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Abundance and Distribution of San Francisco Gartersnakes (*Thamnophis sirtalis tetrataenia*) at Cloverdale Coastal Ranch, San Mateo County, California

Data Summary of Field Observations
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Abstract. We studied San Francisco gartersnakes (*Thamnophis sirtalis tetrataenia*) at Cloverdale Coastal Ranch between 2014 and 2017 using capture-mark-recapture methods. We captured and marked 211 individual San Francisco gartersnakes 260 times in April and May from 2014 through 2017. Estimated abundance within the sampled area on the site was 136 (75 – 349) individuals (62 [30 – 174] males and 72 [34 – 193] females) in 2014, 280 (142 – 909) individuals (140 [51 – 450] males and 162 [69 – 527] females) in 2015, 250 (163 – 443) individuals (156 [94 – 270] males and 92 [53 – 196] females) in 2016, and 211 (128 – 462) individuals (119 [67 – 287] males and 86 [42 – 199] females) in 2017. The probability that abundance in the sampled area of the site was greater than 200 individuals was 0.89 in 2014, 0.95 in 2015, 0.92 in 2016, and 0.78 in 2017. The naïve sex ratio was 0.89 (0.48 – 1.48) males per female in 2014, 0.78 (0.43 – 1.27) in 2015, 1.63 (1.05–2.44) in 2016, and 1.31 (0.79 – 2.06) in 2017. The size distribution indicated a mixed-age population of males and females. Future work with increased sampling effort would allow calculation of important demographic rates that inform conservation planning.

Introduction

San Francisco gartersnakes (*Thamnophis sirtalis tetrataenia*; Fig. 1 and 2) comprise a subspecies of common gartersnakes, *Thamnophis sirtalis.* They were listed as endangered under both the California (California Department of Fish and Game Commission 1971) and federal Endangered Species Acts (Office of the Secretary 1967) and designated as a Fully Protected Species under the California Fish and Game Code (U.S. Fish and Wildlife Service 1985, 2006). The principle threats that led to the listing of San Francisco gartersnakes were the loss and adverse modification of wetlands and adjacent upland habitat by urbanization and commercial development, as well as agricultural conversion, stream and creek channelization, removal of emergent riparian vegetation, and riprapping of streambanks and shorelines (U.S. Fish and Wildlife Service 1985, 2006). Additional threats are illegal collection and decline of native anuran prey (U.S. Fish and Wildlife Service 1985, 2006). No progress to secure habitat for the snakes or to set aside a refuge specifically for the snake had been made until 1978; 23 of 28 extant populations reported in 1978 by Barry were subject to human disturbance or threatened with destruction (U.S. Fish and Wildlife Service 1985). The recovery priority for the San Francisco gartersnake is one of the highest ratings for a federally-listed subspecies (U.S. Fish and Wildlife Service 2006), yet little data exist regarding population trends and demographic characteristics of San Francisco gartersnakes. The San Francisco Garter Snake Recovery Plan (U.S. Fish and Wildlife Service 1985, 2006) initially focused on the protection of six significant existing populations and the creation of four new populations at undefined sites. The six locations were West of Bayshore (San Francisco International Airport), San Francisco State Fish and Game Refuge (San Francisco Public Utilities Commission), Laguna Salada/Mori Point (City of San Francisco/National Park Service), Pescadero Marsh and Año Nuevo State Reserves (California State Parks), and Cascade Ranch (private land owner; U.S. Fish and Wildlife Service 2006). The species may be downlisted from endangered to threatened if 200 or more individuals are maintained at a 1:1 sex ratio at each of the six existing locations for five consecutive years; if these numbers can be maintained at each of the ten locations for 15 consecutive years, then the species will be eligible for delisting (U.S. Fish and Wildlife Service 1985). Studies providing information about habitat requirements, foraging ecology, and demography are imperative for developing conservation and management plans for San Francisco gartersnakes.

The U.S. Geological Survey (USGS), Western Ecological Research Center (WERC), with the cooperation and permission of the U.S. Fish and Wildlife Service (USFWS), conducted trap surveys for San Francisco gartersnakes (*Thamnophis sirtalis tetrataenia*) at Cloverdale Coastal Ranch (hereafter Cloverdale Ranch) in every spring from 2008 through 2017, except 2011. This data summary report provides summary statistics and abundance estimates of San Francisco gartersnakes in Cloverdale Ranch, 2014–2017.

Methods

Field Methods

We used multiple sampling methods to detect and capture San Francisco gartersnakes. We trapped for San Francisco gartersnakes using drift fence and funnel trap arrays and cover objects near the four major water bodies in Cloverdale Ranch. We located 24 trap arrays within Hidden Valley and Goat Ranch, with trap locations selected randomly, but stratified by habitat and constrained to be in proximity to wetlands. We constructed each drift fence from 3.2-mm Masonite strips placed on edge (30 cm tall by 15 m long), and placed two single-ended funnel traps constructed of 3.2-mm hardware cloth secured around a wooden frame on both ends of the drift fence, one on each side, for a total of four traps per array (Halstead et al. 2011). When not in use, we closed traps by plugging the opening with a 5.1-cm Styrofoam ball secured by a small nail pierced through the hardware cloth. In 2016, we also deployed 24 transects of ten artificial cover objects (1.6 cm plywood cut into 0.8 m x 1.2 m pieces and corrugated sheet metal cut into 0.6 m x 1.2 m pieces) within randomly selected 50 m x 50 m blocks, stratified by habitat, and within 200 m of the major water bodies.

We exploited seasonal and thermal activity patterns of San Francisco gartersnakes to maximize capture probabilities for demographic study. We opened traps from the first week of April through the third week of May each year (minimum 45 consecutive days), when snakes have emerged from brumation and are foraging and searching for mates. We checked traps twice daily while open and used moistened sponges to avoid desiccation or thermal stress of captured individuals. We checked cover objects during the early morning or on cold days, when snakes are more likely to take cover under objects with higher heat conductivity (Engelstoft and Ovaska 2000). We also captured San Francisco gartersnakes that were opportunistically encountered by hand, and we used a handheld GPS to mark the location of each capture. For each day of sampling, we monitored environmental conditions relevant to San Francisco gartersnake behavior. In particular, we measured air temperatures, sky condition (cloud cover or haze), and rain or fog within the preceding 24 hours.

We examined the sex of, measured, and uniquely marked each captured San Francisco gartersnake to assess the sex ratio, size distribution, and abundance of the San Francisco gartersnake population at Cloverdale Ranch. We measured snout-vent length (SVL) and tail-vent length (TVL) of each individual to the nearest millimeter, and weighed each individual to the nearest gram. We determined the sex of each individual by probing the cloaca to detect the presence or absence of hemipenes (Fitch 1960). We did not probe small individuals less than 15 g in mass to prevent injury to the snake; extra care was also given to these small individuals when uniquely marking them. After examination, each individual that showed no sign of previous capture was given a unique brand on its ventral scutes (Fig. 4; Winne et al. 2006). We processed most individuals in the field within minutes of their capture. Each individual San Francisco gartersnake was released at its location of capture immediately after processing. We also measured, sexed, and uniquely marked other snake species present at Cloverdale Ranch, including coast gartersnakes (*Thamnophis elegans terrestris*), Santa Cruz gartersnakes (*Thamnophis atratus atratus*), Pacific gophersnakes (*Pituophis catenifer catenifer*), western yellow-bellied racers (*Coluber constrictor mormon*), northern rubber boas (*Charina bottae*), and ring-necked snakes (*Diadophis punctatus*). We neither collected nor handled northern Pacific

rattlesnakes (*Crotalus oreganus oreganus*). To obtain a measure of the local relative abundance and diversity of potential terrestrial prey, we also recorded the vertebrate contents of all traps and then removed them. We did not record invertebrate trap contents.

Analytical Methods

We calculated sex ratios and size distributions of San Francisco gartersnakes at Cloverdale Ranch using standard methods. Sex ratio was assessed with a binomial model using an uninformative prior (*U(minimum = 0, maximum = 1)* for the probability of being male). Because San Francisco gartersnakes exhibit sexual size dimorphism (Barry 1994), we fit a normal model to estimate the mean SVL and mass of males and females independently, and calculated the difference between means as a derived parameter. We used uninformative priors (*U(0,1000)* for means and standard deviations) for this analysis. We conducted a Bayesian analysis of the sex ratio and sexual size dimorphism models using Markov chain Monte Carlo (MCMC) techniques. Models were run on five independent chains of 100,000 iterations each after a burn-in of 10,000; each chain was thinned by a factor of five, so inference was based upon 100,000 iterations from the stationary posterior distribution. We analyzed these models by calling OpenBUGS version 3.2.3 (Thomas et al. 2006) from R version 3.1.0 (R Core Team 2016) using the R package R2OpenBUGS (Sturtz et al. 2005) to run this analysis.

We estimated the abundance of San Francisco gartersnakes at Cloverdale Ranch using Bayesian analysis of capture-mark-recapture (CMR) data using data augmentation (Royle and Dorazio 2008). Data augmentation is an approach to CMR analysis in which a large number of all zero capture histories is appended to the observed capture histories. The abundance estimation problem then seeks to answer the question: How many undetected individuals were actually a part of the population but not observed? This approach is much more flexible than other approaches to estimation of abundance (e.g., it allows models with individual heterogeneity in capture probability to be fit easily) and allows a unified framework for analysis of detection-nondetection and CMR data (Royle and Dorazio 2008).

We fit a full model containing effects of sex, SVL, air temperature, date, an ephemeral behavioral response to capture (capture on day *t-1* affected capture on day *t*, but effects did not persist), and unexplained random temporal variation on daily individual capture probabilities. The model did not contain any interactions among variables. We standardized all continuous variables to improve behavior of the MCMC algorithm and to allow direct comparison of model coefficients. We calculated the posterior probability of each subset of the full model using indicator variables on model parameters (Kuo and Mallick 1998, Royle and Dorazio 2008). We augmented the capture histories of trapped individuals with 500 all-zero capture histories in all years except 2015, for which we augmented with 1000 pseudo-individuals. The number of pseudo-individuals is deemed adequate by the posterior density for abundance falling well below the number of augmented individuals. We used uninformative priors for all parameters: *U(0,1)* for probabilities, *N(mean = 0, standard deviation = 3.162)* (mean, standard deviation) for regression coefficients, *U(0,10)* for standard deviations, and *Bin(n = 1, p = 0.5)* for indicator variables. The model was run on three independent chains of 100,000 iterations each after a burn-in of 10,000; each chain was thinned by a factor of three, so that inference was based on a sample of 300,000 iterations from the stationary posterior distribution. We analyzed the model by calling JAGS version 3.4.0 (Plummer 2014a) from R version 3.2.1 (R Core Team 2016) using

the R package runjags (Denwood 2016). Posterior distributions were summarized by the posterior mode (95% highest posterior density interval), unless otherwise indicated.

Results

Overall, we observed 211 individual San Francisco gartersnakes (115 males and 96 females) 260 times by all methods at Cloverdale Ranch between 2014 and 2017.

The naïve sex ratio of San Francisco gartersnakes at Cloverdale was biased toward males, with 0.89 (0.48 – 1.48) males per female in 2014, 0.78 (0.43 – 1.27) in 2015, 1.63 (1.05 – 2.44) in 2016, and 1.31 (0.79 – 2.06) in 2017. Mean female SVL (441 [371 – 511] mm) was 74 (-18 – 166) mm longer than male SVL (367 [307 – 427] mm; Fig. 4), and mean female mass (63.4 [37.2 – 89.6] g) was 39.9 (12.8 – 66.8) g heavier than mean male mass (23.5 [16.6 – 30.3] g; Fig. 5) in 2014. Mean female SVL (511 [463 – 558] mm) was 124 (63 – 185) mm longer than male SVL (386 [348 – 424] mm; Fig. 4), and mean female mass (83.3 [58.2 – 108.3] g) was 57.1 (31.2 – 82.8) g heavier than mean male mass (26.2 [20.1 – 32.3] g; Fig. 5) in 2015. Mean female SVL (478 [446 – 517] mm) was 67 (-31 – 107) mm longer than mean male SVL (411 [399 – 426] mm; Fig. 4), and mean female mass (54.4 [43.9 – 68.3] g) was 24.9 (-14.4 – 39.4) g greater than mean male mass (30.0 [26.5 – 32.0] g; Fig. 5) in 2016. Mean female SVL (474 [423 – 530] mm) was 54 (-2.6 – 114) mm longer than mean male SVL (420 [397 – 446] mm; Fig. 4), and mean female mass (56.7 [39.5 – 79.1] g) was 28.1 (10.4 – 50.8) g greater than mean male mass (28.6 [24.8 – 32.7] g; Fig. 5) in 2017.

The model-averaged abundance of San Francisco gartersnakes at Cloverdale Ranch was 136 (75 – 349) individuals (62 [30 – 174] males and 72 [34 – 193] females) in 2014, 280 (142 – 909) individuals (140 [51 – 450] males and 162 [69 – 527] females) in 2015, 250 (163 – 443) individuals (156 [94 – 270] males and 92 [53 – 196] females) in 2016, and 211 (128 – 462) individuals (119 [67 – 287] males and 86 [42 – 199] females) in 2017.

In 2014, the null model of constant capture probability had the highest posterior probability (Table 1). In 2015, the model that included an ephemeral behavioral response to capture had the highest posterior probability (Table 1); San Francisco gartersnakes were more likely to be captured if they were captured the day before. In 2016, the null model of constant capture probability had the highest posterior probability, but some support existed for an ephemeral behavioral response to capture (Table 1). In 2017, the model that included an ephemeral behavioral response to capture had the highest posterior probability (Table 1).

The logit-normal standard deviation of unexplained daily variation in capture probability was <0.01 (<0.01 – 0.99) in 2014, <0.01 (<0.01 – 0.14) in 2015, <0.01 (<0.01 – 0.63) in 2016, and <0.01 (<0.01 – 0.90) in 2017. The cumulative capture probability throughout the season was 0.24 (0.10 – 0.44) in 2014, 0.10 (0.04 – 0.27) in 2015, 0.28 (0.14 – 0.42) in 2016, and 0.22 (0.11 – 0.40) in 2017.

The corrected (for capture probability) sex ratio of San Francisco gartersnakes at Cloverdale Ranch, in males per female, was 0.79 (0.25 – 1.91) in 2014, 0.72 (0.14 – 2.05) in 2015, 1.56 (0.59 – 2.62) in 2016, and 1.31 (0.52 – 3.09) in 2017. The probability that abundance in the sampled area was greater than 200 individuals was 0.34 in 2014, 0.95 in 2015, 0.92 in 2016, and 0.78 in 2017.

In addition to San Francisco gartersnakes, we captured and marked coast gartersnakes (*Thamnophis elegans terrestris*), Santa Cruz gartersnakes (*Thamnophis atratus atratus*), Pacific gophersnakes (Pituophis catenifer catenifer), western yellow-bellied racers (*Coluber constrictor mormon*), rubber boas (*Charina bottae*), and four ring-necked snakes (*Diadophis punctatus*). We also recorded the species and numbers of trap bycatch. All vertebrate captures in trap arrays are summarized in Tables 2 to 5.

Discussion

Our surveys between 2014 and 2017 resulted in captures of juvenile and adult San Francisco gartersnakes, and we were able to estimate site-wide abundance, capture probability, and sex ratio at Cloverdale Ranch. Abundance of San Francisco gartersnakes in the sampled area at Cloverdale Ranch was estimated to be in the scores to low hundreds of individuals, and was the lowest in 2014. The area sampled by trap arrays was likely less than the total area available to San Francisco gartersnakes, so our abundance estimates might be lower than the total abundance of San Francisco gartersnakes at Cloverdale Ranch. Even with this caveat, the probabilities that the population in the sampled area exceeds the 200 individual target in the San Francisco Garter Snake Recovery Plan (U.S. Fish and Wildlife Service 1985) were >0.75 between 2015 and 2017. The lowest abundance in 2014 could be due to reduced availability of prey, following drought, particularly for young-of-the-year San Francisco gartersnakes. Availability of the Sierran tree frog (*Hyliola* [=*Pseudacris*] *sierra*) is a critical prey source for successful recruitment of neonatal snakes. Efforts to enhance habitat for the San Francisco gartersnake and its prey, the threatened California red-legged frog (*Rana draytonii*) and the Sierran tree frog, should increase the ability of the site to maintain a population above the threshold of 200 individuals. Continued monitoring of abundance will assess progress toward management goals.

Additional years of CMR data are critical in evaluating the impacts of cattle grazing on the survival, recruitment, and population growth rate, habitat, and prey of San Francisco gartersnakes at Cloverdale Ranch. For example, comparisons could be made between water bodies that are fenced and unfenced from cattle. These estimates of trends will be essential for assessing the health of the San Francisco gartersnake population at Cloverdale Ranch and evaluate the efficacy of management actions for increasing San Francisco gartersnake abundance.

The sex ratio and size distribution of San Francisco gartersnakes were consistent with a healthy population. The naïve sex ratio based on the simple binomial model and the sex ratio calculated from the CMR model, which accounts for different detection probabilities between males and females, differed slightly, but neither estimate was statistically distinguishable from 1:1, and the

sex ratio is unlikely to affect the reproductive potential of this population. As in this study, San Francisco gartersnake sex ratios in the literature are typically near 1:1 (Halstead et al. 2011).

A range of sizes of San Francisco gartersnakes of both sexes was captured, likely indicating a population with a diverse age structure. Sexual size dimorphism, with females the larger sex, was evident at Cloverdale Ranch, though sexual size dimorphism in SVL was not statistically significant. This was consistent with expectations and previous research (Barry 1994, Halstead et al. 2011).

The null CMR model of constant capture probability had the most posterior support, likely because of sparse capture histories caused by low capture probabilities. If capture probabilities are low, it is difficult to detect effects of covariates on capture probability. Environmental variables might have played an influential role in the low capture probabilities in 2014. The extended drought caused the four major water bodies to evaporate rapidly, and therefore the distance between trap arrays and the water's edge was greater than expected. This likely limited foraging habitat and movement to small, isolated areas that held water until the end of May, and reduced the intersection of foraging movements and trap arrays. Because trap arrays passively sample snakes, concentration of snakes at receding wetlands would have taken the snakes farther and farther away from trap arrays and effectively reduced capture probabilities. It will be interesting to note whether higher capture probabilities are realized in years with more precipitation as monitoring continues at Cloverdale Ranch.

Low San Francisco gartersnake capture probabilities limited some aspects of our results. For example, because capture histories were sparse and capture probabilities low, we could not conduct a separate CMR analysis of abundance for each water body. Increasing daily capture probabilities could be achieved by deploying additional drift fence arrays and cover objects at Cloverdale Ranch. We deployed cover objects at Cloverdale Ranch and checked them regularly during the trapping period.

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firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. government.

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Table 1. Posterior probabilities of models for abundance of San Francisco gartersnakes (*Thamnophis sirtalis tetrataenia*) at Cloverdale Coastal Ranch, San Mateo County, California, between 2014 and 2017. A "1" indicates that the variable was included in the model; a "0" indicates that the variable was excluded from the model. Only models with a posterior probability greater than the prior probability for each model (0.031) are included. Models are listed in order of decreasing support.

Year	Variable					Posterior probability
	Air Temperature	SVL	Sex	Behavioral response	Temporal heterogeneity	
2014	0	0	0	0	0	0.249
	0	0	0	0	1	0.177
	0	0	0	1	0	0.128
	0	0	0	1	1	0.097
	0	0	1	0	0	0.060
	0	0	1	0	1	0.046
2015	0	0	0	1	0	0.507
	0	0	1	1	0	0.145
	0	0	0	0	0	0.103
	0	1	0	1	0	0.061
	0	0	0	1	1	0.036
	0	0	1	0	0	0.032
2016	0	0	0	0	0	0.320
	0	0	0	1	0	0.120
	0	0	0	0	1	0.101
	1	0	0	0	0	0.094
	0	0	1	0	0	0.066
	0	1	0	0	0	0.039
	0	0	0	1	1	0.034
2017	0	0	0	1	0	0.229
	0	0	0	0	0	0.154
	0	0	0	1	1	0.106
	1	0	0	1	0	0.075
	0	0	0	0	1	0.064
	0	0	1	1	0	0.058

Table 2. Summaries of vertebrate captures by trap array at Cloverdale Coastal Ranch, San Mateo County, California, 2014.

Common name	Scientific name	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Tota
Rubber Boa	*Charina bottae*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western yellow-bellied racer	*Coluber constrictor mormon*	9	28	2	13	17	4	0	1	7	0	4	6	4	2	1	10	10	11	22	0	2	1	0	0	3	157
Pacific rattlesnake	*Crotalus oreganus oreganus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pacific gophersnake	*Pituophis catenifer catenifer*	1	4	0	2	0	1	1	1	0	2	0	5	1	2	2	0	0	0	3	0	0	0	1	0	0	26
Santa Cruz gartersnake	*Thamnophis atratus atratus*	0	1	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	0	1	6
Coast gartersnake	*Thamnophis elegans terrestris*	1	2	1	1	4	0	0	1	1	2	11	3	1	0	1	1	0	1	3	3	6	3	3	0	5	54
San Francisco gartersnake	*Thamnophis sirtalis tetrataenia*	1	2	0	1	5	1	0	0	0	0	3	0	0	0	0	2	1	1	1	3	1	4	2	0	3	31
Ring-necked snake	*Diadophis punctatus*	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3
Northern alligator lizard	*Elgaria coerulea*	1	3	1	0	1	3	1	0	0	0	1	0	1	1	0	4	2	0	2	2	5	3	1	2	0	34
Southern alligator lizard	*Elgaria multicarinata*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Western fence lizard	*Sceloporus occidentalis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sierran treefrog	*Pseudacris sierra*	9	9	1	1	6	1	1	0	0	4	10	1	0	0	3	0	0	0	1	92	17	71	1	2	7	237
California red-legged frog	*Rana draytonii*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arboreal salamander	*Aneides lugubris*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow-eyed ensatina	*Ensatina eschscholtzii xanthoptica*	0	0	0	0	0	0	0	0	0	1	8	0	0	0	6	0	0	1	0	0	6	0	0	0	0	21
Pacific newt	*Taricha* sp.	0	0	0	1	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	4	0	1	1	0	0	10
Deer mouse	*Peromyscus* sp.	1	0	1	0	2	3	0	1	0	3	2	0	0	0	6	0	4	0	0	9	1	0	3	3	0	39
California vole	*Microtus* sp.	1	1	1	0	0	1	2	0	1	1	0	1	0	0	0	1	0	0	1	3	0	1	1	1	0	17
Shrew	*Sorex* sp.	1	2	0	1	1	0	1	2	1	1	4	2	0	0	1	0	0	0	2	3	0	0	1	0	2	25

Table 3. Summaries of vertebrate captures by trap array at Cloverdale Coastal Ranch, San Mateo County, California, 2015.

Common name	Scientific name	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Total
Rubber Boa	*Charina bottae*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Western yellow-bellied racer	*Coluber constrictor mormon*	6	15	2	15	22	1	4	0	0	0	0	7	0	1	1	19	22	18	13	0	0	0	0	0	0	146
Pacific rattlesnake	*Crotalus oreganus oreganus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Pacific gophersnake	*Pituophis catenifer catenifer*	0	3	1	1	0	0	1	1	0	0	0	0	0	1	0	0	0	2	2	0	0	0	0	0	1	13
Santa Cruz gartersnake	*Thamnophis atratus atratus*	2	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	7
Coast gartersnake	*Thamnophis elegans terrestris*	7	8	0	2	5	1	0	0	0	0	5	1	1	1	4	3	0	6	5	1	4	0	3	0	3	60
San Francisco gartersnake	*Thamnophis sirtalis tetrataenia*	1	6	0	0	4	1	3	1	0	0	4	2	0	0	0	3	1	0	7	0	0	3	0	0	0	36
Ring-necked snake	*Diadophis punctatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern alligator lizard	*Elgaria coerulea*	1	2	1	7	1	3	2	0	2	0	0	1	3	0	1	4	7	0	0	0	0	0	2	0	0	38
Southern alligator lizard	*Elgaria multicarinata*	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	2
Western fence lizard	*Sceloporus occidentalis*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	7
Sierran treefrog	*Pseudacris sierra*	4	3	2	1	11	16	47	12	1	2	8	1	1	0	31	63	16	7	14	254	22	323	0	0	6	845
California red-legged frog	*Rana draytonii*	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
Arboreal salamander	*Aneides lugubris*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Yellow-eyed ensatina	*Ensatina eschscholtzii xanthoptica*	0	0	0	0	0	0	0	0	0	0	7	0	0	0	1	0	0	0	0	0	7	0	0	0	0	15
Pacific newt	*Taricha* sp.	2	0	1	0	0	0	10	0	0	0	4	0	0	0	0	0	1	0	0	2	0	0	0	0	0	18
Deer mouse	*Peromyscus* sp.	1	6	0	1	1	1	2	9	2	3	0	2	1	0	2	2	2	1	1	0	0	0	0	1	9	49
California Vole	*Microtus* sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	1	0	0	0	3	0	0	0	8
Shrew	*Sorex* sp.	8	1	2	0	2	0	0	1	1	2	2	0	0	0	3	0	0	1	0	0	0	0	1	0	0	24

Table 4. Summaries of vertebrate captures by trap array at Cloverdale Coastal Ranch, San Mateo County, California, 2016.

Common name	Scientific name	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Tota
Rubber boa	*Charina bottae*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western yellow-bellied racer	*Coluber constrictor mormon*	11	11	17	4	15	8	8	1	3	0	1	2	1	0	7	19	22	14	17	1	0	1	0	0	163
Pacific rattlesnake	*Crotalus oreganus oreganus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pacific gophersnake	*Pituophis catenifer catenifer*	0	5	0	0	1	2	3	0	0	0	0	0	0	0	1	1	2	1	1	0	0	0	0	0	17
Santa Cruz gartersnake	*Thamnophis atratus atratus*	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	1	0	0	0	0	5
Coast gartersnake	*Thamnophis elegans terrestris*	4	5	2	1	7	0	0	1	0	0	0	1	2	0	10	4	5	2	5	1	0	4	1	0	55
San Francisco gartersnake	*Thamnophis sirtalis tetrataenia*	2	3	3	0	1	1	11	2	1	0	4	0	0	0	4	12	8	1	13	0	0	10	1	1	78
Ring-necked snake	*Diadophis punctatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	0	4
Northern alligator lizard	*Elgaria coerulea*	5	2	0	1	0	0	3	1	5	0	0	7	4	3	3	2	4	0	0	0	0	3	0	2	45
Southern alligator lizard	*Elgaria multicarinata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Western fence lizard	*Sceloporus occidentalis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sierran treefrog	*Pseudacris sierra*	7	4	2	13	3	6	20	48	1	2	8	4	0	0	8	14	1	0	6	386	76	262	6	1	878
California red-legged frog	*Rana draytonii*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow-eyed ensatina	*Ensatina eschscholtzii xanthoptica*	0	0	0	0	0	0	0	0	0	1	5	0	0	0	1	0	0	0	1	0	3	0	0	0	11
Pacific newt	*Taricha* sp.	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	1	0	6
Deer mouse	*Peromyscus* sp.	6	4	1	1	4	1	1	2	0	3	1	2	2	2	2	2	1	0	0	0	3	6	1	1	46
California Vole	*Microtus* sp.	7	20	2	1	0	1	3	1	0	0	1	0	5	1	4	2	1	0	3	7	1	9	2	0	71
Shrew	*Sorex* sp.	4	9	4	0	3	0	1	0	2	6	4	1	0	0	3	1	1	0	4	0	0	1	2	1	47

Table 5. Summaries of vertebrate captures by trap array at Cloverdale Coastal Ranch, San Mateo County, California, 2017.

Common name	Scientific name	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Total
Rubber boa	*Charina bottae*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western yellow-bellied racer	*Coluber constrictor mormon*	9	11	3	3	12	4	4	3	1	0	0	0	6	3	13	19	18	23	12	0	0	0	0	3	147
Pacific rattlesnake	*Crotalus oreganus oreganus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pacific gophersnake	*Pituophis catenifer catenifer*	0	0	3	2	0	0	1	0	1	0	1	1	1	0	2	1	0	0	1	0	0	0	0	2	16
Santa Cruz gartersnake	*Thamnophis atratus atratus*	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	1	0	2	0	1	0	0	0	8
Coast gartersnake	*Thamnophis elegans terrestris*	5	4	2	3	8	1	1	0	0	0	0	0	0	0	1	2	2	2	3	1	4	1	4	6	50
San Francisco gartersnake	*Thamnophis sirtalis tetrataenia*	5	3	1	1	3	0	5	2	0	0	2	0	1	0	0	4	6	1	7	2	0	3	1	0	47
Ring-necked snake	*Diadophis punctatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Northern alligator lizard	*Elgaria coerulea*	3	4	0	2	0	1	4	3	0	1	0	4	4	2	7	2	6	6	4	0	0	0	1	3	57
Southern alligator lizard	*Elgaria multicarinata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western fence lizard	*Sceloporus occidentalis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sierran treefrog	*Pseudacris sierra*	2	2	2	5	3	16	8	58	2	3	12	4	2	1	1	2	0	0	5	232	80	183	4	4	631
California red-legged frog	*Rana draytonii*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow-eyed ensatina	*Ensatina eschscholtzii xanthoptica*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pacific newt	*Taricha* sp.	0	1	7	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	2	3	0	0	1	17

Deer mouse	*Peromyscus* sp.	2	2	1	0	4	3	7	9	1	3	1	2	2	0	2	0	0	0	0	1	2	1	2	1	46
California Vole	*Microtus* sp.	10	22	1	4	14	3	12	4	2	1	2	3	3	6	4	8	3	1	7	1	1	6	0	4	122
Shrew	*Sorex* sp.	9	7	0	7	6	1	0	1	1	3	5	2	2	1	7	3	0	0	2	0	1	2	3	0	63

Figure 1. An adult San Francisco gartersnake (*Thamnophis sirtalis tetrataenia*). Photograph by Sebastian Kennerknecht (www.pumapix.com).

Figure 2. A neonate San Francisco gartersnake (*Thamnophis sirtalis tetrataenia*).

Figure 3. A. Application of a brand to a giant gartersnake (*Thamnophis gigas*) with a medical cautery device, and B. the appearance of a properly completed brand.

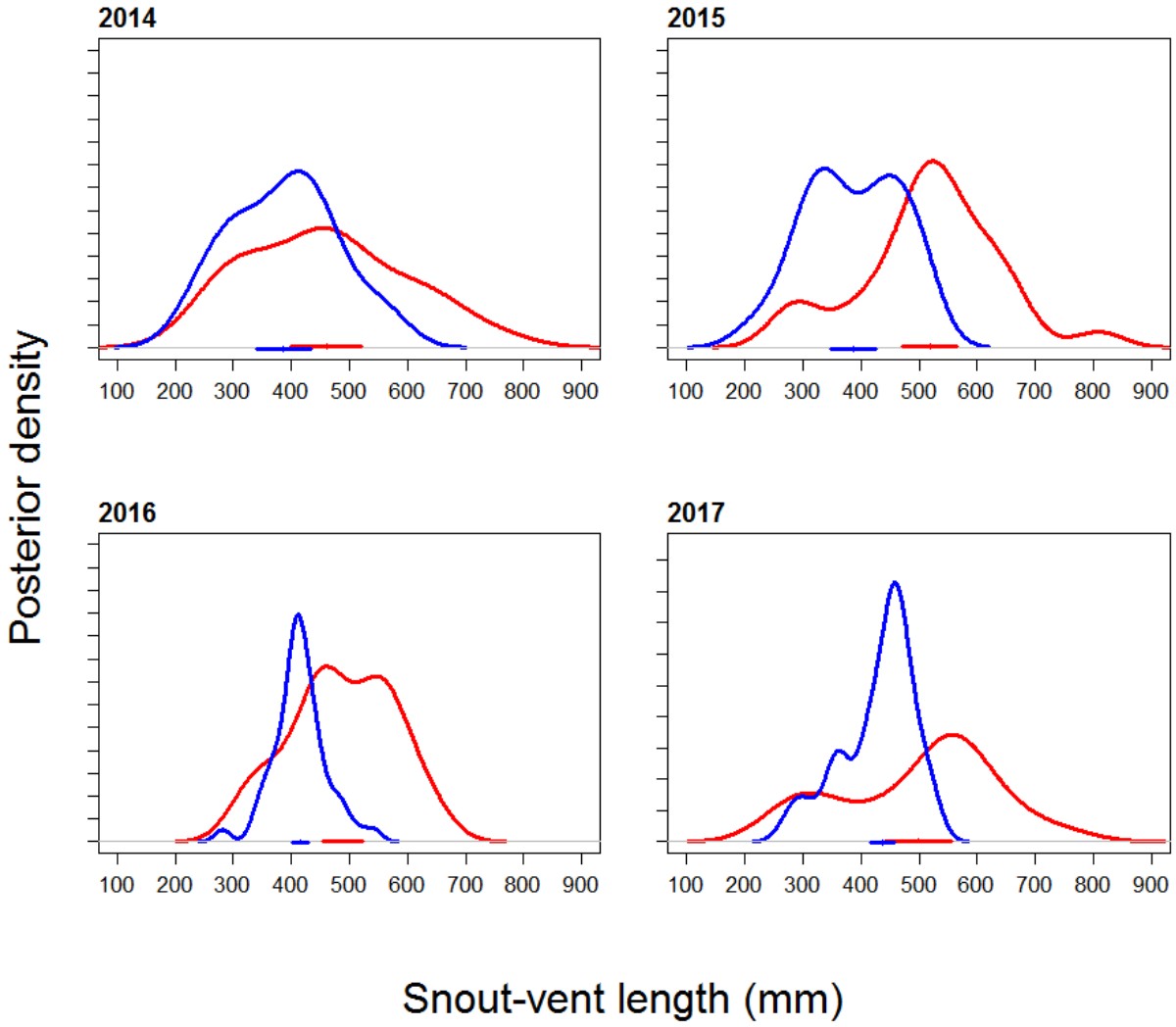

Figure 4. Annual distribution of San Francisco gartersnake (*Thamnophis sirtalis tetrataenia*) snout-vent length (SVL) at Cloverdale Coastal Ranch, San Mateo County, California, from 2014 through 2017. Red lines indicate females, blue lines indicate males. Vertical bars along the x-axis indicate the median of the posterior distribution of mean SVL, horizontal bars along the x-axis indicate the 95% credible of mean SVL.

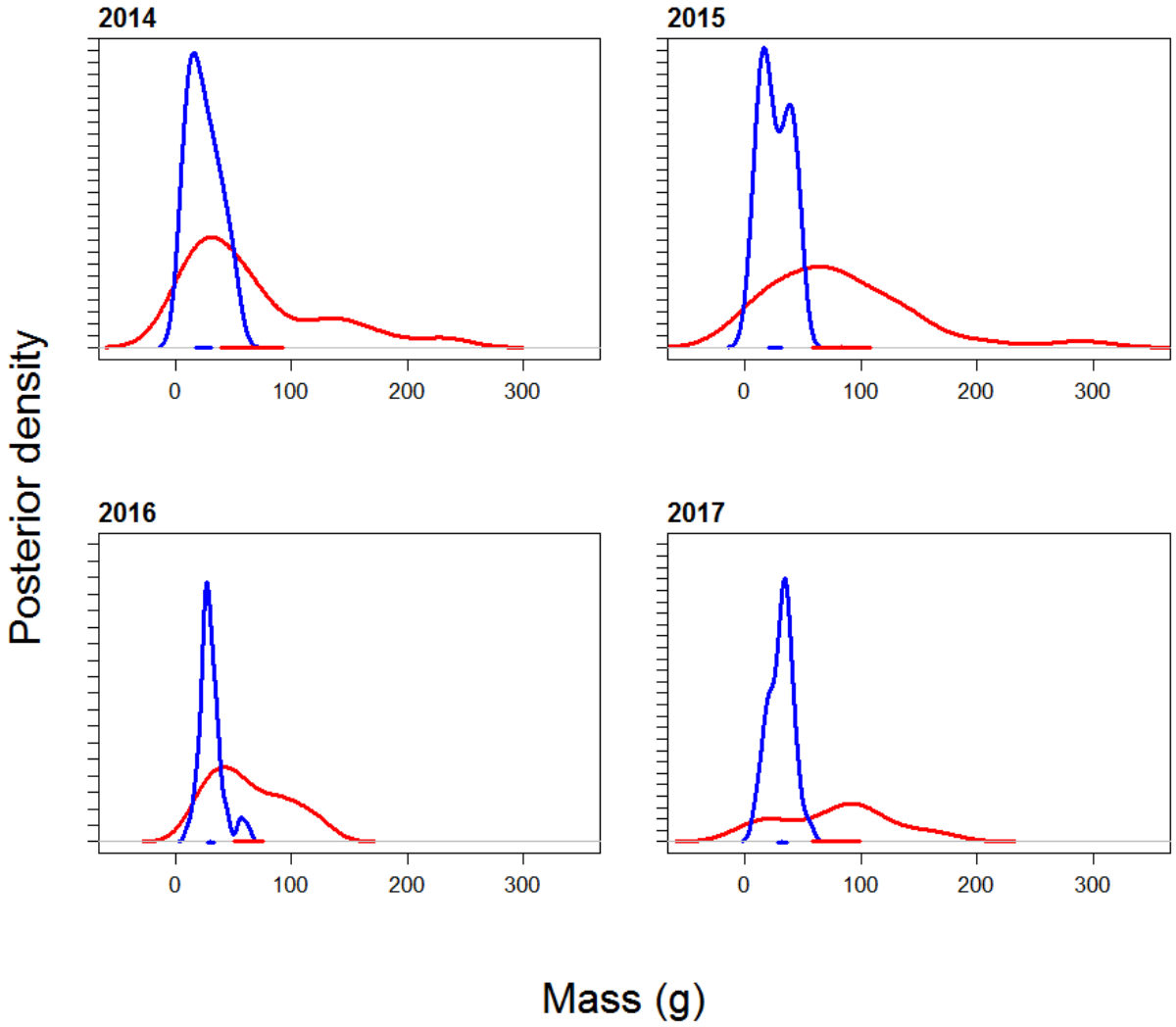

Figure 5. Annual distribution of San Francisco gartersnake (*Thamnophis sirtalis tetrataenia*) mass at Cloverdale Coastal Ranch, San Mateo County, California, from 2014 through 2017. Red lines indicate females, blue lines indicate males. Vertical bars along the x-axis indicate the posterior median of the mean; the horizontal bar associated with each median is the posterior 95% credible interval of the mean.