BIOLOGICAL RESEARCH AND MONITORING PROGRAM REVIEW FOR COUNTY OF ORANGE, CENTRAL AND COASTAL SUBREGION NATURAL COMMUNITY CONSERVATION PLAN & HABITAT CONSERVATION PLAN

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OVERVIEW

IMPORTANCE OF RESEARCH—Effective research programs are essential to conserving and restoring biological diversity. Information from programs serves to: identify and prioritize management and restoration needs; meet agency and organizational mandates to track (i.e. monitor) the status and trends of sensitive species; and heighten public awareness, knowledge, and support of species, their status, and conservation issues. Authors and signatories of the County of Orange, Central and Coastal Subregion, Natural Community Conservation Plan (NCCP)/Habitat Conservation Plan (HCP) recognized the importance of having a strong research program and ensured the procedural and funding mechanisms necessary to allow for such a rigorous program to exist were incorporated into their 1996 conservation plan.

WHY THE REVIEW IS NECESSARY—At the time of the writing of this report, no new documents had been generated by the Nature Reserve of Orange County (NROC) concerning the status of its research program since a revision of the 1997 Umbrella Monitoring Program was completed in 2000. With the last funded project under the program completed in 2004, the revised monitoring program was outdated and the program without clear documented direction. In addition, results of the projects funded under the 1997 program had yet to receive adequate review and synthesis, needed data analysis for a number of projects was incomplete, and there was a noticeable absence of published work referencing the funded research.

OBJECTIVES OF THE REVIEW—Five main objectives exist for the review. 1) Review NCCP/HCP guidelines as they pertain to research and monitoring activities within the reserve system. 2) Provide a comprehensive overview of the research objectives and results of the individual research projects conducted under the Umbrella Monitoring Program. 3) Make program recommendations to facilitate development and implementation of a new research and monitoring program for NROC. 4) Determine whether any of the past-funded projects should be recommended for additional funding and included in the revised schedule of monitoring activities. 5) Complete additional analyses of data collected under the projects for purposes of improving inference concerning the state of the biological resources found on the reserve and publishing the results of the research.

This report represents phase 1 of the review process, fulfilling objectives 1, 2, and 3. Phase 2 will fulfill objective 4 and involve the review and discussion of this report with current members of the Technical Advisory Committee and Principal Investigators of the original monitoring projects. Following completion of phase 2, a revised schedule of monitoring activities will be recommended to the Board of Directors of the Nature Reserve of Orange County for approval. Phase 3 will fulfill objective 5 and is currently ongoing. Extended analyses of the monitoring program datasets has been initiated with the results of these analyses included in the appendices of this report. Additional analyses will be conducted opportunistically as timing and circumstance allow. A quantitative synthesis of the multi-year/taxa datasets is considered a high priority for the Reserve and will follow completion of this report and be run concurrently with phase 2.

NCCP/HCP Guidelines

Review of guidelines as they pertain to research within the reserve system—The NCCP/HCP states that "the fundamental responsibility of the non-profit management corporation is to facilitate implementation of an effective management program"[1]. Research is a critical component to development of any successful management program and the NCCP/HCP clearly outlines the processes through which the Nature Reserve is able to effectively implement and support research activities within the reserve system.

First, the NCCP/HCP is clear that it is the responsibility of NROC to plan and implement research projects on an annual basis[2]. By requiring NROC to conduct research on an annual basis, the NCCP/HCP ensures that a continual stream of information concerning the status of sensitive resources and efficacy of management actions is available for the reserve personnel and directors, wildlife agencies, participating landowners, and the public. Such information is critical for effective evaluation of the success of the conservation program and improvement of the reserve's management program. Because the NCCP/HCP Implementation Agreement covers a period of 75 years, the amount of knowledge concerning the resources on the reserve to be generated by annual projects is significant and without precedent in the field of land management.

Second, the NCCP/HCP is clear on the requirement that participating landowners will allow NROC to access reserve lands for the purposes of conducting annual species and habitat monitoring and inventories, and at their discretion, allow other management, restoration, or enhancement activities[3]. This clause in the document effectively affords NROC the ability to plan and implement basic research activities within the reserve system at its own discretion, while requiring the organization to receive approval from landowners prior to initiating any restoration, enhancement, or other management activities.

Third, the NCCP/HCP states that the subregional habitat reserve system "provides a dynamic, ecosystem-level laboratory that can be used by academic, scientific, and educational institutions for study and research to improve protection and management of the region's remaining biological resources"[4]. Here, the document supports use of the reserve system by research and educational organizations external to the reserve, as long as these organizations are working within the guidelines of NCCP/HCP and under the oversight of NROC[5].

Fourth, the NCCP/HCP is clear that both basic and applied research will be permitted within the reserve system. Uses and activities permitted within the reserve system are to include "field research and studies designed to contribute to the long-term protection of habitats and species and basic research of habitat and species"[6]. The NCCP/HCP encourages use of the reserve for basic research as long as that work is funded by external resources, consistent with the NCCP Conservation Guidelines[7], and regulated by NROC.

Collectively, these guidelines afford NROC the freedom necessary to carryout an aggressive research program designed to inform management decisions concerning the protection and restoration of sensitive species and habitats on the reserve. The guidelines encourage collaboration between NROC and academic/research organizations intending to use the reserve system for educational and information-building purposes, and provide guidance concerning the types of research activities considered acceptable within the reserve system and the mechanisms through which oversight is possible.

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[1] *NCCP/HCP Pg. II-297*; [2] *NCCP/HCP Pg. II-302;* [3] *NCCP/HCP Pg. II-163;* [4] *NCCP/HCP Pg. II-285*; [5] *NCCP/HCP Pg. II-200;* [6] *NCCP/HCP Pg. II-294;* and [7] *NCCP/HCP Pg. II-308*

Umbrella Monitoring Program

BACKGROUND—NROC has been funding biological research on the reserve system since 1997. In that year the Board of Directors for NROC appointed a Technical Advisory Committee (TAC) composed of local scientists, academics, and resource professionals, to assist in development of a formal research program for the Reserve. The general goal of the research program, as directed by the NCCP/HCP, was to allow for adaptive management of the biological resources found on the reserve and evaluation of the effectiveness of the regional conservation plan.

In December of 1997, the framework for the program was completed by the TAC and approved by the Board of Directors. The research program, termed the "Umbrella Plan", was designed to assess habitat value within the reserve and identify the need for management intervention.

Since initiation of the program, thousands of dollars from local assistance grants and income from the Reserve's endowment fund have been spent on the plan's designated research activities. These activities have generated a number of reports (Appendix A) and large multi-year and multi-taxa datasets (table 1). The datasets represent a wide spectrum of the Reserve's biological diversity and are considered an invaluable resource for measuring future change to the biological condition of the nature reserve. With proper review and analysis of the data, the Reserve will be able to begin to answer whether it is meeting its goal of conserving regional diversity and be better positioned to effectively direct restoration efforts within the plan's subregions.

Table 1. Datasets generated from "Umbrella Plan" monitoring program included in Nature Reserve database

Monitoring program	Years covered by dataset	Principal investigator
Ant	*1999, 2000, 2001, 2002*	Robert Fisher
Avian Productivity & Survivorship	*1998, 1999, 2000, 2001, 2002, 2003*	David DeSante
Mammalian Carnivore	*1998.1999, 2000, 2001, 2002*	Kevin Crooks
Raptor	*1998, 1999, 2000, 2001*	Peter Bloom
Reptile & Amphibian	*1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002*	Robert Fisher
Small Mammal	*2001, 2002, 2003*	Jay Diffendorfer
Target Bird Species	*1999, 2000, 2001, 2002, 2003, 2004*	Robb Hamilton

INDIVIDUAL PROGRAM REVIEW—**Monitoring Avian Productivity & Survivorship (MAPS)/David DeSante, Institute for Bird Populations**

Overview—From 1998 through 2003 MAPS program collected productivity and survivorship data on 53 species of landbirds across coastal sage scrub areas of the Nature Reserve of Orange County. Data was collected annually during the spring and summer using 2 to 10 MAPS stations with each station consisting of 10 mist net sites. Program data describes temporal and spatial trends in population size, productivity, and survivorship for most commonly captured birds (population size and productivity data exists for 15 species and survivorship data exists for 8 species collected from 1999 through 2003; see table 2).

Authors argue that monitoring productivity and survivorship allows for improved inference of population or community health over population indices or estimates. Under this program investigators are able to measure and assess the effects of productivity and survivorship as drivers of population trends for landbirds across North America. The Nature Reserve sites contribute to description of regional patterns and provide information on the population dynamics and demographic parameters of the most commonly captured local breeding bird species.

Major results—Authors describe a general population decline (in the total number of adult birds captured) for all species pooled and declining trends for 13 of 15 species. Temporal trends in post-fledging productivity (proportion of young in the catch) and size of adult breeding populations are interrelated through density-dependent mechanisms and explained well by weather patterns with annual estimates of productivity varying widely between years. Although authors argue that patterns of landscape structure can be good predictors of the number of birds captured, as well as their productivity, limited number of sites surveyed on this project reduced their ability to detect and explain spatial patterns in demographic parameters. Survival analyses using capture histories of adult birds allowed for calculation of species-specific survival probabilities that for most species compare well with data collected from other stations in California. Estimates of adult recapture probability and proportion of residents among newly captured adults are also made available for most commonly recaptured species.

Links to management—No management actions and conservation strategies are suggested by researcher to reverse population declines and/or maintain stable or increasing populations (authors do warn that trends and survival estimates based on only 5 years of data may not representative of longer-term population dynamics). No management actions or conservation strategies are being evaluated for their effectiveness in the study. Authors recommend that sampling strategies at smaller landscape scales (i.e. the scale of the Nature Reserve) should be hypothesis driven, although this advice is not taken in the present study.

Challenges to reproducing study design—Location of MAPS stations are provided, however, specific locations of the individual fixed net sites at each station are not given. Net sites are located within 8 hectare area comprising the individual MAPS stations. Selecting novel net sites within the established MAPS stations will introduce a new form of spatial variation into the study and make interpretation of recovered differences between time periods more difficult.

Potential research questions—Reproducing the study after a specified amount of time (e.g. 10 years) will allow researchers to describe changes in populations size of most commonly captured species, evaluate changes in landbird community composition between time periods, and compare responses of birds from different ecological guilds and geographic areas (e.g. the coastal and central reserve). Reproducing the study after a said amount of time allows for the measurement of community resiliency to local land-use changes (e.g. increased regional fragmentation and habitat loss).

Miscellaneous—Information describing interrelationship between weather patterns and local avian productivity is novel and convincing. Tracking annual changes in population indices, productivity, and survivorship for most commonly captured landbird species offers a unique perspective on the health and functionality of the local avian community.

Table 2. Bird species for which recapture probabilities and estimates of survival exist (X = information is available).

Species	Survival Estimates	Population Trends
Western Flycatcher (*Empidonax difficilis*)		X
Ash-throated Flycatcher (*Myiarchus cinerascens*)		X
Bushtit (*Psaltriparus minimus*)	X	X
Bewick's Wren (*Thryomanes bewickii*)	X	X
House Wren (*Troglodytes aedon*)		X
Wrentit (*Chamaea fasciata*)	X	X
California Thrasher (*Toxostoma redivivum*)	X	X
Orange-crowned Warbler (*Vermivora celata*)	X	X
Common Yellowthroat (*Geothlypis trichas*)		X
Spotted Towhee (*Pipilo maculatus*)	X	X
California Towhee (*Pipilo crissalis*)	X	X
Rofous-crowned Sparrow (*Aimophila ruficeps*)		X
Song Sparrow (*Melospiza melodia*)	X	X
House Finch (*Carpodacus mexicanus*)		X
Lesser Goldfinch (*Carduelis psaltria*)		X

Mammalian Carnivore Monitoring/Kevin Crooks, Colorado State University

Overview—From 1999 through 2002 the Carnivore Monitoring Program used a combination of track and remotely-triggered camera surveys to estimate the distribution and relative abundance of 13 target species (including humans) within the Nature Reserve of Orange County. Track data was collected at 8 to 20 sites established within the reserve using 4 to 10 track stations per site, with each station separated by 250m and consisting of a 1m diameter circle of freshly sifted gypsum 1cm deep and scented with carnivore lures. Track stations were surveyed daily for tracks for five consecutive days in both the summer and fall of each year. Camera survey data (i.e. photographs of target species) was collected from 5 to 50 camera stations/sites established within the reserve with each station consisting of a single camera activated for a minimum of one month per year.

Camera and track stations were distributed throughout fragment, edge, and core areas of the reserve in order to compare patterns of use of the different areas by the target species. The authors argue that large mammals are especially vulnerable to the effects of habitat fragmentation and consequently expect to find differences in patterns of use by the large carnivores across the three landscape types (fragment, edge, and core). Additionally, because large carnivores act as dominant predators in terrestrial systems their absence is expected to lead to large increases in activity or abundance of sub-dominant predators. This secondary change to the predator community is also expected to be captured by the program's survey methodology. Because human use of the reserve was also tracked, analysis of the impact of human presence on wildlife activity is also possible.

Major results—At present, only general results are available as detailed analysis of the data has yet to be completed. These results are as follows. The mountain lion and badger appeared to be restricted to the Central Reserve. The bobcat, coyote, and mule deer were detected at most sites (78 to 85% of 2000 camera stations). Gray fox, striped skunk, raccoon, and domestic dog were also somewhat widespread (20 to 35%). Spotted skunks, opossums, and domestic cats maintained a limited distribution with the reserve. Human use of the reserve varied widely by geographic area (highest use: Aliso and Wood Wilderness Park; lowest use: Former Marine Corps Base El Toro).

Links to management—Results of 1998 corridor surveys (not discussed in current review of the program) led authors to conclude that populations of large mammals such as deer and bobcats are effectively isolated in the coastal reserve and should be managed accordingly. The need to improve connectivity (by identifying and removing barriers to dispersal/movement and constructing features that facilitate successful movement) within and between central, coastal, and neighboring reserves is repeatedly argued for in program reports. Identifying and improving linkages between sites where vulnerable or rare species (mountain lions, bobcats, badgers, spotted skunks, and deer) are known to exist is considered to be especially important. The absence of feral cats from much of the survey area suggests that predator control for this species might not be necessary at this point in time form much of the reserve system.

Potential research questions—The dataset establishes baseline distributions for major carnivores and other mammals found within the reserve. Changes in these distributions through time can be measured and provide an assessment of carnivore and deer sensitivity to the changes in landscape structure presently occurring within the planning regions. By reproducing the study after a set period of time (possibly ten years) one would be able to measure these changes directly by comparing the two similarly developed datasets.

Including the use of site occupancy modeling in future analyses will allow for better estimates of the total area used in the reserve and improve inferences concerning the distribution of different species within the reserve. Current absence of probability of detection estimates for each species and methodology (track and camera) makes comparisons between the species difficult and tenuous. For example, if the gray fox is substantially harder to detect (i.e. more elusive) than the coyote using track or camera stations, current indices used by the authors to measure distribution of a species would incorrectly suggest the coyote is much more widespread than the gray fox, when in fact they might be equally well distributed and really only differ in their rate of detection.

Because site occupancy modeling is a flexible approach to the analysis of detection/nondetection data it allows researchers to include locations with different amounts and times of sampling within a single analysis framework. Recently developed multiyear models can incorporate variability in sampling between years and sites and produce robust estimates of site occupancy with known error making it an ideal technique for extracting information from the multi-year carnivore monitoring program dataset.

A secondary strength of taking a site occupancy approach is the ability of the models to include sampling covariate information to describe differences in the rate of detection. Comparison of the results of the camera and track stations points to the importance of understanding how probability of detection can vary between sites and, if unaccounted for, can lead to the misinterpretation of data. For example, in the 2002 dataset, track indices for the coyote suggest the range of activity or abundance of the species varies three-fold between sites, while camera indices suggest the range of activity or use varies thirty-fold between sites. Furthermore, ranking of the sites in order from highest level of activity or abundance to lowest level differs substantially depending on the index that is used. These issues make interpreting the results of the analysis more difficult and the work less informative.

Although to date, analysis of the data collected under this program appears to be limited, the carnivore monitoring project has generated a number of spin-off projects. These projects, recently funded by The Nature Conservancy, Irvine Ranch Land Reserve, and Great Parks Association, specifically a DNA analysis of carnivore hair samples, a study of space-use behavior of mountain lions and bobcats in the central subregion, and a study of bobcat space-use behavior in the coastal subregion, were first mentioned in the annual reports as management recommendations and serve as testament to the value of the carnivore monitoring program and natural evolution of research.

Target Bird Species/Robert Hamilton, Independent Biological Consultant

Overview—From 1999 through 2004 the Target Bird Monitoring Program used repeated walking/observational surveys to track annual changes in the population size of the Cactus Wren and California Gnatcatcher, two of three Target Species identified in the Central/Coastal NCCP/HCP of Orange County. Surveys for the two species took place between March 1 and June 30 of each year and were limited to 40 randomly chosen sites. Sites were each approximately 40 ha in size and located in coastal sage scrub habitats of both the central and coastal reserves. In each year of the program (except 1999 when all sites were surveyed only once) each site was surveyed 2 to 3 times. During a survey event tapes of the calls of cactus wrens and California gnatcatchers were played periodically as investigators traveled an established survey route through each site. California gnatcatcher calls were played a minimum of every 50 m along the route. Cactus wren calls were played opportunistically, requiring the investigators to be in the general vicinity of cactus scrub habitat. Following detection, the location and description of each identified territory was mapped and recorded.

The purpose of the study was to provide a means through which researchers could: (1) monitor changes in the numbers of the two target species through time; and (2) compare the distribution and temporal stability of the two target bird populations across geographic areas (NCCP coastal and central subregions) and landscape types (edge, fragment, and core). The author argues that the information obtained through a targeted monitoring program can be used to trigger direct management actions and/or additional research. The stratification of sites by landscape type is suggested to provide information concerning sensitivity of target species to the effects of habitat isolation and creation of urban/residential edge.

Major results—Number of territories identified fluctuated widely between the years for both species. Annual fluctuations in population size appeared to be well correlated with the patterns of productivity and survivorship expressed by other CSS landbird species as described by the MAPS program data. In general, annual productivity was considered to be largely explained by the amount of precipitation that fell each year during the egg-laying period of early spring and survivorship by the severity of preceding winter storms. As an example of the relationship between precipitation, productivity, and population size, the severe drought of 2002 which resulted in a reserve-wide crash in productivity (as reported by the MAPS program) was followed by a major population decline in both gnatcatchers and wrens in 2003.

The spatial distribution of gnatcatchers in the reserve was of interest as the majority of identified territories were described from a small subset of sites. These "high-density" sites tended to be found along the reserve edge and in habitat fragments, both areas of low elevation and with low topographical relief. Interestingly, high density sites were more resilient than low density sites in staying occupied during inter-annual changes in weather.

Results of the surveys for the coastal cactus wren showed, in addition to the noticeable absence of cactus wrens from core sites located within the perimeter 1993 Laguna Fire, an unexpected decline of the coastal reserve population of cactus wrens in the final year of the monitoring project. This unanticipated decline along with the limited number of juveniles detected in the coastal reserve during the last few years of the project prompted the P.I. to identify the population as of potential conservation concern. The reason for the unexpected decline was largely unexplained and resulted in the Nature Reserve funding a number of research projects in 2006 related to improving inference concerning the status and management options available for protecting and enhancing this population.

Links to management—Annual estimates of population size of sensitive species provide managers and biologists with continual information concerning the status of their resource of interest. Whether this information ultimately can be used to aid-management decisions or direct management actions largely depends on the manner in which the study was designed. The present study was designed to inform land managers and biologists whether trends in population size for both species differed between edge, fragment, and core habitats. Although differences in population size between the different landscape types differed from what was expected, stratification of sample sites permitted land managers to recognize the difference in values (with regard to the two target species) between different land areas within the reserve. It is this spatial information that appears to be of the most value when land managers are faced with making decisions such as selecting future sites for restoration or areas to be of limited recreational use.

Future research questions—In addition to serving as a baseline upon which future comparisons can be made, the datasets provided critical information that prompted additional research studies. In 2006 the Nature Reserve funded a Cactus Wren and Cactus Scrub mapping project as well as a Cactus Wren translocation project. The mapping project was designed to delineate the extent and characteristics of potential habitat for the cactus wren in the coastal subregion and to map detections of cactus wrens within that habitat for purposes of comparing 2006 results with data collected in the subregion in 1992. Upon completion of the fieldwork, analysis of the habitat and occurrence information will allow for improved understanding of the current status of the coastal reserve population of cactus wrens and provide information concerning the reasons for its suggested decline.

The translocation project involves the capture of 2 to 3 family groups of coastal cactus wrens from isolated patches of cactus scrub habitat slated for development in the central subregion of the Orange County NCCP/HCP and subsequent relocation of the birds to protected habitats within the coastal reserve. To monitor the success of the translocation, wrens will be colored banded and observed intermittingly at their release sites over a period of at least 60 days. Project objectives included enhancing the cactus wren population of the coastal reserve while providing an opportunity to study the biological and behavioral response of adult and juvenile cactus wrens to translocation. Because survival of the coastal cactus wren is considered one of the great challenges in bird conservation for southern California, information concerning the feasibility of relocating cactus wrens will aid in determining whether the technique would be a viable tool for restoring coastal California populations of this species.

Extended analysis—Extended analyses of the target species dataset are available in Appendix E. Extended analyses include regression analysis of the relationship between gnatcatcher density and slope and site-occupancy (presence/apparent absence) modeling of the multi-year gnatcatcher data. These analyses represent examples of the additional work that can be done with the existing data and of the conditions where more in-depth analysis is both warranted and welcomed.

Small Mammal (Index of Biological Integrity)/Jay Diffendorfer, San Diego State University

Overview—Note, prior to the commencement of fieldwork, objectives and goals for the Small Mammal Program, as described in the Umbrella Monitoring Program, were changed by the Principal Investigator. With the program no longer focusing strictly on the spatial distribution of the small mammal community within the reserve system, field efforts were modified to allow information collected within reserve boundaries to contribute to implementation of a regional research program focused on development of an index of biological integrity (IBI) for the coastal sage scrub (CSS) plant and animal communities. Although program changes resulted in the research being less specific to the Nature Reserve of Orange County, the changes also led to the expansion of local data collection efforts to include ants, other arthropods, birds, and plants, as well as, small mammals. Most importantly, in working towards development of an IBI, the researchers identified challenges associated with measuring integrity of terrestrial ecological systems; challenges that are relevant to land managers and biologists interested in understanding the ecological condition of the land under their management.

The modified Small Mammal Program, referred to as the IBI Program from here on, used a variety of methods to collect the data necessary to develop an IBI for CSS. As part of this program, presence, abundance, and cover data for a number of terrestrial CSS plant and animal species was collected in 2002 and 2003 on 46 plots in 3 reserves. Twenty-six of the 46, 50 x 50 m plots were located in NROC. Plots were established across a gradient of disturbance, located adjacent to herpetofauna arrays developed by the United States Geological Survey (USGS), and chosen in areas at least 9 years post fire. Sampling occurred four times a year (from January through October) for arthropods, birds, and small mammals. Plants were sampled annually each spring. Arthropods were sampled using 6, 3-inch bowls buried at ground level during 4-day small mammal trapping sessions. Birds were sampled using 7-minute, 100 m radius point counts (1 per plot/sample period). Small mammals were trapped on a 7 x 7 trap grids with 7 m spacing using baited Sherman traps over a 4-day period. Vegetation was sampled using 4, 50 m transects with 100 sampling points spaced every 2 m. Reptile and amphibian data was collected at the herpetofauna arrays by USGS personnel and used opportunistically in analyses.

The authors of the study argue that the value of an IBI for CSS lies in its ability to provide a means through which land managers and biologists could effectively (i.e. at low cost) measure ecological condition. In their report, they review reasons for the poor performance of alternative measures of condition in CSS, such as traditional single species indicators (e.g. California gnatcatcher) and community level metrics (e.g. species richness). They suggest that for diverse ecological systems whose components respond in varied and complex ways to disturbance, general estimators of community structure should be expected to fail as useful variables in monitoring programs. Instead they suggest combining information from a large number of species and taxonomic groups is a more comprehensive approach to assessing the true biological response of a CSS community to disturbance.

Major results—Approximately 350 species, genera, or orders were screened for their response to disturbance in CSS. These responses were used to develop a 16-metric, 6-taxa IBI (see table 3 for list of metrics). Statistical analyses showed that the developed IBI could successfully distinguish between four levels of disturbance in CSS. Furthermore, the IBI was shown to perform equally well with only one year versus two years of data. Interestingly, general measures of community structure such as richness did not show changes across the disturbance gradient for most sampled taxa and the response between taxa was mostly varied and often uncorrelated. The complexity of the observed response across the ~350 plant an animal species suggests that a single metric would not be able to capture the overall community response to disturbance occurring in CSS systems.

Links to management—Following validation of the developed IBI, the index based approach can be used to monitor changes in habitat quality at the local level (~0.25 ha) through time. The IBI allows for the ecological condition of different management units to be readily measured, summarized, and compared. Once IBI plots are established and initial measurements completed, changes to the biological integrity of a collection of sites can be tracked through time. For example, repeated measurements of established sites and subsequent evaluation of changes in IBI scores can be used to track recovery of a stand of CSS following a major disturbance event like a wildfire or used to evaluate the success of a specific management or restoration activity.

The biological patterns observed in the study indicate that a unique suite of CSS-oriented species drop out of sites as levels of exotic cover increase and the total cover of woody species (or shrub cover) declines. Implications of this observation reinforce the need for NROC to recognize the threat of wildfire to native diversity in the reserve system. With fire acting as a mechanism through which type-conversion of shrubland into grassland occurs, fire threatens to change CSS food web structure and negatively impact a broad suite of species.

Future research questions—Use of the data collected on this project might be of limited value for assessing the current ecological condition of the reserve system. Because site selection process was biased towards CSS areas showing a diverse history of disturbance, sample plots are likely not representative of local management areas. Repeated measures of the sampled plots for the 16 described metrics through time, however, would allow researchers to track changes in the biological integrity of the 26 study sites.

For land managers interested in evaluating the ecological condition of specific land areas, the current research program clearly shows the task of selecting appropriate metrics for use in the evaluation process is a critical and potentially difficult component of the analysis. In the IBI program researchers chose metrics based on their observed differential response to varying levels of disturbance. If one is interested in inferring ecological condition of a reserve or land area from diverse, multi-taxa datasets without first defining a relationship between a chosen metric and disturbance history or ecological integrity, interpretation of what each metric is actually measuring will be tenuous at best. In these cases, interpretation of the observed responses will have to be completed with caution, relying on expert opinion, and clear identification of all assumptions being made in the analysis.

Table 3. A summary of the 16 metrics used in the IBI. Species, genera, or order included in metric can be found in referenced report, Diffendorfer et al.

No.	Taxa	Metric
1	Ants	Proportion of Tolerant Genera
2	Ants	Proportion of Intolerant Genera
3	Arthropods	Proportion of Tolerant Orders
4	Birds	Proportion of Intolerant Species
5	Birds	Proportion of Tolerant Species
6	Birds	Relative Abundance of Intolerant Species
7	Birds	Relative Abundance of Tolerant Species
8	Herpetofauna	Proportion of Intolerant Species
9	Herpetofauna	Proportion of Tolerant Species
10	Herpetofauna	Relative Abundance of Intolerant Species
11	Mammals	Native Species Richness
12	Mammals	Proportion of Tolerant Species
13	Mammals	Relative Abundance of Intolerant Species
14	Plants	Absolute Woody Cover
15	Plants	Total Native Woody Richness
16	Plants	Proportion of Tolerant Species

Raptor/Pete Bloom, Independent Biological Consultant

Overview—From 1998 through 2001 researchers conducted field surveys for the presence/apparent absence of raptor species in the coastal and central subregions of the County of Orange Central/Coastal NCCP/HCP. Using information gained from surveys conducted in earlier years, researchers mapped known territories of 10 raptorial species (see table 4) within the subregions. In the years of the monitoring project, researchers used repeat surveys to identify whether such territories were occupied or active. In addition to presence/apparent absence data, researchers also collected information on the breeding success of the observed raptors. Successful breeding was considered to occur if at least one fledgling was observed during the monitoring efforts. If possible, the number of chicks present in a successful nest were counted and banded for purposes of estimating average reproductive output of each species and tracking survivorship and movement in the young birds through time.

The purpose of the research project was to identify trends in the population size (as estimated by the number of active territories) and breeding success of the nesting raptorial species of Orange County. Banding efforts were completed as part of a larger, longer-term regional project conducted by the principal investigator.

Major results—Due to the absence of rigor analysis or discussion of collected data, a limited amount of information exists concerning major project results. Summaries of the proportion of active territories, number of successful nests, and average number of fledged young by each species (excluding the golden eagle) exist for 1998, 1999, 2000, and 2001. Also, former reserve ecologist, Lucy Vlietstra, created a series of summary graphics describing the differential nesting rates, breeding success, and productivity measures for each of the 9 species by year, NCCP/HCP subregion, and USGS topographical quadrangle. Copies of the summary information compiled by Lucy are available upon request. In general, for the 6 species (RTHA, RSHA, COHA, WTKI, BNOW, and GHOW) with sample sizes large enough for us to be confident in annual estimates of occupancy and productivity, nesting attempts dropped substantially in 2000, but rebounded the following year to near pre-crash levels. The reasons for this decline in activity are unclear but according to the lead researcher are likely related to fluctuations in the species' prey base.

Links to management—This research program was carried out in large part to help evaluate the effects of human recreation on the breeding success of raptorial species in the reserve system. Because limited analyses were performed with the data, the relationships between high human-use areas and raptor nesting success remain anecdotal and unresolved empirically.

Future research questions—The data collected under the raptor program represents a good baseline against which future measurements of raptor presence and breeding success can be compared. When designing future studies researchers will likely need to treat the data describing the overall distribution of known territories as a 'presence only' dataset for the purposes of making future comparisons. Because the survey methodology is unclear, we must assume that absence of a known raptor territory from an area is equally likely due to the area not being surveyed, not being surveyed rigorously enough, or because nesting raptors are truly absent. Because of our uncertainty regarding absences, it is best to use this data as a minimum estimate and not a complete census of all raptor nesting territories in the two subregions. Even with this present limitation, repeat surveys of known territories will still allow researchers to detect significant changes in the distribution of raptor species through time, especially if historic nest sites are repeatedly used across generations and species. Furthermore, data collected from future surveys of nesting raptors within specific geographic areas or management units will be comparable with the information found in the present dataset and useful for identifying declines in the distribution/abundance of the local breeding population of raptor species.

Table 4. Raptor species for which data was collected in present study. (X = summary information is available).

Species	Specie Code	Summary information
Red-tailed Hawk (*Buteo jamaicensis*)	RTHA	X
Red-shouldered Hawk (*Buteo lineatus*)	RSHA	X
White-tailed Kite (*Elanus leucurus*)	WTKI	X
Coopers' Hawk (*Accipiter cooperii*)	COHA	X
Great-horned Owl (*Bubo virginianus*)	GHOW	X
Barn Owl (*Tyto alba*)	BNOW	X
Long-eared Owl (*Asio otus*)	LEOW	X
Turkey Vulture (*Cathartes aura*)	TUVU	X
Northern Harrier (*Circus cyaneus*)	NOHA	X
Golden Eagle (*Aquila chrysaetos*)	GOEA	

Ant/Robert Fisher, United States Geological Survey

Overview—From 1999 through 2003 personnel from the USGS used pitfall traps to sample the structure of the ant community present in coastal lowland areas of southern California. Sampling in both the summer and winter of each year, individual sites were sampled on 5 to 14 occasions during the study. A single sampling occasion at a site lasted ten days and involved the use of five pitfall traps (50mL tubes) arranged in shape of the"5" on a die and overlaid on the existing herpetofaunal array present at each site. Pitfall traps were filled with antifreeze and left open to capture and preserve unsuspecting ants during the 10-day collection period. In total, the ant community data represents 1,161 sample occasions collected across 172 sites and 14 geographic areas distributed throughout the whole of Orange County and parts of Los Angeles and San Bernardino Counties.

The authors argue that ants are both sensitive indicators to environmental change and essential components of most terrestrial ecosystems. Because ant performs a variety of roles in most natural systems they are expected to be sensitive to multiple disturbance factors acting on many different ecosystem levels. In addition, their sheer numbers and diversity ensure that they play critical roles in the functioning of key ecosystems processes, such as nutrient cycling and seed dispersal. The authors suggest collection of ant data across southern California provides a measurement of the integrity of sampled conservation lands and improves our understanding of how the ant community is responding to the changes in landscape structure occurring throughout the region. In addition to measuring present-day changes, the ant data is meant to serve as a baseline from which to measure future change as landscapes outside the reserve are developed and vegetation within the reserve boundaries is altered in response to wildfire, recreation, and other forms of disturbance.

The collected ant data will also serve to describe patterns of ant invasions in southern California. In particular, the non-native fire ant (*Solenopsis invicta*) and argentine ant (*Linepithema humile*) are two species considered to have significant economic and ecological consequences tied to there spread. The present study was designed to allow the status of both species to be measured and provide a way to track distributional spread of these exotic species into open-space preserves through time.

Major results—Relative abundance and species richness data was collected for 56 species of ants (see Appendix F). Epigeic, or aboveground, ants were well represented in the collections. Use of the pitfall technique appears to under-sample the hypogeic, or belowground, ant community. *Solenopsis invicta* was not detected at any of the 172 sampled sites. The argentine ant was found in 10 of 14 geographic areas and 58 of 172 sampled sites. Argentine ants were most common in edge environments. Native ant genera were found to have declined by half at sites occupied by argentine ants. Argentine ant abundance was negatively correlated with native ant richness. Number of native ant genera was greatest in core sites, followed by edge sites, and lowest in isolated fragment sites.

Links to management—Baseline surveys clarify the current threats posed to the reserve by the two invasive ant species of interest. Recognizing the impact of the argentine ant on the native ant community, researchers suggest that it is beneficial to better understand the spatial patterns of argentine ant invasion in the reserve. Researchers cite the dependence of argentine ants on urban and agricultural runoff for continued propagation and successful invasion. Minimizing the release/availability of water in natural systems or urban areas bordering natural systems might be a control measure worth investigating if the patterns of invasion are tightly coupled to available water sources.

A future research question—As indicated by the researchers, the ant dataset is a good baseline from which to measure future change. The data can be used opportunistically to measure the response of the native ant community to major disturbance events like wildfire or used to make comparisons of sampled areas after a specified time period. Because the effects of land-use change are cumulative and often not expressed for long-periods of time, the effects of present-day development occurring within the subregions might not be visible for decades to come. Periodic, repeat measurement of the ant community will allow us to monitor for those impacts and ultimately improve our understanding of the resilience of the native community to human activity.

The ant data can be used to describe the differences between ant communities associated with the different sampled terrestrial habitats. Comparison of ant community structure and composition by plant community is without precedent in southern California and would increase our understanding of the southern California terrestrial systems.

The ant data can be directly compared with reptile and amphibian data. Because the two datasets were developed by sampling at identical locations at similar times, both temporal and spatial patterns/correlations can be recovered between the two taxonomic groups and lead to improved understanding of multi-trophic layer responses to land-use change.

Extended analyses—Extended analyses of the ant data are available in Appendix F. Extended analyses include a comprehensive list of the species collected, statistical analysis of the effects of argentine ants on native ant species richness, site-occupancy (presence/apparent absence) modeling of the multi-year data focusing on the sensitivity of most common native ant species to presence of argentine ants and spatial patterns of argentine ant invasion in the reserve.

Reptile and Amphibian/Robert Fisher, United States Geological Survey

Overview—From 1995 through 2002, USGS personnel collected data on the abundance and species richness of 9 amphibian and 26 reptile species (see table 5) present within surveyed areas of Orange County. Using pitfall (or herpetofaunal) arrays researchers sampled 140 sites across 13 geographic areas, with 10 areas falling within the nature reserve boundary. Arrays were distributed across various habitats present within the reserve, including coastal sage scrub, chaparral, grassland, and oak woodland. Each array consisted of seven 5-gallon buckets used as pitfall traps, connected by three 15m long arms of shade cloth drift-fence constructed in the shape of a Y. To compliment the buckets, three hardware cloth funnel traps and 30 x30 cm plywood cover-boards were placed along each of the arms. Herpetofaunal arrays were sampled 10 consecutive days five to six times a year spread evenly across all seasons. In addition to reptiles and amphibians, the arrays effectively captured small mammals and a variety of arthropod species. Data and specimens representing the additional taxonomic groups were collected by the USGS but is not discussed or referenced in this review.

The purpose of the study was to identify the reptiles and amphibian species present, their activity patterns, and habitat associations. In addition, researchers were interested in identifying any immediate management needs regarding maintenance of the observed herpetofaunal diversity. Efforts were also made to sample across the three main landscape types identified in the reserve (edge, fragment, and core) to better understand how reptile and amphibian communities respond to land-use change.

Major results—The work discusses coarse differences in the structure of the reptile and amphibian communities and distribution of species between sampled areas and major landscape types. A discussion of the status of sensitive reptile and amphibian species in Orange County as ascertained by the data collected on the project is also provided. Sensitive species include both the 10 species listed as “Covered” by the NCCP and the 7 species identified in the NCCP as “Species of Interest”. Summary tables exist for capture histories of the 35 species across all sampled areas and arrays.

In general, limited quantitative analysis of the data is provided in the reports. One reason for this is that this research supports larger regional investigations into the persistence and identification of sensitive reptile and amphibian species inhabiting sage scrub habitats in coastal southern California. Regional analyses, in which the NROC data was included, are known to have been completed and have resulted in publication. Because of the availability of regional analyses, similar analyses specific to the reserve were not considered a priority.

Links to management—The reports provide general management recommendations for maintenance of reptile and amphibian diversity within the reserve. Specific recommendations range from: the creation of ponds to improve reproductive opportunities for Pacific tree frogs, western toads, and spadefoot toads, to the posting of signage that warns of the hazards as well as sensitivity of rattlesnakes to human activity.

The reptile and amphibian monitoring program provided detailed information on the status of the Orange-throated whiptail, one of three "Target Species" for the Central and Coastal Subregion NCCP/HCP. Because adult and juvenile whiptails were found in high densities throughout a number of sampled areas in the reserve, the species was considered not to be at risk of local extinction within the reserve system. The improved inference concerning the status of this species aids managers as they make decisions concerning the allocation of research dollars and define necessary management actions.

Future research questions—Similar to the other monitoring programs included under Umbrella Monitoring Program, the reptile and amphibian program generated a multi-taxa/year dataset describing the distribution and abundance of animal species within the nature reserve. Such a dataset represents an invaluable baseline of information from which to measure future change. For example, repeat sampling of the established monitoring sites will provide researchers with a clear measure of the resiliency of the different reptile and amphibian species to land-use change.

Additional analyses that are possible include a more detailed analysis of the habitat associations present between different taxonomic groups and major vegetation types present within the reserve. In addition, comprehensive vegetation sampling conducted by USGS personnel during the present study provides detailed information on the vegetative structure associated with each herpetofaunal array. Because of the availability of this additional dataset, opportunities exist to examine correlations between vegetation structure and composition and the presence/ or apparent absence or abundance of reptile and amphibian species.

Table 5. Reptile and amphibian species captured at field sites in Orange County. A single asterisk (*) identifies a NCCP "Covered Species". A double asterisk (**) identifies a NCCP "Species of Interest".

Amphibian Species
Pacific Slender Salamander (*Batrachoseps pacificus*)
Black-bellied Slender Salamander (*Batrachoseps nigriventris*)*
California Newt (*Taricha torosa*)
Arboreal Salamander (*Aneides lugubris*)*
Monterey Salamander (*Ensatina eschscholtzii*)
Pacific Tree Frog (*Hyla regilla*)
California Tree Frog (*Hyla cadaverina*)
Western Toad (*Bufo boreas*)
Western Spadefoot Toad (*Spea hammondii*)*
Reptile Species
Western Pond Turtle (*Clemmys marmorata*)**
Coastal Banded Gecko (*Coleonyx variegatus*)**
Western Fence Lizard (*Sceloporus occidentalis*)
Granite Spiny Lizard (*Sceloporus orcutti*)
Coast Horned Lizard (*Phrynosoma coronatum*)**
Western Whiptail (*Cnemidophorus tigris*)*
Orange-throated Whiptail (*Cnemidophorus hyperythrus*)*
Side-blotched Lizard (*Uta stansburiana*)
Southern Alligator Lizard (*Elgaria multicarinatus*)
Western Skink (*Eumeces skiltonianus*)*
Gilbert Skink (*Eumeces gilberti*)
Western Blind Snake (*Leptotyphlops humilis*)
Coastal Rosy Boa (*Charina trivirgata*)*
California Kingsnake (*Lampropeltis getulus*)
San Diego Gopher Snake (*Pituophis melanoleucus*)
California Black-headed Snake (*Tantilla planiceps*)
Night Snake (*Hypsiglena torquata*)
Coachwhip Snake (*Masticophis flagellum*)
Striped Racer (*Masticophis lateralis*)
Western Yellow-bellied Racer (*Coluber constrictor*)
Coast Patch-nosed Snake (*Salvadora hexalepis*)**
Western Ringneck Snake (*Diadophis punctatus*)*
Two-striped garter Snake (*Thamnophis hammondii*)**
Lyre Snake (*Trimorphodon biscutatus*)
Southern Pacific Rattlesnake (*Crotalus viridis*)
Red Diamond Rattlesnake (*Crotalus ruber*)*

PROGRAM RECOMMENDATIONS

Web-Based Resource Library—NROC is an information-building organization. The success of this organization will largely depend on its ability to generate and disseminate new knowledge concerning the state of the biological communities present within the reserve as well as the management actions needed to successfully maintain the overall habitat value of the reserve system.

Past efforts to effectively archive, organize, and make-accessible the results of past research conducted on the reserve have largely been unsuccessful. This lack of success has contributed significantly to inter and intra-generational knowledge loss (i.e. poor knowledge transfer) and presently handicaps the ability of NROC to successfully disseminate knowledge concerning the state of the reserve. The ability to transfer knowledge successfully between generations of researchers and employees is critical to the success of the organization. NROC is in the unique position of having to monitor and evaluate change to the biological communities found on the reserve system over long periods of time (i.e. several decades).

In an effort to improve knowledge transfer within and outside the organization, I strongly recommend creation of a Resource Library for NROC. The Resource Library would be an electronic library accessible through the Reserve's website and would act as a depository for materials generated from the full spectrum of NROC supported research (from undergraduate student papers to published peer-reviewed journal articles). The library would be searchable and contents (mainly PDF documents) downloadable. The library would house abstracts, reports, published papers, maps, and possibly electronic data (including GIS). The Library might also include a searchable list of mitigation reports. With mitigation reports organized by title with hard copies kept on file in boxes at a nearby storage facility.

Creation of the Library would require that NROC hire a consultant to organize, catalog, and convert into PDFs existing documents and develop a user friendly search engine for use on website.

Development of the Resource Library would dramatically improve the ability of NROC to archive and disseminate new knowledge, and equally importantly, create a context in which the Reserve is able to evaluate and measure organizational success (e.g. the number of reports or publications generated by NROC-supported research and archived in the Resource Library).

Inclusion of Academic Community—Serving as a living storehouse for natural ecosystems, the reserve system managed by NROC is of exceptional educational value and forms an irreplaceable entity important to all field scientists interested in the study of the biological sciences.

As part of the NROC research program, I strongly advocate that NROC support and encourage university-level research within the reserve system by providing research grants to academics and through facilitating use of the reserve for the purpose of field research.

In providing opportunities to conduct research on reserve lands, NROC supports the acquisition and dissemination of knowledge concerning the make-up and activities of biological systems found within the reserve. Such activities help to raise public awareness, knowledge, and support of local plant and animal species, as well as, allow NROC and the associated scientific community to accelerate their understanding of complex ecological systems.

At present, there are significant gaps in Reserve knowledge concerning the status and ecology of natural systems found within the reserve system as well as the effectiveness and availability of management activities in restoring and enhancing habitats and species historically present within the system. Any new information that addresses these gaps in knowledge will help NROC achieve its organizational goals and hasten the restoration and protection of sensitive habitats found within the reserve system.

The academic community would be a good partner for NROC for a number of reasons. Students and professors alike are routinely looking for research opportunities, of which the Nature Reserve is rich. The dollar amount necessary to fund graduate student research is a small fraction of what it costs to fund similar work performed by consulting biologists. NROC is able to offer university-level researchers a source of matching funds for competitive grants, making the Reserve more attractive to academics and ultimately magnifying the amount of work completed with NROC funds. Academics have access to a number of resources (e.g. laboratory space, online research libraries, and their colleagues) at the University that ultimately improves the quality of research undertaken within the reserve systems. Academics are driven to publish their work, thus improving the likelihood the results of the research will reach a wider audience than if limited to an unpublished report.

To facilitate use of the reserve by the academic community, I have prepared research guidelines (Appendix B) and a general research application (Appendix C) for use by researchers interested in having NROC support their research efforts within the reserve system and encouraged development of a Grant-In-Aid Program (Appendix D) for graduate students. In addition to developing the organizational infrastructure necessary to handle research requests, inclusion of the academic community will ultimately require that NROC reach out to local university faculty and students to make them aware of the organization, and of the research and funding opportunities available to them.

Research Strategy—One of the primary responsibilities of NROC is to fund studies designed to improve inference concerning the state of the biological resources found within the reserve system and inform management decisions. The NCCP/HCP clearly states that the fundamental responsibility of NROC is to facilitate implementation of an effective management program. Realization of such a program requires information both on the status of sensitive resources within the reserve system as well as the effectiveness of management actions on improving the condition of those resources.

At present, there are significant gaps in knowledge in the scientific community concerning how to actively manage, enhance, or restore the natural communities found within the reserve system. As an organization it is important for NROC to realize the time required for land managers and restoration ecologists to build an effective toolbox for management is likely on the order of decades. In the interim period NROC should work to support the research necessary to develop these tools. This will require that NROC become aggressive in defining research priorities for the reserve and creative in the ways that it supports the research activities required to develop effective management options.

When evaluating and prioritizing research projects, the NCCP/HCP recommends that research projects focus on target, identified, and special interest species, but also include naturally rare and/or declining species associated with coastal sage scrub mosaic and special interest communities and associations (e.g. riparian woodland and clay-endemic flora). It is clearly the intent of the NCCP/HCP that research involving species and communities associated with CSS and other upland habitats are to be considered a higher priority than research involving wildlife and habitats associated with other systems. The guidelines, however, do allow for work on other systems to be funded under the appropriate situations.

Funding for much of the research efforts will likely need to come from both Reserve's General Fund as well as its Restoration & Enhancement Fund. To help stretch the value of these research dollars, I strongly recommend NROC utilize these funds as matching or in the form of grants to research personnel and institutions. In this way, limited NROC dollars are stretched further and allow for the development of stronger relationships between the research community and the Nature Reserve. Of equal importance, NROC funded research will need to be directed by the reserve personnel with only the highest priority projects being justified as warranting support.

A research program that is aggressive, opportunistic, and supports finite, publishable studies will likely be more successful than a program that encourages passive, longer-term efforts. Long-term projects are more likely to be unsuccessful as they are more vulnerable to inherent cycles in availability of funding, turn-over in research and reserve personnel, and suffer from the absence of regular program review and rigorous analysis of data. Short-term projects have a higher likelihood of publication and are typically more closely tied to funding and personnel cycles.

Upon development of effective management options for protecting or enhancing sensitive species or disturbed communities, implementation of a rigorous management program will require that NROC coordinate and develop an effective management plan with participating landowners and other organizations involved with management of the reserve system. Management in the form of restoration and enhancement is typically an expensive endeavor and many projects will require external funding. Grant writing will need to be a critical component of the program and will be necessary to fund large-scale restoration efforts within the reserve system. When built upon a successful research program, proposed management programs are more likely to win external funding as well as achieve program goals.

APPENDIX A. BIBLIOGRAPHY OF MONITORING REPORTS

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Appendix B. Research Use Guidelines

Use of the reserve for scientific purposes will be allowed if the proposed activity and level of use are deemed consistent with landowner and NCCP/HCP guidelines. All researchers using the reserve must have valid academic qualifications. Activities likely to cause irreversible harm to the native biodiversity found on the reserve will not be allowed. Activities considered likely to degrade native habitat or impede or disrupt natural processes for an appreciable amount of time on the reserve will not be allowed. All manipulations should be of such minor nature that no permanent or long-term transitory changes in the natural environment results.

Application—All researchers must complete a general NROC Research Use Application, agree to comply with all landowner and reserve regulations, and sign a waiver of liability, assumption of risk, and indemnity agreement. Depending on the location of the proposed research activities, additional forms may be required of researchers.

The Nature Reserve research use application describes: contact information, proposed project duration, dates of reserve use, funding information, a detailed statement of purpose describing motivation for research, prospective research site and methodology, and any potential disturbances to the reserve's ecosystem or cultural resources. Completed applications must be sent to the Nature Reserve for review by the Reserve's Research Review Committee.

Review—Research Review Committee will use the following criteria to evaluate each application for research use: potential impacts on naturals systems; compliance with applicable state and federal laws; feasibility and scientific merit of proposed project; researcher's academic credentials and affiliation with institution of higher education, governmental agency, or research institute; certification of grant approval by the applicant's funding source; availability and proximity of alternative sites; and ability of researcher to conduct research in a safe manner.

Decision—The Research Review Committee will inform the applicant that his/her request has been approved, denied, or approved with conditions. If an application is approved, the researcher must comply with all applicable Reserve regulations, and provide all required state and federal permits.

Progress reports—Researchers are required to submit an annual progress report. Report is to summarize the past year's activities and discuss any significant changes to original research proposal.

Data—At the close of their study, if requested, all researchers are required to provide the Nature Reserve copies of mature data sets derived from work on the reserve. Accompanying the data set will be a text file that describes the data set derived from their work on the reserve and a summary of research results. The minimum required metadata includes the title of each data set, the investigator's name, mailing address, e-mail address, and an abstract. The abstract is to clearly establish topic of research, main objective of research, methodology used and main findings and conclusions. All data will be archived in the Reserve's database. Guidelines describing data sharing and publication procedures have been formed and are available for prospective researchers to review.

Publications and Reports—All researchers must identify the Nature Reserve of Orange County in any publications or reports that results from use of the reserve. A copy of the each publication or thesis (electronic or paper) resulting from work done at a reserve shall be provided to the reserve as soon as they become available.

APPENDIX C. RESEARCH USE APPLICATION

Fill in all applicable information.

1. Contact information.

    Applicant name:

    Applicant's title or academic status:

    Advisor (if applicable):

    Institution (do not abbreviate):

    Department (do not abbreviate):

    Office address:

    City/State/Zip:

    Office phone:

    Office fax:

    Email:

2. Project duration (month/year to month/year):

3. Requested arrival and departure dates (exact dates of use):

4. Project title:

5. Detailed statement describing proposed research project.

    Clearly describe the following.

    Motivation for research (i.e. scientific merit of work):

    Research methodology:

    Location of study areas:

    Plant and animal populations that may be affected by proposed research:

    Potential impacts to natural ecosystem or cultural resources:

    Any resources needed during the project:

    Timeline:

6. Contract/grant information.

Is project self-funded? (Yes/No)

Is project currently being supported by a contract or grant? (Yes/No)

Has a contract or grant application been submitted but not yet been approved? (Yes/No)

If this project is currently being supported by a contract or grant please complete the following for each award received.

Principal Investigator:

Principal Investigator's affiliation:

Sponsor:

Award amount:

Date award granted:

Grant duration:

Grant number:

Funded project title:

7. Permit requirements.

Researchers will not be allowed access to the reserve until they obtain the appropriate permit(s). A research project involving the use of vertebrate animals must receive approval from the animal care committee at your home institution. Written approval needs to be appended to this application.

A. Does your project involve vertebrate animals? (Yes/No)

Indicate all that apply: __Reptile __Amphibian __Fish __Bird __Mammal

Will any animals be captured? (Yes/No)

Will any animal be held longer than 12 hours? (Yes/No)

Will any animal be held longer than 24 hours? (Yes/No)

Will any birds be banded and/or colored marked? (Yes/No)

Will any animal's skin be broken or tattooed (needles, tags, surgery, etc.)? (Yes/No)

Is there potential for any animal's behavior to be altered? (Yes/No)

B. Does your project involve the collecting (including banding and/or color marking) of vertebrate wild animals, invertebrates, or marine plants? (Yes/No)
If "Yes," you will need to obtain a scientific collecting permit from the California Department of Fish and Game. Please append permit.

Does your project involve the collection, banding, and/or color marking of birds? (Yes/No)
If "Yes," you will need to obtain a federal permit from the U.S. Fish and Wildlife Service. Please append permit.

Does your project involve working with plants or animals that are California state listed of special concern, threatened, or endangered species? (Yes/No)
If "Yes," you will need to obtain a memorandum of understanding (MOU) from the California Department of Fish and Game. Please append permit.

Does your project involve working with plants or animals that are Federally listed threatened or endangered species? (Yes/No)
If "Yes," you will need to obtain a federal permit from the U.S. Fish and Wildlife Service. Please append permit.

8. Necessary information in case of emergency.

Contact:

Phone:

9. Nature Reserve regulations.

(1) Compliance with applicable all laws, rules, and regulations.
(2) All users must sign a waiver of liability, assumption of risk, and indemnity agreement before they are allowed to enter the reserve.
(3) Researcher is responsible for getting permits from individual landowners to conduct work (NROC will facilitate this process).

(4) Researchers agree to submit a brief annual report by the end of each year and a final report no later than one year after final data has been collected. If researcher is receiving funding from NROC, a portion of total amount of money awarded to the grantee will be withheld until receipt of an acceptable final report.

(5) Researchers agree, if requested, at the time of submittal of the final report to also provide NROC with copies of their data (including metadata) with the understanding the data will be used for management and planning purposes only. Any other use of the data will require written permission from the original PI.

(6) All abstracts (with contact information), final reports, and peer-reviewed journal articles resulting from research will be archived on NROC website in the Resource Library

(7) All publications resulting from the use of the reserve must acknowledge the Nature Reserve of Orange County. Researchers will need to provide the research with the full bibliographic citation within six months of publication. In addition, researchers are required to provide paper copies of all publications or an electronic version to the reserve ecologist.

(8) Materials approved for the collection by the land owner belongs to the land owner. You and your institution may only use the material in that scientific research activity described in this application.

(9) Visitors may not bring animals to the reserve, unless they are part of an approved research project or are necessary to help a disabled user.

(10) Firearms are forbidden on the reserve, unless the reserve and landowner has granted special permission.

(11) All users are required to remove all materials brought into the reserve during the life of the research project, unless other arrangements are made with local landowner.

I have read and agree to abide by the Nature Reserve of Orange County use regulations listed above and any reserve-specific rules appended to this application, and I am aware that it is my responsibility to disseminate this information to all members of my party.

Applicant’s Signature:

Date:

Nature Reserve of Orange County Ecologist’s Approval:

Date:

10. Please submit completed application to: Ecologist, Milan Mitrovich, of the Nature Reserve of Orange County at mitrovich@naturereserveoc.org or the following mailing address:

Milan Mitrovich
Nature Reserve of Orange County
15600 Sand Canyon Avenue
Irvine, CA 92618

*Receipt of application via email is comparable to applicant’s signature.

APPENDIX D. GRANT-IN-AID PROGRAM

Grant-In-Aid Program was created to assist university students in their pursuit of knowledge in the field of biological sciences and support the ongoing study of biological resources found in the Nature Reserve of Orange County (NROC).

General program information.

(1) Grants are available to undergraduate and graduate students currently enrolled in degree-seeking program.

(2) Research grants may be used to support work in the fields of ecology, evolutionary biology, and/or conservation biology.

(3) Research project must involve the study of biological resources associated with NROC.

(4) Grants range in value from $250 to $2,500.

(5) Funding may be used for purchase of equipment or supplies necessary to undertake the proposed research project and/or travel to and from research site.

(6) Funding does not cover manuscript preparation and publication costs, salaries or stipends for applicants or assistants, and/or travel to scientific meetings or symposia.

Eligibility requirements.

(1) Grants are available to undergraduate and graduate students currently enrolled in a degree-seeking program.

(2) Undergraduates must complete research prior to graduation.

(3) Applicants seeking support for continuation of a project or a new project must turn in a new application.

(4) Applicants are eligible to receive a total of two grants in their lifetime.

(5) Applicants need not be United States citizens, international students are eligible to apply.

APPENDIX E. TARGET BIRD SPECIES EXTENDED DATA ANALYSIS

Relationship between shallow slopes and California Gnatcatcher density—At the request of biologists and planners involved with development of Multiple Species Conservation Plans for San Diego County, Robb Hamilton and I analyzed and reported on the relationship between gnatcatcher density and slope present in the monitoring data. Using GIS data from the County of Orange and gnatcatcher monitoring data, we found a strong positive relationship between gentle slopes (0-15%; S) and density of California Gnatcatchers (CAGN) in the NROC (fig. 1). As the proportion of the surveyed area between 0 and 15% slope increased, so did the likelihood the site supported a high density of California Gnatcatchers. In other words, almost all of the high-density gnatcatcher sites identified by the targeted bird surveys occurred in areas with gentle slopes.

Note: Proportion surveyed area 0-15% slope was calculated by dividing the total area between 0-15% slope by the total survey area (total survey area = land area encompassed by a 100m buffer of the survey route, see fig. 2).

Figure 1. Six-year (1999-2004) average density of California Gnatcatcher territories at the 40 long-term target bird species monitoring sites plotted against the proportion of each site that falls between 0 and 15% slope. The line represents a linear regression with 95% confidence intervals (Equation for the linear regression: CAGN = 0.428*S -0.143, R^2adj = 0.254, n = 40, $p<0.001$).

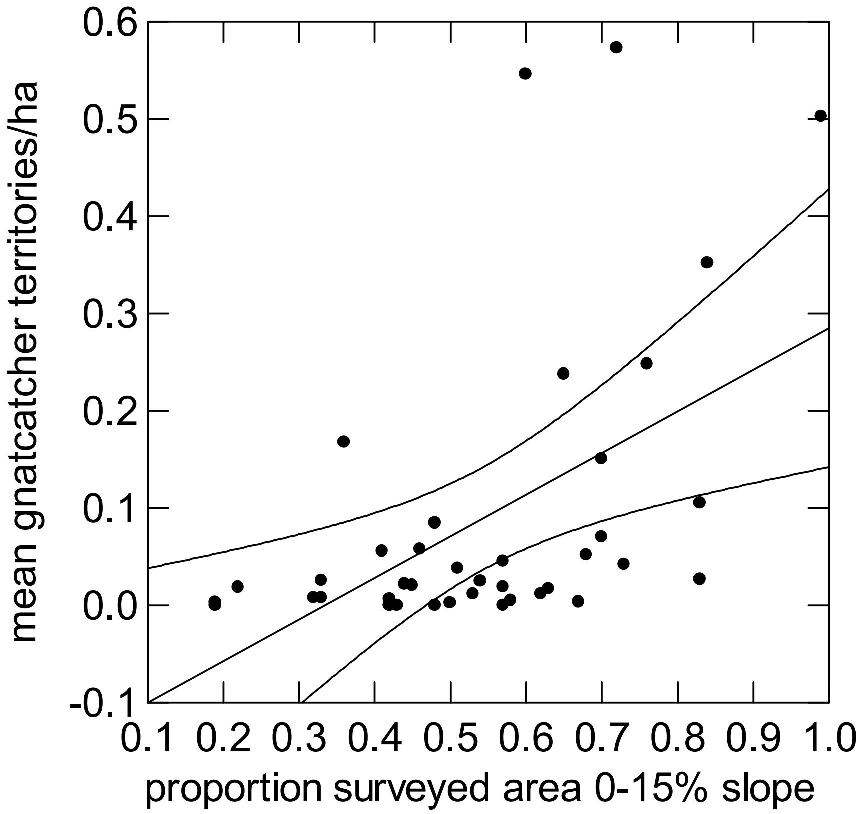
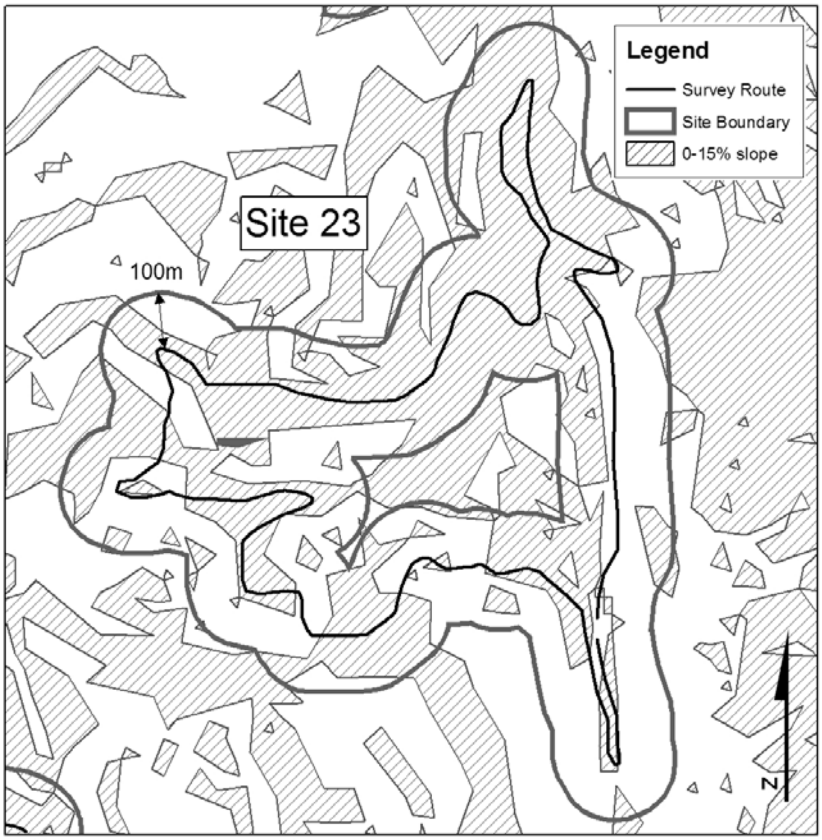


Figure 2. Site No. 23 of 40. Buffer distance from survey route equals 100 m. Enclosed polygon surrounding survey route defines surveyed area. Land areas with 0-15% slope are represented by hatched polygons.



Site occupancy modeling of California gnatcatcher (Polioptila californica)—In the following summary report I describe my motivation and efforts to reanalyze the California gnatcatcher monitoring data collected under the Target Bird Species Program. I undertook the reanalysis of the dataset because new methods and statistical programs were recently made available for analyzing multiyear presence/apparent absence data that were not available a few years earlier when this data was first analyzed.

The recently developed methods use likelihood based models of site occupancy to estimate key population parameters, including occupancy, extinction, colonization, and probability of detection. Use of this analytical method is considered to be superior to the currently widespread technique of using direct counts as measurements of population size. One reason for this evaluation is that the new methods make fewer assumptions of the data or conditions surrounding its collection. When using direct counts as an absolute measure or index of population size researchers are forced to assume either that all target animals or plants are detected during a survey (i.e. probability of detection = 1.0), or if used as an index, that the probability of detecting a species does not vary between sites, season, or observer. Because these assumptions are often violated in most field studies, the conclusions drawn from such work are often times biased and unreliable. Occupancy models, on the other hand, directly estimate detection probability. Furthermore, the method presented in the program PRESENCE allows sample covariates to be included in the model building process, allowing researchers to take into account differences in the timing and location of data collection events and abilities of multiple observers. By being explicit about the relationships between sampling covariates and detection probability and incorporating detection probability in its estimates of site occupancy the new methods ultimately make fewer assumptions concerning the data. In addition, unlike when using direct counts, in modeling site occupancy, error estimates are generated for each calculated parameter ultimately improving certainty when drawing final conclusions from an analysis.

Reanalysis of the monitoring data using site occupancy models affords managers and biologists the chance to compare the results of count and occupancy estimates side-by-side. I expect use of the new analytical techniques will lead to an improved understanding of the true status and population dynamics of the gnatcatcher population present in the reserve system.

Methods—In order to analyze the gnatcatcher data, I first converted the presence only data into a presence/apparent absence dataset. To do this, I used GIS information describing the route traveled by researchers when completing the target bird surveys to identify sites and determine whether a site was considered surveyed or not.

Survey sites were defined through a multi-step process. The first step involved the overlay of a 250 m by 250 m grid over the land areas within the central and coastal subregions. This was done using GIS and allowed for definition of unique grid cells that collectively covered the entire survey area. The second step involved calculating the total length of the walking transect or survey route for each cell within which a walking survey occurred. A grid cell was considered surveyed if a minimum of 250 m of an established walking transect occurred in the cell. The next step involved identifying the number of times each year that a site or cell was surveyed (this is equivalent to a sample occasion). Note, as described in the review of the target bird species research program, each site, and thus each cell, was surveyed from one to three times per year. Using GIS information describing the date and location of gnatcatcher detections during the six-year program, I recorded whether at least one gnatcatcher was detected or not during a single sampling occasion for a given cell. From this information I constructed a table of detection data (1s and 0s with 1 = present and 0 = non-detection) for input into the program PRESENCE for each of the surveyed cells for all sampling occasions.

Using the newly constructed matrix of 1s and 0s, I built two sets of multi-year occupancy models that provided estimates of the proportion of sites occupied, probability of local extinction, colonization, and detection. With the first set of models I tested for the importance of route length and year in determining detection probability by including "route" and "year" as sampling covariates in the nested models. I also tested for the importance of including a local extinction parameter, "ε", in model structure and "year" as a site covariate describing annual changes in occupancy estimates. In the second set of models I estimated only the first year's site occupancy rate, and then annual extinction and colonization ("γ") rates. The covariate "year" was included in the set of models to test for the importance of inter-annual variation in rates of extinction and colonization.

I ranked models according to AIC scores to identify the best models in each set and in effect test for the importance of the different site and sampling covariates. Model-averaged covariate coefficients were weighted by the AIC weights and included as best estimates of calculated parameters.

Results—276 sites were defined using the rules described above. The total number of sampling occasions equaled 3,759 for the six-year study. In the first set of models, the highest ranking model accounted for 93% of the total model weights and included the site covariate "year", annual extinction rate "ε", and sample covariates "year" and "route" in model structure (table 1). Model-averaged estimates of annual occupancy ranged from 26 to 34% of total sites surveyed, annual extinction was 23%, and detection probability ranged from 73 to 82%.

In the second set of models, the highest ranking model accounted for 98% of all model weights and included annual extinction "ε" and colonization "γ" rates (table 2). Model-averaged rates of extinction and colonization ranged from 11 to 37% and 1 to 15%, respectively. Using the model-averaged estimates of year-specific colonization and extinction rates we can determine the proportion of occupied sites from 1999-2004 was 0.34, 0.22, 0.27, 0.34, 0.25, and 0.28. Estimates of the rate of change (*lambda*) between years are $\{\lambda_{1999}, \lambda_{2000}, \lambda_{2001}, \lambda_{2002}, \lambda_{2003}\}$ = {0.65, 1.24, 1.26, 0.75, and 1.09}.

Interestingly, model-averaged estimates of site occupancy (reported in table 1) showed less year-to-year variability than the count data provided by Hamilton (2004) (see fig. 3). In the years between 2000 and 2004, occupancy estimates ranged between 76 and 94% of 1999 estimates (6-year high), while count data during a similar time period ranged between 51% and 88% of 1999 value. Estimates of the proportion of sites occupied compare well with the number of counted gnatcatcher territories except for the years 2000 and 2003. The two years represent significant declines for the gnatcatcher population in both datasets. Comparison of the results of the two methods suggests the count data overestimates annual declines and/or overemphasizes the loss of territories from high density sites relative to local site extinctions. If this is true, this has important implications for management of the gnatcatcher. Population stability is typically well correlated with population persistence or viability in fragmented systems. If the gnatcatcher population in the reserve is more stable that what is implied by the count data alone, this will likely influence the level of management concern applied to the species. In addition, if the site occupancy models are indeed more accurately tracking the population dynamics of the gnatcatcher, this would suggest that history of occupancy at site and annual changes in detection probability both need to be accounted for in the estimates of state variables used in monitoring programs.

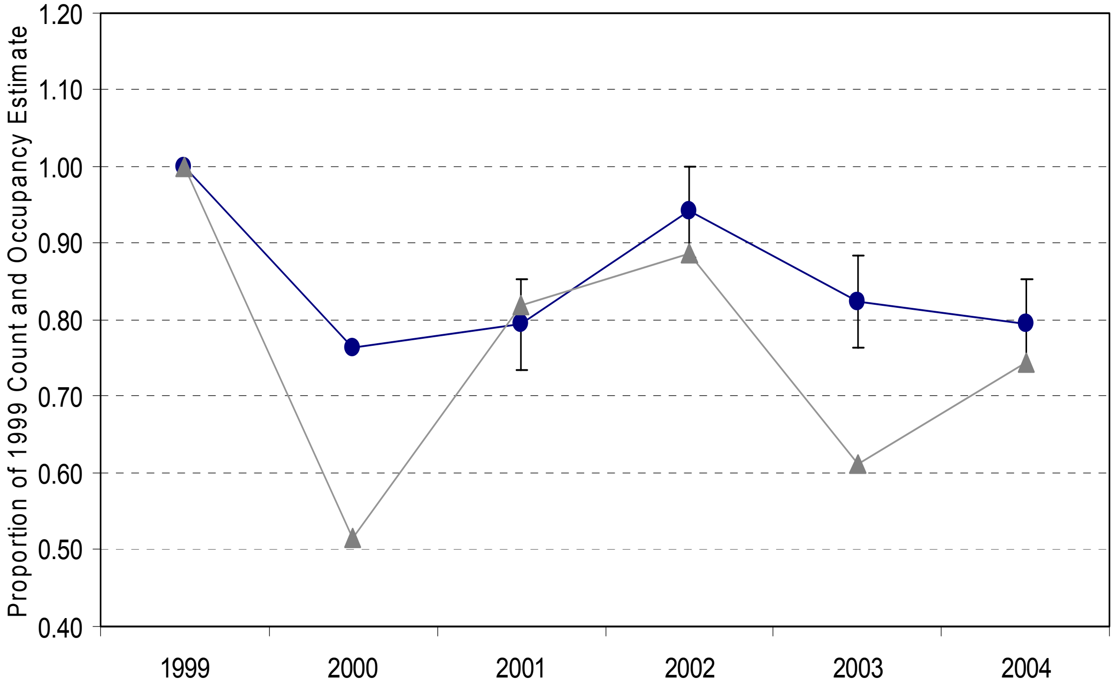
Table 1. Summary of model selection procedure and parameter estimates for the California gnatcatcher (*Polioptila californica*). Difference in AIC values between each model and the low-AIC model (ΔAIC); AIC model weights (w), number of parameters in the model (K); overall estimate of the fraction of sites occupied (ψ), annual extinction rate (ε), probability of detection (P), and associated standard error (in parentheses).

Model	ΔAIC	w_i	K	ψ_{1999}	ψ_{2000}	ψ_{2001}	ψ_{2002}	ψ_{2003}	ψ_{2004}	ε	P_{1999}	P_{2000}	P_{2001}	P_{2002}	P_{2003}	P_{2004}
ψ(year)ε(·)*p*(year,	0.00	0.93	14	0.34	0.26	0.27	0.32	0.28	0.27	0.23	0.78	0.73	0.73	0.73	0.74	0.82
route)				(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)	(0.00)	(0.06)	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)
ψ(year)ε(·)*p*(route)	5.12	0.07	9	0.34	0.26	0.27	0.32	0.28	0.27	0.23	0.78	0.78	0.78	0.78	0.78	0.78
				(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)	(0.00)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
ψ(·)ε(·)*p*(route)	14.44	0.00	4	0.28	0.28	0.28	0.28	0.28	0.28	0.23	0.79	0.79	0.79	0.79	0.79	0.79
				(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
ψ(·)*p*(year, route)	85.14	0.00	8	0.20	0.20	0.20	0.20	0.20	0.20	0.00	Nonsensical	0.77	0.78	0.77	0.82	0.83
ψ(·)*p*(route)	104.04	0.00	3	0.20	0.20	0.20	0.20	0.20	0.20	0.00	0.80	0.80	0.80	0.80	0.80	0.80
				(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.0)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
ψ(·)*p*(·)	106.16	0.00	2	0.20	0.20	0.20	0.20	0.20	0.20	0.00	0.74	0.74	0.74	0.74	0.74	0.74
				(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Model-averaged				0.34	0.26	0.27	0.32	0.28	0.27	0.23	0.78	0.73	0.73	0.73	0.74	0.82
estimates				(0.00)	(0.00)	(0.02)	(0.02)	(0.02)	(0.02)	(0.00)	(0.06)	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)

Table 2. Summary of model selection procedure and parameter estimates for models with initial occupancy, and colonization (γ) and local extinction (ε) probabilities. *Note:* definitions are as in table 1.

Model	ΔAIC	w_i	K	ψ_{1999}	ε_{1999}	ε_{2000}	ε_{2001}	ε_{2002}	ε_{2003}	γ_{1999}	γ_{2000}	γ_{2001}	γ_{2002}	Γ_{2003}	P
ψ(1999)ε(year)γ(year)*p*(route)	0.00	0.98	13	0.34	0.37	0.11	0.14	0.35	0.17	0.01	0.10	0.15	0.05	0.09	0.79
				(0.04)	(0.07)	(0.05)	(0.05)	(0.06)	(0.05)	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.04)
ψ(1999)ε(year)γ(·)*p*(route)	7.73	0.02	9	0.32	0. 41	0.10	0.15	0.36	0.17	0.09	0.09	0.09	0.09	0.09	0.79
				(0.03)	(0.07)	(0.05)	(0.05)	(0.06)	(0.05)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)
ψ(1999)ε(·)γ(·)*p*(route)	21.68	0.00	5	0.30	0.24	0.24	0.24	0.24	0.24	0.09	0.09	0.09	0.09	0.09	0.79
				(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)
Model-averaged estimates				0.34	0.37	0.11	0.14	0.35	0.17	0.01	0.10	0.15	0.05	0.09	0.79
				(0.04)	(0.07)	(0.05)	(0.05)	(0.06)	(0.05)	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.04)

Figure 3. Proportion of 1999 count data (triangles) and 1999 site occupancy estimates (circles) ±1 SE by year for the California gnatcatcher. Note: count data is from Hamilton (2004).



APPENDIX F. ANT EXTENDED DATA ANALYSIS

The following analyses fulfill a need to provide more detailed analysis of the ant community data collected as part of the Umbrella Monitoring Program. The results of this work provide land managers with information concerning the susceptibility of the Reserve System to invasion by argentine ants and the subsequent effects of the invasion on the native ant community.

General overview of the importance of ants in terrestrial ecosystems—Ants are surface and subterranean predators of small arthropods, generalist scavengers, granivores/seed harvesters, leaf-cutters that farm fungus, and tenders of aphids and scale insects. Ants perform a variety of ecological functions in terrestrial ecosystems, including cycling of nutrients and organic matter, dispersal of seeds, and predation and scavenging of small animals. Their sheer number and great diversity make them significant components of most any terrestrial community.

Brief overview of the ant fauna of California (see synoptic review by Ward [2005] for material)—The California ant fauna shows considerable diversity and regional endemism, 281 recognized species in 44 genera, 39 endemic species (15% of total native ant species). Twenty-six introduced species are present within the state although they are largely confined to disturbed sites at low elevations. One of the most ecologically important introduced ant species is the argentine ant (*Linepithema humile*). Argentine ants are restricted primarily to disturbed areas, but have shown the ability to invade natural areas. Where argentine ants are present, the native ant fauna is often displaced.

Research questions specific to the present study—We describe both the structure of the native ant community present in coastal lowland areas of southern California, comparing our results with other studies of regional ant fauna, and the distribution of argentine ants within the region.

We ask if distance to urban/agricultural edges, and watercourses explains much of the distribution of argentine ants within the region. We ask how the native community changes in the presence of argentine ants.

Based on the recovered spatial patterns of argentine ant invasion we predict what the impact will be for the ant fauna found within the nature reserve as development of open space surrounding the reserve continues.

Methods—172 sites were sampled on 5 to 14 occasions from October 1999 through January 2003. A single sampling occasion consisted of a ten-day sample period conducted at a single site. At each site five pitfall traps (50mL tubes) filled with antifreeze were left open to capture and preserve ants during each 10-day collection period. In total, the ant community data represents 1,161 sample occasions collected across 14 geographic areas (see table 1).

In order to compare patterns of occupancy, rates of detection, and site extinction between the native ant species collected, site occupancy models were developed for top 12 most frequently detected native ant species. Site occupancy models allow for estimation of probability of detection, site occupancy, and site extinction.

More detailed site occupancy models were also developed for the argentine ant. These models include site covariates in order to assess the importance of landscape features in explaining species presence and absence. Using GIS (California Department of Forestry and Fire Protection; Fire and Resource Assessment Program 2002; statewide composite of digital vegetation and habitat data) we characterized sites by their distance from urban/agricultural edges and watercourses, defining four distance categories (<100m, <200m, <300, and <500m) from urban/agricultural areas and a single distance category (<50m) from watercourses. Site covariates included in the analysis were chosen because of their suspected importance in explaining patterns of occupancy for the argentine ant.

We tested for differences in species richness of native ants between geographic areas, sites with and without argentine ants present, as well as between sites located within and without 200m of urban/agricultural areas. At sites with argentine ants, we asked if argentine ant activity level influenced species richness of native ants.

Results—Native Ant Community. A total of 54 native ant species (in 24 genera) and two exotic species (*Linepithema humile* and *Cardiocondyla ectopia*) were found in the surveys (table 2). Total native species detected represents approximately 21% of total number of native species and 55% of genera recognized to occur within California.

For most species included in the modeling process, naïve estimates of site occupancy closely matched model estimates (fig. 1). For three species, however, this was untrue. Naïve estimate of site occupancy for *Temnothorax andrei* (LEAN) was 60% compared to the model estimate of 83%. Similarly, naïve estimates for *Neivamyrmex californicus* (NECA) and *Neivamyrmex nigrescens* (NENI) were19% and 17%, compared to model estimates of occupancy of 49% and 31%, respectively. Large difference in estimates for these three species appears to be largely due to each species being rarely detected even when present. Detection probabilities for all three species were less than 19%, and for both *Neivamyrmex* species less than 8%. These values are far below the mean probability of detection (mean ± SE: 40 ± 5%) calculated for the other nine species included in the modeling effort.

Results—Argentine Ant. The argentine ant was detected as being present in 12 of 14 geographic areas (86%) and 58 of 172 surveyed sites (naïve estimate of occupancy: 34%).

Highest ranking occupancy model included the site covariate <200m from urban/agricultural areas. Model-averaged estimate of site occupancy for the species was 29 ± 1% (± 1 SE), annual extinction rate (offset by an uncalculated colonization rate0 was 9 ± 3%, and probability of detection was 76 ± 2% (table 3).

According to the highest ranking model there is a 77% chance that sites falling within 200m of an urban or agricultural area are occupied by argentine ants. Outside of 200m, the model indicates that the probability of site occupancy drops to 12%.

Whether or not watercourses were present within 50m of survey sites was not important when distance to urban/agriculture was already included in the model.

Results—Affect of Argentine Ants on Native Ants. The number of native ant species detected within a geographic area declines as the proportion of sites with argentine ants increases across geographic areas (t = -4.594, R^2 = 0.64, P < 0.001, n = 14; fig. 2).

Large differences existed (U = 4351, P < 0.0001, n = 172) in the number of native ant species detected between sites located less than 200m away from urban and agricultural areas (Mean ± 1 SE: 5.4 ± 0.6, n = 44) versus sites located greater than 200m away from urban and agricultural areas (8.8 ± 0.3, n = 128).

The richness of the native ant community is much reduced in the presence of argentine ants (fig. 3). Density of native species at sites with *Linepithema humile* is significantly lower than sites without *L. humile* (U = 5272.5, P < 0.0001, n = 173; mean, median, and SE of native ant species at 58 sites with *L. humile* is 4.9, 3.5, and 0.5, at 115 sites without *L. humile* the values change to 8.9, 9.0, and 0.3).

The number of native ant species present at a site is sensitive to the activity level expressed by argentine ants, with fewer native species present at sites having higher argentine ant capture rates (F = 7.137, df = 2, P < 0.002, n = 58, fig.4).

Of the top 12 distributed native ants of the genus *Neivamyrmex* (army ants), *Tapinoma sessile* (maloderous house ant), *Crematogaster californica*, and *Pheidole hyatti* are most sensitive to the presence of argentine ants and *Temnothorax Andrei* and *Solenopsis molesta* (thief ant) are the least sensitive (fig. 5).

Results—Acreage within the reserve system considered to be vulnerable to argentine ant invasion. Acreage of the Nature Reserve (as mapped) is 36,923 acres. As of 1992, 8,889 acres of the total area of the Nature Reserve (or 24%) fell within 200m of mapped urban and agricultural areas (fig. 6). With complete build-out of lands surrounding the reserve, 16,283 acres (or 44%) of the total reserve area will be located within 200m of urban and/or agricultural areas (fig. 6).

Conclusion—Given that: (1) native ants are considered to be critical components of most terrestrial ecosystems; (2) native ant community is largely displaced in the presence of argentine ants; and (3) such a large area of the reserve system is vulnerable to invasion, we can identify the argentine ant as a significant threat to the ecological integrity of the reserve and predict that many basic ecological processes will be disrupted in areas occupied by the argentine ants.

Table 1. Proportion of sites with argentine ant (*Linepithema humile*) present and average number of native ant species (±1 SE) by geographic area

Area no	Area ID	No Sites	Proportion of sites with *L. humile*	Number of *L. humile* workers captured at occupied sites per sample period (Mean ±1 SE)	Native ant species richness (Mean ±1 SE)
1	Puente Hills	19	0.84	100.6 ± 13.9	4.4 ± 0.6
2	Chino Hills State Park	32	0.12	0.5 ± 0.2	6.7 ± 0.6
3	Unocal	3	1.00	2.3 ± 0.4	1.0 ± 0.0
4	Weir Canyon	12	0.00	–	11.5 ± 0.7
5	Orange Hills	5	1.00	1.0 ± 0.2	2.4 ± 0.5
6	Peters Canyon Regional Park	5	1.00	1.2 ± 0.1	9.6 ± 2.5
7	Rattlesnake Reservoir	5	1.00	1.2 ± 0.1	3.4 ± 0.9
8	Limestone Canyon	19	0.16	0.2 ± 0.1	10.0 ± 0.9
9	Agua Chinon	7	0.29	1.0 ± 0.2	7.1 ± 1.5
10	UC Irvine, Ecological Preserve	5	1.00	8.1 ± 1.1	2.2 ± 0.8
11	Southern California Edison Parcel	5	0.00	–	14.2 ± 1.4
12	San Joaquin Hills	21	0.33	3.3 ± 0.7	8.2 ± 0.7
13	Audubon Starr Ranch Sanctuary	17	0.06	0.2 ± 0.0	10.0 ± 0.7
14	Aliso and Wood Canyons Wilderness Park	17	0.29	1.6 ± 0.3	7.1 ± 0.5

Table 2. List of ant species detected within the 14 geographic areas across the 173 sites. Asterisk indicates exotic species. Numbers describing geographic areas where species were detected refer to table 1.

Family Formicidae	Geographic Area Number
Subfamily Ecitoninae	
Neivamyrmex californicus	2, 4, 6, 7, 8, 11, 12, 13, 14
Neivamyrmex nigrescens	2, 4, 8, 9, 11, 12, 13
Neivamyrmex opacithorax	13
Subfamily Pseudomyrmecinae	
Pseudomyrmex apache	2, 11
Subfamily Dolichoderinae	
Dorymyrmex bicolor	2, 4, 6, 7, 8, 9, 11, 12, 13
Dorymyrmex insanus	1, 2, 3, 4, 6, 8, 9, 11, 12, 13, 14
Forelius foetidus	2, 4, 7, 8, 11, 13
Forelius pruinosus	2, 4, 5, 6, 7, 8, 11, 13, 14
*Linepithema humile**	1, 2, 3, 5, 6, 7, 8, 9, 10, 12, 13, 14
Liometopum occidentale	2, 4, 13, 14
Tapinoma sessile	1, 2, 4, 8, 9, 10, 11, 12, 13, 14
Subfamily Formicinae	
Brachymyrmex depilis	12
Camponotus sayi	6, 8, 11, 14
Camponotus semitestaceus	5, 14
Camponotus spp. CA-01	2, 4
Camponotus vicinus	1
Formica francoeuri	2, 9, 14
Formica moki	1, 2, 4, 6, 8, 9, 10, 11, 12, 13, 14
Formica xerophila	13
Myrmecocystus kennedyi	1, 2, 4, 9, 11
Myrmecocystus mexicanus	2, 6
Myrmecocystus mimicus	1, 2, 4, 6, 8, 9, 11, 12, 13, 14
Myrmecocystus semirufus	6, 14
Myrmecocystus testaceus	2, 4, 6, 8, 9, 11, 12
Paratrechina c.f. terricola	1, 2, 4, 6, 8, 9
Polyergus breviceps	11
Prenolepis imparis	1, 2, 3, 4, 6, 8, 10, 12, 13, 14
Subfamily Myrmicinae	
*Cardiocondyla ectopia**	8, 14
Crematogaster californica	1, 2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14
Crematogaster coarctata	2, 4, 6, 8, 11, 12, 13, 14
Crematogaster hespera	1, 2, 4, 6, 8, 11, 12, 13
Crematogaster mormonum	2, 8, 12, 13, 14
Cyphomyrmex wheeleri	4, 8
Temnothorax andrei	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
Temnothorax nevadensis	14
Temnothorax nitens	13
Temnothorax sp CA-06	2
Messor andrei	4, 6, 8, 11, 12, 13
Messor stoddardi	2, 4,
Monomorium ergatogyna	1, 2, 4, 6, 8, 11, 12, 13, 14
Monomorium minimum	1, 4, 11, 12, 13
Monomorium pharaonis	3
Myrmecina Americana	4, 12
Pheidole cerebrosior	1, 2, 6
Pheidole clementensis	1, 2, 8
Pheidole hyatti	1, 2, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14

Table 2. *continued*

Family Formicidae	Geographic Area
Pheidole vistana	1, 4, 5, 6, 8, 9, 13
Pogonomyrmex californicus	1, 2, 6, 8, 9, 14
Pogonomyrmex rugosus	4, 8, 12, 13
Pogonomyrmex subnitidus	1, 2, 4, 8
Solenopsis amblychila	2, 4, 7, 8, 9, 13
Solenopsis aurea	1, 2, 4, 5, 6, 8, 9, 11, 13, 14
Solenopsis molesta	1, 2, 7, 8, 10, 11, 12, 13, 14
Solenopsis xyloni	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14

Table 3. Difference in AIC values between each model and the low-AIC model (ΔAIC); AIC model weights (*w*), number of parameters in the model (*K*); overall estimate of the fraction of sites occupied (ψ), annual extinction rate (ε), probability of detection (*P*), and associated standard error (in parentheses).

Model	ΔAIC	w_i	*K*	*Ψ*	*ε*	*P*
ψ(<200m)ε(·)*p*(·)	0.00	0.62	4	0.29	0.09	0.76
				(0.01)	(0.03)	(0.02)
ψ(<200m, <50m)ε(·)*p*(·)	1.04	0.37	5	0.29	0.09	0.76
				(0.01)	(0.03)	(0.02)
ψ(<300m)ε(·)*p*(·)	7.32	0.02	4	0.29	0.08	0.76
				(0.01)	(0.02)	(0.02)
ψ(<500m)ε(·)*p*(·)	19.82	0.00	4	0.29	0.08	0.76
				(0.01)	(0.02)	(0.02)
ψ(<100m)ε(·)*p*(·)	47.87	0.00	4	0.29	0.08	0.76
				(0.03)	(0.02)	(0.02)
ψ(·)ε(·)*p*(·)	79.42	0.00	3	0.29	0.08	0.76
				(0.03)	(0.02)	(0.02)
ψ(·)*p*(·)	188.43	0.00	2	0.17	0.00	0.78
				(0.02)	(0.00)	(0.02)
Model-averaged estimates				0.29	0.09	0.76
				(0.01)	(0.03)	(0.02)

Figure 1. Top graph: Naïve estimates (dark circles) and site occupancy estimates of site occupancy (gray bars with error bar equaling +1 SE) for 12 most widely detected native ant species. Bottom graph: probability of detection (+1 SE) for same 12 species as estimated by program PRESENCE. PHHY = *Pheidole hyatti*; CRCA = *Crematogaster californica*; LEAN = *Temnothorax Andrei*; TASE = *Tapinoma sessile*; PRIM = *Prenolepis impairs*; FMMO = *Formica moki*; SOXY = *Solenopsis xyloni*; DOIN= *Dorymyrmex insanus*; MEAN = *Messor andrei*; SOMO = *Solenopsis molesta*; NECA = *Neivamyrmex californicus*; and NENI = *Neivamyrmex nigrescens*.

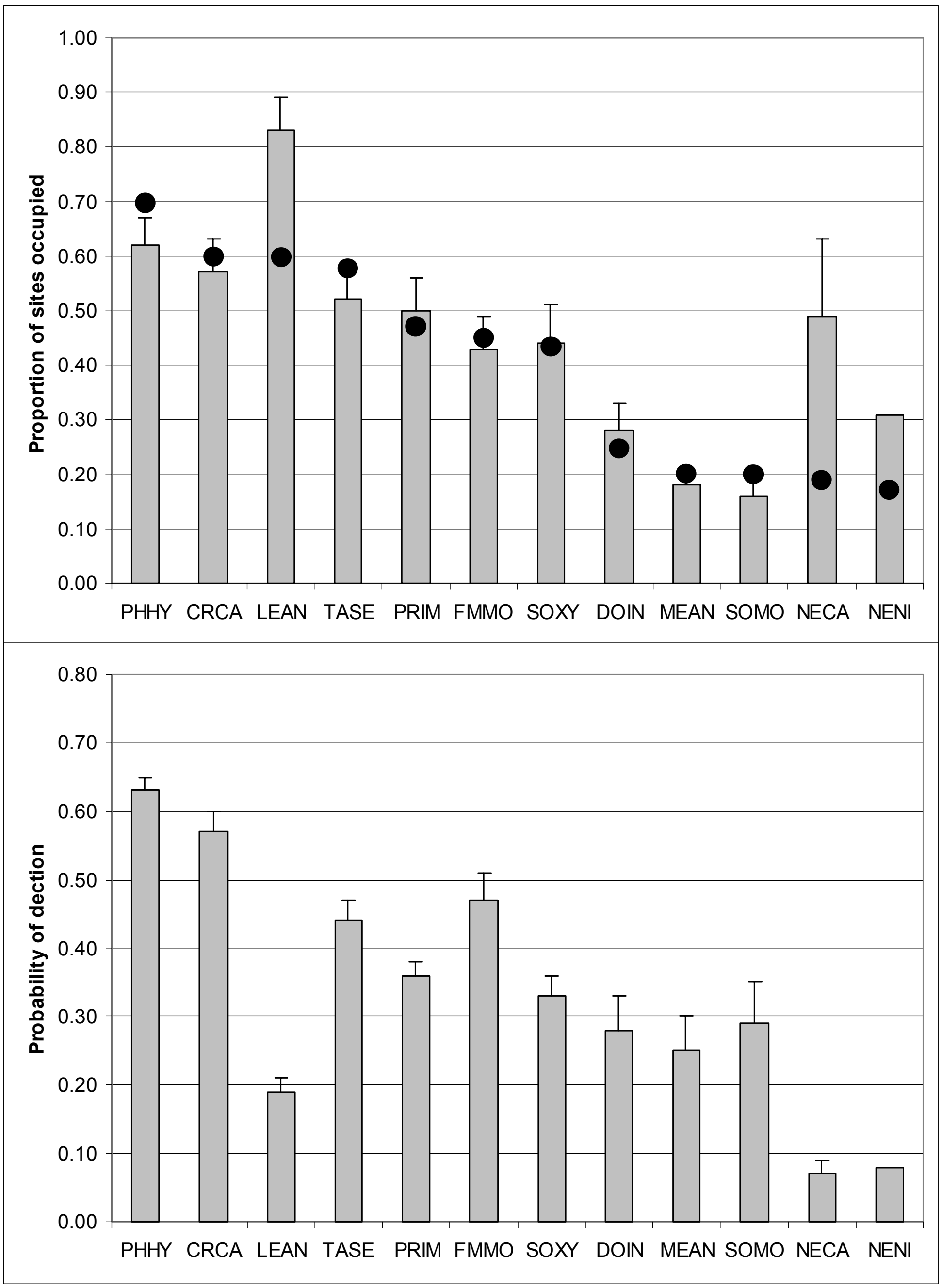


Figure 2. Regression of the average number of native ant species per site versus the proportion of sites within a sampled area with *L. humile*. Outlier in the graph (circled) is Peters Canyon Regional Park (proportion of sites sampled with argentine ants present: 1.0; average native ant species richness: 9.6).

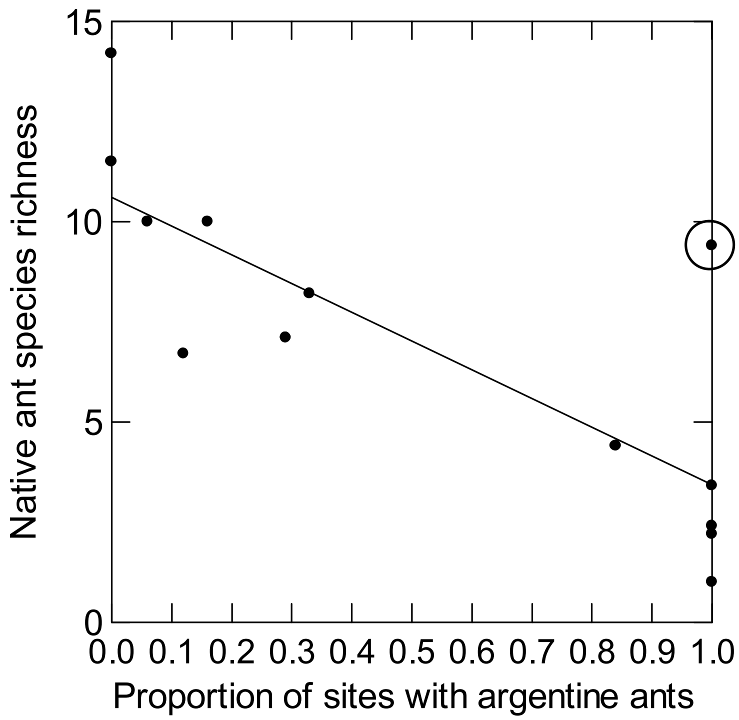


Figure 3. Differences in the distribution of density of species at sites with and without *Linepithema humile*.

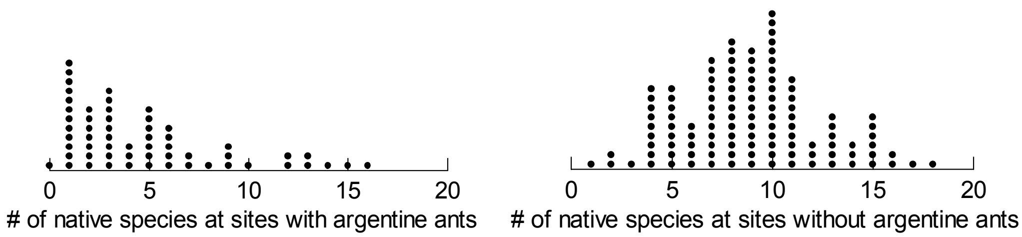


Figure 4. Number of native ant species (Mean ± 1 SE) by average level of activity exhibited by argentine ants. Level 1: < 1 argentine ant collected per 10-day sample period (7.2 ± 0.9, *n* = 22); 2: ≥ 1 and < 10 (3.8 ± 0.7, *n* = 26); and ≥ 10 (2.7 ± 0.8, *n* = 10).

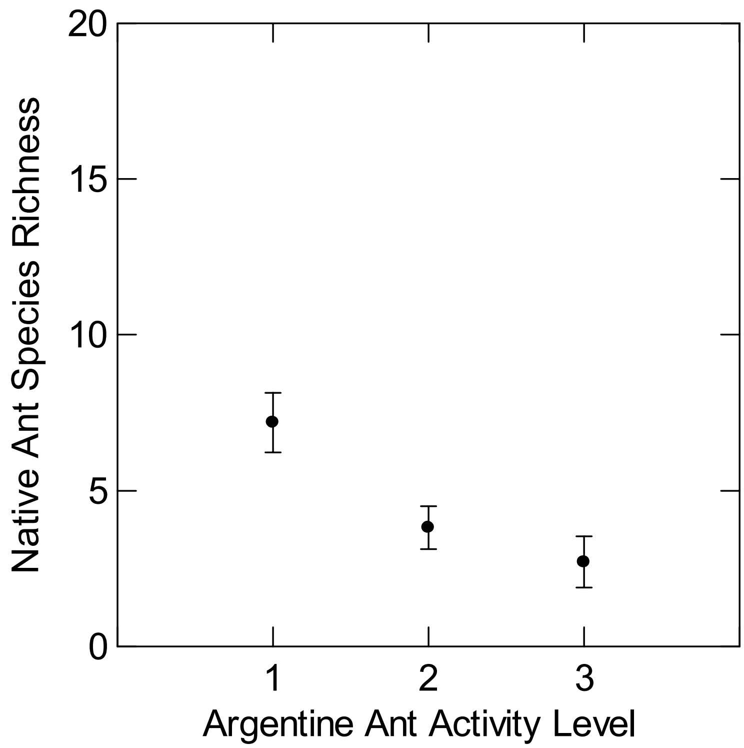


Figure 5. Species-specific sensitivity to the presence of argentine ants as indicated by the inverse of the log-ratio for the covariate L.humile calculated by program PRESENCE. Note, a value of 1.0 indicates no observed sensitivity to *L. humile* (i.e. model with the presence/absence of *L. humile* included as a site covariate did not rank higher than models that did not take into the distribution of *L. humile*), a value of 10.0 indicates that a species is 10 times less likely to be present at sites where *L. humile* was detected versus sites where *L. humile* was not detected.

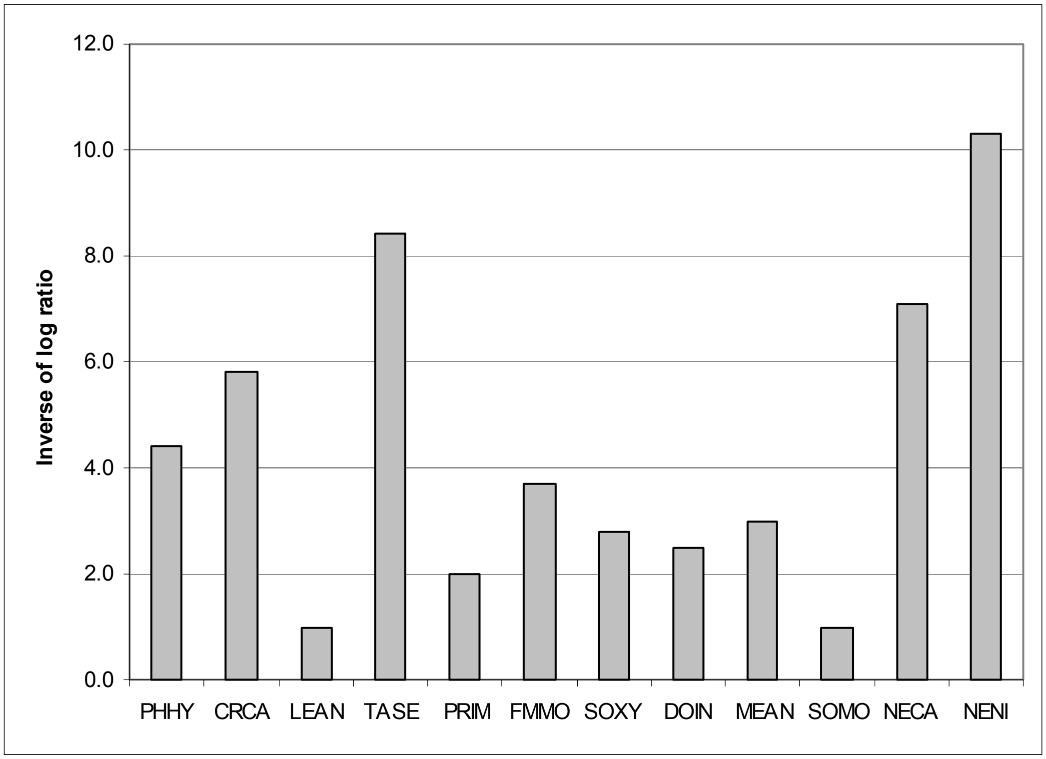
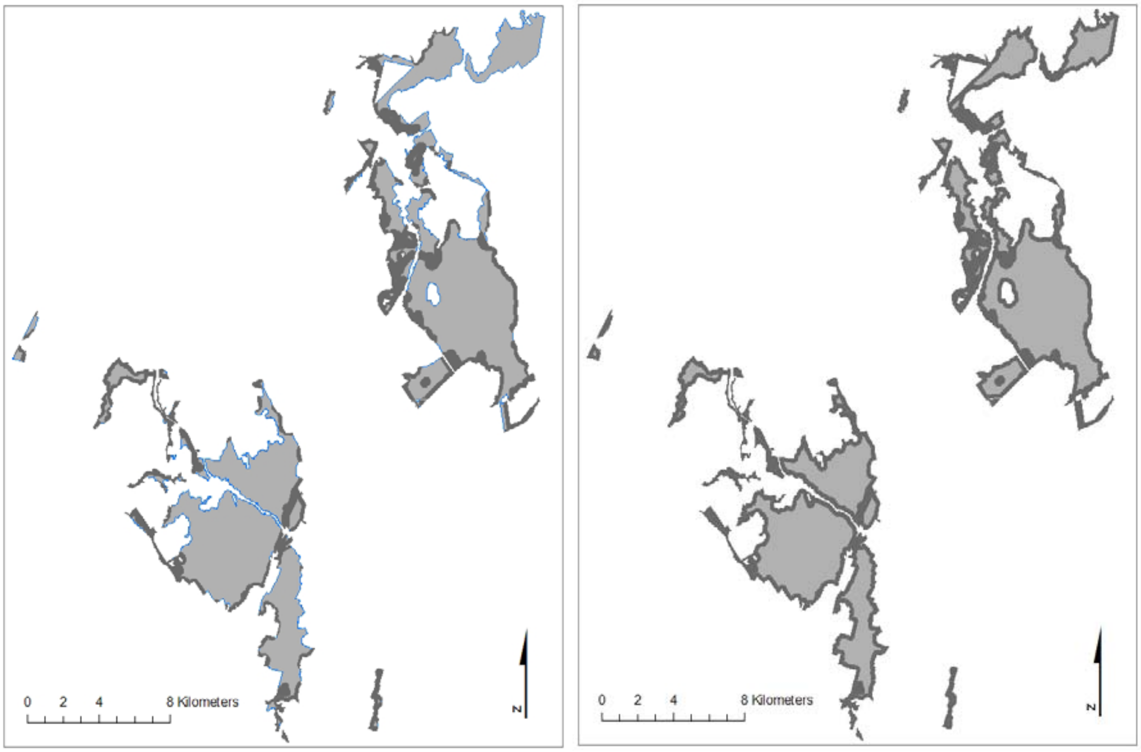


Figure 6. Geographic distribution of The Nature Reserve of Orange County. Reserve is comprised of a coastal and central reserve (both shaded in light gray). Areas within the reserve located within 200m of urban/agricultural areas are shaded in dark grey. Left figure is based off of 1992 GIS land-cover map for Orange County. Right figure shows the extent of the reserve within 200m of urban/agricultural areas following complete build-out of land-areas lying adjacent to the reserve. Notice both urban and agricultural areas are incorporated within reserve boundaries.



1992

Complete Build-Out