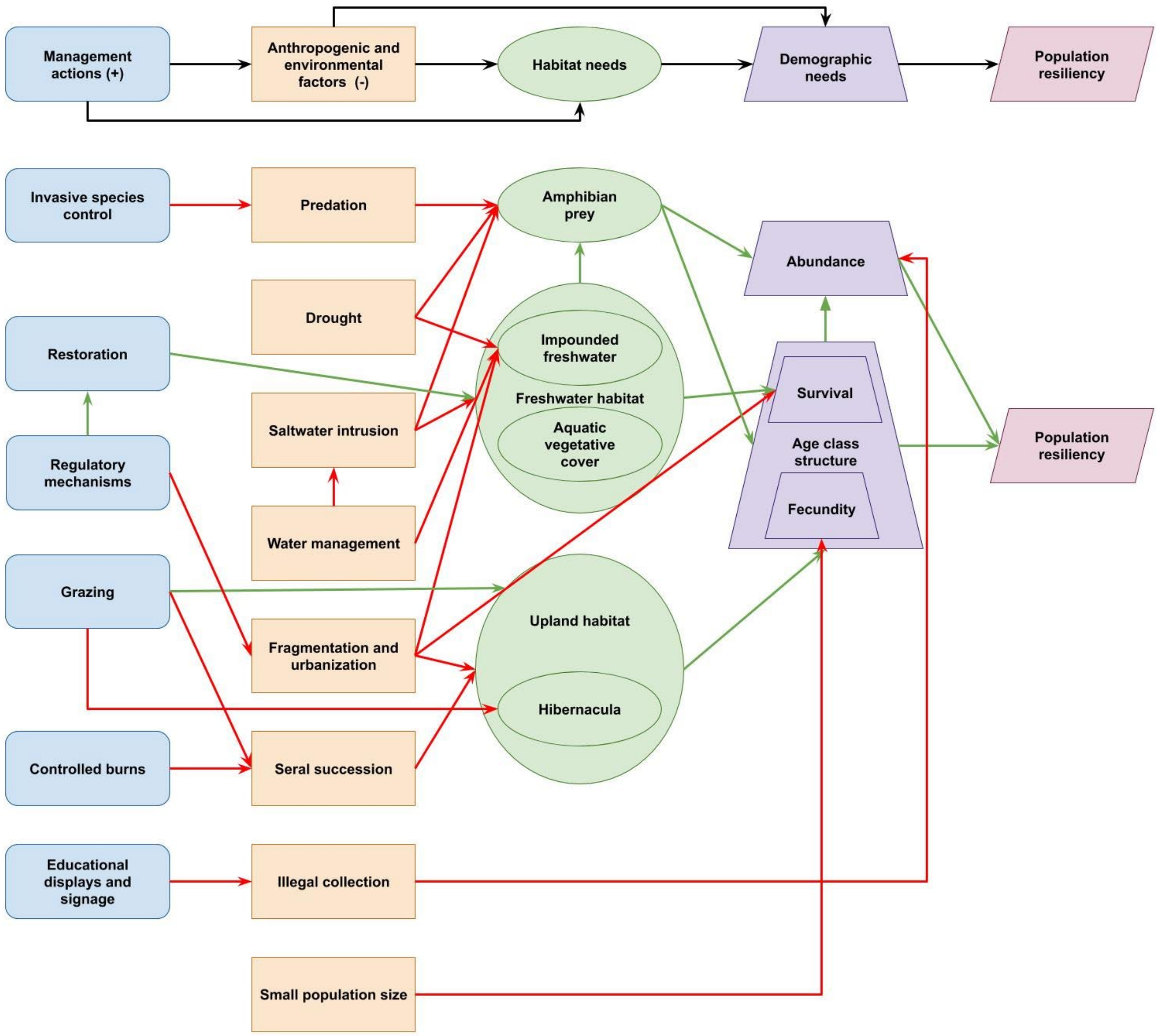

Figure 12. Influence diagram illustrating pathways between management actions and anthropogenic or environmental factors that can influence San Francisco gartersnake habitat needs or demographic parameters. Red lines represent negative relationships and green lines represent positive relationships.

Habitat Modification and Destruction

Alteration and isolation of habitats resulting from urbanization was identified as the primary reason for decline of San Francisco gartersnakes in the Recovery Plan (Service 1985, p. 13). Habitat loss and the degradation of remaining habitat continue to be the primary threats to the species' recovery. Contributing factors include urbanization and associated habitat fragmentation, seral succession, and hydrologic changes, including drought.

Habitat modification can also take place on a smaller scale. Barry (1978, p. 12) stated that San Francisco gartersnakes will not recolonize an area with cut emergent vegetation until at least one new generation of new plant growth has died back to form mats around living emergent plants. However, as mentioned in Individual and Population Habitat Needs (Chapter 3), he also stated that artificial aquatic habitats could attract the species within a year of development (Barry 1996, p. 42).

Fragmentation and Urbanization

Urbanization was historically a direct threat to the San Francisco gartersnake through development resulting in destruction of its habitat (Service 1985, p. 13). Known population extirpations linked to development included the once numerous population in the sag ponds near Skyline Boulevard (Banta and Morafka 1966, p. 233) and several other nearby occurrences (CNDDB 2018). Modification in habitat quality (not leading to extirpations) from urbanization through 2006 is detailed in the status review (Service 2006, pp. 15-17). Risks from urbanization include direct morality, habitat loss, fragmentation, and habitat isolation.

Although not as pressing of a threat as it was historically, today loss and degradation of San Francisco gartersnake habitat continues to threaten the species. Mortality on roads and bike trails can be a risk in urbanized areas and are even a threat in protected areas with limited traffic (Terry *in litt*. 2020). Brehme *et al.* (2018, pp. 928-929) rated the San Francisco gartersnake as being at "very high risk" from roads at the population- and species-levels. Even if not directly causing San Francisco gartersnake mortality, fragmentation by the expansion of infrastructure supporting increasing residential and commercial developments, including new roads, improved utilities matrices, and recreational facilities (Service 2006, p. 15), can limit connectivity within and between populations. Limiting movements between populations can reduce dispersal and corresponding gene flow, reducing population resiliency. Populations left isolated can be particularly vulnerable to environmental or anthropogenic stochastic and/or catastrophic events. In fragmented habitat, when occurrences become extirpated the chance of recolonization from any remaining populations is reduced.

Agricultural conversion of San Francisco gartersnake habitat on private lands is a potential threat, particularly to upland habitat for the species. From 2009 to 2018, over 340 acres (138 hectares) of grassland within the San Francisco gartersnake historical range have been converted to crops or other habitat types that would not be suitable for the species (USDA National Agricultural Statistics Service Cropland Data Layer 2019). However, this habitat change analysis was done using a polygon encompassing all occurrences of San Francisco gartersnakes and the land in between those occurrences, so it is unclear how much of this land conversion would have actually impacted the species. An additional 669 acres (271 hectares) of grassland changed to shrubland in the same time period (see *Seral Succession* below).

Changes to Aquatic Habitat

In addition to modifying or altering San Francisco gartersnake habitat, changes in water depth, inundation period, salinity, waterbody structure, and/or associated vegetation, can have negative consequences for the species by reducing its available amphibian prey and/or facilitating invasive species populations that can further reduce prey. In this section we talk about a variety of changes to aquatic habitat, of which saltwater intrusion and drought are the most likely to have population-level effects on the species. Various threats associated with changes to aquatic habitat are also discussed in the status review (Service 2006, pp. 15-20).

Saltwater Intrusion

Intrusion of ocean water into San Francisco gartersnake habitat can affect the species indirectly by reducing amphibian prey. Treefrogs and California red-legged frogs can both survive without apparent harm at salinity levels of 5 parts per thousand (ppt), but both frog species showed reduction in growth or health at 6 or 7 ppt, tadpole mortality starting at 8 ppt, and adult mortality starting at 9 ppt (McGinnis 1986, p. 5). Egg masses are more vulnerable than adults, with some red-legged frog embryos experiencing deformities or mortality when exposed to salinity levels as low as 4.4 ppt (Jennings and Hayes 1990, pp. 17-18, 40-41). Salinization has had negative effects on San Francisco gartersnake populations at Laguna Salada/Mori Point, WOB, and Pescadero Marsh (Service 2006, pp. 19-20).

Drought

Drought reduces available food because early drying of marshes can kill amphibian prey (Larsen 1994, p. 74). Reduced availability of prey following drought, particularly if drought reduces reproduction in tree frogs, can be especially difficult for neonates that rely on the availability of newly metamorphosed treefrogs for successful recruitment into the population. Reduced prey was suggested as a potential correlate to the lowest abundance of San Francisco gartersnakes across 4 years of sampling at a well-studied population on a private ranch (Kim *et al.* 2017, p. 5). Drought could also have negative impacts on habitat vegetative features, although to our knowledge the impacts to prey are of more concern. If water recedes such that there is no longer emergent vegetation along the edge of the aquatic feature, this can increase predation risk for foraging San Francisco gartersnakes, and/or decrease foraging opportunities.

Water Management

Water management activities, including fluctuations in water levels at reservoirs, flood control, and channelization, can all impact habitat quality. Siltation is also of concern at some sites, including within habitat for the Pescadero population complex. Some water management activities, such as dredging, could be either a threat or a positive management activity depending on the implementation. Dredging and silt dumping at Denniston Reservoir decreased habitat quality at that site, potentially making it unusable by San Francisco gartersnakes (McGinnis 1988b, p 2; Barry in litt. 2003). However, dredging in the canals at WOB is an important part of the restoration work at that site (San Francisco Airport and LSA 2017, p. 4). Many of the reservoirs that support San Francisco gartersnakes are managed waterbodies with water regimes that could affect water depth or period of inundation. Dropping water levels quickly during the San Francisco gartersnake breeding season could limit food availability for females and neonates following parturition near the water edge (Barry pers. com. 2019). In contrast, maintaining deep water levels can support habitat for invasive carnivorous fish or bullfrogs, which can reduce amphibian prey for the San Francisco gartersnake.

Seral Succession

Upland habitat used by the San Francisco gartersnake was historically maintained by periodic disturbance. Elimination of disturbance to these habitats, including fire control and elimination of grazing, has led to the persistence and expansion of seral ecosystems that alter upland grassland habitat used by the San Francisco gartersnake. Note that grazing and controlled burns are still practiced in some population localities, as discussed in *Grassland Management* below. Seral succession is included here as a potential threat to populations, although the severity of this threat is unknown. We note that habitat structural complexity is an important aspect of high-quality habitat for the species and discuss the potential impacts of extensive seral succession with this caveat in mind. Although the species probably uses areas with extensive seral succession, the upper limit of habitat that the species can use is not known.

Domination of woody species across the coastal landscape limits the extent of grasslands, which were likely important movement corridors for populations of San Francisco gartersnake in their migrations between aquatic habitats (Hankins in litt 2006; McGinnis *et al.* 1987, pp. 14-16). However, the actual threshold limit of scrub in areas that San Francisco gartersnakes use is unclear. Despite extensive scrub encroachment throughout the area surrounding the Año Nuevo visitor center pond, current population estimates are almost as high as those in the 1980s when the site was thought to have one of the healthiest populations (McGinnis 1991, p. 5; Rose *et al.* 2018, p. 9). Succession of grasslands can also reduce rodent populations, which in turn influences San Francisco gartersnakes because 1) rodent burrowing activities help to maintain grasslands, and 2) San Francisco gartersnakes use rodent burrows for hibernacula (discussed in *Habitat and Activity Patterns* above). Continuous soil disturbance by gophers living in grass-dominated uplands can help to inhibit successional processes by bringing nitrogen-poor soil to the surface (Stromberg and Griffin 1996, pp. 1204-1206). However, when brush species begin to dominate former grasslands despite this soil disturbance, it can potentially preclude burrowing animals (Service 2006, p. 25).

Illegal Collection

The Recovery Plan lists illegal collection as one of the primary threats to the species (Service 1985, pp. 1, 13-14). The snake is targeted largely because of its beauty, its rarity, and its ability to be kept in captivity (Barry 1978, p. 12). Illegal collection is of particular concern in easily accessible populations, and historically contributed to population declines at WOB (Larsen 1994, p. 99), Laguna Salada, and Lower Crystal Springs Reservoir (Barry 1978, p. 12). Collection at WOB has subsided, likely because hybridized appearance of the individuals at this location makes them less desirable to collectors (S. Barry *in litt.* 2006). Although current amounts of illegal collection and its effect on the species is not clear (Service 2006, pp. 20-21), it is still likely a threat that could have population-level affects without enforced regulations.

Predation

San Francisco gartersnakes have a diverse group of potential predators, including mammalian, reptilian, amphibian, avian, and predatory fish species. Many San Francisco gartersnakes have scars or signs of injuries, such as missing tail tips, presumably acquired during attacks by predators (Barry 1996, p. 62). Predation by two invasive species and feral cats is described below. Other known or potential predators are summarized in Barry 1996 (pp. 2, 62-64) and Larsen 1994 (p. 64).

Of particular concern is depredation by invasive species. Non-native American bullfrogs (*Lithobates catesbeianus*) and largemouth bass (*Micropterus salmoides*) both have a similar role of preying on both the snake and its prey (Barry 1996, pp. 36, 63), and there is the possibility that habitats with both species present could have an increased impact (i.e., Invasional Meltdown Hypothesis, Simberloff and Von Holle 1999, p. 22). The relative impact of predation by the American bullfrog on San Francisco gartersnake populations and its amphibian prey are debated (discussed in Service 2006, p. 22), although bullfrogs are generally argued to have a negative impact on the species. Bullfrogs do prey on San Francisco gartersnake (Kim 2017, p. 33), although the extent of predation is not known. Bullfrog predation on congeners can be significant, with estimates that bullfrogs prey upon about 22 percent of neonatal giant gartersnakes (*Thamnophis gigas*) (Wylie *et al.* 2003, pp.141-144). Perhaps more importantly, the bullfrog likely has a strong impact on San Francisco gartersnake populations as a competitor for amphibian prey. The introduction of bullfrogs has negative impacts on native amphibian species (Kupferberg 1997, pp. 1741-1746; Boone *et al.* 2004, pp. 686-687), including red-legged frogs (Service 2002, p. 24) and treefrogs (Kim 2017, p. 34). However, bullfrog introductions are usually concurrent with changes to waterbodies or water management, making it difficult to pinpoint bullfrogs as the cause of associated reductions in San Francisco gartersnakes or their prey (Barry 1996, pp. 30-31). The status of bullfrogs in waterbodies with San Francisco gartersnake complexes is summarized in Table 6.

Table 6. Status of bullfrogs within San Francisco gartersnake population complexes.

	Bullfrogs	**Source**
Northern San Mateo County	NA	
Pacifica	Yes	Fong and Kindall 2019
West-of-Bayshore	No	Reeder pers. comm. 2019
Northern SFPW	Yes	CNDDB 2018
Southern SFPW	Yes	Lim pers. comm. 2019
Half Moon Bay	Unknown	
Woodside	Unknown	
San Gregorio	Unknown	
La Honda	Yes	Kim et al. 2018
Pomponio	Yes	CNDDB 2018
Pescadero	Yes	Olson and Dexter 2008
Año Nuevo	Yes	Service 2006
Northern Santa Cruz County	No	SBI 2006

Feral cats also pose a potential threat that may or may not have population-level effects. Researchers documented five presumed cases of feral cat injury or predation on San Francisco gartersnakes within the WOB population in one year (Swaim 2018, pp. 11-12), suggesting that the impact of feral cats could be significant in some populations. A large number of feral cats was also noted at WOB in the 1990s and several deceased San Francisco gartersnakes were recovered at that location that showed injuries consistent with cat kills (Larsen 1994, p. 88). A trap-neuter-release program at WOB was recently started in an attempt to better understand feral cat dynamics at the site (Reeder pers. com. 2019; but see Longcore *et al.* 2009, pp. 890-891). Feral cats have also been noted near other San Francisco gartersnake habitat at Mori Point, another population that is adjacent to residential communities (Swaim Biological, Inc. 2009, p. 24).

Small Population Sizes

Low population abundances in small or fragmented habitat patches have the potential to lead to inbreeding depression and loss of genetic diversity. Both of these genetic factors can contribute to extinction risk (reviewed in Frankham 2005, entire). Effective population sizes (N_e) for six of seven sampled San Francisco gartersnake populations were below the short-term threshold recommendation of $N_e \geq 100$ for inbreeding depression in Frankham *et al*. (2014, p. 58); the only population with an effective population size greater than this threshold was WOB (Wood et al. 2019, pp. 21, 40). Effective population size, the size of an idealized population that would give rise to the same variance of gene frequency, or rate of inbreeding, as the actual population under consideration, is often much lower than census population size (Frankham 1995, entire; Frankham 2005, p. 95). The ratio between effective population size and census population size varies based on factors such as unequal sex ratios, variance in family size, and population fluctuations. Comparison of effective population size from genetic analyses with census size from mark-recapture studies offer the first values of the ratio of effective population size to census population size in San Francisco gartersnakes (Wood et al. 2019, pp. 20-21, 25-27, 40). The ratio at sampled San Francisco gartersnake sites varied considerably, from 0.16 to 0.78 (Wood et al. 2019, p. 40). The highest ratio at Pescadero could indicate additional suitable habitat outside of the area surveyed in the census (Wood et al. 2019, p. 26).

Wood *et al*. (2019, pp. 16, 21) also used estimates of inbreeding coefficients to evaluate the possibility that genetic erosion had occurred across the seven sites in their genetic analysis. In the northern regional cluster, their data suggested that Pacifica is suffering from genetic erosion, and in the southern cluster, Mindego (in the population complex we refer to as La Honda in this SSA) showed evidence of genetic erosion. Both of these sites are isolated from other San Francisco gartersnake populations.

Other evidence exists that isolation may limit gene flow between populations. For example, within the northern genetic cluster, both the Pacifica and WOB subgroups are isolated from the other northern populations by habitat fragmentation (Wood et al. 2019, p. 18). The effects of this isolation are most pronounced at the Pacifica site, where there is some evidence that the population may have experienced a population bottleneck. A decline in population abundance related to saltwater inundation that affected amphibian prey for the Pacifica population (discussed above in *Historical and Current Abundance and Population Trends*) is likely reflected in genetic analyses that show low N_e and low heterozygosity for San Francisco gartersnakes at that site.

Evaluation of a temporal dataset (sampled in two time periods approximately a decade apart) indicated an increase in pairwise estimates of genetic differentiation over time, especially for the sites that are the most geographically isolated due to fragmentation (Wood et al. 2019, pp. 20-21, 39). Increasing or introducing genetic diversity in the absence of natural gene flow is a possible avenue that could be explored in development of the captive breeding and population augmentation program discussed below.

Disease

Snake Fungal Disease (SFD) is an emerging threat to wild snakes caused by *Ophidiomyces ophiodiicola* (Lorch *et al.* 2016). The infection has been documented throughout the eastern United States, with clinical signs including skin lesions, thickened skin, and facial swelling (Lorch *et al.* 2015). In a field study across 15 species, SFD was more prevalent in snakes with aquatic habitat affiliations than terrestrial (McKenzie *et al.* 2019). Cases of SFD range from mild to life-threatening. In late 2019, SFD was confirmed in a California kingsnake (*Lampropeltis californiae*) in Amador County and a deceased Florida watersnake (*Nerodia fasciata pictiventris*) in Sacramento County (CDFW 2019). At this time, we are not aware of any cases of SFD in San Francisco gartersnakes. It is unknown how SFD may affect the species, but CDFW plans increased surveillance and implementation of precautions to minimize risk of human-caused spread (CDFW 2019).

Management Activities and Conservation

Management activities that can positively influence the San Francisco gartersnake include restoration, invasive species control, grassland management, educational displays and research, and habitat conservation plans. Water management, described above, can also have positive influences in San Francisco gartersnake habitat, including limiting saltwater intrusion.

Invasive Species Control

Management in some habitats includes control of invasive species such as bullfrogs. Bullfrog control in 2014 and 2015 at the permanent waterbody on a private ranch, combined with a drought in 2014, likely extirpated bullfrogs from the site (Kim *et al.* 2018, pp. 4, 62). This reduction in the invasive species correlated with increased recruitment in the San Francisco gartersnake population (Kim *et al.* 2018, pp. 62, 72). Kim (2017, p. 37) suggested that the mechanism for this increased recruitment was reduction in competition for treefrogs, particularly for smaller San Francisco gartersnakes that rely more strongly on treefrogs compared to red-legged frogs. The eradication of bullfrogs at WOB has been correlated with increases in the San Francisco gartersnake population (Larsen pers. com. 2019).

Restoration

Habitat restoration activities in areas occupied by San Francisco gartersnakes include creation and restoration of aquatic and upland habitat, with a focus on the creation of habitat for the amphibian prey of the species.

Restoration activities for the Laguna Salada/Mori Point population have occurred in habitats on both properties supporting the species. Creation of a seawall along the Sharp Park golf course beachfront was intended to eliminate seawater intrusion into Laguna Salada (as recommended in McGinnis 1986, p. 7). Habitat creation and enhancement at Mori Point specifically aimed to increase foraging habitat for the San Francisco gartersnake (Fong *et al.* 2004, p. 2). Prior to habitat creation beginning in 2004, the area contained seasonal wetlands but did not have permanent water sources that would provide a consistent prey source. Restoration consisted of construction of two ponds and modification of two others (Swaim Biological, Incorporated 2009, pp. 3-4). Verification of breeding by treefrogs and red-legged frogs, in combination with San

Francisco gartersnakes, indicates that the species is capable of finding and using newly created habitat (Swaim Biological, Incorporated 2009, pp. 23-24).

At the WOB site, declines in San Francisco gartersnake observations in the 1990s led to the creation of a recovery action plan (RAP), with the goals of increasing breeding habitat for amphibian prey and supporting a stable or increasing population of San Francisco gartersnakes (LSA Associates 2008, p. 40). The original RAP was renewed in 2019 to address future habitat enhancement and management actions (Dudek 2019, entire). These RAPs are specific to the WOB site and represent a cooperative effort between the San Francisco International Airport, the Service, and the California Department of Fish and Game to manage and protect the San Francisco gartersnake at the site (LSA Associates 2008, entire; Dudek 2019, entire). The RAPs are separate documents from the Recovery Plan for the species (Service 1985). Implementation of the RAP included restoring canals, pond construction, removal of overgrown and non-native vegetation, increased site security, and monitoring San Francisco gartersnake and prey populations (Reeder *et al.* 2015, p. 79; Dudek 2019, p. 2). Between 2008 and 2013, this resulted in the creation of approximately 0.6 acres of open water habitat and restoration of an additional 1 acre of open water, upland habitat enhancement on 0.4 acres, and additional activities related to security and road infrastructure (Dudek 2019, p. 3). The renewed RAP aims to: increase aquatic prey availability through habitat restoration and enhancement, reduce sediment input into the canals, and continue to enhance upland habitat. Descriptions of proposed actions, including continuation of prior RAP activities and new operations or maintenance activities is provided in Dudek (2019, pp. 21-32).

Near Pescadero, restoration activities in 2006 included efforts to restore connectivity between Pescadero Creek and adjacent floodplain outside of the Pescadero Marsh Natural Area. Restoration activities in 2006 included removal of a levee to restore connectivity between the creek and floodplain, and the creation of new aquatic features that they expected to fill naturally from the creek and rainfall (Olson and Dexter 2008, p. 1). Post-restoration trapping in 2008 failed to detect San Francisco gartersnakes. More recently, restoration of Butano Creek is in progress to restore flow where the creek flows through Pescadero Marsh Natural Preserve. The San Mateo Resource Conservation District is working to re-establish 8,000 feet of the historic creek channel, remove 45,000 cubic yards of sediment, and re-use the dredge material to fill historical human-made pits to restore 28 acres of degraded marsh (CBEC, Inc. 2018). A healthy individual San Francisco gartersnake was found during restoration work in 2019 (Halbert in litt. 2019), demonstrating use of the area by San Francisco gartersnakes and potential for these projects to benefit the species by improving foraging habitat.

Regulatory Mechanisms that Provide Conservation Benefits

There are several State and Federal laws and regulations that are pertinent to listed species, each of which may contribute in varying degrees to the conservation of listed and non-listed species. In addition to being listed as a federally endangered species, the San Francisco gartersnake was listed as endangered (and fully protected) species by the State of California in 1971. Below we provide details on protection of San Francisco gartersnake through the Endangered Species Act

(ESA); additional information relating to state and federal protections is included in the status review (Service 2006, pp. 23-25).

The Endangered Species Act of 1973, as amended, is the primary Federal law providing protection for the San Francisco gartersnake. The Service has responsibility for administering the Act, including sections 7, 9, and 10 that address take. Section 9 prohibits the taking of any federally listed endangered or threatened species. Take is defined in Section 3 as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harass is defined by Service regulations at 50 CFR 17.3 as an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering. Harm is defined by the same regulations as an act which actually kills or injures wildlife. Harm is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering. The Act provides for civil and criminal penalties for the unlawful taking of listed species.

Since listing, the Service has analyzed the potential effects of Federal projects under section 7(a)(2), which requires Federal agencies to consult with the Service prior to authorizing, funding, or carrying out activities that may affect listed species. For projects without a Federal nexus that would likely result in incidental take of listed species, the Service may issue incidental take permits to non-Federal applicants pursuant to section 10(a)(1)(B). Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity (50 CFR 402.02). To qualify for an incidental take permit, applicants must develop, fund, and implement a Service-approved Habitat Conservation Plan that details measures to minimize and mitigate the project's adverse impacts to listed species. Many of these Habitat Conservation Plans are coordinated with the State of California's related Natural Community Conservation Planning program.

The status of the San Francisco gartersnake as a species listed under the ESA can reduce the severity of the effects of habitat loss due to fragmentation and urban development, which continues to be a threat to the San Francisco gartersnake throughout its range (see Habitat Modification and Destruction above). Development projects that are subject to section 7 consultation or result in the issuance of an incidental take permit under section 10 typically include habitat compensation, which can reduce the severity of overall habitat loss typically associated with these projects. Habitat compensation can occur via a variety of mechanisms, including the purchase of credits at approved conservation banks, through permittee responsible mitigation, and through the development of habitat conservation plans (HCPs) and Safe Harbor Agreements. Additional information about these mechanisms of habitat compensation can be found at: https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=C002; note that at this time there are no approved conservation banks or Safe Harbor Agreements for the San Francisco gartersnake. In addition to reducing the amount of overall habitat loss for the species, Section 10(a)(1)(A) of the Act allows for permits to be issued for recovery activities that result in take. Recovery activities are those activities that are specifically implemented for scientific purposes or to enhance the propagation or survival of the affected species, including interstate commerce activities.

Permittee-Responsible Mitigation

Permittee-responsible mitigation includes activities or projects undertaken by a permittee (or authorized agent) to provide compensatory mitigation for which the permittee retains full responsibility. Permittee-responsible mitigation projects are typically not established in advance of the impacts they are offsetting and they do not have credits that can be used at a later time to offset different impacts, like conservation banks.

Habitat compensation through permittee-responsible mitigation for the San Francisco gartersnake has occurred throughout the subspecies range for a number of projects. For example, there have been a number of restoration actions implemented by the San Francisco Public Utilities Commission in the Crystal Springs Reservoir watershed as mitigation for the effects of the Lower Crystal Springs Dam Improvement Project and other Water Storage Investment Program (WSIP) projects. Additionally, mitigation for PG&E projects has resulted in aquatic and upland habitat enhancement and preservation near the WOB and Pescadero population complexes (various Service biological opinions; Terry *in litt*. 2020)

Habitat Conservation Plans

Habitat Conservation Plans provide a pathway forward to balance wildlife conservation with development. 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 means that measures will be implemented to avoid or minimize take of the covered species within the area the HCP covers, as agreed upon and permitted by the Service. Specifics for each HCP are included within each agreement, including habitat will be set aside and managed for the species as compensation for covered activities, such as planned urban development, within the area the HCP covers; avoidance and minimization measures; and other conservation measures (e.g. monitoring, seasonal work windows, habitat management, etc.). Currently, there are three HCPs that include the San Francisco gartersnake as a covered species (Table 7), including the San Bruno HCP under its fifth amendment.

The PG&E Bay Area Operations and Maintenance HCP includes avoidance and minimization measures to be implemented during activities that could affect the San Francisco gartersnake (ICF 2017, pp. 5.9-5.16). Although the HCP covers almost the entire range for the San Francisco gartersnake (with the exception of Santa Cruz County), impacts to the species are anticipated to be limited. In developing the HCP, core and dispersal San Francisco gartersnake habitat within the HCP area was modeled. PG&E anticipates that covered activities in the Plan Area could: permanently remove 0.04 acre of core habitat (a 59-ft. × 59-ft. area) and 0.04 acre of dispersal habitat for San Francisco gartersnake annually, and no more than 2 acres of core habitat and 2 acres of dispersal habitat over 30 years; and temporarily disturb 0.3 acre of core habitat and 0.2 acre of dispersal habitat annually, and no more than 16 acres of core habitat and 10 acres of dispersal habitat over 30 years (ICF 2017, p. 4.54). The plan calls for mitigation of temporary impacts at a 1:1 ratio and of permanent impacts at a 3:1 ratio (ICF 2017, p. 5.38).

The San Bruno Mountain HCP included the San Francisco gartersnake because of uncertainty regarding the species' presence at the site. However, the species has not been seen over the entire monitoring period of the HCP, and is unlikely to be present (Ormshaw 2018, p. 44).

The Stanford HCP includes monitoring, management, and enhancement activities (Stanford University HCP 2013, pp. 3-22), including pond construction and trapping non-native species. A permanent conservation easement set aside 90 acres of high-quality habitat to be used by covered species, including the San Francisco gartersnake.

Table 7. HCPs that include the San Francisco gartersnake as a covered species.

Plan Name	Permit Period
PG&E Bay Area Operations and Maintenance HCP	2017-2047
San Bruno Mountain Amendment #5 (North East Ridge revision)	2009-2039
Stanford University HCP	2013-2063

Recovery Permits

Recovery permits, also referred to as 10(a)1(A) permits, allow scientists to take listed species as a means to ultimately contribute to the recovery of the listed species. The data acquired from some actions covered under recovery permits (e.g., occurrence, abundance, distribution, etc.) allow the Service to make informed decisions for the species that will enhance their survival and recovery. Recovery permits can be issued for activities that directly aid the recovery of a species, such as captive breeding, reintroductions, habitat restoration, removal or reduction of threats, and educational programs. The Service's recovery permitting program aids in the conservation of listed species by ensuring permittees have adequate field experience and qualifications for conducting activities with the target listed species and, for most species, ensures that permittees are following standardized protocols while surveying. The recovery permitting application process ensures that scientific proposals are crafted using the recommended actions laid out in the Recovery Plan for the target species. There is currently no protocol survey guidance for the San Francisco gartersnake; however, there are minimum qualifications to obtain a recovery permit for the species. Minimum qualifications and species specific protocols can be found at: https://www.fws.gov/sacramento/es/Permits/.

Research and surveys performed by biologists with recovery permits has resulted in a number of peer-reviewed papers, and has contributed to our knowledge of San Francisco gartersnake ecology, population dynamics, and genetics incorporated throughout this document.

Grazing

Both grazing and controlled burns (discussed below) are grassland management techniques that are recommended in the previous status review for the species (Service 2006, pp. 26, 31). Recent publications highlight the need for additional studies on these techniques (e.g., Kim *et al.* 2017, p. 5; Halstead *et al.* 2019, p. 238).

Private ranches that have San Francisco gartersnake populations are often grazed. Although we discuss grazing in the context of management, cattle can also threaten aquatic resources or amphibian prey (if grazing occurs near ponds during amphibian breeding), thus the relationship between grazing and San Francisco gartersnakes is not clear. Although grazing can help to reduce the spread of woody brush and increase grassland diversity, it can also reduce burrowing rodents (e.g. gophers) that create burrows used by San Francisco gartersnakes for hibernacula (Stromberg and Griffin 1996, p. 1205, and references discussed within). Grazing also significantly lowers grass heights in meadows, which could potentially lead to upland habitat that is more open than that typically used by the species. Ideal habitat can be described as early successional, with adequate grass and other heterogeneous vegetation to provide dappled sunlight that allows both basking for thermoregulation and cover for predator protection. Kim *et al.* (2017, p. 5) discusses how additional monitoring or studies looking at grazed verses ungrazed areas might help elucidate the use of grazing as a management tool for San Francisco gartersnake habitat. Although population monitoring at one of these ranches specifically lists evaluating the effects of grazing on San Francisco gartersnake demography (Kim *et al.* 2018, p. 3), the authors note that the effects of grazing on distribution or demography could not be quantified in their study to date (Kim *et al.* 2018, p. 73). However, they suggest that the species might benefit from low-intensity grazing if it promotes habitat heterogeneity in or near aquatic habitat (Kim *et al.* 2018, p. 73).

Controlled Burns

Controlled burns have also been used at several sites occupied by San Francisco gartersnakes. Prescribed burns on the west side of the Visitor Center at Año Nuevo State Reserve (now Año Nuevo State Park) were conducted in 2004 and 2005 to maintain a more open shrub community in upland habitat for the species (Swaim Biological Consulting 2007, p. 1). Larsen (*in litt.* 2019) hypothesized that the 2004 burn may have supported a temporary boost in snake abundance (see Swaim Biological Consulting 2006, pp. 4-5) because associated vegetation changes made prey more available to foraging snakes. Trapping in 2007 resulted in fewer captures than in previous years, but lack of a thorough baseline study or control plot makes it difficult to link trapping data to the controlled burns or to offer specific fire-related management recommendations (Swaim Biological Consulting 2007, pp. 4-5). Indeed, Halstead *et al.* (2019, p. 232) mention the lack of specific studies on the effects of prescribed fire on San Francisco gartersnake populations despite a call for their use in habitat management in a status review for the species. Prescribed fires at a private ranch (Swaim Biological, Inc. 2006 and 2007, entire) did not appear to have population-level effects on San Francisco gartersnakes at the site. Because the study found that prescribed fire had relatively small effects on San Francisco survival and movements, the authors concluded that prescribed fire in areas with robust populations are a useful management tool to maintain grasslands. However, the authors include the caveat that their recommendations are specific to the conditions of their study and “perhaps other conditions” (Halstead *et al.* 2019, pp. 234-238), thus further studies on the specific effects and mechanisms through which fire can influence San Francisco gartersnake populations may be useful.

Educational Displays and Signage

Educational displays are present at a number of public lands that support the San Francisco gartersnake. These signs facilitate public awareness of the threatened and endangered species that occur at the parks, as well as including information about the ecology of the species and/or habitat restoration activities to support these species. Additionally, signs identifying areas with restricted access for endangered species are often located outside of fenced areas. These restrictions may have helped with reduction in illegal take. In addition to signage, cover boards in areas with higher public presence are camouflaged, located out of public view in fenced areas, and secured to the ground to deter poaching (Fong and Townsend 2018, pp. 4-5).

Current Condition of Population Complexes (Resiliency)

For a San Francisco gartersnake population complex to be considered in high condition, it needs to meet the needs identified in Chapter 3 of this SSA as being important for resiliency. At the population level, we identified habitat needs as amphibian prey, freshwater habitat (including impounded freshwater and aquatic vegetation), and upland habitat (including hibernacula) (Figure 8). We included all of these factors in our analysis of current condition. However, after consulting with experts and taking into account data availability, we split important components of freshwater habitat into two categories (impounded freshwater and aquatic vegetative cover) but included hibernacula as part of upland habitat in one category (upland habitat). Although it is clear that hibernacula (e.g., rodent burrows) are important for resilient San Francisco gartersnake populations, little data exists on what would distinguish high verses low conditions, and it is unlikely that hibernacula availability is currently limiting the species. We identified the following demographic needs as being useful for assessing the current condition of population complexes: abundance and age class structure (which incorporates fecundity and survival). Because no current, range-wide, demographic data measuring fecundity and/or survival rates have been collected, we assessed condition using categories to assess only abundance and age class structure. For both categories, we focus on the core population within each complex because it aligns these categories with available trapping data, population estimates, and observations.

We measured four factors that influence habitat (Impounded Freshwater, Aquatic Vegetative Cover, Upland Habitat, and Amphibian Prey) and two factors based on demographics (Abundance and Age Class Structure). We used the habitat evaluation system developed by McGinnis (1987, pp. 15-17) as a framework for the impounded freshwater, vegetative cover, and amphibian prey categories in our condition category table, with some modifications based on consultation with species experts. We did not include the competitive gartersnake category from McGinnis (1987, p. 16), but included a category assessing upland habitat and the two demographic needs categories as discussed above.

We classified each of our 12 extant population complexes as being in “high,” “moderate,” or “low” condition for each of the six factors (Table 8). Population complexes that are in high condition are healthier and have higher resilience than those in lower condition, meaning they are less vulnerable to stochastic events. Having multiple, high condition population complexes spread throughout the range of the species is associated with higher species viability.

Table 8. Condition category table for San Francisco gartersnake.

	Habitat features				Demographic parameters	
Condition	**Impounded Freshwater**	**Aquatic Vegetative Cover**	**Upland Habitat**	**Amphibian Prey**	**Abundance**	**Age Class Structure**
High	Multiple freshwater features of various sizes present all year; large shallow inshore zone	Intermediate density reed-shrub cover throughout marsh or in a wide band around the entire edge of impounded waterbodies	Early successional grassland habitat adjacent to aquatic habitat with heterogeneous shrub cover and abundant rodent burrows available	Red-legged frogs and treefrogs readily available	Core population has greater than 200 adults with an approximately 1:1 male:female sex ratio	Lots of adults, lots of neonates, and evidence of size classes in between
Moderate	Multiple freshwater features present all year	Cover patchy throughout or in a narrow band around entire edge of impounded waterbodies, or patchy aquatic vegetation but abundant cover in immediately adjacent habitat	Upland habitat adjacent to aquatic habitat with relatively heterogeneous habitat complexity and rodent burrows available	Treefrogs and red-legged frogs present but may be limiting	Core population has a minimum of 50 adult SFGS	Adults and neonates (unknown numbers)
Low	Ephemeral pools dry completely by late summer, or saltwater inundation in some years	Reed-shrub cover in small clumps along one half or less of water edges	Upland habitat adjacent to aquatic habitat with extensive scrub succession, low vegetative diversity, or few rodent burrows available	Amphibian prey available (treefrogs OR red-legged frogs, might also include other prey e.g. newts)	Present, but unknown numbers or fewer than 50 adults	Adults only

We assessed condition in habitat factors through consultation with species experts and land managers of properties within the different population complex areas. Although McGinnis (1987, pp. 24, 31) assessed habitat conditions for some population complexes (e.g., Half Moon Bay and La Honda) in the 1980s, we left habitat condition as unknown if complexes had not had relatively current surveys. We used population monitoring reports and consultations with species experts to assess demographic condition. We pulled out 'core' populations when assessing the abundance and age class structure of San Francisco gartersnakes within each complex because of limited trapping data, using each of these core populations as a surrogate to assess the condition of the complex as a whole. This also allows us to align the current condition analysis with abundance targets identified in the Recovery Plan, which calls for resilient populations containing at least 200 adults.

Each population complex was given a numeric score relative to each factor: 1 for low condition, 2 for moderate condition, and 3 for high condition. We conservatively scored unknown rankings as if the population complex was in low condition for that category. We next translated the overall condition score into an overall habitat condition and overall demographic condition ratings of high, moderate, or low. We separate overall habitat condition from overall demographic condition because oftentimes habitat condition was higher than demographic condition for the species. For example, historical saltwater inundation in the Pacifica population complex likely drastically reduced prey populations for the San Francisco gartersnake, and the population demographics may be lagging behind habitat conditions in responding to habitat restoration. We did not evaluate overall habitat or demographic condition for the Northern San Mateo County population complex, instead giving it an overall condition of extirpated.

For habitat condition, a complex with all low, all moderate, or all high ratings for the factors would have overall habitat conditions scores of 4, 8, or 12, respectively. We took the difference between the lowest and highest possible overall condition scores and divided this into three equal intervals representing the breadth of possible scores. A score of less than 6.7 means the complex is in overall low condition, a score greater than 9.3 means the complex is in overall high condition, and scores between 6.7 and 9.3 mean that the complex is in moderate condition.

When assessing overall demographic condition, we doubled the weight of abundance relative to age class structure. Although both categories are important towards identifying resilient populations, those with higher abundances are more likely to be able to withstand stochastic disturbances that could have temporary effects on survival or reproduction. A complex with all low, all moderate, or all high ratings would have overall demographic condition scores of 3, 6, or 9, respectively. We took the difference between the lowest and highest possible overall condition scores and divided this into three equal intervals representing the breadth of possible scores. A score of 5 or less means the complex is in overall low condition, a score greater than 7 means the complex is in overall high condition, and scores between 5 and 7 mean that the complex is in moderate condition. To be conservative, we considered scores that were on the cusp between condition categories (i.e. 5 or 7) to be in the lower category.

The results of our current condition analysis are presented in Table 9. There are 12 extant population complexes and one extirpated population complex (Northern San Mateo County). Of the 12 extant population complexes, there are currently eight population complexes with high overall habitat condition and four in low condition. For overall demographic condition, there are currently one population complex in high condition, five population complexes in moderate condition, and six population complexes in overall low condition.

Table 9. Current condition of San Francisco gartersnake populations in habitat complexes.

	Habitat features					Demographic parameters		
Population complex	**Impounded Fresh Water**	**Aquatic Vegetative Cover**	**Upland habitat**	**Prey**	**Overall Habitat Condition**	**Abundance**	**Age Class Structure**	**Overall Demographic Condition**
Northern San Mateo County	N/A	N/A	N/A	N/A	Extirpated	Extirpated	Extirpated	Extirpated
Pacifica	High[1]	High[1]	High[1]	High[1]	High	Moderate[6]	Moderate[2]	Moderate
West-of-Bayshore	Moderate[2]	High[2]	High[2]	High[2]	High	High[7]	High[7]	High
Northern SFPW	High[2]	High[2]	High[2]	High[2]	High	Moderate[6]	Moderate[2]	Moderate
Southern SFPW	High[2]	High[2]	High[2]	High[2]	High	Low[7]	Unknown	Low (Unknown
Half Moon Bay	Unknown[3]	Unknown[3]	Unknown	Unknown	Low (Unknown)	Unknown	Unknown	Low (Unknown
Woodside	High[4]	High[4]	High[4]	High[4]	High	Low[4]	Unknown	Low (Unknown
San Gregorio	Unknown	Unknown	Unknown	Unknown	Low (Unknown	Unknown	Unknown	Low (Unknown
La Honda	High[5]	High[5]	High[5]	High[5]	High	Moderate[5]	High[5]	Moderate
Pomponio	Unknown	Unknown	Unknown	Unknown	Low (Unknown	Unknown	Unknown	Low (Unknown
Pescadero	High[2]	High[2]	High[2]	High[2]	High	Moderate[6]	High[2]	Moderate
Año Nuevo	High[2]	High[2]	Moderate[2]	High[2]	High	Moderate[6]	High[2]	Moderate
Northern Santa Cruz County	Unknown	Unknown	Unknown	Unknown	Low (Unknown	Low[2]	Unknown	Low (Unknown

[1]Fong and Kindall 2019 (including photos of habitat)
[2]Expert elicitation
[3]McGinnis 1987, pp. 23-24 describes low condition of these site, but we are unaware of more recent surveys.
[4]Stanford HCP Annual Report 2019
[5]Kim *et al.* 2018
[6]Rose *et al.* 2018
[7]Swaim 2018
[8]CNDDB 2018

Current Condition in Relation to Recovery Criteria

Recovery criteria for downlisting of the San Francisco gartersnake focuses on abundance estimates at six significant populations defined in the Recovery Plan. Specifically, the criteria calls for 200 or more individuals at a 1:1 sex ratio at each of the sites for five consecutive years. Our analysis of demographic condition categorized population complexes as being in high condition for abundance if they had a core population with greater than 200 adults, thus all complexes in high condition for that category would count towards achieving this recovery criterion. The only complex that meets this abundance criterion is WOB. Thus, the downlisting criteria for this species are not met.

Synopsis of Current Condition

The San Francisco gartersnake tends to have higher overall condition related to habitat factors than demographic factors. According to our basic analysis of relevant habitat factors, the San Francisco gartersnake currently has eight population complexes in overall high condition and four population complexes in overall low condition. With regard to demographic condition, the species has one population complex in overall high condition, five population complexes in moderate condition, and six population complexes in low condition (Figure 13). It is important to note that the population complexes with high habitat conditions tended to be those with management activities, including habitat restoration, invasive species control, grassland management, and educational signs. The continuation of these management activities is important to maintain these resilient populations. All of the populations with high or moderate overall demographic condition had high habitat conditions.

Habitat and demographic condition were unknown across many of the population complexes, especially in the center of the range. Because of our conservative approach to assume that categories with unknown conditions were in low condition, this may have biased our analysis towards suggesting that these populations have low resiliency. However, we also note the lack of recent observations for many of these locations. Populations that had recent trapping surveys tended to have habitat features in higher condition. However, this is not surprising given that these populations were subjectively chosen to assess possible source locations for a captive breeding program (see Captive Propagation section below).

Redundancy for the species hinges on having multiple resilient population complexes distributed throughout the species range. There is only one population with both high habitat and demographic resiliency, but the distribution of population complexes with high habitat condition and moderate demographic condition across the species range makes it likely that the species could withstand any catastrophic events that may occur. For example, the presence of population complexes with high habitat condition and moderate demographic condition in both coastal and inland locations means that some population complexes would be protected from a catastrophic tsunami or earthquake impacting waterways. However, because population complexes exist in a fragmented landscape that likely has limited connectivity, recolonization of some areas following local extirpations may be unlikely.

The presence of population complexes with high habitat condition and high or moderate demographic condition at both the northern and southern edge of the species' range, in combination with the distribution of populations, indicates that the species exhibits moderate representation. The population complexes with high habitat condition are distributed throughout the species range and relatively evenly mixed between the northern and southern genetic clusters. Both clusters have multiple populations with either high or moderate demographic condition. There are also population complexes with high or moderate resiliency along the coast and more inland. Together, this indicates that the species may have the ability to adapt to changing environmental and biological conditions. However, we note that results from the draft genetic study found that the northern genetic cluster tended to have greater population structure, lower effective population sizes, and lower genetic diversity. Improving habitat and demographic condition in those populations with low resiliency, in particular in the northern regional cluster and along the central coastal portion of the species range, will improve representation for the species.

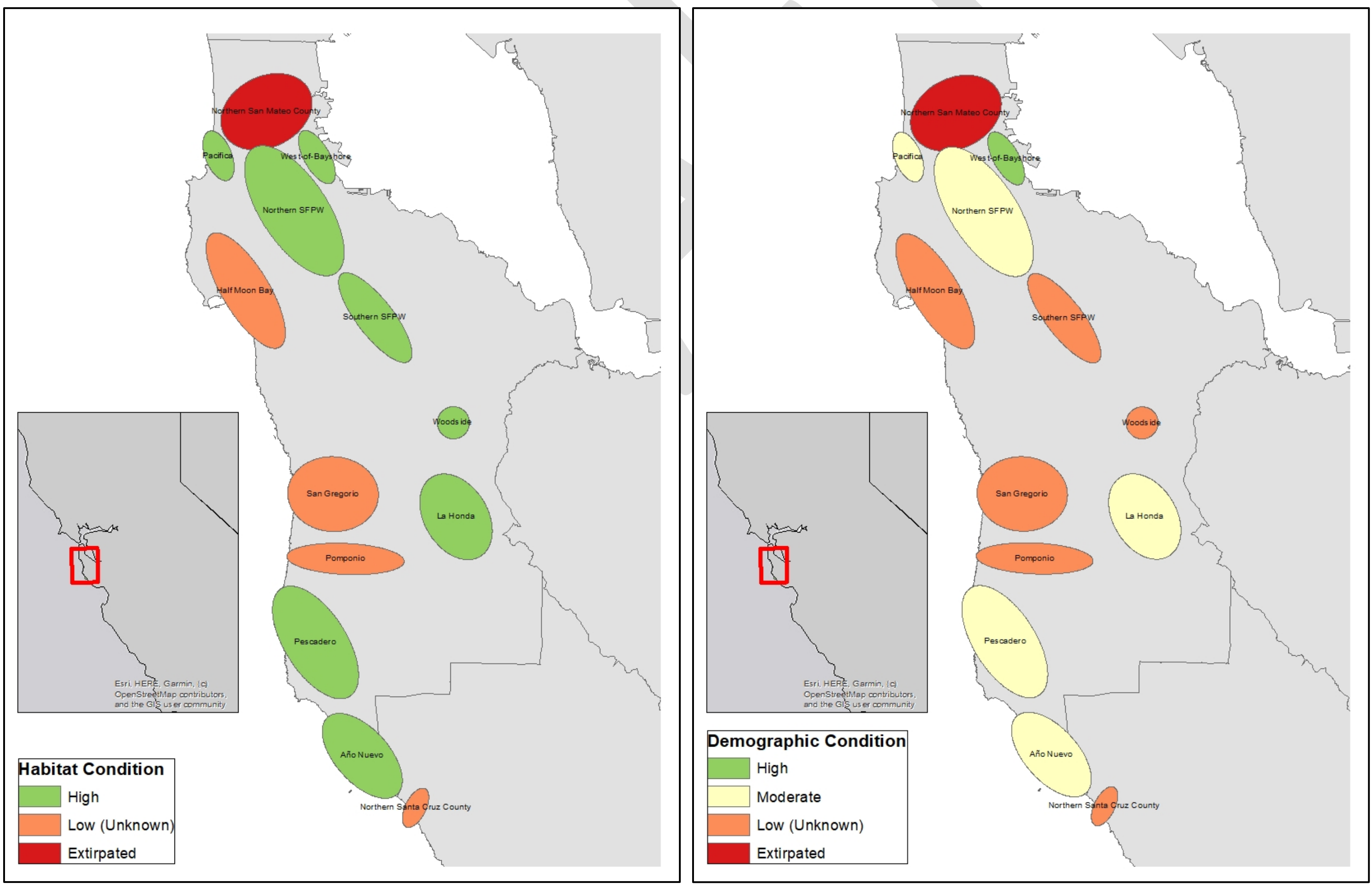

Figure 13. Overall habitat and demographic condition for San Francisco gartersnake population complexes.

Chapter 5. Future Condition

In this chapter, we predict the future viability of 12 San Francisco gartersnake population complexes under three plausible scenarios. We did not include the extirpated Northern San Mateo County complex in this analysis. The future scenarios use different combinations of climate change impacts and conservation efforts, and are evaluated on a time frame of approximately 80 years (through 2100) to align with climate projections for the area. This analysis will help us predict how viability of the San Francisco gartersnake may change in the future. We discuss San Francisco gartersnake resiliency, representation, and redundancy in the context of these scenarios.

Before discussing the scenarios and analysis results, we first describe how conditions are expected to change in the future. Factors influencing viability of the San Francisco gartersnake are assessed in the context of climate change. We also discuss captive propagation as a potential future management action for the species. Figure 14 updates the influence diagram presented in Chapter 4 with the addition of climate change and captive propagation, with expected changes through their effects on habitat or demographic parameters.

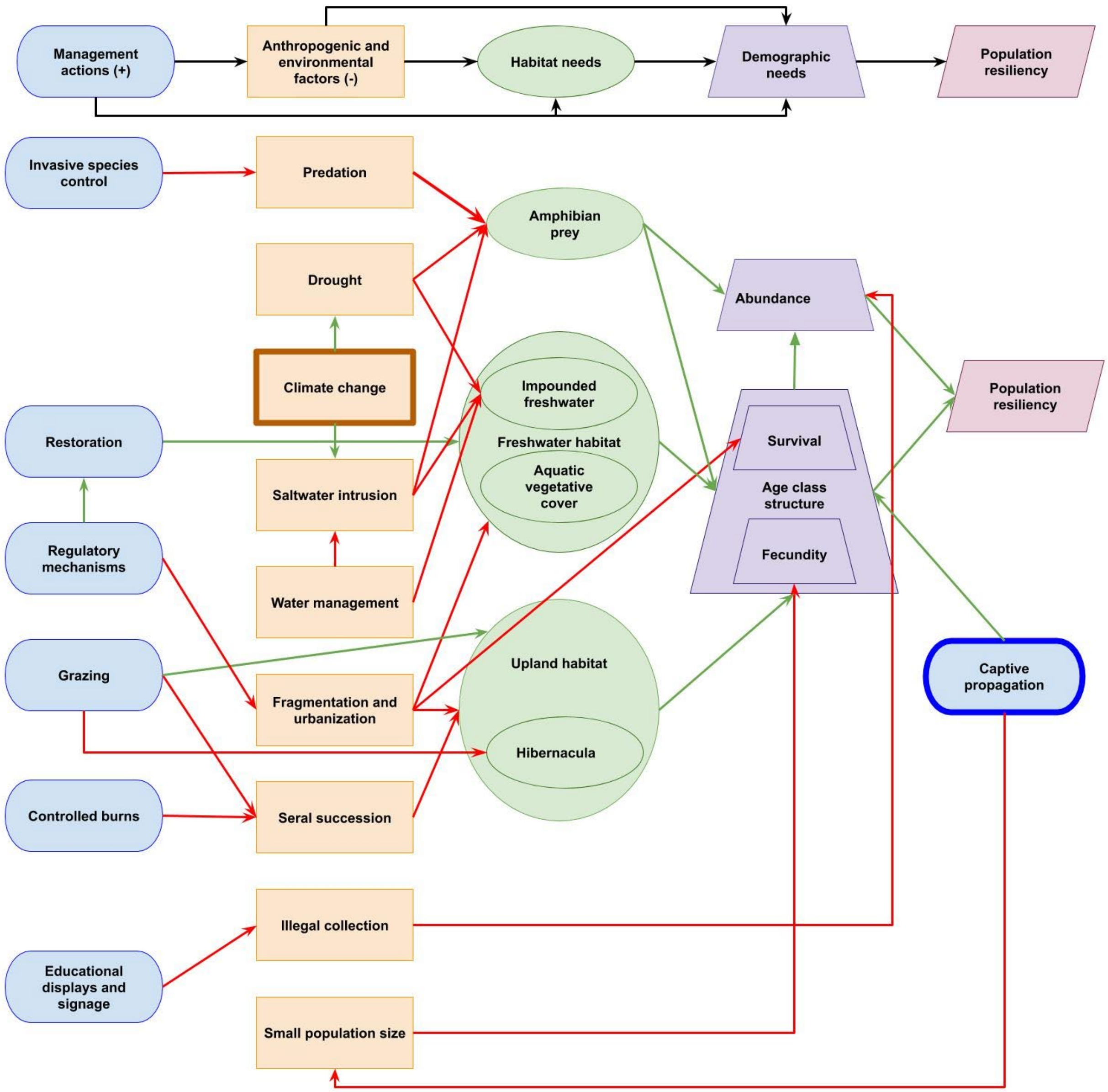

Figure 14. Updated influence diagram including climate change and captive propagation with expected influence on habitat and demographic needs. These new factors are outlined in bold in the diagram.

Potential future changes to factors influencing viability such as illegal collection or predation are unclear and are not discussed in this section. Additionally, although development or agricultural conversion of undeveloped private property remains a potential threat that is expected to continue or increase in the future, we do not have enough information about San Francisco gartersnake populations on private land to attempt to estimate effects of future development on the species. The potential impacts of small population size are unclear and largely depend on the future condition of populations or complexes.

Climate Change

Climate change impacts in national parks in the San Francisco Bay Area are summarized, including original analyses, in Gonzalez 2016 (entire). This report focuses on national parks in Marin, San Francisco, and northern San Mateo Counties, but for the purposes of this document, we assume that the data and trends presented in Gonzalez (2016) are representative of expected impacts throughout the San Francisco gartersnake range. Direct effects of climate change on San Francisco gartersnakes are difficult to assess. Increased temperature may increase growth rates for individual San Francisco gartersnakes, which may allow females to reach reproductive status more quickly, increase reproductive output of females (based on a correlation between female size and number of offspring), or allow individuals to reach size classes that are less vulnerable to predation. However, the magnitude of these potential changes for individuals, and the population-level effects of these potential morphological or demographic changes, are unclear, thus we do not make assumptions about direct effects of climate change on San Francisco gartersnakes. Instead, climate change is expected to have mainly indirect effects on the San Francisco gartersnake. In this section, we discuss anticipated indirect impacts to San Francisco gartersnake from sea level rise, precipitation, temperature, and drought. We also briefly discuss changes to fog, although we don't have enough information to expect impacts from these possible changes.

Climate change-induced sea level rise risks saltwater inundation of San Francisco gartersnake habitat. This threat is greatest in habitat along the coast. Historically, sea level rise of 22 cm (9 in) from 1854 to 2016 is attributed to human climate change (Gonzalez 2016, p. 5). Sea level is expected to continue to increase globally through both expansion of ocean water when it warms and increased volume of water in oceans from melting glaciers and ice (Gonzalez 2016, p. 12). The Intergovernmental Panel on Climate Change projects global sea level rise of 26-55 cm (10-22 in) under the lowest emissions scenario and 52-98 cm (20-39 in) under the highest emissions scenario by 2100, and it is expected that the San Francisco Bay Area will be similar to the global average. Saltwater inundation can make habitat unsuitable for amphibian prey, which in turn is expected to negatively influence San Francisco gartersnake survival and reproduction. Further, observations of bullfrogs in brackish water in North Carolina suggests that this species may be more tolerant of saltwater intrusion than treefrogs and red-legged frogs, which could lead to further reductions in prey species for the San Francisco gartersnake.

Total annual precipitation did not significantly change from 1950 to 2010, but models in general show an increase in precipitation under various emissions scenarios. Precipitation extremes are expected to increase, as evidenced by a prediction for higher frequency of both extremely wet and extremely dry years (Swain *et al.* 2018, pp. 427-433). Average annual temperatures within the boundaries of San Francisco Bay Area National Parks significantly increased from 1950 to 2010, and are expected to increase by 3.8 degrees Celcius (6.8 degrees Fahrenheit) on average from 2000 to 2100. Temperature changes are expected to increase further from the coast (Gonzalez 2016, p. 7). Anticipated changes to precipitation and temperature have the potential to impact amphibian populations with indirect effects on San Francisco gartersnake populations. However, the distribution of red-legged frogs and treefrogs in areas throughout California that are highly variable in precipitation and temperature measures suggests flexibility of amphibians to persist given the projected changes. Precipitation increases are expected to decrease with distance from the Pacific, while temperature increases are projected to be higher further from the coast (Gonzalez 2016, p. 7). Taken together, this means that inland populations could see less change in precipitation combined with higher temperatures, which is discussed in the context of drought below. Changes in precipitation and temperature have the potential to impact upland habitat for the San Francisco gartersnake, but specific ways in which these variables may influence the threat of seral succession are unclear.

Despite overall predictions of increased precipitation, hotter temperatures are expected to increase the probability and frequency of droughts (Diffenbaugh *et al.* 2015, pp. 3932-3933). San Francisco gartersnake and its prey, red-legged frogs, are both listed as highly vulnerable to drought in an assessment of vertebrate taxa in Golden Gate National Recreation Area (CDFW 2016, p. 14). Drought-related changes to impounded freshwater habitat can reduce reproduction of amphibians in these habitats, which will in turn reduce prey availability for San Francisco gartersnakes. In the interior coast range, increased temperatures combined with decreased precipitation may lead to shortened hydroperiods which can reduce amphibian reproduction. This may disproportionately affect neonate and juvenile San Francisco gartersnakes that rely on small amphibian prey as food sources. Monitoring of San Francisco gartersnake populations spread throughout the range of the species (e.g., the Pescadero, WOB, and Pacifica complexes) all suggest that amphibian prey may be limiting during drought years (Kim *et al.* 2017, Larsen 1994).

Potential changes to coastal fog could impact basking conditions in upland habitat. Studies demonstrate that Pacific coast and Bay Area fog has decreased in recent years relative to the beginning of the century (Johnstone and Dawson 2010, p. 4534), potentially associated with urbanization and pollution (summarized in Ackerly *et al.* 2018, pp. 25-27). Future changes in the fog belt related to climate change are possible, but there is a lot of uncertainty because of the interplay between heat and humidity across various sources (i.e., land, ocean, air). Although significant increases in fog could alter the thermal environment in upland habitat, we don't take this into consideration in this SSA.

Fragmentation and Urbanization

Protected areas relative to San Francisco gartersnake population complexes are shown in Figure 15. Although fragmentation and urbanization may increase throughout the range of the species, all of the population complexes that have rankings for habitat and demographic condition (i.e., not categorized as "unknown") have protected habitat within the complex that supports the species, so we did not anticipate large-scale affects from this threat for these populations. Of the population complexes that have unknown habitat conditions, the San Gregorio and Pomponio population complexes both occur in areas that are on largely unprotected lands, and we expect that continued urban development and fragmentation could occur which could directly or indirectly influence San Francisco gartersnakes in these areas. Populations within these complexes occur primarily in areas that the San Mateo County General Plan classifies as having land use of "Agriculture" (Figure 16). We note that the Half Moon Bay population complex as mapped also has the majority of the polygon within area that is marked as "Agriculture".

However, inspection of population occurrences from CNDDB reveals that the actual occurrences within this polygon are on protected land.

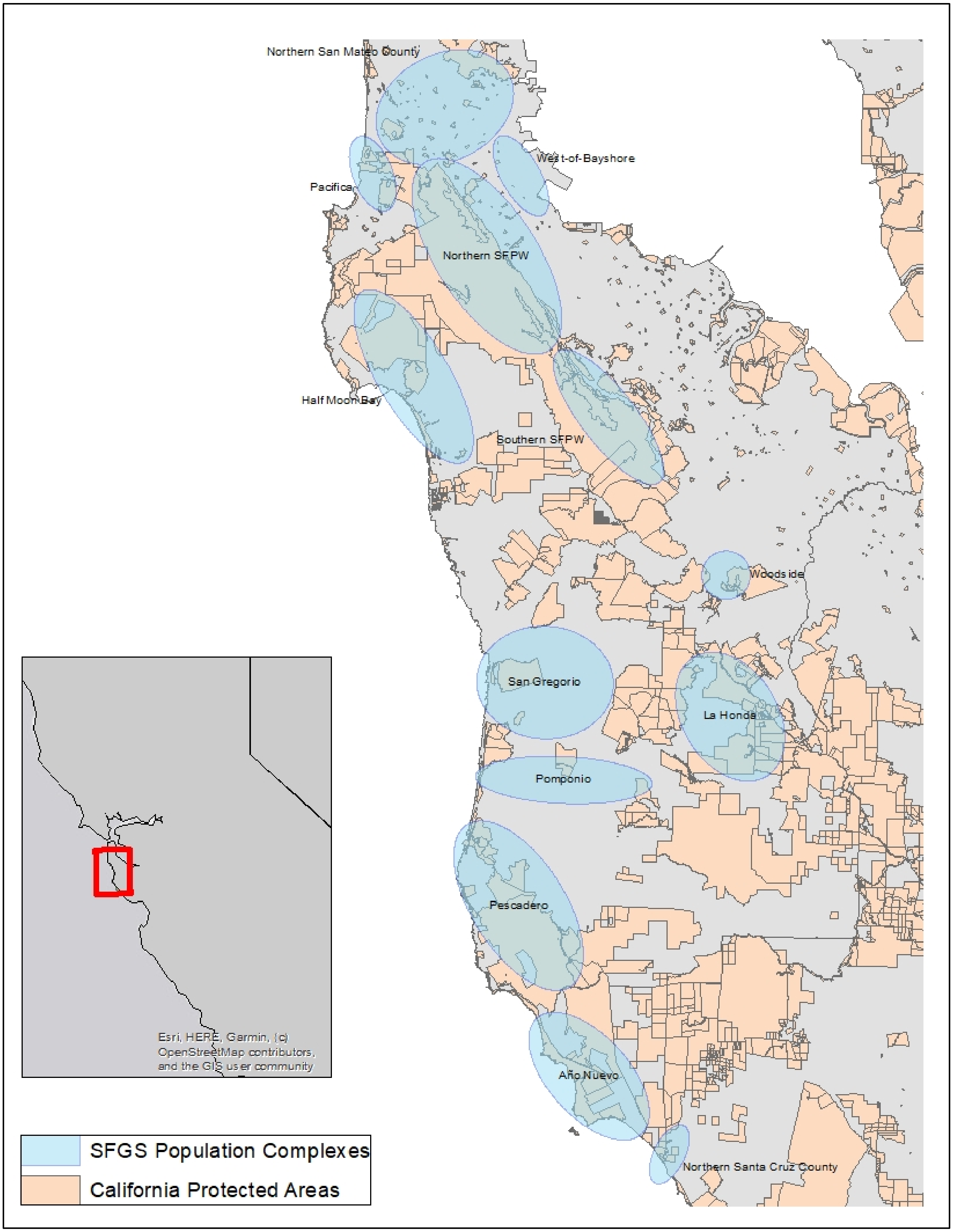

Figure 15. Protected lands within the range of the San Francisco gartersnake. Protected areas are from the California Protected Areas Database.

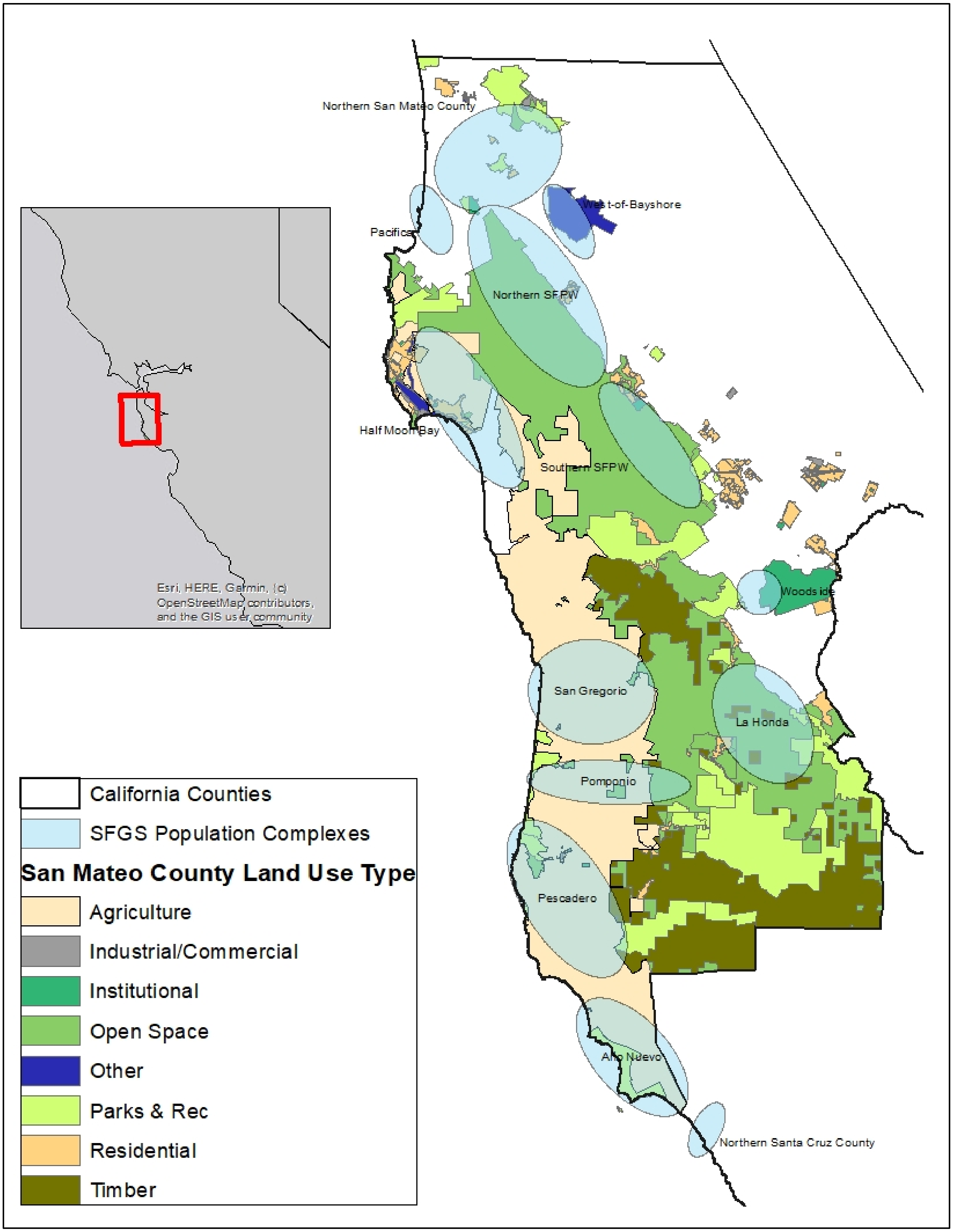

Figure 16. Land use in San Mateo County, using available data from the San Mateo County General Plan Land Use from areas within the County's planning jurisdiction.

Captive Propagation

Planning and permitting is currently underway for a captive breeding and/or headstarting facility that is intended to contribute to the conservation and recovery of imperiled California species, including the San Francisco gartersnake. Captive breeding or headstarting will be carefully integrated with the recovery strategy for this species. As part of an agreement with the Service, the Western Ecological Research Center of the U.S. Geological Survey (USGS) sampled for San Francisco Gartersnakes at six sites from April–June 2018 and 2019 to identify potential donor populations for captive breeding and translocation/reintroduction efforts (Rose *et al.* 2018, entire). The sampling included sites within the Pacifica, Northern SFPW, and Año Nuevo population complexes. In a concurrent study, USGS is evaluating the population structure and genetic diversity of the species (Wood *et al*. 2019), which could be integrated into a genetic management strategy for the captive facility. Captive breeding or headstarting through this facility is expected to lead to population augmentation at sites with suitable habitat but low abundance of San Francisco gartersnakes. Population augmentation may also be used to increase population abundance and/or genetic diversity in areas threatened by small population size. However, there is some uncertainty regarding the projected success of this facility, as many details of the proposed actions here still need to be determined.

Future Scenarios

We assess the condition of the San Francisco gartersnake in three potential scenarios using predicted changes in threats to the species (Table 10).

Table 10. Predicted future change to threats influencing viability of the San Francisco gartersnake.

Threat	Predicted Change
Fragmentation and Urbanization	May increase
Changes to Aquatic Habitat: Saltwater Intrusion	May increase
Changes to Aquatic Habitat: Drought	May increase
Changes to Aquatic Habitat: Water Management	Unknown
Seral Succession	Unknown
Illegal collection	Unknown
Predation	Unknown
Small Population Size	May decrease

In Scenario 1 we assume a sea level rise of 55 cm (22 in). This amount is the greatest projected sea level increase under low emissions, and has the potential to increase the threat of saltwater inundation. We also assume that there will be increased drought years, even with low emissions. Rather than influencing the condition of impounded freshwater habitat, we anticipate that drought may reduce prey availability to San Francisco gartersnakes such that it may become limiting in some population complexes and years. Reductions in availability of amphibian prey may be exacerbated by the presence of bullfrogs, thus we expected changes to amphibian prey under this scenario only for those population complexes known to have bullfrogs present. We assume that the captive breeding program is successful in rearing San Francisco gartersnakes and releasing them back into the populations where they originated. Because of the projected success of this program, we do not anticipate population declines within the population complexes currently included in the study assessing captive breeding.

In Scenario 2 we assume a sea level rise of 98 cm (39 in). This amount is the greatest projected sea level increase under high emissions, and is likely to increase the threat of saltwater inundation. We analyzed the condition of the population complexes assuming that there would be some infrastructure failures (e.g., sea wall failure) and that saltwater intrusion protections near the San Francisco airport remain at current levels. Under the high emissions scenario we assume that there will be increased drought years, with potential to decrease amphibian prey availability. We assume that the captive propagation program is not successful for various potential reasons including, but not limited to, funding issues, difficulty rearing in captivity, or problems related to translocations.

In Scenario 3, we again use a high emissions scenario with sea level rise of 98 cm (39 in), which is likely to increase the threat of saltwater inundation. However, in this scenario we assumed that additional infrastructure designed to protect the Bay Area from saltwater intrusion also lessons the potential impacts from sea water for San Francisco gartersnakes and its habitat. We also assumed there would be increased drought years and potential reductions in amphibian prey. Reductions in availability of amphibian prey may be exacerbated by the presence of bullfrogs. We assume that the captive breeding and translocation program is highly successful. In addition to limiting population declines in those areas being evaluated in the captive breeding study, we also anticipate translocations into other population complexes with suitable habitat but low abundance. We assume that range-wide surveys are used to estimate population abundances prior to translocations, such that individuals can be used to augment those populations with the lowest numbers.

In all scenarios, we assume that habitat fragmentation continues to occur on unprotected lands, and that conservation efforts and management activities on public lands continue at their current levels. Current management activities occur on public lands that have management plans in place that promote recovery of the San Francisco gartersnake, or on state or federal lands in areas where we expect continued restoration for the species. Scenarios are summarized in Table 11.

Table 11. Scenarios used to analyze future condition of San Francisco gartersnake population complexes.

Scenario 1	**Scenario 2**	**Scenario 3**
Low emissions	High emissions	High emissions
Sea level rise of 22 in	Sea level rise of 39 inches	Sea level rise of 39 inches

Potential to increase threat of saltwater inundation	Increased threat of saltwater inundation, with infrastructure failures	Likely to increase threat of saltwater inundation, but infrastructure somewhat protects key areas
Interaction between drought and predation reduces prey availability at sites with bullfrogs	Increases in drought frequency reduces prey availability such that it may be limiting	Increases in drought frequency reduces prey availability such that it may be limiting
Captive breeding maintains abundance and age class structure at select sites	Captive breeding program not implemented or has low success	Captive breeding and translocations maintain or increase abundance and age class structure
Continued habitat fragmentation occurs on unprotected lands	Continued habitat fragmentation occurs on unprotected lands	Continued habitat fragmentation occurs on unprotected lands
Management and restoration continues at current levels	Management and restoration continues at current levels	Management and restoration continues at current levels

Analysis of Future Condition

We predicted the future conditions of each population complex based on the variations of saltwater inundation, drought, fragmentation, and success of the captive breeding program. Predicted changes to habitat and demographic conditions are provided for each scenario. Specifically, we predicted changes to the same habitat and demographic needs measured in our current condition analysis. Continuation of management and restoration activities is expected in all scenarios. For population complexes with unknown condition for any habitat condition categories, we did not change future habitat except in those situations where we expected condition to be low in the future. In these cases, we changed "unknown" to "low", which did not actually change the calculation for overall habitat quality, but provides more certainty. For example, the San Gregorio population complex has the potential to be impacted by saltwater inundation, which could change habitat quality in multiple categories and making the species less likely to persist in this area. For populations that currently have unknown demographic conditions, we changed abundance to low/extirpated in populations where we expected pressures that could challenge the persistence of the population. For example, on unprotected habitat in areas where we determined that fragmentation may increase as a threat, we changed abundance to low/extirpated.

We calculated overall habitat and demographic conditions for each population complex in our future condition analysis in the same way as in our current condition analysis (see explanation in

Current Condition of Population Complexes (Resiliency). For those populations with an abundance condition of low/extirpated, we assumed that the overall demographic condition would also be low/extirpated.

Scenario 1

We assessed changes relative to drought based on suggestions that drought may lead to reductions in amphibian prey. Because we do not have specific information about amphibian populations within each complex, we assumed that condition in that category would be decreased under a low emissions scenario only for population complexes known to have bullfrogs. The presence of bullfrogs can also reduce availability of amphibian prey, and we assumed a potential synergistic reaction between these two factors both associated with decline of amphibian prey. This method has the potential to overestimate or underestimate the potential for drought to affect future conditions for the species. We assumed that habitat fragmentation could reduce abundance of San Francisco gartersnakes in population complexes predominantly on unprotected lands to low/extirpated. Accordingly, we reduced the abundance for the San Gregorio and Pomponio population complexes to low/extirpated.

We assessed future changes in saltwater inundation by mapping sea level rise using the Our Coast Our Future online mapping tool (http://data.pointblue.org/apps/ocof/cms/). We used the tool to project flooding under 50 cm of sea level rise and with an annual storm scenario. We assume that 50 cm of sea level rise is roughly equivalent to the 55 cm projected sea level rise we used in this scenario. Under these parameters, the population complexes that would potentially be affected include Pacifica, WOB, and San Gregorio. In the Pacifica population complex, waves could lead to saltwater inundation of Laguna Salada, but not the ponds at Mori Point (Figure 17). We therefore decreased the condition for freshwater condition to moderate condition, because the available freshwater habitat would be limited to the ponds at Mori Point which are relatively similar in size and are smaller than Laguna Salada. We assumed that WOB would be somewhat protected from saltwater inundation under the low emissions scenario because of protections put in place by the San Francisco Airport, such that condition of impounded freshwater habitat would be reduced to moderate (Figure 18). We also assumed that saltwater seepage could reduce availability of amphibian prey to moderate condition, changing that category condition to moderate as well. For San Gregorio we reduced the condition for impounded freshwater habitat and aquatic vegetation to low condition (Figure 19). Although the Pescadero population complex has some populations that could likely be inundated with saltwater under this flooding scenario (Figure 20), the most resilient populations within this complex are inland and unlikely to be affected by saltwater. The Año Nuevo population complex shows saltwater inundation that will approach, but not reach, the Visitor Center Pond, thus we did not think it was likely that saltwater inundation would impact this population complex (Figure 21).

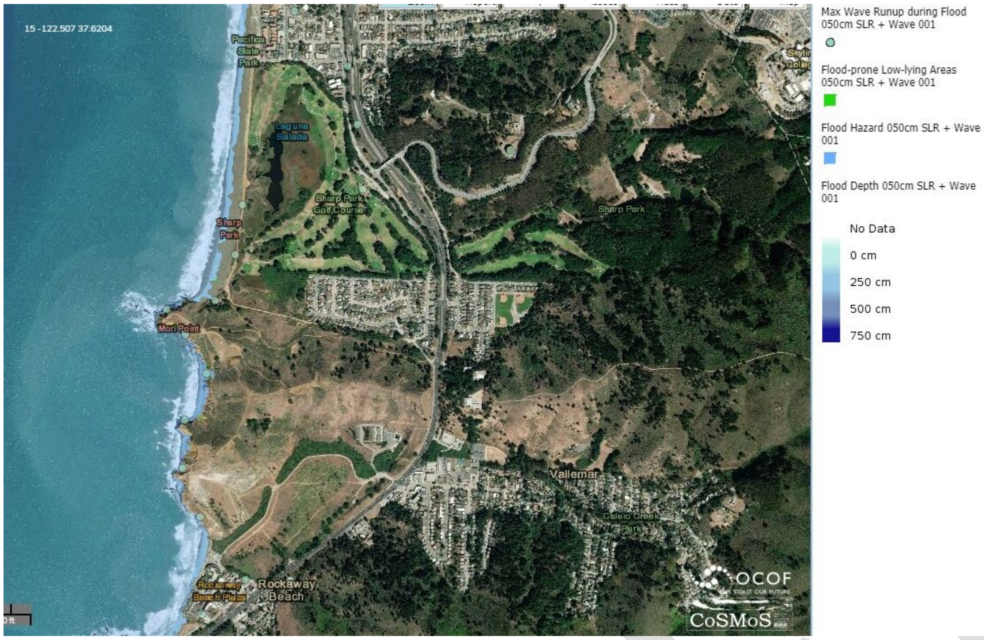

Figure 17. Habitat near the Pacifica San Francisco gartersnake population complex showing predicted flooding under 50 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

Figure 18. Habitat near the WOB San Francisco gartersnake population complex showing predicted flooding under 50 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

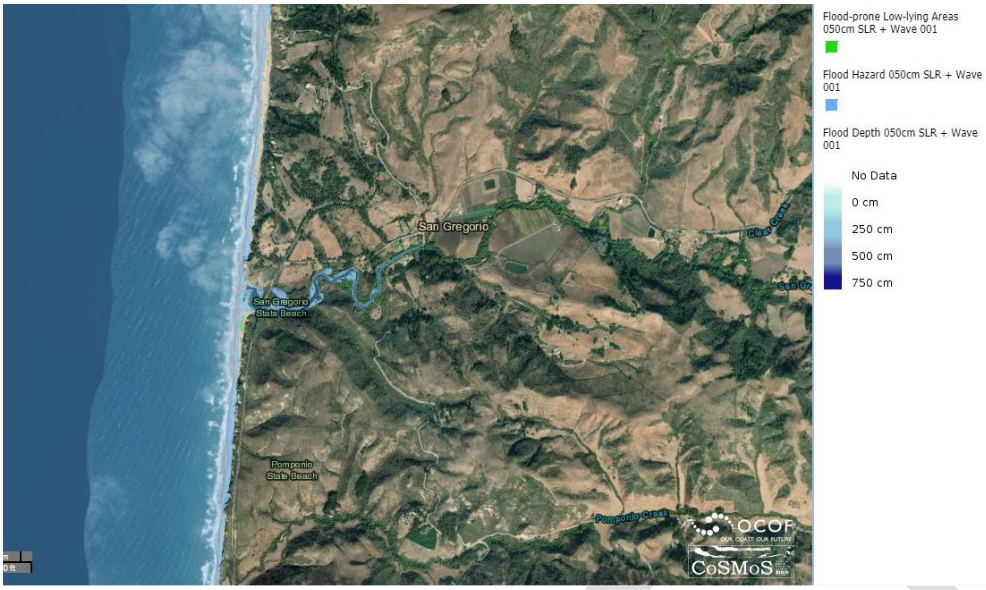

Figure 19. Habitat near the San Gregorio San Francisco gartersnake population complex showing predicted flooding under 50 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

Figure 20. Habitat near the Pescadero San Francisco gartersnake population complex showing predicted flooding under 50 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

Figure 21. Habitat near the Año Nuevo San Francisco gartersnake population complex showing predicted flooding under 50 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/). The Visitor Center Pond is visible near the center of the image.

We assessed future changes based on population augmentation under moderate success of the captive breeding facility. Under moderate success, we assumed that population complexes with moderate abundance of San Francisco gartersnake would have captive breeding and reintroductions into those populations that would maintain abundance. We assumed that this would increase the condition for age class structure for those populations currently in moderate condition.

Conditions under Scenario 1 are presented in Table 12.

Table 12. Population complex conditions under Scenario 1.

	Habitat features					Demographic parameters		
Population complex	**Impounded Fresh Water**	**Aquatic Vegetative Cover**	**Upland habitat**	**Prey**	**Overall Habitat Condition**	**Abundance**	**Age Class Structure**	**Overall Demographic Condition**
Northern San Mateo County	N/A	N/A	N/A	N/A	Extirpated	Extirpated	Extirpated	Extirpated
Pacifica	Moderate	High	High	Moderate	High	Moderate	High	Moderate
West-of-Bayshore	Moderate	High	High	Moderate	High	High	High	High
Northern SFPW	High	High	High	Moderate	High	Moderate	High	Moderate
Southern SFPW	High	High	High	Moderate	High	Low	Unknown	Low
Half Moon Bay	Unknown	Unknown	Unknown	Unknown	Low	Unknown	Unknown	Low
Woodside	High	High	High	High	High	Low	Unknown	Low
San Gregorio	Low/Extirpated	Unknown	Unknown	Unknown	Low/Extirpated	Low/Extirpated	Unknown	Low/Extirpated
La Honda	High	High	High	Moderate	High	Moderate	High	Moderate
Pomponio	Unknown	Unknown	Unknown	Unknown	Low	Low/Extirpated	Unknown	Low/Extirpated
Pescadero	High	High	High	Moderate	High	Moderate	High	Moderate
Año Nuevo	High	High	Moderate	Moderate	High	Moderate	High	Moderate
Northern Santa Cruz County	Unknown	Unknown	Unknown	Unknown	Low	Low	Unknown	Low

Scenario 2

We assessed changes relative to drought based on suggestions that drought may lead to reductions in amphibian prey. Under a high emissions scenario, we assumed that availability of amphibian prey could become a limiting factor for all population complexes in some years. We therefore reduced prey availability to moderate for all populations that are in high condition currently. We assumed that habitat fragmentation could reduce abundance of San Francisco gartersnakes in population complexes predominantly on unprotected lands to low/extirpated. Accordingly, we reduced the abundance for the San Gregorio and Pomponio population complexes to low/extirpated.

We assessed future changes in saltwater inundation by mapping sea level rise using the Our Coast Our Future online mapping tool (http://data.pointblue.org/apps/ocof/cms/). We used the tool to project flooding under 100 cm of sea level rise and with an annual storm scenario. We assume that 100 cm of sea level rise is roughly equivalent to the 98 cm projected sea level rise we used in this scenario. Under these parameters, the population complexes that would potentially be affected include Pacifica, WOB, and San Gregorio. For Pacifica, we assumed that waves and saltwater inundation at Laguna Salada would change condition of impounded freshwater habitat to low (Figure 22). We also changed aquatic habitat to moderate, assuming some vegetative changes, and upland habitat to moderate assuming that there might be less burrows available. At WOB, we assumed that saltwater inundation would be more extensive (Figure 23). Because we assumed that saltwater intrusion protections near the San Francisco airport would remain at current levels, we decreased most habitat conditions to low; we decreased impounded freshwater to low/extirpated, and correspondingly changed demographic conditions to low/extirpated. For San Gregorio we reduced the condition for impounded freshwater habitat to low condition (Figure 24). Although the Pescadero population complex has some populations that could likely be inundated with saltwater under this flooding scenario (Figure 25), the most resilient populations within this complex are inland and unlikely to be affected by saltwater. Accordingly, we did not change habitat conditions despite likely impacts from saltwater inundation. The Año Nuevo population complex shows saltwater inundation that will approach, but not reach, the Visitor Center Pond, thus we did not think it was likely that saltwater inundation would impact this population complex (Figure 26).

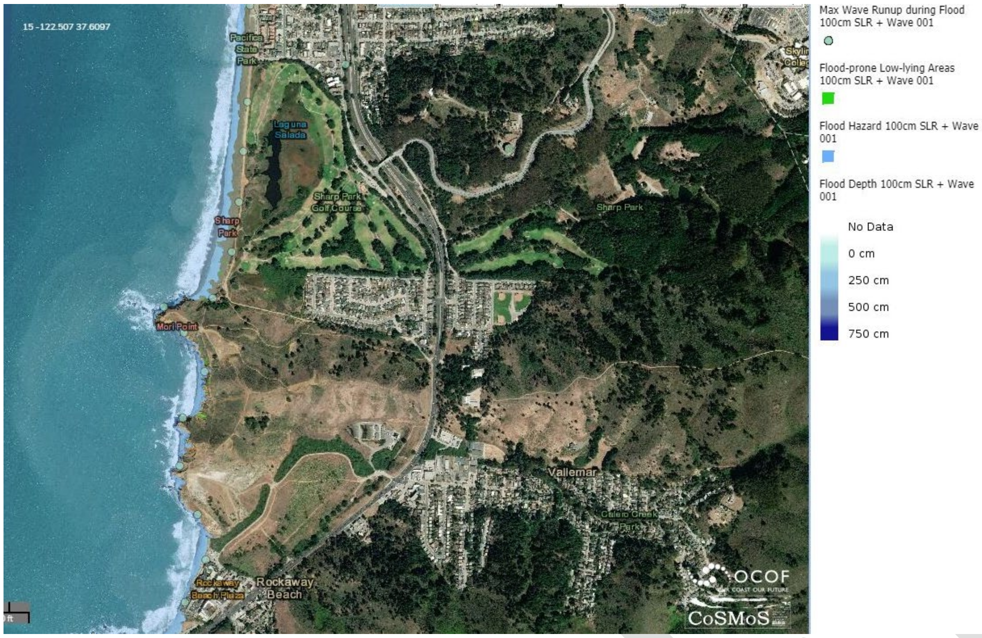

Figure 22. Habitat near the Pacifica San Francisco gartersnake population complex showing predicted flooding under 100 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

Figure 23. Habitat near the WOB San Francisco gartersnake population complex showing predicted flooding under 100 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

Figure 24. Habitat near the San Gregorio San Francisco gartersnake population complex showing predicted flooding under 100 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

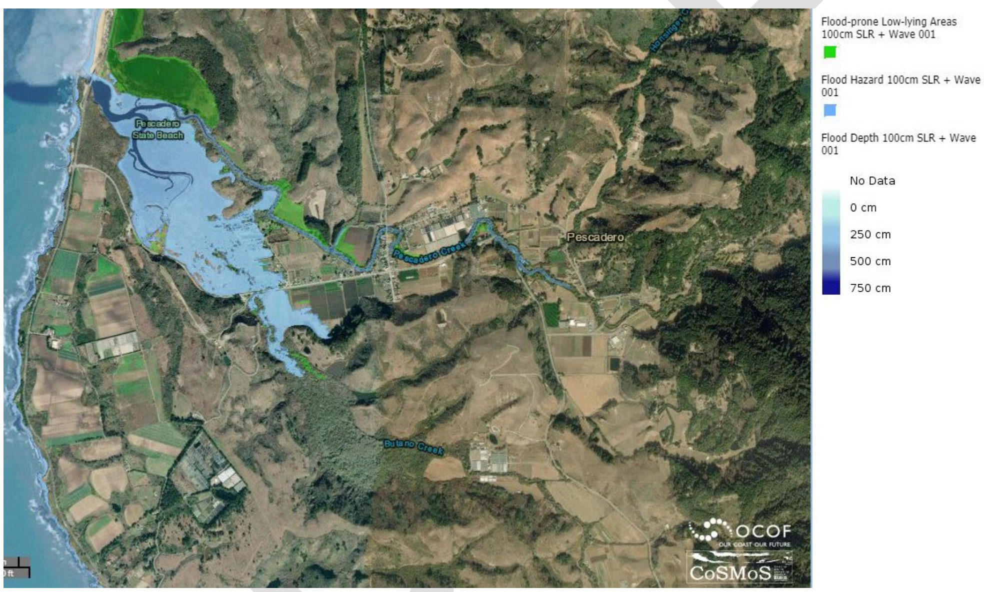

Figure 25. Habitat near the Pescadero San Francisco gartersnake population complex showing predicted flooding under 100 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

Figure 26. Habitat near the Año Nuevo San Francisco gartersnake population complex showing predicted flooding under 100 cm of sea level rise with an annual storm scenario. Data from Our Coast Our Future (http://data.pointblue.org/apps/ocof/cms/).

We did not make changes to demographic conditions related to captive propagation because we assumed the program would not be successful.

Conditions under Scenario 2 are presented in Table 13.

Table 13. Population complex conditions under Scenario 2.

	Habitat features					Demographic parameters		
Population complex	**Impounded Fresh Water**	**Aquatic Vegetative Cover**	**Upland habitat**	**Prey**	**Overall Habitat Condition**	**Abundance**	**Age Class Structure**	**Overall Demographic Condition**
Northern San Mateo County	N/A	N/A	N/A	N/A	Extirpated	Extirpated	Extirpated	Extirpated
Pacifica	Low	Moderate	Moderate	Moderate	Moderate	Moderate	High	Moderate
West-of-Bayshore	Low/Extirpated	Low	Low	Low	Low/Extirpated	Low/Extirpated	Low	Low/Extirpated
Northern SFPW	High	High	High	Moderate	High	Moderate	High	Moderate
Southern SFPW	High	High	High	Moderate	High	Low	Unknown	Low
Half Moon Bay	Unknown	Unknown	Unknown	Unknown	Low	Unknown	Unknown	Low
Woodside	High	High	High	Moderate	High	Low	Unknown	Low
San Gregorio	Low/Extirpated	Unknown	Unknown	Unknown	Low/Extirpated	Low/Extirpated	Unknown	Low/Extirpated
La Honda	High	High	High	Moderate	High	Moderate	High	Moderate
Pomponio	Unknown	Unknown	Unknown	Unknown	Low	Low/Extirpated	Unknown	Low/Extirpated
Pescadero	High	High	High	Moderate	High	Moderate	High	Moderate
Año Nuevo	High	High	Moderate	Moderate	High	Moderate	High	Moderate
Northern Santa Cruz County	Unknown	Unknown	Unknown	Unknown	Low	Low	Unknown	Low

Scenario 3

As in the other high emissions scenario, we assumed that availability of amphibian prey could become a limiting factor for all population complexes in some years. We therefore reduced prey availability to moderate for all populations that have high condition currently. We assumed that habitat fragmentation could reduce abundance of San Francisco gartersnakes in population complexes predominantly on unprotected lands to low/extirpated. Accordingly, we reduced the abundance for the San Gregorio and Pomponio population complexes to low/extirpated.

We assessed future changes in saltwater inundation by mapping sea level rise using the Our Coast Our Future online mapping tool (http://data.pointblue.org/apps/ocof/cms/). As in Scenario 2, we used the tool to project flooding under 100 cm of sea level rise and with an annual storm scenario. Figures presented under Scenario 2 are also applicable to this scenario. However, we made some modifications to our analysis in this scenario because we assumed that additional infrastructure designed to protect the Bay Area from saltwater intrusion lessons the potential impacts from sea water for San Francisco gartersnakes and its habitat. We still expected the population complexes that would potentially be affected to include Pacifica, WOB, and San Gregorio. For Pacifica, we assumed that waves and saltwater inundation would be limited to Laguna Salada, changing the condition of impounded freshwater habitat to moderate. We also changed aquatic habitat to moderate, assuming some vegetative changes, and upland habitat to moderate assuming that there might be less burrows available. At WOB, we assumed that saltwater inundation would be more extensive than that under 50 cm of sea level rise, although we did still assume in this scenario that protections put in place by the airport would maintain some habitat at the site. Consistent seepage of saltwater would change impounded freshwater habitat condition to low and could change aquatic vegetation, so we also reduced condition in that category to moderate. We further assumed that reduction in habitat quality and prey would increase competition for the species, which could result in a significant reduction in abundance at that site and decreases in reproduction or survival (assessed in our analysis as age class structure). Because the current abundance is over five-fold of our minimum target for high condition in abundance, it is likely that the population will maintain high condition for this category, but we decreased the age structure condition to moderate because breeding may not be as consistently successful. For San Gregorio we reduced the condition for impounded freshwater habitat and aquatic vegetation to low condition. Although the Pescadero population complex has some populations that could likely be inundated with saltwater under this flooding scenario, the most resilient populations within this complex are inland and unlikely to be affected by saltwater. Thus, some Pescadero complex populations could be extirpated in this scenario, but overall the complex is not. The Año Nuevo population complex shows saltwater inundation that will approach, but not reach, the Visitor Center Pond, thus we did not think it was likely that saltwater inundation would impact this population complex.

We assessed future changes based on population augmentation under high success of the captive breeding facility, assuming both captive propagation and population augmentations. We assumed that population complexes with moderate abundance of San Francisco gartersnake would have captive breeding and reintroductions into those populations that would maintain abundance, and that this would increase the condition for age class structure for those populations currently in moderate condition. We also assumed that complexes with high quality habitat and moderate abundance would be augmented such that abundance changes to high, and those with high quality habitat condition but low abundance would be augmented such that abundance and age class structure are both moderate.

Conditions under Scenario 3 are presented in Table 14.

Table 14. Population complex conditions under Scenario 3.

	Habitat features					Demographic parameters		
Population complex	**Impounded Fresh Water**	**Aquatic Vegetative Cover**	**Upland habitat**	**Prey**	**Overall Habitat Condition**	**Abundance**	**Age Class Structure**	**Overall Demographic Condition**
Northern San Mateo County	N/A	N/A	N/A	N/A	Extirpated	Extirpated	Extirpated	Extirpated
Pacifica	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	High	Moderate
West-of-Bayshore	Low	Moderate	Moderate	Moderate	Moderate	High	Moderate	High
Northern SFPW	High	High	High	Moderate	High	Moderate	High	Moderate
Southern SFPW	High	High	High	Moderate	High	Moderate	Moderate	Moderate
Half Moon Bay	Unknown	Unknown	Unknown	Unknown	Low	Unknown	Unknown	Low
Woodside	High	High	High	Moderate	High	Moderate	Moderate	Moderate
San Gregorio	Low/Extirpated	Unknown	Unknown	Unknown	Low/Extirpated	Low/Extirpated	Unknown	Low/Extirpated
La Honda	High	High	High	Moderate	High	High	High	High
Pomponio	Unknown	Unknown	Unknown	Unknown	Low	Low/Extirpated	Unknown	Low/Extirpated
Pescadero	High	High	High	Moderate	High	High	High	High
Año Nuevo	High	High	Moderate	Moderate	High	High	High	High
Northern Santa Cruz County	Unknown	Unknown	Unknown	Unknown	Low	Low	Unknown	Low

Synopsis of Future Condition Analysis

The results of the future condition analysis show differences based on variation mainly due to potential negative impacts from saltwater inundation related to sea level rise, and increases in demographic condition due to captive propagation. For demographic condition, there were reductions across all scenarios for the San Gregorio and Pomponio populations to low/extirpated, and additional decreases in condition for other population complexes based on expected impacts from sea level rise. However, in Scenarios 1 and 3 we also predicted varying success in the proposed captive propagation program would lead to increases to demographic conditions in some population complexes. Continued occurrence of the most resilient population currently, the WOB population, relies on protections put in place by the San Francisco airport to combat sea level rise that may also protect habitat for the San Francisco gartersnake at that site.

Under Scenario 1, there are no changes to overall habitat or demographic condition for most population complexes, but there were potential extirpations of population complexes at San Gregorio and Pomponio. Changes to individual habitat factors could slightly lower the resiliency of some population complexes, but these subtle changes were not large enough to change the overall conditions scores in our analysis. Scenario 2 had the most pessimistic outlook for the species, assuming extensive saltwater inundation and no success of the captive propagation program. Under this scenario, one population complex would be potentially extirpated because of habitat conditions and that population complex and one additional would be potentially extirpated because of demographic conditions. Populations along the coast and bay are most at risk in this scenario, whereas inland populations had relatively consistent habitat conditions. Scenario 3 was the most optimistic, with both increases and decreases in demographic condition for several population complexes. Both Pacifica and WOB had decreases in habitat condition, but remained in moderate and high demographic condition, respectively. Populations along the coast and bay are still most at risk, but successful implementation of the captive breeding program, with population augmentation in the La Honda, Año Nuevo, and Pescadero population complexes could bring these population complexes up to high demographic condition, and the Southern SFPW and Woodside population complexes into moderate demographic condition.

Chapter 6. Species Viability

Status Assessment Summary

We used the best available information to evaluate the current condition and forecast the likely future condition of the San Francisco gartersnake (Table 15, Table 16). We have considered what the San Francisco gartersnake needs at the individual, population, and species-level and how they relate to viability (Chapter 3), and we evaluated the species' current condition in relation to those needs (Chapter 4). We also forecast how the species' condition may change in the future under three different scenarios (Chapter 5). In this chapter, we synthesize the results from our historical, current, and future analyses and discuss the potential consequences for the future viability of the San Francisco gartersnake, with emphasis on resiliency, redundancy, and representation.

The San Francisco gartersnake faces a variety of risks from habitat modification and destruction, illegal collection, predation from non-native species, small population size, and climate change. Results of our analysis in various scenarios show variation based on effects from sea level rise and success of a captive propagation program and rely on continued conservation and management of species' habitat to maintain resilient populations across the species range. Range-wide habitat and population surveys are necessary to fill in data gaps that left current and future condition of some population complexes unclear.

Table 15. Summary of population complex overall habitat condition under current and future conditions using three plausible scenarios.

	Habitat Overall Condition			
Population complex	**Current Condition**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Northern San Mateo County	Extirpated	Extirpated	Extirpated	Extirpated
Pacifica	High	High	Moderate	Moderate
West-of-Bayshore	High	High	Low/Extirpated	Moderate
Northern SFPW	High	High	High	High
Southern SFPW	High	High	High	High
Half Moon Bay	Low	Low	Low	Low
Woodside	High	High	High	High
San Gregorio	Low	Low/Extirpated	Low/Extirpated	Low/Extirpated
La Honda	High	High	High	High
Pomponio	Low	Low	Low	Low
Pescadero	High	High	High	High
Año Nuevo	High	High	High	High
Northern Santa Cruz County	Low	Low	Low	Low

Table 16. Summary of population complex overall demographic condition under current and future conditions using three plausible scenarios.

	Demographic Overall Condition			
Population complex	**Current Condition**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Northern San Mateo County	Extirpated	Extirpated	Extirpated	Extirpated
Pacifica	Moderate	Moderate	Moderate	Moderate
West-of-Bayshore	High	High	Low/Extirpated	High
Northern SFPW	Moderate	Moderate	Moderate	Moderate
Southern SFPW	Low	Low	Low	Moderate
Half Moon Bay	Low	Low	Low	Low
Woodside	Low	Low	Low	Moderate
San Gregorio	Low	Low/Extirpated	Low/Extirpated	Low/Extirpated

La Honda	Moderate	Moderate	Moderate	High
Pomponio	Low	Low/Extirpated	Low/Extirpated	Low/Extirpated
Pescadero	Moderate	Moderate	Moderate	High
Año Nuevo	Moderate	Moderate	Moderate	High
Northern Santa Cruz County	Low	Low	Low	Low

We emphasize that for some of the population complexes where surveys have not been conducted for decades, habitat and demographic conditions are not known. In these cases where current conditions were unknown, we only made projections into the future when we thought conditions would be lowered. Success of the captive breeding facility has the potential to increase demographic conditions for additional populations once we have more information about the habitat and occurrences for those sites where conditions are currently unknown. Although the condition for the species under Scenario 3 is promising, the successful recovery of the San Francisco gartersnake relies on increases in demographic conditions for additional populations than those with assessed changes in this SSA report.

Resiliency

Resiliency describes the ability of the species to withstand stochastic disturbance events, an ability that is associated with population size, growth rate, and habitat quality.

Historically, the San Francisco gartersnake experienced large population losses due to habitat development and urbanization, as well as illegal collection because of the species' beauty and rarity. The largest historical population at the sag ponds along Skyline Boulevard was extirpated prior to federal listing of the species, and it is unclear how abundant the population once was. We used the best available science to assess the resiliency of current populations. To do so, we grouped the populations into 12 extant complexes across the species range. Based on the habitat factors in our analysis, the species has eight complexes with high habitat condition and four complexes with low habitat condition. Regarding demographic condition, the species currently has one population complex in high condition, five in moderate condition, and six in low condition. For the most part, the low habitat and demographic conditions are in population complexes that have not been assessed for a number of years.

Population complex resiliency varied somewhat across three potential future scenarios. For several, there were reductions in habitat condition based on projected impacts from saltwater inundation, which has the potential to affect at least three population complexes. There were also potential extirpations in 2 population complexes in all scenarios, as well as the population complex that is currently the most resilient, in 1 scenario. In the most optimistic scenario there were increases or maintenance of resiliency in some population complexes because of anticipated captive breeding and population augmentation.

Maintenance of resilient population complexes, which in turn contribute to species redundancy and representation, is contingent on continued management and restoration efforts that are currently being undertaken to promote health of the species and its habitat. Although not explicitly factored into our future condition analysis, we assumed that these measures would be continued in all scenarios, and stress that the continued health of the species depends on this assumption.

Redundancy

Redundancy describes the ability of a species to withstand catastrophic events, an ability that is related to the number, distribution, and resilience of populations.

The current distribution of the San Francisco gartersnake is similar to the known historical distribution, with the caveat that range-wide surveys were not conducted until the species had already suffered extensive population declines from habitat urbanization. Although we have identified more population complexes in this SSA than were originally targeted as needing resilient populations in the downlisting criteria for the species, many of these complexes have unknown habitat or demographic conditions, thus are not considered to have resilient populations currently and in most of the future scenarios. However, presence of extant populations in high quality habitat throughout the species range makes it unlikely that a catastrophic event could extirpate all of the analysis units at once.

The continued presence of population complexes at both the northern and southern edge of the species' range with either high or moderate habitat and demographic conditions, in combination with the distribution of these populations, suggest that the species has the potential to retain redundancy. This is particularly true in Scenario 3, where some population complexes increase in resiliency, including those spread throughout the species range. Reduction in the number of population complexes because of the possible extirpations along the central coastal part of the species range would lower redundancy somewhat, but these complexes are not resilient currently. It is unlikely that a catastrophic event would extirpate the species under any of the scenarios, but potential reductions in condition, particularly in Scenario 2, highlight the potential for redundancy to be lowered.

Representation

Representation describes the ability of a species to adapt to changing environmental conditions, which is related to the breadth of genetic and ecological diversity within and among populations.

The San Francisco gartersnake will likely maintain its current level of genetic diversity into the future since the species is projected to continue to have population complexes distributed across in both the northern and southern genetic clusters under all three scenarios, although some of these population complexes may have reduced resiliency. However, potential reductions in habitat conditions for both the Pacifica and WOB population complexes could lower representation for the species because these population complexes are both in the northern genetic cluster (and are two of the more resilient populations currently). Further, if saltwater inundation affects these areas, it could lower the ecological diversity of the species because these are two of the more resilient coastal population complexes. Thus, the species is likely to maintain its genetic diversity but may have reduced ecological diversity in the future.

References

Ackerly, D. D., A. Jones, M. Stacey, B. Riordan. 2018. San Francisco Bay Area Summary Report. California's Fourth Climate Change Assessment. Publication number: CCCA4-SUM-2018-005

Banta, B. H. and D. Morafka. 1966. An annotated check list of the recent amphibians and reptiles inhabiting the city and county of San Francisco, California.

Barry, S. J. 1996. The San Francisco Garter Snake and the San Francisco Watershed. Unpublished technical report of 5 year study.

Barry, S. J. 1978. Status of the San Francisco garter snake. California Department of Fish and Game, Inland Fisheries Endangered Species Program, Special Publication 78-2. October 1978. 21 pp

Barry, S., and M. Jennings. 1998. *Coluber infernalis* Blainville, 1835 and *Eutaenia sirtallis tetrataenia* Cope in Yarrow, 1875 (currently *Thamnopus sirtalis infernalis* and *Ts. tetrataenia;* Reptilia, Squamata): proposed conservation of the subspecific names by the designation of a neotype for *T.s. infernal is.* Bulletin of Zoological Nomenclature 55(4): 224-228.

Barry, S. 1994. The Distribution, Habitat, and Evolution of the San Francisco Garter Snake, Thamnophis sirtalis tetrataenia. Master's thesis, University of California, Davis.

BioMaAS and AECOM. 2016. 2016 San Francisco Garter Snake Trapping Results. Memorandum from Milton Yacego and Bill Stagnaro, BioMaAS, and Tammy Lim, AECOM, to Scott Simono and Ellen Natesan, San Francisco Public Utilities Commission. 21 pp.

Biosearch Associates. 2012. San Francisco Gartersnake Habitat Management Plan, Site A, Russian Ridge Open Space Preserve, San Mateo County, California. Aptos, CA.

Biosearch Associates. 2005. Final Biological monitoring at the Whitehouse Creek Road conservation easement, San Mateo County, California, 2001-2005. Unpublished report prepared for: Steve Gregory, Costanoa Project Manager, San Luis Obispo, California. Dated 28 November 2005.

Boone, M., E. L. Little, and R. D. Semlitsch. 2004. Overwintered bullfrog tadpoles negatively affect salamanders and anurans in native amphibian communities. Copeia 3: 683-690.

Brehme, C. S., S. A. Hathaway, and R. N. Fisher. 2018. An objective road risk assessment method for multiple species: ranking 166 reptiles and amphibians in California. Landscape Ecology 33: 911-935.

Brodie, E. D., B. J. Ridenhour, and E. D. Brodie. 2002. The evolutionary response of predators to dangerous prey: hotspots and coldspots in the geographic mosaic coevolution between garter snakes and newts. Evolution 56:2067-2082.

California State Park and Recreation Commission. 2008. Reclassification and addition of Año Nuevo State Natural Reserve into the existing Año Nuevo State Park. Resolution 27-2008 adopted by the California State Park and Recreation Commission at its regular meeting in Pescadero, CA. October 31, 2008.

CBEC, Inc. 2018. Butano Creek channel reconnection and resilience project. Report prepared for San Mateo Resource Conservation District and California Department of Parks and Recreation. 327 pp.

Cope, E. D. 1875. Check-list of North American Batrachia and Reptilia; with a systematic list of the higher groups, and an essay on geographical distribution based on the specimens contained in the United States National Museum. Bulletin U.S. National Museum 1: 1-104.

(CDFW) California Department of Fish and Wildlife. 2019. Snake Fungal Disease detected in California. Available online at https://cdfgnews.wordpress.com/2019/11/05/snake-fungal-disease-detected-in-california/. Accessed November 6, 2019.

(CDFW) California Department of Fish and Wildlife. 2016. A rapid assessment of the vulnerability of sensitive wildlife to extreme drought. Report by the Wildlife Branch, Nongame Wildlife Program July 15, 2015. Revised January 22, 2016.

Cover J. F., Jr., and D. M. Boyer. 1988. Captive reproduction of the San Francisco garter snake Thamnophis sirtalis tetrataenia. Herpetological review 19: 29-33.

(CNDDB) California Department of Fish and Wildlife, Natural Diversity Database. 2018. Element occurrence reports for San Francisco gartersnake. Unpublished cumulative data current to December 12, 2018.

Diffenbaugh, N. S., D. L. Swain, and D. Touma. 2015. Anthropogenic warming has increased drought risk in California. Proceedings of the National Academy of Sciences of the United States of America, 112: 3931-3936.

Dudek. 2019. San Francisco garter snake recovery actionplan 2019-2029 West-of-Bayshore property, San Francisco International Airport, San Mateo County, California. Prepared for San Francisco International Airport. 96 pp.

Fitch, H. S. 1941. Geographic variation in garter snakes of the species Thamnophis sirtalis in the Pacific Coast region of North America. American Midland Naturalist 26:570-592.

Fitch, H. S. 1940 A biogeographical study of the Ordinoides Artenkreis of garter snakes (Genus *Thamnophis*). University of California Publications in Zoology (J. F. Daniel, H. Kirby, S. F. Light, and A. H. Miller, eds.). Volume 44: 1-150. University of California Press, Berkeley, CA.

Fitch, H. S. 1965. An ecological study of the garter snake, *Thamnophis sirtalis*. University of Kansas Publications Museum of Natural History 15:493-564.

Fitch, H. S. 1980. *Thamnophis sirtalis*. Pages 270.1-270.4 in Catalogue of American Amphibians and Reptiles.

Fong, D., D. Collman, T. Elliot and E. Martin. 2004. Habitat Enhancement for the Endangered San Francisco Garter Snake: Construction Summary Report. Golden Gate National Recreation Area (National Park Service) and Golden Gate National Parks Conservancy. 11 pp.

Fong, D. and K. Kindall 2019. San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) visual encounter and coverboard surveys at Golden Gate National Recreation Area, 2018. Unpublished report prepared for U.S. Fish and Wildlife Office Sacramento Field Office. 23 pp.

Fong, D. and R. Townsend. 2018. San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) visual encounter and coverboard surveys at Golden Gate National Recreation Area, 2017. Unpublished report prepared for U.S. Fish and Wildlife Office Sacramento Field Office. 21 pp.

Ford, N. B. 1986. The Role of Pheromone Trails in the Sociobiology of Snakes. In: Duvall D., Müller-Schwarze D., Silverstein R.M. (eds) Chemical Signals in Vertebrates 4. Springer, Boston, MA.

Fox, W. 1951. The status of the gartersnake, *Thamnophis sirtalis tetrataenia*. Copeia 1951: 257−267

Fox, W. 1955. Mating aggregations of garter snakes. Herpetologica 11:176.

Frankham, R. 1995. Effective population size/adult population size ratios in wildlife: a review. Genetics Research 66: 95-107.

Friesen, C. R., R. T. Mason, S. A. Arnold, and S. Estes. Patterns of sperm use in two populations of red-sided garter snake (Thamnophis sirtalis parietalis) with long-term female sperm storage. Canadian Journal of Zoology 92: 33-40.

Gonzalez, P. 2016. Climate change in the National Parks of the San Francisco Bay Area, California, USA. Report by Natural Resource Stewardship and Science, U. S. National Park Service, Berkeley CA. 54 pp.

Gregory, P. T. and K. W. Stewart. 1975. Long-distance dispersal and feeding strategy of the red-sided garter snake (Thamnophis sirtalis parietalis) in the Interlake of Manitoba. Canadian Journal of Zoology 53: 238-245.

Halstead, B. J., G. D. Wylie, M. Amarello, J. J. Smith, M. E. Thompson, E. J. Routman, and M. L. Casazza. 2011. Demography of the San Francisco gartersnake in coastal San Mateo County, California. Journal of Fish and Wildlife Management 2:41–48.

Halstead, B. J., M. E. Thompson, M. Amarello, J. F. Smith, G. D. Wylie, E. J. Routman, and M. L. Casazza. 2019. Effects of prescribed fire on San Francisco gartersnake survival and movement. The Journal of Wildlife Management 83: 231-240.

ICF. 2017. Bay Area Habitat Conservation Plan operations & maintenance. Final plan prepared for Pacific Gas & Electric Company, Environmental Policy. September 2017. 548 pp.

ICZN. 2000. *Coluber infernalis* Blainville, 1835 and *Eutaenia sirtallis tetrataenia* Cope in Yarrow, 1875 (currently *Thamnopus sirtalis infernalis* and *T.s. tetrataenia;* Reptilia, Serpentes): subspecific names conserved by the designation of a neotype for *T.s. infernalis.* Bulletin of Zoological Nomenclature 57(3): 191-192.

Janzen, F.J., J.G. Krenz, T.S. Haselkom, E.D. Brodie, Jr., and E.D. Brodie, III. 2002. Molecular phylogeography of common garter snakes *(Thamnophis sirtalis)* in western North America: implications for regional historical forces. Molecular Ecology 11: 1739-1751.

Jayne, B. C., and A. F. Bennett. 1990. Selection on locomotor performance capacity in a natural population of garter snakes. Evolution 44: 1204-1229.

Jennings, M.R., and M.P. Hayes. 1990. Final Report of the Status of the California Red-Legged Frog (Rana aurora draytonii) in the Pescadero Marsh Natural Preserve. Prepared for the California Department of Parks and Recreation under Contract No. 4-823-9018 with the California Academy of Sciences.

Johnstone, J. A., and T. E. Dawson. 2010. Climatic context and ecological implications of summer fog decline in the coast redwood region. PNAS 107:4533-4538.

Kim, R., B. J. Halstead, P. Lien, G. D. Wylie, and M. L. Casazza. 2017. Abundance and distribution of San Francisco gartersnakes (Thamnophis sirtalis tetrataenia) at Cloverdale Coastal Ranch, San Mateo County, California. Report prepared by the Western Ecological Research Center, U. S. Geological Survey for the U. S. Fish and Wildlife Service Sacramento Field Office.

Kim, R., B. J. Halstead, G. D. Wylie, and M. L. Casazza. 2018, Distribution and demography of San Francisco gartersnakes (Thamnophis sirtalis tetrataenia) at Mindego Ranch, Russian Ridge Open Space Preserve, San Mateo County, California: U.S. Geological Survey Open-File Report 2018-1063. 80 pp.

Kupferberg, S. J. 1997. Bullfrog (*Rana catesbeiana*) invasion of a California river: the role of larval competition. Ecology 76: 1736-1751.

Larsen, S. S. 1994. Life History Aspects of the San Francisco garter snake at the Millbrae habitat site. M.S. Thesis. California State University, Hayward. 105pp.

Lim, T., K. Swaim, and E. J. Routman. 2009. A phylogeography of the San Francisco garter snake (*Thamnophis sirtalis tetrataenia*). Masters Thesis, San Francisco State University. San Francisco, CA.

Lind, A. J. and H. H. Welsh, Jr. 1994. Ontogenic changes in foraging behavior and habitat use by the Oregon garter snake, *Thamnophis atratus hydrophilus*. Animal Behaviour 48: 1261-1273.

Lorch J. M., S. Knowles, J. S. Lankton, K. Michell, J. L. Edwards, J. M. Kapfer, R. A. Staffen, E. R. Wild, K. Z. Schmidt, A. E. Ballmann, D. Blodgett, T. M. Farrell, B. M. Glorioso, L. A. Last, S. J. Price, K. L. Schuler, C. E. Smith Jr., J. F. X. Wellehan, and D. S. Blehert. 2016. Snake fungal disease: an emerging threat to wild snakes. Philosophical Transactions of the Royal Society B: Biological Sciences 371:20150457

Lorch J. M., J. Lankton, K. Werner, E. A. Falendysz, K. McCurley, and D. S. Blehert. 2015. Experimental infection of snakes with *Ophidiomyces ophiodiicola* causes pathological changes that typify snake fungal disease. mBio 6:1–9

LSA. 2008. *Recovery Action Plan for the San Francisco Garter Snake, West-of-Bayshore Property, San Francisco International Airport*. Prepared for San Francisco International Airport, San Francisco, California. April 24, 2008.

McGinnis, S.M. 1986. The status of the San Francisco garter snake *(Thamnophis sirtalis tetrataenia)* at the Sharp Park Golf Course, Pacifica California. Prepared for Geomatrix Consultants, Inc.

McGinnis, S.M. 1987. The distribution and feeding habitat requirements of the San Francisco garter snake (*Thamnophis sirtalis tetrataenia*). Final report prepared for the California Department of Fish and Game Interagency Agreements C-673 and C-1376.

McGinnis, S. M., P. Keel, and E. Burko. 1987. The use of upland habitats by snake species at Ano Nuevo State Reserve. Report to California Department of Fish and Game. December 30, 1987. 13 pp.

McGinnis, S. 1988a. Life history of the San Francisco garter snake (*Thamnophis sirtalis tetrataenia*). Final Report for the California Department of Fish and Game Interagency Agreement -2045 (FY 87-88). 47 pp.

McGinnis, S. M. 1988b. The status of the San Francisco garter snake *Thamnophis sirtalis tetrataenia* in the Pilarcitos Creek drainage between its mouth and its confluence with Corinda Los Trancos Creek. Submitted to U.S. Fish and Wildlife Service July 7, 1988. 15pp.

McGinnis, S. M. 1991. Habitat requirements and population estimate for the San Francisco garter snake *(Thamnophis sirtalis tetrataenia)* at Ano Nuevo State Reserve, San Mateo, California. Unpublished report, submitted to: The Department of Parks and Recreation. Sacramento, California.

McKenzie, J. M., Price, S. J., Fleckenstein, J. L., Drayer, A. N., Connette, G. M., Bohuski, E., and J. M Lorch. 2019. Field diagnostics and seasonality of *Ophidiomyces ophiodiicola* in wild snake populations. EcoHealth 16: 141-150.

Olson, E. and W. Dexter. 2008. Pescadero Marsh Natural Preserve San Francisco garter snake habitat improvement assessment. Report prepared for California State Parks. 15 pp.

Ormshaw, H. 2018 San Bruno Mountain Habitat Conservation Plan 2017-18 activities report for federally listed species. Prepared by San Mateo County Parks Department for U. S. Fish and Wildlife Sacramento Field Office. 98 pp.

Our Coast Our Future. 2019. Online interactive mapping application. Available online at http://data.pointblue.org/apps/ocof/cms/. Accessed November 6, 2019.

Philip Williams & Associates, Ltd., Wetlands Research Associates, Inc., and Associated Consultants T. Steiner and J. Hafernik. 1992. Laguna Salada resource enhancement plan. Plan submitted to City of San Francisco and the State of California Coastal Conservancy. 173 pp.

Recuero, E., I. Martinez-Solano, G. Parra-Olea, and M. Garcia-Paris. 2006a. Phylogeography of *Pseudacris regilla* (Anura: Hylidae) in western North America, with a proposal for a new taxonomic rearrangement. Molecular Phylogenetics and Evolution 39: 293-304.

Recuero, E., I. Martinez-Solano, G. Parra-Olea, and M. Garcia-Paris. 2006b. Corrigendum to "Phylogeography of *Pseudacris regilla* (Anura: Hylidae) in western North America, with a proposal for a new taxonomic rearrangement" [Mol. Phylogenet. Evol. 39 (2006) 293-304]. Molecular Phylogenetics and Evolution 41: 511.

Reeder, N. M. M., A. P. Pessier, and V. T. Vredenburg. 2012. A reservoir species for the emerging aphbibian pathogen Batrachochytrium dendrobatidis thrives in a landscape decimated by disease. PloS ONE 7: e33567.

Reeder N. M. M., R. M. Byrnes, R. W. Stoelting, and K. E. Swaim. 2015. *An endangered snake thrives in a highly urbanized environment*. Endangered Species Research 28:77-86.

Rose, J. P., J. A. S. Ersan, E. J. Schoenig, D. A. Macias, E. M. Armistead, P. C. Lien, and B. J. Halstead. 2018. Abundance estimation of San Francisco gartersnakes (*Thamnophis sirtalis tetrataenia*) at six sites for evaluation of captive breeding and translocation donor sites. Report prepared by Western Ecological Research Center, U. S. Geological Survey, for U.S. Fish and Wildlife Office Sacramento Field Office.

Rossman, D. A., N. B. Ford, and R. A. Seigel. 1996. The garter snakes: evolution and ecology. University of Oklahoma Press, Norman, Oklahoma.

San Francisco International Airport and LSA Associates, Inc. (SFO and LSA). 2017. Ninth Annual Progress Report for the Recovery Action Plan for the San Francisco Garter Snake, West-of-Bayshore Property, San Francisco International Airport. San Francisco International Airport, San Mateo County, California. February 2, 2018

Seigel, R. A. 1984. The foraging ecology and resource partitioning patterns of two species of garter snake. Ph. D. dissertation, University of Kansas, Lawrence.

(Service) U.S. Fish and Wildlife Service. 2013. Stanford University Habitat Conservation Plan. Revised March 2013. 152 pp.

(Service) U.S. Fish and Wildlife Service. 1985. San Francisco garter snake recovery plan. U. S. Fish and Wildlife Service, Endangered Species Program, Portland, Oregon. 77pp.

(Service) U.S. Fish and Wildlife Service. 2006. *San Francisco Garter Snake (Thamnophis sirtalis tetrataenia) 5-Year Review: Summary and Evaluation*. U.S. Fish and Wildlife Service, Sacramento, California.

(Service) U.S. Fish and Wildlife Service. 2016. USFWS Species Status Assessment Framework: an integrated analytical framework for conservation. Version 3.4 dated August 2016.

(Service) U.S. Fish and Wildlife Service. 2017. Final Environmental Assessment for the Pacific Gas & Electric Company Bay Area Operations and Maintenance Habitat Conservation Plan. September. (NSR No. 26301). Redding, CA. With technical assistance from North State resources, Inc., Redding, CA.

Simberloff, D., and B. Von Holle. 1999. Positive interactions of nonindigenous species: invasional meltdown? Biological Invasions 1:21-32.

Shaffer, H. B., G. M. Fellers, S. R. Voss, J. C. Oliver, and G. B Pauly. 2004. Species boundaries, phylogeography and conservation genetics of the red-legged frog (Rana aurora/draytonii) complex. Molecular Ecology 13: 2667-2677.

Shine, R., M. J. Elphick, P. S. Harlow, T. Moore, P. LeMaster, and R. T. Mason. 2001. Movements, mating, and dispersal of red-sided gartersnakes (Thamnophis sirtalis parietalis) from a communal den in Manitoba. Copeia 2001: 82-91.

Smith, D., N. C. Allan, C. P. McGowan, J. A. Szymanski, S. R. Oetker, and H. M. Bell. 2018. Development of a Species Status Assessment process for decisions under the U.S. Endangered Species Act. Journal of Fish and Wildlife Management 9: 302-320.

Stebbins, R.C. 1985. A field guide to western reptiles and amphibians. Houghton Mifflin Company, Boston, Massachusetts and New York, New York. 335 pp.

Stewart, J. A. E., J. H. Thorne, M. Gogol-Prokurat and S. D. Osborn. 2016. A climate change vulnerability assessment for twenty California mammal taxa. Information Center for the Environment, University of California, Davis, CA.

Stromberg, M., and J. Griffin. 1996. Long-term patterns in coastal California grasslands in relation to cultivation, gophers, and grazing. Ecological Applications 6: 1189-1211.

Swain, D. L., B. Langenbrunner, J. D. Neelin and A. Hall. 2018. Increasing precipitation volatility in twenty-first-century California. Nature Climate Change 8: 427-433.

Swaim Biological Consulting. 2006. Results of 2005 surveys for the San Francisco garter snake *(Thamnophis sirtalis tetrataenia)* at Año Nuevo State Reserve, San Mateo County, California, draft report. 16 pp.

Swaim Biological Consulting. 2007. 2007 spring trapping survey for San Francisco garter snake *(Thamnophis sirtalis tetrataenia)* at Año Nuevo State Reserve, San Mateo County, California. 15 pp.

Swaim Biological, Incorporated. 2009. San Francisco garter snake habitat improvement project at Mori Point, Pacific, California, 2004-2008. Document No. 801818 prepared for U.S. Fish and Wildlife Service, Sacramento, CA. 54 pp.

Swain, K. E. 2018. 2017 summary annual report. Prepared for U.S. Fish and Wildlife Service Sacramento Field Office. 76 pp.

Swaim Biological, Incorporated. 2018. San Francisco garter snake monitoring report 2007-2017 mark-recapture survey results. Unpublished report prepared for San Francisco International Airport Bureau of Planning and Environmental Affairs. 67 pp.

Tatarian, P., and G. Tartarian. 2010. Chytid infection of Rana daytonii in the Sierra Nevada, California, USA. Herpetological Review 41: 325-327.

(USGS) U.S. Geological Survey and U.S. Department of Agriculture, Natural Resources Conservation Service. 2013. Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD) (4th edition): U.S. Geological Survey Techniques and Methods 11–A3. 63 p.

USDA National Agricultural Statistics Service Cropland Data Layer2019

Wharton, J. C., J. M. Brode, and M. Knudsen. 1987. Ecological and life history aspects of the San Francisco garter snake (*Thamnophis sirtalis tetrataenia*) at the San Francisco International Airport study site. Final report for Caltrans Interagency Agreements C-226 and C-975 (FY 82/83-85/86). 21 pp.

Wood, D. A., J. P. Rose, B. J. Halstead, R. E. Stoelting, K. E. Swaim, and A. G. Vandergast. 2019. Combining genetic and demographic monitoring better informs conservation of an endangered urban snake. Draft report submitted to the USFWS.

Wood, D. A., J. P. Rose, B. J. Halstead, R. E. Stoelting, K. E. Swaim, and A. G. Vandergast. *in press*. Combining genetic and demographic monitoring better informs conservation of an endangered urban snake. PLOS One.

Wylie, G. D., M. L. Casazza, and M. Carpenter. 2003. Diet of *L. catesbeianus* in relation to predation on giant garter snakes at Colusa National Wildlife Refuge. California Fish and Game 89:139-145.

Yarrow, H. C. 1875. Report upon the collections of batrachians and reptiles made in portions of Nevada, Utah, California, Colorado, New Mexico, and Arizona, during the years 1871, 1872, 1873, 1874. In: Report upon the geographical and geological explorations made west of the 100th meridian. Engineer Dept., U.S. Army. Vol. 5 (Zoology):509-594.

***In litteris* citations**

Barry, S. 2003. Email to Anne Corbett regarding recent San Francisco gartersnake information. August 11, 2003.

Barry, S.J. 2006. Electronic mail to Lucy Triffleman, U.S. Fish and Wildlife Service, Sacramento, of April 10, 2006.

Bauer, W. 2019. Email to Samantha Lantz regarding San Francisco gartersnake genetic work. Received March 12, 2019.

Halbert, P. 2019. Email to Leif Goude regarding San Francisco gartersnake at Pescadero Marsh. Received July 25, 2019.

Halstead, B. Email to Samantha Lantz regarding San Francisco gartersnake condition category table and species needs. Received March 31, 2019.

Hankins, D. 2006. Email to Lucy Triffleman, U.S. Fish and Wildlife Service, Sacramento, on June 26, 2006.

Kim, R. 2019. Email to Samantha Lantz regarding San Francisco gartersnake status. Received March 30, 2019.

Lim, T. 2019. Email to Samantha Lantz regarding San Francisco gartersnake phylogeny. Received March 12, 2019.

Terry, J. 2020. Comments on draft SSA. Received by Samantha Lantz on January 13, 2020.

Personal Communication

Larsen, S. 2006. Personal communication cited in Service 2006.

Larsen, S. 2019. Conversation with Samantha Lantz regarding San Francisco gartersnake status and bullfrogs at WOB. March 16, 2019

McGinnis, S. 2007. Phone call with Lucy Triffleman regarding gartersnake feeding in irrigation ditches in Half Moon Bay. April 23, 2007.

Reeder, N. 2019. Site visit and discussion between Samantha Lantz and Natalie Reeder at WOB site. August 22, 2019.

Stoltz, J. 2006. Personal communication with SFPUC biologist cited in Service 2006.

USGS 2019 (or cite genetics report) I remember this conversation, so you could site this or the paper either way.