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Sampling Design Optimization and Establishment of Baselines for Herpetofauna Arrays at the Point Loma Ecological Reserve

Photos by Chris Brown, U. S. Geological Survey

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INTRODUCTION

Cabrillo National Monument is the terminal point of the Point Loma Peninsula and part of the Point Loma Ecological Reserve, which protects the natural lands remaining on the peninsula in urban San Diego, California. This reserve is isolated from other natural lands by the ocean and urbanization, and is an effective island of rare habitats. These habitats include maritime succulent scrub, coastal sage scrub, and chaparral, and are the home to many sensitive species of plants and animals. Historically (through the 1930s), 19 species of reptiles and amphibians occurred on the peninsula, of which 6 are now considered sensitive at the state or federal level. Herpetofauna inventories were initiated by Robert Fisher of the U.S. Geological Survey (USGS) and Ted Case of the University of California at San Diego in August 1995, utilizing 17 arrays of pitfall traps and drift fences (Stokes et al., 2004). Data collection occurred from 1995 through 2001 to collect baseline data for the development of a long-term monitoring plan (Fisher and Case, 2000).

OBJECTIVES

The National Park Service will be taking over the monitoring arrays for herpetofauna at the Point Loma Ecological Reserve from USGS. The purpose of this analysis is to examine the baseline data set and determine how many arrays, sampling periods, and days per sampling period are needed to assess whether herpetofauna diversity is being maintained on the reserve and suggest points for when management actions should be considered. The specific objectives listed below were identified by the reserve science manager as the ones most important to target. Although financial costs are a consideration in reducing the amount of sampling that is occurring, environmental impact is of greater concern. Erosion due to foot traffic is occurring at some sampling arrays placed on steeper slopes. Thus the benefits of maintaining the current number of sampling days and sampling arrays must be weighed against possible environmental costs. An additional constraint is that although reductions in sampling effort would be considered, increases in the number of arrays are not likely to be funded.

Primary objectives

1) What species are currently found at Point Loma Ecological Reserve versus species that have been historically found in this area?
2) Are any of the targeted species showing significant declines at present?
3) How many arrays, sampling periods, and sampling days per sampling period would be needed to detect a
- 30% drop in species richness compared with the baseline years 1996-2000,
- 30% drop in the relative abundance of orange-throated whiptail (*Cnemidophorus hyperythrus*) and striped racer (*Masticophis lateralis)*, compared with the baseline years.
- some measure of drop in abundance or occupancy of western ring-necked snake (*Diadophis punctatus)* and southern Pacific rattlesnake (*Crotalus viridis*) compared with the baseline years.

Secondary objective

4) What relationships are found between targeted species and environmental variables?

METHODS

Pitfall trap array protocol and sampling locations

The draft herpetofauna pitfall trap array protocol, techniques, and design are described in Stokes et al. (2004). To better understand the status and distribution of reptiles and amphibians throughout the Point Loma Ecological Reserve, pitfall trap array sites were chosen to represent the range of habitats found in the peninsula. Point Loma was stratified by vegetation, and the numbers of arrays were placed in each habitat type in approximate proportion to the proportion of that habitat type present, with the additional inclusion of unique landscape features if present (e.g., open sandy washes). The primary components of native vegetation at Point Loma include baccharis, black sage, buckwheat, cacti, chamise, cliffspurge, and manzanita and vary depending on aspect, exposure and slope, substrate, and disturbance.

Several additional considerations affected array site locations including feasibility, access, visibility, habitat sensitivity. Arrays could not be placed on steep slopes or in areas where it was not possible to bury 5-gallon buckets and drift fencing in the ground. Soil type, however, did not limit array location, because the substrates on the peninsula include mostly soils, sand and sandstone deposits. Arrays were placed near roads and trails so that they could be reasonably accessed by surveyors on a daily basis without trampling large amounts of native vegetation. Sensitivity to habitat was considered. Arrays were built with caution to impact native vegetation as little as possible, with arms bent around plants rather than running through them. Visibility of the array to park visitors was another important factor. To minimize visitation to the arrays by park visitors, arrays within the park were placed on slopes facing away from trails and in areas that had sufficient vegetation to hide the array.

Although the locations of arrays within vegetation types were not chosen with strict random procedures, the area of Point Loma is so small and so much of the terrain has steep slopes that arrays were placed in nearly all locations where it was physically feasible to do so and access was allowed. The sampling design contains some admitted biases, since areas with steep slopes are not sampled and areas that are far from roads and trails may be underrepresented. However, given the small size of the park, the effects of these biases are expected to be minimal. Locations of the 17 pitfall trap arrays are shown in Figure 1.

Steps were taken to minimize direct impacts by park visitors on the survey efforts, including careful array placement as previously mentioned. Trails to arrays were often covered with brush to discourage off-trail travel, and information labels were placed on the array equipment. However, the large numbers of visitors and relatively small size of the park resulted in trails and roads being heavily traveled. Arrays #13-17 are located near a popular trail. Arrays #13 and #14 are directly below the Old Lighthouse, which attracts many visitors. Arrays #1-4 are near the tide pools, another area with high traffic. Although not documented, it is likely that visitation rates to these arrays are much greater than to arrays #5-12, which require security clearance to be accessed.

The sampling protocol may have some inherent biases towards capturing fauna that are very active and mobile and travel on the surface of the ground, rather than those that move infrequently or travel beneath the soil surface. The traps are passive, not baited. For animals to be captured by the traps, the animals must be active enough to encounter and enter the traps. In general, animals that move around more actively through an area may be more likely to

encounter the traps. For example, the striped racer, an active forager, may move around in an area more than a southern Pacific rattlesnake, generally a sit-and-wait predator. Live traps similar to the funnel traps used in this survey are documented to work better with medium-sized snakes. Larger-bodied snakes including gopher snakes and rattlesnakes are more commonly detected by visual observation than captured (Fitch, 1992). Furthermore, the trap openings are above ground or on the immediate surface. Animals that spend larger amounts of time underground, such as the silvery legless lizard (*Anniella pulchra*), may encounter the trap openings less frequently than other species.

Data used in analysis

Analyses were conducted on data collected from the 17 existing herpetofauna arrays at the reserve during the years 1996–2000. Each year consisted of 5 sampling periods (see Table 1). Although data are available for years 1995 and 2001, these data did not consist of a complete set of sampling periods at the time of analysis and thus are not included in this analysis.

Table 1. Start dates for 10-day sampling periods within each year.

Period within year	Year				
	1996	1997	1998	1999	2000
1	2/20	2/18	2/3	1/27	2/9
2	4/23	4/22	3/31	4/6	4/5
3	6/25	6/24	6/2	6/8	6/6
4	8/27	9/3	8/4	8/18	8/29
5	10/29	10/28	10/6	11/10	11/10

Data from all 5 sampling periods within each year were combined into a total capture rate per array per year for analysis. Although sampling dates were not exactly the same in all years, they were roughly comparable. Animals recaptured at the same array within the same 10-day sampling period were only counted once.

It should be noted that 1998 was considered an El Niño year, with associated increases in rainfall. The years 1996, 1999, and 2000 were considered drought years with very low rainfall.

Historical species list

A historical list of species present or presumed present at Point Loma was compiled by examining species records at the San Diego Natural History Museum, California Academy of Sciences, Los Angeles County Museum, University of California at Berkeley Museum of Vertebrate Zoology, and the field notes and species maps of Laurence M. Klauber (unpublished notes from San Diego Natural History Museum).

Trend analysis and determination of number of arrays, number of sampling days per year, and timing of sampling periods

The overall process to optimize the sampling design was in fact multi-dimensional. The level of sampling effort could be affected in three ways:

- number of arrays
- number of sampling days per year
- timing of sampling throughout the year (i.e., number and timing of sampling periods and days per sample period)

Additional factors that affected the final result were the species and variables of interest plus the acceptable level of Type I error (α) and Type II error (β =1-Power) (described further below).

The process used to optimize the sampling design and identify potential management thresholds was broken into six steps. These included:

1) Select the variables to be analyzed.
2) Sort variables into three analysis groups, depending on the type of data involved.
3) Conduct regression analyses to test for existing trends.
4) Conduct sample size calculations for the number of arrays needed to detect a change, assuming different numbers of sampling days per year (i.e., 20, 30, 40, and 50 sampling days per year).
5) Develop preliminary 90%, 95% and 99% control limits, where possible, to determine when the capture rate during a new year is outside the range of variation experienced in the baseline years.
6) Determine optimum number of arrays, number of sampling days per year, and timing of sampling periods by examining the results.

Step 1) Select the variables to be analyzed.

The variables analyzed include

- Number of species detected per array (used as surrogate for species richness)
- Simpson's measure of species evenness [1]
- Total herpetofauna captures (lizards, snakes, and salamanders)
- Lizard captures
- Snake
    - captures or sightings
    - # arrays with 1 or more snake captures
- Orange-throated whiptail (*Cnemidophorus hyperythrus*)
    - Total captures
    - Juveniles captures
    - # arrays with 1 or more captures
    - # arrays with 1 or more juvenile captures

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[1] Simpson's evenness is a measure that evaluates the degree to which all species present are equally common (i.e., is the community dominated by a few species and all other species put in rare occurrences, or are all species present equally common).

Simpson's evenness is calculated as $E = (1 / \sum_1^s (p_i)^2) / s$

where s = # species in the sample and

p_i = proportion of total sample belonging to the *i*th species   (Krebs, 1999, p.449)

- Striped racer (*Masticophis lateralis*)
  - captures or sightings
  - juvenile captures or sightings
  - # arrays with 1 or more striped racer captures
- Ring-necked snake (*Diadophis punctatus)* captures or sightings
- Southern Pacific rattlesnake (*Crotalus viridis*) captures or sightings

Step 2) Sorting variables into three analysis groups depending on the type of data involved.

Variables were separated into three different "analysis groups" depending on the number of captures that occurred and the distributions of the variables (see Table 2).

Group 1 – Variables in this group had large numbers of captures at all or nearly all arrays. It was possible to analyze these data using averages per array per year, and these were the variables used to conduct sample size calculations. Analyses for this group included a) a regression analysis in which arrays were treated as class variables and years were treated as a regression variable, b) sample size calculations, and c) calculation of control limits.

Group 2 – This group involved species such as striped racer which had much smaller numbers of captures than Group 1 species, even when captures were summed across all arrays (15 or less captures per year). This group of variables consists of either i) total number of captures summed across all arrays or ii) the number of arrays at which an organism was present. Analyses for this group included: a) a regression analysis and b) calculation of control limits.

Group 3 – This group involves species with very low capture rates summed across all arrays per year (i.e., 3 or less captures per year). Analysis included calculation of the control limits for the observed number of years with zero captures.

Since variance strongly increased with number of captures, a square root transformation was used on most variables in Group 1 with the exception of species evenness.

Sample size analyses on orange-throated whiptail were performed on all arrays and then a subset of arrays #1-4, 9-10, and 13-17. Arrays #5-8 and 11-12 were dropped from the analysis, since they had fewer than 2 captures across all 5 years and this artificially inflated the variance and coefficient of variation (CV) during sample size calculations.

Although separate analyses were not conducted on all species, the number of captures per year for all species are included in Table 3.

Step 3) Conduct regression analyses to test for existing trends.

A regression analysis was performed on variables in Groups 1 and 2 to test for trends occurring in the existing data sets. This was both of interest biologically and as a necessary prerequisite for calculating control limits in the next section. Results are given in Tables 4 and 5.

Table 2. Variables grouped by analysis Groups 1, 2, and 3. Group 1 was analyzed by year and array. Direct sample size calculations were performed on this group. Group 2 variables were summed across arrays and were analyzed as total captures per year or number of arrays with organism present. Group 3 consisted of small numbers of captures (i.e., 3 or fewer captures per year) and were analyzed using Poisson probability calculations.

Analysis Group	Variable name	Specific variables	Data transformation
1 — Analysis performed by array and year; - Sample size calculations; - Regression analysis; - Control limits	Number of species detected	# species detected / array / year	Square root
	Simpson's evenness	Evenness / array / year	
	Herpetofauna capture rates	Captures / array / year	Square root
	Lizard capture rates	Captures / array / year	Square root
		Captures / array / year (all arrays included)	Square root
	Orange-throated whiptails capture rates	Captures / array / year (arrays 1-4,9-10,13-17)	Square root
		Juvenile captures/array/year (arrays 1-4,9-10,13-17)	Square root
2 — Analysis performed on totals or percentages across all arrays by year; - Regression analysis; - Control limits	Orange-throated whiptails	# arrays with whiptails present	
		# arrays with juveniles present	
	Snake capture rates	Captures / year	
		# arrays with snakes present	
	Striped racer capture rates	Captures / year	
		# arrays with racers present	
3 — Analysis performed on totals across all arrays by year; - Estimated probabilities of consecutive years with zero captures	Striped racers – juvenile capture rates	Captures / year	
	Ring-necked snakes	Captures / year	
	Southern pacific rattlesnake	Captures / year	

<u>Step 4) Conduct sample size calculations for the number of arrays needed to detect a change assuming different numbers of sampling days per year (i.e., 20, 30, 40, and 50 sampling days per year).</u>

Sample size calculations (i.e., number of arrays) were done directly for variables in Group 1 and indirectly for Groups 2 and 3. For Group 2, confidence intervals were calculated to determine if there was any power to detect change. If the lower confidence limit is a 1 or 0, then the number of arrays was considered too small to detect any change whatsoever. Group 3 calculations were also very indirect. In Group 3, the probabilities for increasing numbers of years with zero captures were calculated. If this number of years with zero captures seemed exceedingly high, then a higher level of effort would be needed to realistically track the species. Thus, although an assessment of the power to detect differences could be made for Group 1, no assessment of power could be made for Groups 2 and 3 variables.

To detect a change in the future, the recommended method of analysis for Group 1 variables is to a) conduct an analysis of variance and perform a contrast analysis that compares any future year's data with the baseline set of 5 years, and b) conduct a regression analysis. The analysis of variance offers greater power for detecting future trends, if no trend is occurring in the baseline data set. The regression analysis offers greater power for detecting a trend, if a trend is occurring in the baseline data set.

To calculate the recommended sample size, an analysis of variance was performed in which both years and arrays were included as class variables (i.e., each year was treated as a separate class rather than as a single regression variable). The error variance (i.e., the mean square error or MSE), from this analysis is used to estimate sample sizes. The following equation:

$$n \geq 2(s/d)^2 * (Z_{\alpha/2} + Z_{\beta})^2 \quad \text{(Steel and Torrie, 1980, p.232)} \qquad \text{Eqn 1.1}$$

was converted into a more easily used format by dividing both s and d by the mean $\bar{x}$ for ease of calculation. Z values were replaced by t-values as recommended by Geng and Hills (1989) when dealing with potentially small sample sizes.

$$n \geq 2(CV/D)^2 * (t_{\alpha/2,df} + t_{\beta,df})^2 \quad \text{(Geng and Hills, 1989, p.86-87)} \qquad \text{Eqn 1.2}$$

where n = number of arrays

CV= $s/\bar{x}$ = Coefficient of Variation

D= $d/\bar{x}$ = proportional difference from mean (i.e., a 30% drop in the mean)

$\bar{x}$ = sample mean of all 5 years

s^2 = mean square error (MSE) from the analysis of variance

d = difference from the mean

df = error degrees of freedom = (number of years – 1) * (number of arrays – 1)

α = probability of a Type I error

β = probability of a Type II error, (Note: Power = 1- β)

Note: A Type I error is the conclusion that a capture rate in a new year *is* different from the baseline when in fact it *is not*. A Type II error is the conclusion that a capture rate in a new year *is not* different from the baseline years when in fact it *is* different.

Sample size calculations were conducted for α =0.05 and β =0.10, 0.20, and 0.30 (i.e., power levels of 1- β = 90%, 80%, and 70%, respectively). All sample size calculations for Group 1 variables were based on two-tailed tests, since it was assumed that managers would be interested and likely to report increases as well as declines of species of interest.

To evaluate the effect of reducing the number of sampling days, four versions of the data were created for each species including all 10 days, and the first 8 days, 6 days, and 4 days of each sampling period, resulting in data sets of 50, 40, 30, or 20 sampling days per year. Separate sample size calculations were conducted on each data set on each Group 1 variable. These results are shown in Tables 4 and 5.

Based upon the results, orange-throated whiptail capture rates appeared to be a driving factor in determining sample size. Figure 2 shows how the Coefficient of Variation for orange-throated whiptail captures varies in response to number of sampling days per year.

Step 5) Develop preliminary 90%, 95% and 99% control limits where possible to determine when the capture rate during a new year is outside the range of variation experienced in the baseline years.

Control limits is a technique used in industrial quality control to monitor whether a process such as the frequency of defective units (e.g., toys with defective packaging) is under "control" (i.e., within acceptable limits) without having to continually re-run statistical analyses. We are adapting these methods to allow easier analysis by reserve managers for Group 2 variables (McBean and Rovers, 1998; Manly, 2001; Montgomery, 2001). Analysis of Group 1 variables should preferably use an analysis of variance coupled with a contrast analysis to achieve greater sensitivity. However, if a year falls outside the control limits for Group 1 variables, it will also be found to be significantly different in an analysis of variance. Thus, the control limits can be used as a coarse guide for Group 1 variables, in addition to Groups 2 and 3. All control limits were calculated as two-tailed control limits, with the exception of Group 3 variables which were calculated as one-tailed only, i.e. only able to detect declines.

Frequently, these control limits are calculated from 90%, 95% and 99% confidence limits. Calculation of these confidence limits varies, depending on whether the data are normally distributed or are Poisson distributed.

Normal distribution

Confidence Limits = $\bar{x} \pm Z_{\alpha/2} S$ (based on Montgomery, 1998, p. 207-208)   Eqn 1.3

Poisson distribution

Lower limit = $\chi^2_{(1-\alpha/2, \nu)} / 2$ where $\nu = 2*\bar{x}$

Upper limit = $\chi^2_{(\alpha/2, \nu)} / 2$ where $\nu = 2*(\bar{x}+1)$ (Zar, 1999, p.574-574)   Eqn 1.4

Since only five years of data were used to create these control limits, they should be considered "preliminary" control limits.

It's important to note that the calculation of these control limits and number of years of zero captures are dependent on the assumption that variation observed during the baseline 5 years was

due to normal fluctuations and not due to longer-term directional trends in the target resource. If a long-term trend occurred during this period, then these limits are not valid. Any data transformations performed prior to calculation of these limits must also be applied to data collected in the future before comparing with these limits.

Group 1 control limits
All the control limits for Group 1 variables were calculated using equation 1.3 and are based upon the average capture rate per array per year for each of the five years.

If the average per array in some future year falls outside the control limits, then those data are considered significantly different from the baseline. Please note that such averages <u>must</u> be calculated from appropriately transformed data as mentioned in the tables. Control limits are given in Tables 4 and 5.

Group 2 control limits
For Group 2 variables, the control limits given in this report, coupled with regression analyses will be the primary ways of determining whether a new year of data collection is considered significantly different from the baseline 5 years. Since these data consist primarily of small numbers in which the variance is approximately equal to the mean, the Poisson control limits were most appropriate (i.e., Equation 1.4). The exception was number of arrays with orange-throated whiptail present which had such a small variance that the normal distribution calculation was more appropriate, (i.e., Equation 1.3). Control limits are given in Table 6.

Group 3 control limits: Number of years with zero captures
Analyses for this group consisted of calculating the probability of observing two or more consecutive years with zero captures based upon a Poisson distribution. Group 3 consisted of species with 8 or fewer captures summed across all 5 years, or 3 or fewer captures in any single year (i.e., southern Pacific rattlesnake, ring-necked snake, and juvenile striped racers; see Table 7). Snakes observed while walking to and from the arrays were included under the assumption that the amount of effort was roughly equivalent across years. If the number of years with zero captures at the 5% probability level was unrealistically high, then a larger sample size would be recommended.

Probability of zero captures per array = $P(0) = e^{-\mu}$ (Steel and Torrie, 1980, p.528) Eqn 1.5
Probability of multiple zero captures = $(e^{-\mu})^{n \cdot y}$

μ = true population average number of captures per array per year assuming an infinite number of years (this analysis substituted $\bar{x}$, the average across all arrays and 5 years, for μ)
n = number of arrays
y = number of years

Control limits were calculated based on when the probability for a given number of consecutive years of zero captures fell below 5%. One capture was added and subtracted from the calculations to determine how robust the limit was, and if the number of years calculated changed, the control limits were expanded accordingly. The control limit range given represents the number of years with zero captures when the expected probability is below 5% (see Table 7). *These control limits should be used with extreme caution and wisdom, since they were calculated based on an exceedingly small samples.*

The following factors were taken into consideration in optimizing the sampling design:

- *Optimal design needed to assess trends in number of species detected per array, orange-throated whiptails, striped racers, ring-necked snakes, and southern Pacific rattlesnakes.* To start determining the optimum number of arrays and number of sampling days per year required looking at the results of all the response variables and determining which would require the highest number of arrays to detect a desired level of change (see Tables 4, 5, 6, and 7). In addition, species that appeared to be experiencing declines during baseline years were flagged, because the sampling design would need to continue tracking these species effectively (e.g., striped racer). Other factors, such as the time required to detect rarer species under differing numbers of sampling days per year (see Figure 3) and the decline in the capture rate late in the sampling period compared with early in the sampling period, were also taken into account (see Figure 4 and Table 8).
- *Species captured at each array.* Not all species were captured consistently at all arrays. The number of captures of each species at each array is shown in Table 9, and in greater detail for striped racer in Table 10. Since the number of arrays was so small, rather than randomly selecting arrays to eliminate, arrays were identified that were consistently yielding low captures of targeted species and expected to continue doing so in the future.
- *Capture rates during different sampling periods.* The number and timing of sampling periods per year were examined qualitatively after the other sample size calculations were conducted (see Table 11) to determine if some sampling periods could be eliminated without affecting results, e.g. sampling periods that consistently yielded low captures for all species.

All of these factors were taken into consideration for making final recommendations to optimize the sampling design.

Analysis of associations between species and habitat variables
A stepwise forward/backward regression analysis was conducted to determine the variables most strongly correlated with the distribution of various species and categories of fauna. The variables used are shown in Table 12 and are defined more completely in Fisher et al. (2002) and Case and Fisher (2001). The data set was expanded to include all data collected for 1995-2001.

For "number of lizards and salamanders" and "number of orange-throated whiptails," the analysis was run first with environmental variables only, and then a second time with the Argentine ant density category included.

For the "number of snake captures" and "number of striped racer captures only," the analysis was run including environmental variables plus the number of small mammals captured, the number lizards and salamanders captured, and Argentine ant density category as possible independent variables.

In our analysis of Argentine ant density category, only environmental variables were considered as potential explanatory variables. Results are shown in Table 13.

Comparison of current species captured versus historical list

Table 14 contains a list of species currently found during sampling at Point Loma versus those found historically (see page 3). Only 12 of the 19 historic species were detected between 1995 and 2001 after 294 sampling days and 1696 herpetofauna observations. Night Snake (*Hypsiglena torquata)* was not known from museum records but was added to the historical species list when a single individual was found in 1997 by a park ranger (i.e. not at the pitfall traps). This is a very cryptic species which is difficult to detect and could easily have been missed during earlier surveys, and thus is considered to have historically occurred in this area. Further targeted surveys found only one more individual in 2001 (Yang and Fisher, 2003). Neither detection occurred as part of the systematic sampling addressed in this report. Two occurrences of coastal rosy boa (*Charina trivirgata)* were recorded. Both were along a roadside and are thought to have been released pets (and probably the same released pet), based on its historic absence and high detectability (Brown and Fisher, 2002). A radio-tracking study included this individual and found it had the largest home range of any of the rosy boas tracked (Rochester et al, 2001), another indication that this was probably an introduced animal. Neither the night snake or the coastal rosy boa were included in this analysis.

Trend analysis

Significant negative trends were detected during the baseline period (1996-2000) for the following variables: numbers of species detected per array per year (p= 0.0370), annual captures of striped racer (p= 0.0079) and number of arrays with striped racer present (p= 0.0418) (see Tables 3, 4 and 6). In the case of striped racer, however, this decline was very marked with 12 individuals being found in 1996 and only 4 being found in 2000 (see Tables 6 and 9). The declining number of species detected per year may be explained by demographic responses to climatic variation during the past decade. Both 1995 and 1998 were El Niño years, while 1999 and 2000 were both below average rainfall years (see Table 3).

Optimization of Sampling Design

Number of species detected per array (used as surrogate for species richness)

Only 5 arrays sampled 50 days per year or 8 arrays sampled 20 days per year would be needed to detect a decline of 30% with a power of 80% (see Table 4).

However, decreases in the number of sampling days per year can increase the number of years needed to detect rare species (see Figure 3).

Orange-throated whiptails

Given the high level of variance in orange-throated whiptail capture rates compared with the mean (CV=44% with all arrays or 32% with only arrays with >2 captures), detection of a decline of 30%, as originally requested by the reserve science manager, would require increasing the number of arrays (see Table 5). However, a decline of 40% could be detected with 80% power with the 11 arrays that currently capture high numbers of whiptails (i.e., arrays #1-4, 9-10, 13-17). If the number of sampling days per year were reduced from 50 to 40 sampling days, these 11 arrays could detect a decline of approximately 45% with 80% power. Any further decrease in sampling effort will result in increases in the CV and will require increasing the number of arrays (see Figure 2).

Juvenile orange-throated whiptails have a very high level of variance from array to array and from year to year (see Figure 5). The 11 arrays with high orange-throated whiptail captures will only detect a 65% decline with 80% power even when sampled 50 days per year. At 40 sampling days per year, those 11 arrays will detect a 75% decline with 80% power.

Thus, to detect changes in orange-throated whiptail capture rates, the 11 arrays which have high capture rates should be maintained (i.e., arrays #1-4, 9-10, 13-17).   The number of sampling days per year should be kept to 40-50 days per year.

Striped racer, ring-necked snakes, and southern Pacific rattlesnake

Given the small number of captures of striped racer, ring-necked snake, and southern Pacific rattlesnake, only a small reduction in sampling effort, if any, would be advised to maintain any ability to detect changes in these species, especially since there is concern that striped racer abundance may be declining (see Tables 6, 7, and 10). Any arrays that are eliminated should not include arrays with large numbers of captures of any of these snake species (see Table 9).

Patterns of species captures at different arrays

Maintaining the ability to detect changes in capture rates for orange-throated whiptail, striped racer, ring-necked snake, and southern Pacific rattlesnake appears to be driving the sampling design optimization.

The only array that showed no captures of any snakes or orange-throated whiptails is array #6 (see Table 9). Arrays #2 and 16 had no striped racer captures but did have high capture rates of orange-throated whiptails. Array #12 had only one capture of orange-throated whiptail and only one capture of striped racer in 1996. Arrays #5, 7, 8, and 11 all had 3-4 captures of striped racer and ring-necked snakes and thus should be maintained, if the ability to detect changes in these snake species is desired.

Analysis of sample periods per year

In order to maintain captures of striped racers and also the potential to detect all species, sampling should continue during all 5 sample periods. The number of species captured in each sampling period is included in Table 11. Based upon the sampling design optimization analysis, capture rates for orange-throated whiptail, striped racer snake, ring-necked snake, and southern Pacific rattlesnake drove the determination of the number of arrays necessary. Thus, any reduction or alterations to the number of sample periods per year must not increase variability in captures of these four species. None of these species was captured in large numbers in the Jan/Feb sampling period (period 1). Eliminating period 1 would have little impact on analysis of orange-throated whiptail but would possibly affect capture rates of striped racer. In addition, Jan/Feb is the primary period when the garden slender salamander is collected. If tracking at least the continued presence of the garden slender salamander is important, then some sampling needs to be maintained in this period.

Note: Although the only detection of the silvery legless lizard occurred during the Jan/Feb sampling period in this data set, it was also captured once each in 1995 and 2001 during summer, so its detection is not limited to winter months.

<u>Analysis of associations between species and habitat variables</u>
The results of the stepwise regression are given in Table 13. Only a few highlights are mentioned here, as a more comprehensive analysis is planned for 2004 using data from multiple sites. The overall number of snakes captured was positively associated with percent cover but negatively associated with canopy height. However, striped racer capture rates were most tightly correlated with the number of small mammals, lizards, and salamanders captured at the same array. Argentine ants were positively associated with percent grass cover and negatively associated with percent coastal sage scrub cover. When the density category of introduced Argentine ants (1, 2 or 3) was added to the analysis, this variable replaced one or more environmental variables in the regression equations for number of lizards and salamanders, and for number of orange-throated whiptails. Thus, higher densities of Argentine ants were negatively associated with lizard and orange-throated whiptail capture rates.

DISCUSSION

Declines in species and missing species
Only 12 of the 19 historically reported species were detected during the pitfall trap array sampling during 1995-2001. Only 11 of these species were represented in the 1996-2000 data used to determine necessary sample sizes (Table 14). A single night snake (*Hypsiglena torquata)* was found in a bucket in array #10 in 2001. Species that were not detected include Coronado skink (*Eumeces skiltonianus*), coast horned lizard (*Phrynosoma coronatum*), California glossy snake (*Arizona elegans*), yellow-bellied racer (*Coluber constrictor*), red diamond rattlesnake (*Crotalus exsul ruber*), coachwhip/red racer (*Masticophis flagellum*), and long-nose snake (*Rhinocheilus lecontei*). All of these species have been detected using pitfall trap arrays or walking to and from these arrays at other sites in southern California, although the number of red diamond rattlesnakes, long-nose snakes, California glossy snakes, and night snakes generally tended to be detected in low numbers (Fisher and Case, 2000b). Thus the failure to detect these species at the Point Loma Ecological Reserve is a concern and suggests that 36% of the herpetofauna species that were historically detectable are either missing or present in very low numbers below thresholds detectable by this large sampling effort (i.e., 294 sampling days across 17 arrays).

The sharp downward trend (p= 0.0079) in striped racer (*Masticophis lateralis*) captures from 1996-2000 is a concern. Three different hypotheses have been put forward: 1) the species is in decline at Point Loma Ecological Reserve, 2) the snakes are learning to avoid the traps, 3) the decline is an artifact of 1998, an El Niño year, preceding 2000, a drought year, thereby creating a downward trend in captures that is a response to annual rainfall variation rather than a larger trend, or some combination thereof.

Table 10 shows the pattern of striped racer captures by array and the pattern of juvenile captures. The pattern does not immediately suggest that learning by snakes is occurring. However, a larger scale analysis of Robert Fisher's data of herpetofauna captured from pitfall trap arrays throughout San Diego County will occur in 2004 and the data can be examined to see if other sites show similar immediate declines in striped racers after initiation of sampling. Another way of separating these hypotheses is to pay particular attention to juvenile striped racers and see if they are experiencing a decline, since juveniles would not have experience with the traps.

Regardless, the capture rates of striped racers should be closely watched in the near future to see if this apparent decline continues.

The slight negative trend in the number of species detected per array (p= 0.0370) and marginal trend in number of arrays with orange-throated whiptail present (p= 0.0805) should be watched but may be an artifact of the 1998 El Niño year preceding the 2000 drought year (see Tables 4 and 6).

The stepwise regression analysis showed that Argentine ant density category was negatively associated with capture rates of lizards and salamanders in total (p=0.0004) and for orange-throated whiptail in particular (p=0.0008) (see Table 13). This result is similar to the findings that Argentine ants have negative impacts on shrews (Laakkonen et al., 2001) and coastal horned lizard (Fisher et al., 2002) and are frequently associated with urban edges. Management of Argentine ants to prevent establishment and expansion throughout the reserve is thus assumed to be important for maintaining native herpetofauna species diversity.

Brown and Fisher (2002) recommended management strategies to try and prevent further declines in herpetofauna species at the Point Loma Ecological Reserve, including suggestions for curbing road mortality, protecting continuous habitat, reducing pet collection and disturbance of fauna, public education regarding rattlesnakes, controlling invasive vegetation such as ice plants and eucalyptus, controlling irrigation runoff into reserve which may promote spread of argentine ants, and encouraging pet owners to keep cats indoors.

Recommended sample design optimization

The ability to detect changes in orange-throated whiptails and in snake species such as striped racer, ring-necked snake, and southern Pacific rattlesnake were what most strongly influenced recommendations regarding sampling design. In short, the recommendations are:
- Reduce the number of sampling days per year from 50 to 40.
- Eliminate arrays #6 and 12

Maintaining all 11 arrays at which orange-throated whiptails are currently captured in large numbers is recommended, as this will allow detection of trends in orange-throated whiptail captures of 40% - 50% with a power of 80% (1-β). Specifically these are arrays #1-4, 9, 10, 13-17 (see Table 9). The variables of number of species detected per array and total herpetofauna capture rates required even fewer numbers of arrays to detect trends (see Tables 4 and 5). However, so few snake captures were occurring (63 across all 5 years), that only small changes in the sampling design would be advisable to maintain an ability to detect trends in snakes, especially since there is concern that striped racer may be showing a decline. Only arrays with little to no snake captures should be considered for elimination. And the number of sampling days per year should not be reduced below 40 unless the ability to detect snakes can somehow be improved.

Looking at the pattern of species captured across arrays, only arrays # 6 and 12 should be considered for elimination at this time. Neither of these arrays captured orange-throated whiptails or snakes in large numbers and both are spatially redundant with nearby arrays. Captures at array #6 had the lowest species detected of all the arrays, and array #12 had the lowest overall capture rate of all the arrays. Array #6 is placed closely in between arrays #5 and

#7 but features fewer habitat elements than the other two arrays. While all three arrays are located in the same sandy wash habitat, arrays #5 and 7 have arms located in chaparral elements that are not immediately proximate to array #6. While array #6 may be useful in determining movements across an open wash from arrays #5 or 7 if recapture rates are high enough, the wash is a sensitive area, containing a population of the protected Orcutt's Spineflower (*Chorizanthe orcuttiana*). Removing array #6 will have little effect on detecting trends in the targeted herpetofauna species and will prevent any unintended impacts to the rare plant by researchers walking through the area. Array #12 has the lowest number of herpetofauna captures of any of the arrays and is located near arrays #10 and #11 and so is somewhat redundant in spatial coverage. Only 1 striped racer capture occurred at array #12 and none at array #6 and elimination of these arrays shouldn't affect the control limits for this species. No other snake species were captured at these arrays. Arrays #5, 7, 8, and 11 all had one or fewer captures of orange-throated whiptails. However they all had at least 3 snake captures and should therefore be maintained at present.

The pattern of species captures changes depending on the season. The garden slender salamander (*Batrachoseps major*) was primarily captured during January-February with no captures in June-September. However less than 2% of the orange-throated whiptail captures occurred in January-February and only 5% of the snake captures occurred in this time period. It might be possible to reduce the sampling in this time period from 10 days to 4 days rather than from 10 days to 8 days as in the other sample periods, unless the ability to detect trends in the salamander is a concern. To optimize detection of salamanders, sampling during this time period should occur after rain events.

If these recommendations are implemented this should result in a 30-35% reduction in effort. If a further reduction in effort is necessary due to budget limitations, it would be better to sample the 15 arrays every other year than to further reduce the number of arrays to enable sampling every year.

Changes from five sampling periods to ten

Once the decision was made to reduce the number of sampling days per year from 50 to 40 days, divided as five 8-day sample periods that would occur at approximately the same time of year as the original five 10-day sample periods used in 1996-2000, the question was raised as to whether this could be divided into ten 4-day sample periods instead. From a management point of view, 4-day sample periods are easier to schedule since they can be completed in a single week and don't require surveyors to work weekends or overtime.

While technically it is preferable to follow the protocol used during the baseline years as closely as possible, using ten 4-day sample periods instead of five 8-day sample periods will probably have little effect on the results. The five sample periods during the baseline years varied in their start date by about a month anyway. So shifting to ten 4-day sample periods sampled approximately a month apart is still roughly comparable to five 8-day sample periods sampled about two months apart.

Biases in array locations

Array location selection was limited because arrays could only be placed in areas that did not have steep slopes and were accessible to surveyors while being out of sight from park visitors. Thus areas that had steep slopes or were otherwise inaccessible to surveyors are under-sampled.

Given the small size of the reserve, this is expected to have minimal impact on the results. However, it is possible that some species that were not detected may remain in these under-sampled areas, albeit in small numbers. Results from the arrays will have the strongest inference in areas near the arrays. Extrapolation of results from the arrays to robust population size estimates across the entire peninsula is not possible. However, trends at the arrays can be used to identify when problems are developing, at least in the areas nearest the arrays, and used to hypothesize (infer) the status of species on the peninsula.

Improvements to the protocol
Capture rates for all snake species were much lower than for lizards and salamanders. The ability to assess trends in ring-necked snake and southern Pacific rattlesnake were especially poor with very low power to detect changes— these snake species will need to be virtually wiped out in the reserve before a decline is detectable with statistical certainty. Thus the control limits for these species, in effect, provide a warning of when such species are falling below detectable thresholds and managers may need to consider reintroductions from other larger reserves. To improve the protocol, it may be worthwhile to investigate supplementing the current monitoring methods (buckets and wire snake traps, random encounters at array sites) with additional techniques to increase detectability of snakes. Although Fitch (1992) suggests supplementing with artificial shelters such as boards about 0.75 m^2, which could be checked by turning them over while at array sites. We have experimented with boards 0.09 m^2 in size without improvement in capture rates. Such boards can also become shelters for Argentine ants (Robert Fisher, personal observation). However, ideas to improve detectability of snakes should continue to be explored.

Recommended future analyses
Group 1: Number of species detected, species evenness, herpetofauna captures, lizard captures, and orange-throated whiptail captures per array per year.

Two alternatives are presented for analyzing these variables. Although control limits were calculated for these variables, using an analysis of variance coupled with a contrast analysis is preferred because it will be more sensitive to detecting changes.
- Alternative 1) Conduct an analysis of variance and covariance on appropriately transformed data
    - Trend detection: Conduct an analysis of covariance with arrays set as a "class" variable and years set as a "regression" or "quantitative" variable. It may be more appropriate to only perform this analysis on the most recent 5-7 years.
    - Comparison with baseline years: Conduct an analysis of variance with arrays and years as "class" variables. Arrays can be treated as "random" effects or as "fixed" effects. Years 1996-2000 should be considered the "base" years. A contrast analysis should be performed to test whether the results of the latest monitoring year is different from these first 5 years. (Steel and Torrie, 1980, p. 177). Differences between individual years are less important than whether a given year is different from the 5 base years.
- Alternative 2) Transform data from each new year, calculate the average per array for that year, and compare with control limits (see Table 15). If the average is outside the control limits, then the analysis of variance (Alternative 1) should also result in a significant difference detected, since the control limits are less sensitive than the analysis of variance.

After 5 additional years of monitoring, if no trends have been discerned, the "Baseline data" years (i.e., 1996-2000) could be extended to include all 10 years, and control limits recalculated so they can be based upon a larger sample of data. It may even be possible to include rainfall as a covariate in the analysis.

Group 2: Snake captures per year, striped racer captures per year, number of sites with snakes present, number of sites with striped racer present, number of sites with orange-throated whiptail present, number of sites with juvenile orange-throated whiptail present.
- Trend detection: Conduct a regression analysis on the total counts per year or number of arrays that an organism is present per year with year set as a "regression" or "quantitative" variable. It may be more appropriate to perform this analysis on only the most recent 5-7 years.
- Comparison with baseline years: Compare total count per year or number of arrays with organism present per year with control limits (see Table 15).

After 5 years of data collection, if no trends have been discerned, recalculate the control limits.

Group 3: Striped racer juvenile counts per year, southern Pacific rattlesnake counts per year, ring-necked snake counts per year (counts include both captures and sightings of the species).
- Comparison with baseline years: If no individuals are collected that year, compare with control limits for number of zero years in a row (see Table 15).

After 5 years of data collection, if no trends have been discerned, recalculate the control limits.

Using control limits and analyses to assist management

A summary of all the control limits calculated for analysis Groups 1, 2, and 3 is given in Table 15. When a variable drops below a control limit or is found to be significant at the 5% significance level, what this means is that given the variation seen in the baseline 5 years, we would only expect such results to occur by random chance about 5% of the time. Thus usually we conclude in natural resource management that the result did not occur by random chance and we instead accept our alternative hypothesis (i.e., that a trend is occurring). Basically in a big picture sense we are checking to see if a new year falls within a range we would expect given the amount of variation seen in the baseline 5 years.

However, it is important to realize that there is nothing "magical" about this number. These control limits and significance levels are guides to assist management but do not replace common sense. If resource managers see a problem occurring that will likely result in a decline in herpetofauna over the next several years (i.e., non-native plant invasion, new predator, increased pet collection), they should not wait until a control limit is exceeded before acting. The earlier intervention occurs, the easier and less costly it is to correct a problem. This is especially important in the case of Group 2 and Group 3 variables whose control limits have very low power to detect change. Group 2 variables will need to decline by 60-70% before a trend is detectable, and Group 3 species, i.e. ring-necked snakes and southern Pacific rattlesnakes, will need to be virtually wiped out in the reserve before their decline is detected with statistical certainty, i.e. with statistical power of greater than 80%. However, such management interventions should also be evaluated for their effectiveness and possibly set up as experiments, depending on the degree of uncertainty involved.

As another example, a severe drought could result in a significant decline compared with the baseline years. Managers will have to decide if intervention is required to prevent species loss, or whether it is simply best to wait for higher rainfall years to return.

The five years from 1996-2000 used in this analysis include a range of weather conditions including an El Niño year in 1998 and drought years in 1996, 1999, and 2000. This variation appeared to be reflected in the large variation in captures of the 11 species and, hopefully, has improved the robustness of the sample size calculations and control limits. However, the results and conclusions should be tempered with the understanding that only 5 years of data were used and this may not encompass the full range of "naturally occurring" variation. In industry, it is preferred that 20-25 points be gathered before calculating control limits (Montgomery 2001). In addition, it is suspected that annual rainfall may be an important cofactor, but there were not enough data to provide a good test for this. After monitoring continues for another 5 years and if no trends are detected, this sampling design optimization analysis can be repeated, control limits re-evaluated, and the number of arrays and sampling days needed reassessed. The relationship between capture rates of different species and annual rainfall could also be assessed.

It is important for the sake of future analyses that the same number of sampling days per year be used in all years and that sampling be conducted at roughly the same times during each year. Comparison of data in subsequent years with the 5 baseline years (1996-2000) assumes that data is collected in the same way with the same number of overall sampling days and with comparable error rates and sources of variation. If sampling is not conducted consistently, it becomes difficult to separate changes within the species from changes in the methods of collecting. Also, although snakes seen on trails while samplers go to and from the arrays should be included, herpetofauna seen during other activities such as weed control efforts, along roads, or routine maintenance should not be used in the analysis (e.g., not counted in the number of captures compared with the control limits). However, such observations are useful in other ways such as documenting where species are occurring in the preserve and the continued presence of the species in the preserve.

This analysis and resulting recommendations have assumed that it is preferable to control a Type II error than a Type I error. A Type I error occurs when it is concluded that a change (e.g. a decline) has occurred when in fact the results are nothing more than randomly occurring variation and no change has in fact occurred. A Type II error occurs when one concludes that no change has occurred when in fact a decline is actually happening. However, in management of sensitive species, it is better to err on the side of giving a false alert of a problem to management than to fail to detect a change. Several factors may increase the probability of a Type I error in this analysis.

- If data are highly autocorrelated (i.e., capture rates in one year are related to the capture rates in a previous year), then there can be an increased probability of a Type I error (Montgomery, 2001). This may be a small problem with this data.
- Use of Poisson regression and a Poisson distribution in the analysis of variance is preferred when dealing with such small whole numbers. If the analysis of variance assumes a normal distribution, there can be an increased likelihood of a Type I error. However, calculations using a Poisson distribution require sophisticated computer packages and may not change the final conclusion (i.e., that a decline is or is not occurring).

- The control limits are calculated using a Z-distribution rather than a t-distribution. While this is typical in quality control literature, this does increase the probability of a type I error.

These problems are assumed to be slight and manageable. However if "false alarms" are occurring too frequently, then analysis of variance incorporating the Poisson distribution can be used (SAS statistical software provides this option), or alternatively the 99% control limit can be used instead of the 95% control limit (i.e., an $\alpha=0.01$ rather than $\alpha=0.05$).

Why conduct both a regression analysis and an analysis of variance (or comparison with control limits)? If a downward trend (decline) is already occurring within the baseline data set, a regression analysis will detect this trend, whereas the control limits will be set too low, are not really valid, and will tend to cause Type II errors. However, if a trend is not occurring in the baseline data set and only starts, for example, 5 -10 years from now, the control limits will detect it more quickly. Since several variables may be showing a decline (i.e., striped racer capture rates, number of species detected per array per year, and number of sites occupied by orange-throated whiptail), conducting a regression analysis as well as using the control limits is advised.

SUMMARY

Only 12 of the original 19 species thought to be present at Point Loma Ecological Reserve were detected during pitfall trap sampling from 1995-2001 (see Table14) and only 11 during the actual time period used in this analysis (1996-2000). Monitoring for declines in species still present at Point Loma is necessary to provide information for timely management intervention. Striped racer captures and number of species detected per array declined from 1996 to 2000. While striped racer declines could be caused by the snakes learning to avoid the traps, the decline is a concern and should be monitored. Declines in the number of juvenile striped racers would be especially important to track, since they will not yet have learned to avoid the traps.

The following recommendations are made for refining monitoring for herpetofauna using pitfall trap arrays at Point Loma Ecological Reserve at Point Loma, California. Refinements should provide some reduction in sampling effort while maintaining an ability to detect approximately a 20% drop in the number of species detected per array, a 40-50% drop in orange-throated whiptail (*Cnemidophorus hyperythrus*) capture rates, and an ability to continue monitoring trends in striped racer (*Masticophis lateralis*), ring-necked snake (*Diadophis punctatus*), and southern Pacific rattlesnake (*Crotalus viridis*), which were variables requested by the reserve manager.
- The number of sampling days per year could be reduced from 50 to 40.
- Only arrays #6 and #12 should be discontinued.
- Control limits were calculated for the various response variables (see Table 15 for a summary of all control limits).
- The 40 sampling days per year could be distributed across five 8-day sampling periods (similar to the original design of five 10-day sample periods) or alternatively across ten 4-day sampling periods with little effect on the results, provided they occur at approximately the same time during the year as the baseline data. This should allow work to be scheduled within a single work-week.
- If further reductions in sampling are required due to budget considerations, sampling the 15 arrays every other year is preferred to reducing the number of arrays sampled. In addition, it may be possible to reduce sampling in the January-February sampling period to only 4 days if tracking declines in salamanders is not a concern. Sampling in January-February should be timed after rain events to maximize detection of salamanders.

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Table 3. Total herpetofauna captures per year for years 1996-2000. Data for 1995 and 2001 were excluded (see text). Recaptures within same sampling period not included. Snakes observed by surveyers while walking to and from arrays are included. The species *Hypsiglena torquata* (night snake) was detected in 2001. Note: 1998 was an El Niño year with elevated rainfall. The years 1996, 1999, and 2000 were considered drought years with very low rainfall.

	Species	Year					Totals
		1996	1997	1998	1999	2000	
Amphi-bians	*Batrachoseps major* — Garden slender salamander	19	4	39	22	2	86
Lizards	*Anniella pulchra* — Silvery legless lizard			1			1
	Cnemidophorus hyperythrus — Orange-throated whiptail	55	91	114	63	60	383
	Elgaria multicarinatus — Southern alligator lizard	25	36	49	14	22	146
	Sceloporus occidentalis — Western fence lizard	100	66	104	81	73	424
	Uta stansburiana — Side-blotched lizard	47	53	61	78	56	295
Snakes	*Crotalus viridis* — Southern Pacific rattlesnake		1	1		3	5
	Diadophis punctatus — Ring-necked snake		2	2	1	2	7
	Hypsiglena torquata — Night snake (detected in 2001)						
	Lampropeltis getula — California king snake			2	3		5
	Masticophis lateralis — Striped racer	12	9	7	7	4	39
	Pituophis melanoleucas — San Diego gopher snake		1	3	2	1	7
Summary statistics	Total herpetofauna captures / year	258	263	383	271	223	1398
	Total lizard captures / year	246	250	368	258	213	1335
	Total snake captures / year	12	13	15	13	10	63
	# species detected across all arrays	6	9	11	9	9	11
Diversity indices	Average # species detected / array	4.06	4.12	4.59	3.65	3.41	
	Simpson's species eveness	0.72	0.72	0.68	0.70	0.75	
	Shannon-Weiner diversity index	1.14	1.15	1.22	0.95	1.00	

Table 4. Trend analysis and optimization analysis for average number of species detected, species evenness, total herpetofauna captures, and lizard captures per array per year. Results are presented assuming 20, 30, 40, and 50 sampling days per year (i.e., 4-day, 6-day, 8-day, or 10-day sample period). Mean Square Error (MSE) is taken from an analysis of variance which included year and array as class variables. Regression analyses were performed on all variables using the 10-day sample period data to determine if a trend existed from 1996 - 2000. All data presented have been transformed with a square root transformation, with the exception of Simpson's Evenness. Confidence Limits are given as a rough guide to determine when variables are different from baseline years, but using a contrast analysis is expected to detect a change earlier.

		Number species detected # species/array/yr				Simpson's Evenness evenness index/array/yr				Herpetofauna captures captures/array/yr				Lizard captures captures/array/yr			
	sampling days per year	20	30	40	50	20	30	40	50	20	30	40	50	20	30	40	50
Averages (Transformed Data)	1996	1.65	1.81	1.92	1.99	0.85	0.81	0.75	0.72	2.57	2.97	3.41	3.78	2.40	2.80	3.18	3.52
	1997	1.71	1.88	1.96	2.00	0.82	0.78	0.75	0.72	2.49	3.07	3.43	3.75	2.34	2.92	3.26	3.57
	1998	1.88	1.98	2.03	2.12	0.76	0.72	0.71	0.68	3.08	3.90	4.25	4.61	2.84	3.59	3.88	4.22
	1999	1.59	1.73	1.85	1.87	0.83	0.77	0.73	0.70	2.74	3.15	3.47	3.79	2.53	2.90	3.18	3.48
	2000	1.49	1.67	1.74	1.82	0.89	0.83	0.78	0.75	2.12	2.72	3.12	3.42	2.04	2.63	3.01	3.32
Summary	average	1.66	1.81	1.90	1.96	0.829	0.781	0.746	0.715	2.60	3.16	3.53	3.87	2.43	2.97	3.30	3.62
	MSE	0.12	0.11	0.09	0.08	0.016	0.022	0.024	0.021	0.46	0.43	0.39	0.40	0.45	0.41	0.38	0.36
	CV	0.21	0.18	0.16	0.14	0.150	0.188	0.210	0.201	0.26	0.21	0.18	0.16	0.28	0.22	0.19	0.17
	Transformation	square root				---				square root				square root			
Regression	Is trend present?	yes				not significant				not significant				not significant			
	slope	-0.048															
	prob. > |t|	p=0.0370															
Confidence Limits	upper 99% CL	2.03	2.13	2.19	2.27	0.95	0.89	0.81	0.78	3.51	4.31	4.62	5.00	3.19	3.91	4.16	4.52
	upper 95% CL	1.94	2.05	2.12	2.20	0.92	0.87	0.80	0.77	3.29	4.03	4.36	4.73	3.01	3.68	3.96	4.30
	lower 95% CL	1.38	1.57	1.69	1.73	0.74	0.70	0.70	0.66	1.91	2.29	2.70	3.01	1.86	2.25	2.65	2.94
	lower 99% CL	1.29	1.50	1.62	1.65	0.71	0.67	0.68	0.65	1.69	2.02	2.44	2.74	1.68	2.03	2.44	2.73

arrays recommended at given power and 0.05 alpha level
(Cells in gray would require an increase in number of arrays)

Sample size estimates for contrast analysis

Power	Difference to detect	NSD 20	30	40	50	SE 20	30	40	50	Herp 20	30	40	50	Liz 20	30	40	50
90%	30%	11	8	7	6	6	9	11	10	17	11	8	7	19	12	9	7
	40%	7	5	4	4	4	6	7	6	10	7	5	4	11	7	6	5
	50%	5	4	3	3	3	4	5	4	7	5	4	3	7	5	4	3
	60%	4	3	3	2	3	3	4	3	5	4	3	3	5	4	3	3
	70%	3	3	2	2	2	3	3	3	4	3	3	2	4	4	3	2
80%	30%	8	7	5	5	5	7	9	8	13	8	6	6	14	9	7	6
	40%	5	4	4	3	3	4	5	5	8	5	4	4	8	5	4	4
	50%	4	3	3	3	3	3	4	4	5	4	3	3	6	4	3	3
	60%	3	3	2	2	2	3	3	3	4	3	3	2	4	3	3	2
	70%	3	2	2	2	2	2	3	2	3	3	2	2	4	3	3	2
70%	30%	7	5	5	4	4	6	7	6	10	7	5	5	11	7	6	5
	40%	4	4	3	3	3	4	4	4	6	4	3	3	7	5	4	3
	50%	3	3	2	2	2	3	3	3	4	3	3	3	5	3	3	3
	60%	3	2	2	2	2	2	3	3	3	3	2	2	4	3	2	2
	70%	2	2	2	2	2	2	2	2	3	2	2	2	3	2	2	2

Table 5. Trend analysis and optimization analysis for orange-throated whiptail captures and juvenile orange-throated whiptail captures per array per year. Results are presented assuming 20, 30, 40, and 50 sampling days per year (i.e., 4-day, 6-day, 8-day, or 10-day sample period). Mean Square Error (MSE) is taken from an analysis of variance which included year and array as class variables. Regression analyses were performed on all variables using the 10-day sample period data to determine if a trend already existed from 1996 - 2000. All data presented have been transformed with a square root transformation. Confidence Limits are given as a rough guide to determine when variables are different from baseline years, but using a contrast analysis is expected to detect a change earlier. Results for orange-throated whiptails are presented with data from all arrays included and again with only arrays that had >2 captures of whiptails.

			Orange throated whiptail — All Arrays				Orange throated whiptail — Arrays 1-4, 9-10,13-17				Juv. Orange throated whiptail — Arrays 1-4, 9-10,13-17			
			sampling days per year				sampling days per year				sampling days per year			
			20	30	40	50	20	30	40	50	20	30	40	50
Averages (Transformed Data)		1996	0.76	0.95	1.25	1.41	1.18	1.37	1.85	2.00	0.47	0.60	0.75	0.89
		1997	1.05	1.40	1.60	1.70	1.63	2.07	2.38	2.54	0.94	1.27	1.41	1.52
		1998	1.37	1.76	1.84	2.00	2.02	2.64	2.75	3.00	1.11	1.49	1.53	1.64
		1999	1.10	1.23	1.33	1.40	1.69	1.90	2.05	2.16	0.66	0.71	0.80	0.82
		2000	0.55	0.87	1.07	1.22	0.55	1.26	1.57	1.79	0.18	0.27	0.53	0.64
Summary		average	0.96	1.24	1.42	1.55	1.47	1.85	2.12	2.30	0.69	0.87	1.00	1.10
		MSE	0.32	0.46	0.43	0.46	0.42	0.55	0.54	0.56	0.26	0.26	0.35	0.34
		CV	0.58	0.55	0.46	0.44	0.44	0.40	0.35	0.32	0.74	0.59	0.59	0.53
		Transformation	square root				square root				square root			
Regression		Is trend present?	not significant				not significant				maybe			
		slope									-0.12			
		prob. > $|t|$									p=0.0792			
Confidence Limits		upper 99% CL	1.78	2.17	2.19	2.34	2.94	3.29	3.30	3.53	1.65	2.15	2.13	2.25
		upper 95% CL	1.59	1.95	2.01	2.15	2.59	2.94	3.02	3.24	1.42	1.84	1.86	1.97
		lower 95% CL	0.34	0.54	0.83	0.95	0.36	0.75	1.22	1.36	-0.04	-0.11	0.14	0.23
		lower 99% CL	0.15	0.31	0.64	0.76	0.01	0.41	0.93	1.07	-0.27	-0.42	-0.13	-0.05
Sample size estimates for contrast analysis	Power	Difference to detect												
	90%	30%	80	71	51	46	46	38	29	25	130	83	82	67
		40%	45	40	29	26	26	22	17	15	74	47	47	38
		50%	29	26	19	17	17	14	11	10	47	30	30	25
		60%	21	18	13	12	12	10	8	7	33	21	21	17
		70%	15	14	10	9	9	8	6	5	25	16	16	13
	80%	30%	60	53	38	34	35	29	22	19	97	62	62	50
		40%	34	30	22	20	20	17	13	11	55	35	35	29
		50%	22	20	14	13	13	11	8	8	36	23	23	19
		60%	16	14	10	9	9	8	6	6	25	16	16	13
		70%	12	10	8	7	7	6	5	4	19	12	12	10
	70%	30%	48	42	30	27	28	23	17	15	77	49	49	40
		40%	27	24	17	16	16	13	10	9	44	28	28	23
		50%	18	16	12	11	11	9	7	6	28	18	18	15
		60%	13	11	8	8	8	6	5	5	20	13	13	11
		70%	9	9	6	6	6	5	4	4	15	10	10	8

arrays recommended at given power and 0.05 alpha level
(Cells in gray would require an increase in number of arrays)

Table 6. Calculation of 95% and 99% confidence levels for total number of snake captures per year, striped racer captures per year, and number of arrays occupied by snakes, striped racers only, orange-throated whiptails and juvenile orange-throated whiptails. Results are presented assuming 20, 30, 40, and 50 sample days per year (i.e. a 4-day, 6-day, 8-day, or 10-day sample period). The type of distribution determined the method of calculation for confidence limits (Poisson, normal). Warning limits are the 90% and 95% confidence limits converted to whole numbers of individuals captured or numbers of arrays with individuals present. Regression analyses were conducted on all variables using the 10-day sample period data to determine if a trend already existed from 1996 - 2000.

		All snakes captures/year				All snakes # arrays present/year				Striped Racer captures/year				Striped Racer # arrays present/year				Orange Throated Whiptail (Juveniles+Adults) # arrays present/year				Orange Throated Whiptail - Juveniles # arrays present/year			
Response variable = Sampling days per year =		20	30	40	50	20	30	40	50	20	30	40	50	20	30	40	50	20	30	40	50	20	30	40	50
Data	1996	4	5	9	12	3	4	6	8	4	5	9	12	3	4	6	8	8	10	12	13	4	5	6	7
	1997	8	9	11	13	8	9	9	9	7	8	9	9	7	8	9	9	8	10	11	11	8	8	8	9
	1998	6	9	11	15	6	9	10	12	3	3	5	7	3	3	5	6	11	11	11	12	7	9	9	9
	1999	7	8	11	12	4	5	6	7	3	4	6	7	3	4	5	6	10	11	11	11	5	5	6	6
	2000	3	5	8	8	3	4	5	5	0	2	4	4	0	2	4	4	6	8	9	10	2	2	4	4
Summary	average	5.6	7.2	10.0	12.0	4.8	6.2	7.2	8.2	3.4	4.4	6.6	7.8	3.2	4.2	5.8	6.6	8.6	10.0	10.8	11.4	5.2	5.8	6.6	7.0
	Std. Dev.	2.1	2.0	1.4	2.5	2.2	2.6	2.2	2.6	2.5	2.3	2.3	2.9	2.5	2.3	1.9	1.9	1.9	1.2	1.1	1.1	2.4	2.8	1.9	2.1
	Variance	4.3	4.2	2.0	6.5	4.7	6.7	4.7	6.7	6.3	5.3	5.3	8.7	6.2	5.2	3.7	3.8	3.8	1.5	1.2	1.3	5.7	7.7	3.8	4.5
	CV	0.37	0.28	0.14	0.21	0.45	0.42	0.30	0.32	0.74	0.52	0.35	0.38	0.78	0.54	0.33	0.30	0.23	0.12	0.10	0.10	0.46	0.48	0.30	0.30
	Type of distribution	Poisson				Poisson				Poisson				Poisson				Normal				Poisson			
Reg.	Trend present?	not significant				not significant				yes				yes				maybe				not significant			
	prob. > |t|									0.0079				0.0418				0.0805							
Confidence Limits	upper 99% CL	14.9	17.1	21.4	24.1	13.4	15.7	17.1	18.6	11.0	12.6	16.4	17.9	11.0	12.6	14.9	16.4	13.6	13.2	13.6	14.3	14.1	14.9	16.4	17.1
	upper 95% CL	12.4	14.4	18.4	21.0	11.0	13.1	14.4	15.8	8.8	10.2	13.7	15.1	8.8	10.2	12.4	13.7	12.4	12.4	12.9	13.6	11.7	12.4	13.7	14.4
	upper 90% CL	11.2	13.1	17.0	19.4	9.8	11.8	13.1	14.4	7.8	9.2	12.5	13.8	7.8	9.2	11.2	12.5	11.8	12.0	12.6	13.3	10.5	11.2	12.5	13.1
	lower 90% CL	2.3	3.3	5.4	6.9	1.7	2.6	3.3	4.0	0.8	1.4	2.9	3.6	0.8	1.4	2.3	2.9	5.4	8.0	9.0	9.5	2.0	2.3	2.9	3.3
	lower 95% CL	1.9	2.8	4.8	6.2	1.4	2.2	2.8	3.5	0.6	1.1	2.5	3.1	0.6	1.1	1.9	2.5	4.8	7.6	8.7	9.2	1.6	1.9	2.5	2.8
	lower 99% CL	1.3	2.0	3.7	4.9	0.9	1.5	2.0	2.6	0.3	0.7	1.8	2.3	0.3	0.7	1.3	1.8	3.6	6.8	8.0	8.5	1.1	1.3	1.8	2.0
	Warning -90% CL ** (# captures or # arrays)	2	3	5	6	1	2	3	4	0	1	2	3	0	1	2	2	5	8	9	9	2	2	2	3
	Warning -95% CL ** (# captures or # arrays)	1	2	4	6	1	2	2	3	0	1	2	3	0	1	1	2	4	7	8	9	1	1	2	2
	Warning -99% CL ** # captures or # arrays)	1	2	3	4	0	1	2	2	0	0	1	2	0	0	1	1	3	6	8	8	1	1	1	2

** Calculation of "Thresholds" is based on the assumption that variation occuring during 1996-2000 is randomly occuring variation. If a trend is in fact occuring during that time period, then the thresholds are not valid.

Table 7. Calculation of control limits for juvenile striped racers, ring-necked snakes and southern Pacific rattlesnake. Control limits were determined as the point when the probability for multiple years in a row with zero captures or sightings of these snakes at the pitfall trap arrays drops below 5%. One capture was added and subtracted to each calculation to determine how robust the calculation was, and the control limits were expanded accordingly. (Numbers remain the same if array # 6 and #12 are dropped from the analysis since none of these snakes were found in array #6 or #12.)

		Juvenile Striped Racer *Masticophis lateralis*				Ring-necked Snake *Diadophis punctatus*				Southern Pacific Rattlesnake *Crotalus viridis*			
Year		20 days/yr	30 days/yr	40 days/yr	50 days/yr	20 days/yr	30 days/yr	40 days/yr	50 days/yr	20 days/yr	30 days/yr	40 days/yr	50 days/yr
1996		1	1	1	2	0	0	0	0	0	0	0	0
1997		2	2	2	2	0	0	1	2	0	0	0	1
1998		0	0	1	1	1	2	2	2	1	1	1	1
1999		1	2	2	2	0	0	1	1	0	0	0	0
2000		0	1	1	1	1	1	2	2	3	3	3	3
Total		4	6	7	8	2	3	6	7	4	4	4	5
Average		0.8	1.2	1.4	1.6	0.4	0.6	1.2	1.4	0.8	0.8	0.8	1.0
Probability of zero captures P(0)		0.4493	0.3012	0.2466	0.2019	0.6703	0.5488	0.3012	0.2466	0.4493	0.4493	0.4493	0.3679
Probability of multiple years with zero captures in a row	1 year	0.4493	0.3012	0.2466	0.2019	0.6703	0.5488	0.3012	0.2466	0.4493	0.4493	0.4493	0.3679
	2 years	0.2019	0.0907	0.0608	0.0408	0.4493	0.3012	0.0907	0.0608	0.2019	0.2019	0.2019	0.1353
	3 years	0.0907	0.0273	0.0150	0.0082	0.3012	0.1653	0.0273	0.0150	0.0907	0.0907	0.0907	0.0498
	4 years	0.0408	0.0082	0.0037	0.0017	0.2019	0.0907	0.0082	0.0037	0.0408	0.0408	0.0408	0.0183
	5 years	0.0183	0.0025	0.0009	0.0003	0.1353	0.0498	0.0025	0.0009	0.0183	0.0183	0.0183	0.0067
	6 years	0.0082	0.0007	0.0002	0.0001	0.0907	0.0273	0.0007	0.0002	0.0082	0.0082	0.0082	0.0025
	7 years	0.0037	0.0002	0.0001	0.0000	0.0608	0.0150	0.0002	0.0001	0.0037	0.0037	0.0037	0.0009
Control Limit : # of years with zero captures or sightings at arrays =		3-5 years	3 years	2-3 years	2-3 years	5-? years	4-8 years	3 years	2-3 years	3-5 years	3-5 years	3-5 years	3-4 years

Table 8. Captures during each day in sample period summed across all sampling periods from 1996-2000. The rate of new captures declines as the day in the sampling period progresses.

| | Species | Day in sampling period (1-10) | | | | | | | | | | Total |
		1	2	3	4	5	6	7	8	9	10	
Amphibians	*Batrachoseps major* — Garden slender salamander	6	10	17	3	7	12	14	3	4	10	86
Lizards	*Anniella pulchra* — Silvery legless lizard				1							1
Lizards	*Cnemidophorus hyperythrus* — Orange-throated whiptail	65	40	40	43	55	35	36	23	22	23	383
Lizards	*Elgaria multicarinatus* — Southern alligator lizard	13	7	15	18	25	15	10	13	19	11	146
Lizards	*Sceloporus occidentalis* — Western fence lizard	66	42	57	41	36	45	35	29	36	37	424
Lizards	*Uta stansburiana* — Side-blotched lizard	54	42	24	20	36	24	16	27	28	24	295
Snakes	*Crotalus viridis* — Southern Pacific rattlesnake				3	1					1	5
Snakes	*Diadophis punctatus* — Ring-necked snake	1	1	1				3			1	7
Snakes	*Hypsiglena torquata* — Night snake (detected in 2001)											
Snakes	*Lampropeltis getula* — California king snake		1		2	2						5
Snakes	*Masticophis lateralis* — Striped racer	5	4	3	5	4	1	9	2	3	3	39
Snakes	*Pituophis melanoleucas* — San Diego gopher snake	1	1		2			1		1	1	7
Summary	Total herpetofauna captures	211	148	157	138	166	132	124	97	113	111	1398
Summary	# species detected	8	9	7	10	8	6	8	6	7	9	11

Table 9. Total herpetofauna captures per array for years 1996-2000. Recaptures within same sampling period are not included. Array #6 and array #12 could be discontinued. Three snake observations were not recorded with an array number and were seen while walking on trails to arrays.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Not Recorded	Total
Batrachoseps major																			
Garden slender salamander		3				2	8	5	35	2	19	4	1	3		1	3		86
Anniella pulchra																			
Silvery legless lizard			1																1
Cnemidophorus hyperythrus																			
Orange-throated whiptail	59	22	112	41	1	1			14	6	2	1	27	43	21	23	10		383
Elgaria multicarinatus																			
Southern alligator lizard	9	15	22	14	2		5	2	5	7	8	9	22	8	10	5	3		146
Sceloporus occidentalis																			
Western fence lizard	17	8	40	34	20	12	27	20	25	9	16	15	41	53	27	30	30		424
Uta stansburiana																			
Side-blotched lizard	3	27	22	14	39	54	8	3	1	3	1	1	13	34	32	21	19		295
Crotalus viridis																			
Southern Pacific rattlesnake										1			1		1			2	5
Diadophis punctatus																			
Ring-necked snake								1	2		2						1	1	7
Lampropeltis getula																			
California king snake		1	2	1									1						5
Masticophis lateralis																			
Striped racer	3		3	1	4		3	3	7	3	1	1	3	3	3		1		39
Pituophis melanoleucas																			
San Diego gopher snake	1	1	1	1				1	1							1			7
Grand total # captures	92	77	203	106	66	69	51	35	90	31	49	31	109	144	94	81	67	3	1398
Number species detected	6	7	8	7	5	4	5	7	8	7	7	6	8	6	6	6	7	2	11

Table 10. Striped racer (*Masticophis lateralis*) captures by year and by array for adults plus juveniles and for juveniles only.

Striped Racer (Adults + Juveniles)

Array #	1996	1997	1998	1999	2000	Total
1	2	1				3
2						0
3	1	1		1		3
4				1		1
5		1	1	2		4
6						0
7	2		1			3
8	1	1	1			3
9	3	1	2	1		7
10		1	1		1	3
11					1	1
12		1				1
13	1	1			1	3
14	1		1		1	3
15	1	1		1		3
16						0
17				1		1
Total captures	12	9	7	7	4	39
# arrays present	8	9	6	6	4	14

Striped Racer (Juveniles Only)

Array #	1996	1997	1998	1999	2000	Total
1	1	1				2
2						0
3		1				1
4						0
5				1		1
6						0
7						0
8						0
9			1			1
10						0
11					1	1
12						0
13	1					1
14						0
15				1		1
16						0
17						0
Total captures	2	2	1	2	1	8
# arrays present	2	2	1	2	1	7

Table 11. Number of captures by sampling period from years 1996-2000. Based upon 50 sample days per year (i.e., 10-day sample periods).

Species	Sampling Period Time in Year					Grand Total
	Jan/Feb	Apr/May	June/Jul	Aug/Sep	Oct/Nov	
Batrachoseps major Garden slender salamander	72	12	0	0	2	86
Anniella pulchra Silvery legless lizard	1	0	0	0	0	1
Cnemidophorus hyperythrus Orange-throated whiptail	5	54	180	55	89	383
Elgaria multicarinatus Southern alligator lizard	34	70	20	6	16	146
Sceloporus occidentalis Western fence lizard	63	133	98	61	69	424
Uta stansburiana Side-blotched lizard	48	56	58	66	67	295
Crotalus viridis Southern Pacific rattlesnake	0	1	1	2	1	5
Diadophis punctatus Ring-necked snake	1	0	3	1	2	7
Lampropeltis getula California king snake	0	1	4	0	0	5
Masticophis lateralis Striped racer	2	11	8	11	7	39
Pituophis melanoleucas San Diego gopher snake	0	1	3	1	2	7
Grand total # captures	226	339	375	203	255	1398
# species detected	8	9	9	8	9	11

Table 12. Dependent and independent variables in stepwise regression analysis.

Dependent variables	Independent variables		
	Fauna**	**Vegetation**	**Physical**
# Snakes # Striped racers # Lizards and salamanders # Orange-throated whiptails Argentine ants category	# Lizards # Small mammals Argentine ants category	Canopy height % Cover # Shrub hits # Herb Hits % Coastal Sage Scrub % Chaparral % Grass	Elevation (meters) Slope (degrees) Cosine aspect Leaf litter Sandy soil Cryptogamic rock Bare Rock Cryptogamic soil Organic soil Moss

** Note: # lizards and # small mammals variables were only used in analysis for number of snakes captures and number striped racer captures. Dependent variables were first analyzed without including the argentine ant category so the habitat associations could be examined. The dependent variables were then reanalyzed with argentine ant categories included as a potential independent variable.

Table 13. Environmental variables stepwise regression results. The results from the stepwise regression analyses to determine what environmental variables were most strongly associated with each dependent variable are summarized below. For a variable to enter or exit the regression model required a probability >F of at least 0.15. Dependent variables are shown in bold in the table below. The data transformation and the associated R^2 of the model are also given. Although Argentine ant density category was not included initially in the analysis for number of lizards and salamanders and number orange-throated whiptails, when this variable was added, it became significant in the stepwise regression for these variables and replaced some environmental variables in the resulting equations. Argentine ant density category did not alter the regression equations for number of snakes or number of striped racers.

Parameter Name	Parameter	Probability >F
Results when Argentine ant density category *is not* allowed as regression variable		
# snakes (transformation = Ln(n+1); R^2 = .53)		
Intercept	-0.7768	0.2208
Canopy Height	-0.9385	0.0782
% Cover	0.0326	0.0020
# striped racers (transformation =Ln(n+1); R^2=.48)		
Intercept	-6.4391	0.0335
Ln (# mammals)	1.2939	0.0041
Ln (# lizards and salamanders)	0.6876	0.0860
# lizards & salamanders (transformation=square root (n); R^2=.60)		
Intercept	4.0046	0.0001
# herbaceous plant hits	0.0249	0.0028
% grasses	-0.0316	0.0007
# orange-throated whiptails (transformation =square root (n); R^2=.46)		
Intercept	3.5261	0.0559
# Shrub hits	-0.0709	0.0485
% coastal sage scrub	0.0807	0.0057
Argentine ants density category (no transformation; R^2=.82)		
Intercept	1.9316	0.0001
% Coastal sage scrub	-0.0104	0.0030
% Grass	0.0174	0.0027
Results when Argentine ant density category *is* allowed as regression variable		
# lizards and salamanders (transformation=square root(n); R^2=.63)		
Intercept	6.4112	0.0001
# Shrub hits	-0.0140	0.0082
Argentine ant density category	-0.7836	0.0004
# orange-throated whiptails (transformation =square root (n); R^2=.63)		
Intercept	6.9950	0.0001
# Herb hits	0.0939	0.0044
Argentine ant density category	-3.7502	0.0008

Table 14. List of species detected since 1995 versus historical records. The coastal rosy boa (*Charina trivirgata)* was a single individual found by the roadside and is thought to have been a released pet, since this species is not known historically from the peninsula. The night snake *(Hypsiglena torquata)* was not known historically in museum records, but a single specimen was documented in 1997 as well as in current surveys. This is a very cryptic, difficult to detect species and could easily have been missed during earlier surveys, and thus is considered to have historically occurred in this area.

SPECIES	Current surveys	Historical records
Amphibians		
Batrachoseps major 　Garden slender salamander	X	X
Lizards		
Anniella pulchra 　Silvery legless lizard	X	X
Cnemidophorus hyperythrus 　Orange-throated whiptail	X	X
Eumeces skiltonianus 　Coronado skink		X
Elgaria multicarinatus 　Southern alligator lizard	X	X
Phrynosoma coronatum 　Coast horned lizard		X
Sceloporus occidentalis 　Western fence lizard	X	X
Uta stansburiana 　Side-blotched lizard	X	X
Snakes		
Arizona elegans 　California glossy snake		X
Charina trivirgata 　Coastal rosy boa	X (introduced)	
Coluber constrictor 　Yellow-bellied racer		X
Crotalus exsul 　Red diamond rattlesnake		X
Crotalus viridis 　Southern Pacific rattlesnake	X	X
Diadophis punctatus 　Ring-necked snake	X	X
Hypsiglena torquata 　Night snake	X	X
Lampropeltis getula 　California king snake	X	X
Masticophis lateralis 　Striped racer	X	X
Masticophis flagellum 　Coachwhip / red racer		X
Pituophis melanoleucas 　San Diego gopher snake	X	X
Rhinocheilus lecontei 　Long-nose snake		X

Table 15. Summary table of preliminary control limits for detecting changes from the baseline years 1996-2000. These control limits and data in this table assume that specified data transformations have been conducted, that arrays #6 and #12 are discontinued, and that the number of sampling days per year has been reduced from 50 to 40 days, either divided as 5 8-day sampling periods per year or as 10 4-day sampling periods per year.

Variable name	Variable	Transformation	Is Trend Significant	1996	1997	1998	1999	2000	Lower Control Limit 90%	Lower Control Limit 95%	Lower Control Limit 99%
# Species detected	Average # species / array / year	Square root	Yes P=.0370	1.99	1.99	2.08	1.91	1.75	≤1.74*	≤1.70*	≤1.62*
Relative Species Evenness	Average Evenness / array / year		No	.75	.73	.70	.73	.80	≤0.68**	≤0.67**	≤0.65**
Herpetofauna	Average # herpetofauna Captures / array / year	Square root	No	3.54	3.54	4.44	3.57	3.10	≤2.84**	≤2.68**	≤2.38**
Lizards	Average # lizard captures / array / year	Square root	No	3.29	3.39	4.03	3.27	2.99	≤2.76**	≤2.64**	≤2.41**
Snakes	Total snake captures / year across all arrays		No	9	10	11	11	8	5	4	3
	# arrays with snakes present / year		No	6	8	10	6	5	3	2	2
	Average # captures / array / year	Square root	No	1.42	1.81	2.02	1.50	1.22	≤1.07**	≤ 0.97**	≤0.77**
Orange-throated whiptail	# arrays with adults or juveniles present / year		Maybe P=0.0805	12	11	10	11	9	8	8	7
	# arrays with juveniles only present / year		No	6	8	9	6	4	2	2	1
Striped racer (adults & juveniles)	Total captures / year		Yes P=0.0079	9	8	5	6	4	2*	2*	1*
	# arrays with adults or juveniles present / year		Yes P=0.0418	6	8	5	5	4	2*	1*	1*
Striped racer (juveniles only)	# consecutive years with zero captures			1	2	1	2	1		2-3 years***	
Ring-necked snake	# consecutive years with zero captures			0	1	2	1	2		3 years***	
Southern Pacific rattlesnake	# consecutive years with zero captures			0	0	1	0	3		3-5 years***	

* If a trend is present then limits are not valid. A test for a trend should be conducted in subsequent (new) years before using control limits.

** A contrast analysis will have greater power to detect a change. However if a variable drops below the given control limit, there will also be a significant difference if a contrast analysis is conducted. Data must be transformed before comparing with control limits (see variable description)

*** These control limits represent the # of consecutive years with no captures that would be expected to occur with a probability of 5% or less if no trend were occurring. A range is given because the limits were re-calculated after adding and subtracting 1 snake from the actual number of captures and the limits were adjusted to include any changes.

Figure 1. Map of Point Loma Ecological Reserve herpetofauna arrays
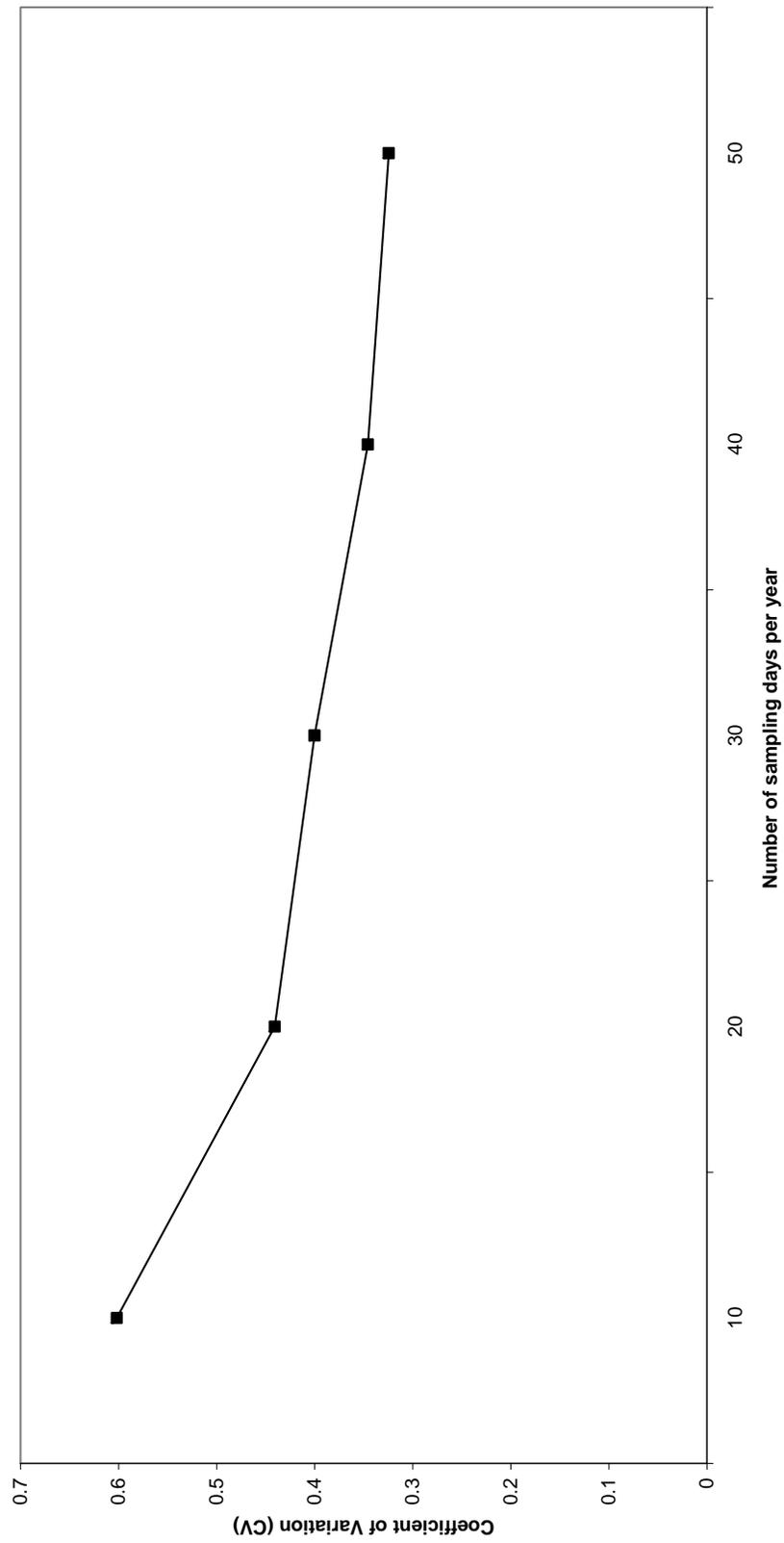
Figure 2. Coefficient of Variation (CV) for orange-throated whiptail capture rates for arrays with > 2 captures.
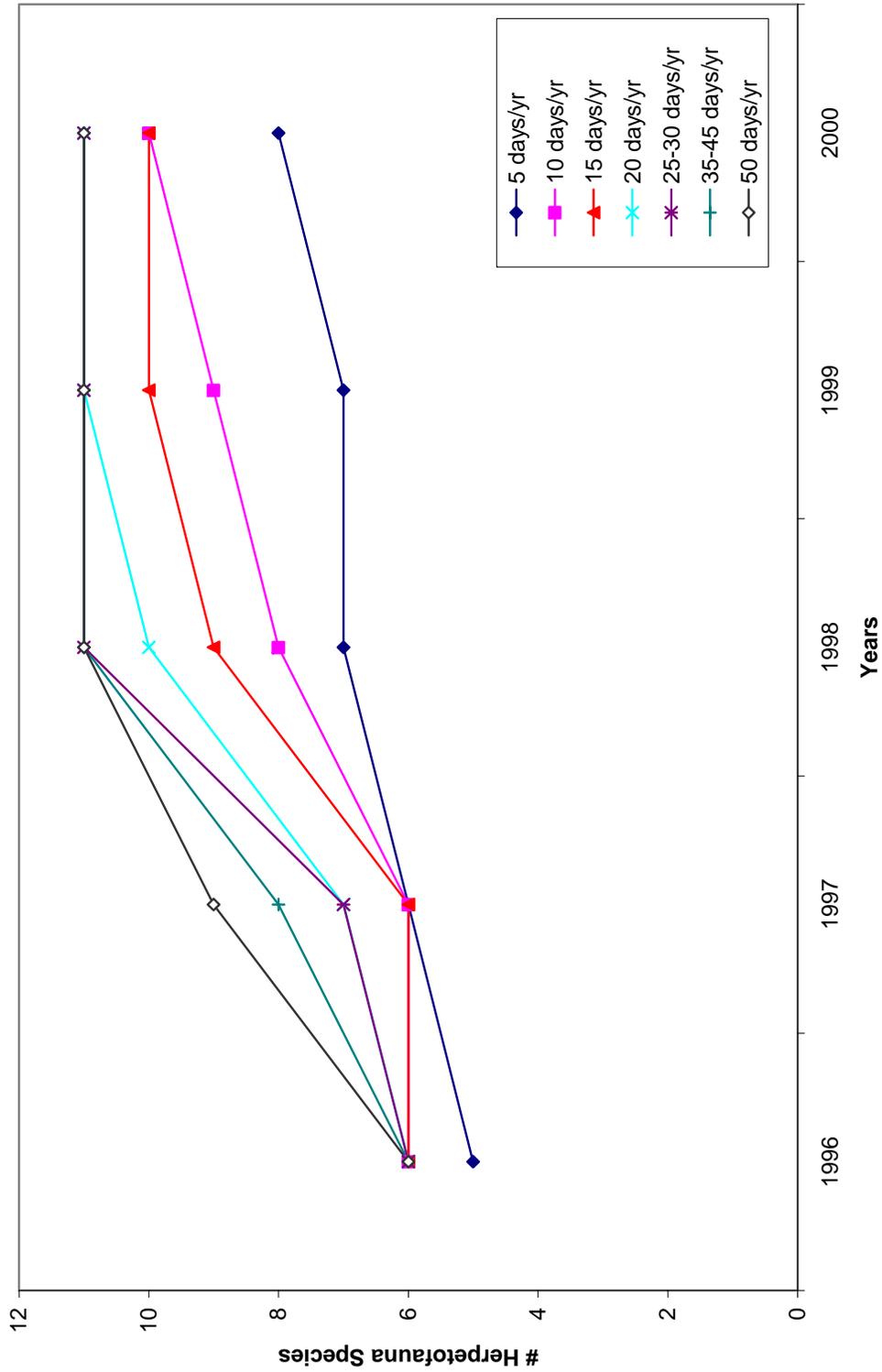
Figure 3. Cumulative number of herpetofauna species detected across all 17 arrays at increasing number of sampling days per year. Please note that night snake (*Hypsiglena torquata*), the twelfth species, was not captured until 2001.
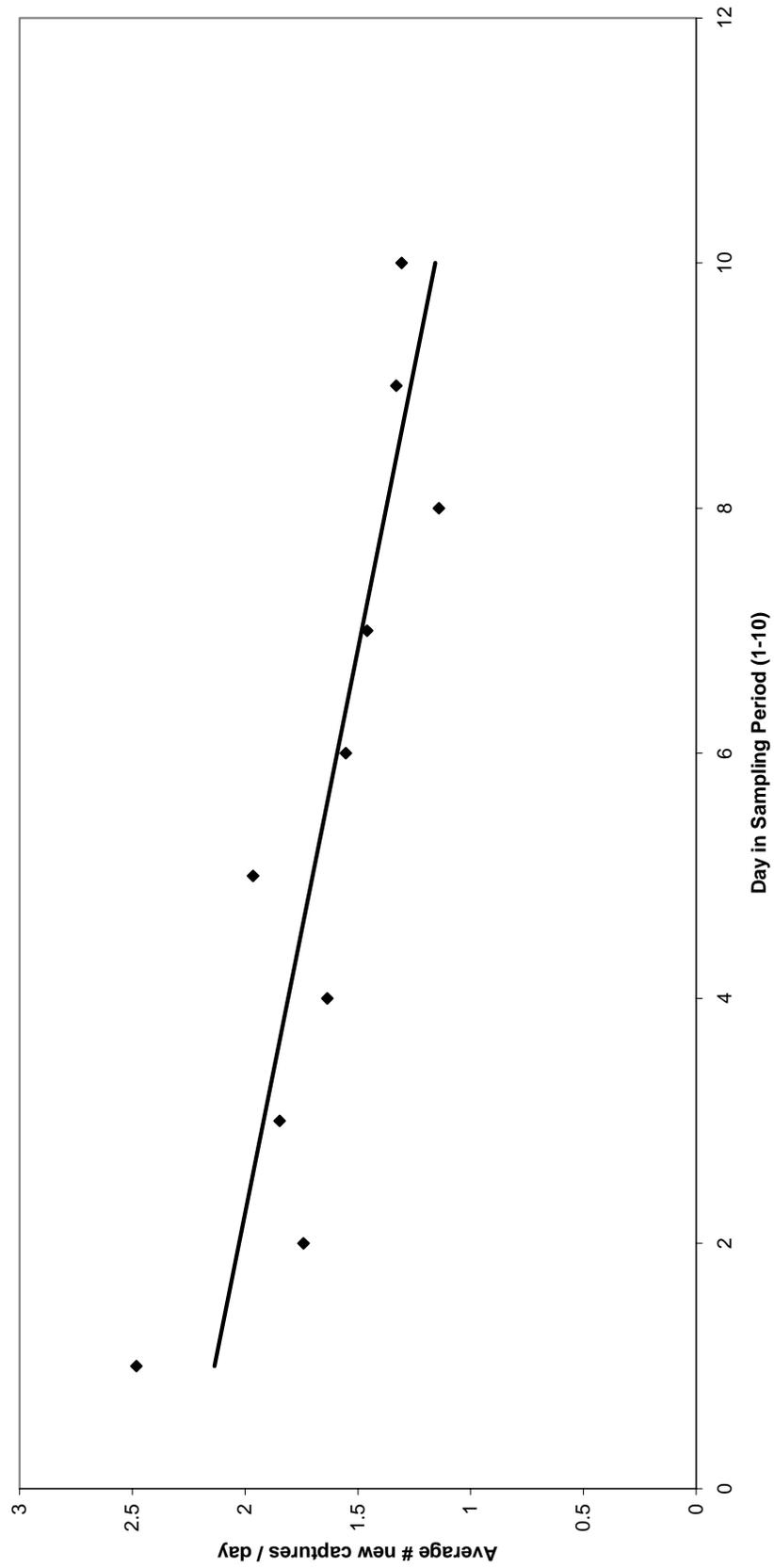
Figure 4. Number of new captures per day by sampling day within the sampling period. Recaptures within same 10-day sampling period were not included.
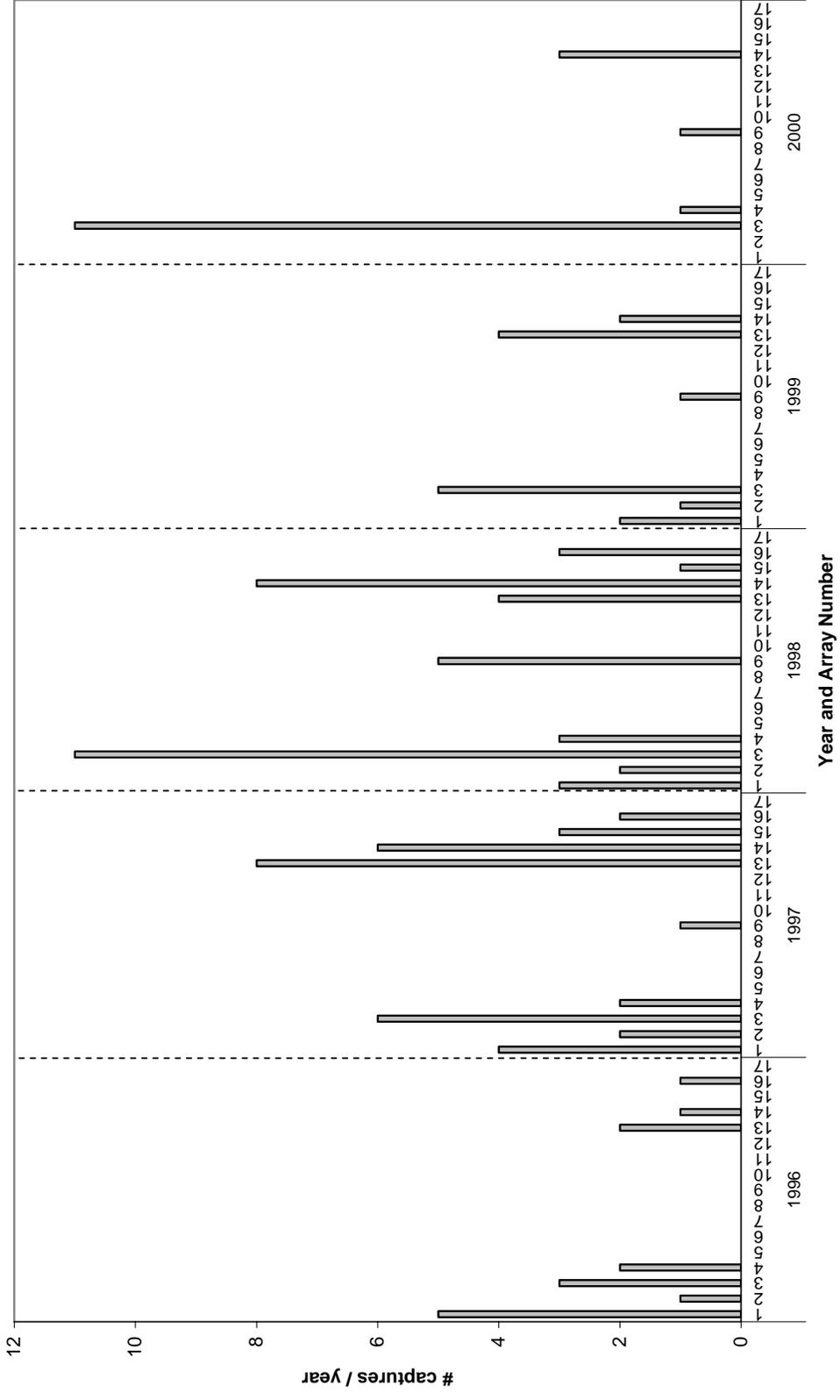
Figure 5. Juvenile orange-throated whiptails: Number of captures by year and array.