A Spatial Analysis of the Burrowing Owl (*Speotyto cunicularia*) Population in Santa Clara County, California, Using a Geographic Information System

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Abstract .— A small population of Burrowing Owls (*Speotyto cunicularia*) is found in the San Francisco Bay Area, particularly in Santa Clara County. These owls utilize habitat that is dispersed throughout this heavily urbanized region. In an effort to establish a conservation plan for Burrowing Owls in Santa Clara County, a spatial analysis of owl distribution and habitat was performed using remote sensing and geographic information system (GIS) technologies. Land areas that could provide valuable habitat for owls in the future and that could link together groups of owls throughout the region, were identified.

The Burrowing Owl (*Speotyto cunicularia*), a grassland species, utilizes open sparsely vegetated areas with available burrows (Zarn 1974). Historically, owls were common in natural areas of open prairies or in shrub-steppe habitat (Butts 1971, Coulombe 1971). Increasing human population and land use changes have caused Burrowing Owls to utilize man-altered habitats, such as agricultural irrigation ditches (Coulombe 1971) and vacant lands in urban areas (Thomsen 1971, Collins and Landry 1977, Wesemann and Rowe 1987, Trulio 1995). Burrowing Owls are tolerant of humans near their burrows, given suitable nesting and foraging habitat (Trulio 1992).

Nesting and foraging habitat requirements for the Burrowing Owl include sparse vegetative cover, availability of suitable burrows typically built by fossorial mammals, and the presence of perches that provide increased visibility. The amount of vegetative cover and overall plant height are significant factors in predator avoidance and prey location (Zarn 1974, Coulombe 1971, Green and Anthony 1989, Trulio 1992). In general, vegetative cover and height that allow the owl to stand near the burrow entrance and watch for approaching predators from any direction is most desirable. Burrows built and abandoned by fossorial mammals are taken over by Burrowing Owls throughout most of its North American range, excluding Florida, where Burrowing Owls dig their own burrows (Zarn 1974). The burrow provides protection from both predators (Green and Anthony 1989, Butts 1971) and adverse weather conditions (Coulombe 1971), and creates a microhabitat for arthropods (such as earwigs and crickets), which may form the owls' primary food source (Coulombe 1971). Perches adjacent to the burrow entrance increase visibility for the Burrowing Owl while it watches for predators or prey (Green and Anthony 1989).

The Burrowing Owl is considered a rare animal throughout most of its range. In Minnesota, Iowa, and Canada, it is listed as an endangered species. In California, Florida, Montana, North Dakota, Oregon, Washington, and Wyoming, the Burrowing Owl is listed as a species of special concern (Martell 1990). The Burrowing Owl has been on the *Journal of American Birds*' blue list since 1971 (Arbib 1971), which indicates that bird researchers identify it as a declining species. The California Department of Fish and Game listed the Burrowing Owl as a "Species of Special Concern" in 1979 due to declining populations throughout the State (Remsen 1978). In November 1994, the U.S. Fish and Wildlife Service classified the Burrowing Owl as a federal Category 2 candidate for listing as threatened or endangered. Additional evidence (DeSante and Ruhlen, unpubl. data) has shown that this species is unquestionably at risk throughout California.

In California, distribution of the Burrowing Owl is not uniform. There are an estimated 9,450 pairs of Burrowing Owls within the State

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(DeSante and Ruhlen, unpubl. data). Seventy-one percent of the breeding pairs of owls can be found in the Imperial Valley, 14 percent are in the southern Central Valley, and 14 percent are distributed throughout the San Francisco Bay area, middle and northern Central Valley and southern interior portions of the State. Flat, lowland valleys, basin bottoms, and coastal plains are the habitat of 90 percent of breeding Burrowing Owls in California (DeSante and Ruhlen, unpubl. data). These lowland areas, in addition to supporting the greatest number of breeding pairs of owls, have also been subjected to the greatest human population growth throughout the 1980's and early 1990's, particularly in the San Francisco Bay area and Central Valley locations (DeSante and Ruhlen, unpubl. data, Medvitz and Sokolow 1995).

The focus of this study is Santa Clara County, in the San Francisco Bay Area. It was a major agricultural center 30 years ago. Thousands of acres of farmland existed across the valley floor with some of the richest agricultural soil in the world. However, the 1970's brought explosive human population growth to the county. Today, over half the valley floor in Santa Clara County is developed (Bell *et al*. 1994). Within the last century, at least 90 percent of the County land in agriculture was abandoned, and for the most part, urbanized (Faye *et al*. 1985).

The Burrowing Owl population in Santa Clara County represents a window into the future of the remaining owl habitat throughout California. Urbanization represents a permanent loss of available habitat for the species, and this small population of owls is surrounded by urbanization with very few options for long-term protection.

The Institute for Bird Populations (IBP) conducted a census of Burrowing Owls in California from 1991-1993. The findings of the IBP study indicate a population decline greater than 50 percent in the last decade (DeSante and Ruhlen, unpubl. data). Today there are approximately 170 pairs of owls in the south San Francisco Bay Area (fig. 1). Most of the owls in this area utilize undeveloped or limited use lands throughout the urban matrix. Nesting populations of Burrowing Owls have been extirpated in the past 15 years from several counties in and around the San Francisco Bay Area, including Santa Cruz, Marin, and San Francisco, and nearly eliminated from several others.

Human population growth predictions indicate the population of California will double its current level by the year 2040 (Medvitz and Sokolow 1995). The Imperial Valley and the southern Central Valley are among the fastest growing regions within the State. In the Imperial Valley, the population is increasing by 3.6 percent per year and San Joaquin Valley's population is increasing by 2.5 percent per year. These increases are directly linked to the loss of agricultural lands due to urban expansion (Medvitz and Sokolow 1995). By the year 2040, the predicted loss of agricultural land in California is expected to be 5 million acres (2.02 million ha), or 17 percent of today's farmland base. Urbanization directly impacts Burrowing Owls because over 85 percent of the Burrowing Owl population in California is found on agricultural land in the Central Valley (DeSante and Ruhlen, unpubl. data).

In this study a geographic information system (GIS) was used to spatially link nest locations to current land uses across the entire Santa Clara County creating a landscape perspective for the evaluation of Burrowing Owl habitat protection. A landscape perspective is essential because habitat protection requires all cities within the county to participate equally in the protection of the species. In Santa Clara County, the conservation of Burrowing Owls and availability of habitat can't be solved by relying on each city to develop an individual habitat protection plan. Some cities have more owls and less habitat available for the future, while others have more habitat available but fewer owls.

Knowledge of owl locations and habitats that are most likely to be lost to development in the coming years is critical in the development of mitigation plans that offset the environmental impacts of development. Mitigation plans can include conservation easements or mitigation banks to define best available habitat without the limitation of city boundaries. Successfully protecting owl habitat in Santa Clara County in the future relies upon understanding where owls are found, how development will change available habitat in the future, and which lands are most appropriate to protect to ensure a viable population.

Figure 1.—*This image is a composite of SPOT satellite images dated May 1994 and May, June 1994. The south end of San Francisco Bay can be seen at the top of this image. Overlaid on the image are owl locations shown as white squares. These locations are from census data for the years 1991-1994. Each point identifies a nesting burrow with one or more owls at each point.*

The IBP census of Burrowing Owls revealed that the decline in the state-wide population was approximately 8 percent per year (DeSante and Ruhlen, unpubl. data). It was also estimated that 50 percent of the population of Burrowing Owls in the State was lost from 1985-1995. The owl is still broadly distributed throughout the State and occupies a variety of habitats, but small local populations (like the one in the San Francisco Bay area) may have limited long-term viability unless the population is increased and a permanent system of protected areas is established (DeSante and Ruhlen, unpubl. data; Trulio, unpubl. data).

GIS and Remote Sensing

Ecosystem management requires information on many system components and their interactions in the landscape, at different spatial scales. Modeling landscapes and species distribution with GIS and remotely sensed data has relieved researchers of difficult and time-consuming processes involving traditional cartographic methods. Integration of diverse databases, spatial analysis, and a final map product are all benefits of using a GIS. Utilization of a GIS in ecosystem management makes recording and spatial analysis of the data time-efficient, while creating the environment for a flexible visualization process to display complex relationships.

GIS demonstrated its utility in the development of a reserve design for the Northern Spotted Owl (*Strix occidentalis*) (Murphy and Noon 1992). Four primary map layers were compiled to spatially display information relevant to the species' ecology. The first layer represented species distribution at a scale dependent on species level response to environmental variation and the spatial extent of environmental disturbances. Map layer number two contained the distribution of historical and present locations of suitable habitat, including disturbed areas that had the potential of recovery to suitable habitat. The third map layer consisted of survey and census data on the Northern Spotted Owl. Land ownership and use patterns made up the final map layer. The intersection of all four map layers became the initial conservation map representing a starting point in the design of a reserve system for the Northern Spotted Owl. Pertinent biological variables were applied to this initial map to create different map patterns. Additional iterations of maps were statistically analyzed in the development of a final map product which is considered a scientifically valid approach to the development of a conservation reserve for the Northern Spotted Owl.

This study of Burrowing Owls and their habitat in Santa Clara County follows a methodology similar to that described above. Several map layers, including census data, historical data on the population, and land ownership, were combined in the context of a plan for protection of Burrowing Owls and their habitat in Santa Clara County. This study differs from Murphy and Noon in that less is known about Burrowing Owl demographics and distribution than Spotted Owls, and the study focuses on "basemap" information. Important information is compiled on owl distribution in relation to habitat type and land uses, and potential Burrowing Owl habitat and owl reserves are identified. This study forms a foundation on which Burrowing Owl conservation plans can be developed.

METHODS

Remote sensing, in conjunction with GIS, were the tools for this study. Three data sets were used to analyze Burrowing Owls and their habitat use in Santa Clara County, California. Population data from the IBP and local researchers provided locations of owls within the study area. A Landsat Thematic Mapper (TM) image was classified and combined with owl location data to analyze habitat use within the study area. A land use data set from the city of San Jose was overlaid on the classified image with owl locations to identify potential owl habitat areas which should be protected.

Study Site

Santa Clara County is located in northern California, at the southern end of San Francisco Bay. It is a broad, flat valley surrounded by the Santa Cruz Mountains to the west, the Diablo Range to the east, and San Francisco Bay to the north. This study focused on the central portion of Santa Clara County, approximately 730 km^2 of the valley floor. Current land uses within the study area include industrial, residential, commercial, open space, and vacant land. Intermixed within all of these land uses is a Burrowing Owl population of approximately 170 breeding pairs (DeSante and Ruhlen, unpubl. data; Trulio, unpubl. data).

Burrowing Owl Location Data

When the IBP censused Burrowing Owls in California during the years 1991-1993, all potential habitat was included in their census except for the Great Basin and desert areas in southern California. IBP divided the State into 1,835 census blocks that were 5 km x 5 km. Each 5 km x 5 km block was extracted from a 7.5 minute topographic map and this became the data sheet where volunteer census takers recorded owl locations during the Burrowing Owl nesting season, May 15 to July 15. An owl location is where one or more owls are observed at a burrow.

In preparation for the census, the IBP gathered information on the historical locations of Burrowing Owls for the years 1986-1990 from breeding bird surveys, Christmas bird counts, and mitigation studies. In addition to the historical and census data from IBP, this study utilized 1994 owl location information from local researchers. These researchers included Dr. L. Trulio, P. Delevoryas, Biosystems Analysis Incorporated, and the author.

All geographic locations of Burrowing Owls in Santa Clara County, historical records for the years 1986-1990, census records from the IBP for the years 1991-1993, and local census information for the year 1994, were digitized as points using ARC/INFO GIS software, v. 7.0 (ESRI 1994). Five georeferenced data layers were generated representing historical locations (pre-1991) of owls and the 4 years (1991-1994) of census data. Each point was attributed with the year it was referenced, the map sheet number, and a specific location number recorded in the census for that location.

Habitat Classification

A June 20, 1990, Landsat TM scene (path 44, row 34, ID 52302-18061), which includes the San Francisco Bay Area, was used to characterize six categories of land cover. The image, in its raw data format, was registered to a 30-m Universal Transverse Mercator (UTM) grid using corner and center coordinates supplied by EOSAT (C. Bell, NASA/Ames 1993). A subset of the full Landsat scene, which included over 95 percent of the known owl locations in Santa Clara County (both past and present) was made by excluding land above 250 ft (76 m) in elevation. Lands over this elevation were eliminated based on information gathered by the IBP which showed that 98 percent of the Burrowing Owls in Santa Clara County occupied sites below 200 ft (61 m) in elevation. The southern-end of the Santa Clara County, including the towns of Morgan Hill and Gilroy, had very few reported sightings of Burrowing Owls, and was not included in the study.

The software program "Spectrum" was used to classify the six of the seven TM bands in the Landsat image. The seventh TM band, thermal, was excluded from this analysis. Spectrum, developed by Los Alamos National Laboratory, pre-processes the raw data utilizing intrinsic properties from each of the six bands. Raw spectral data were grouped into 240 clusters using a nearest-neighbor algorithm, creating a smaller, more compressed, data set while retaining the integrity of the original spectral data. Each pixel in the original six-band image was assigned to one cluster. The output was a single-band image, called a clustered image. The 240 clusters were then grouped into six categories of land cover defined for this study.

The six land cover categories included water, developed land, bare soil, dense vegetation, dry grassland, and irrigated grassland. Of these six categories, emphasis was placed on dry and irrigated grasslands, habitat owls were most likely to be utilizing. The final product, a classified landsat image with six defined land cover classes, was colored coded for identification.

Spatial Analysis of Burrowing Owl Locations

A spatial analysis of the owl locations included interpretation of distribution patterns over time. Five GIS data layers, one for each year (pre-1991, 1991-1994), consisted of a point for each owl location. Maps generated from these five data layers were compared to one another visually. Polygons were drawn around groups of owl locations based on criteria from studies done by the IBP and Trulio (unpubl. data): groups of five or more locations in a single habitat area have a much lower chance of extinction and all existing large colonies should be maintained intact in the future. Stochastic environmental factors such as drought or prey reduction are likely to eliminate a small group of birds (DeSante and Ruhlen, unpubl. data; Trulio, unpubl. data).

Burrowing Owl Habitat Analysis

The amount of area was calculated for each of the six land cover categories. Since dry and irrigated grassland provided the greatest amount of available habitat for Burrowing Owls in Santa Clara County, the amount of this habitat type was calculated at each owl location, within 90 m buffers around each owl location, and within the polygons around groups of five locations or more.

Future Land Use

An analysis of potential future habitat or reserves for the Burrowing Owl in parts of Santa Clara County was conducted by evaluating the location of owls with respect to potential habitat and future development throughout the cities of San Jose and Santa Clara. Visual inspection, in conjunction with information about land ownership, was used to evaluate whether the known owl locations within the city of Santa Clara were protected from habitat loss in the future. Future habitat in the city of San Jose was also evaluated. This was accomplished by overlaying the vacant lands inventory, a projection of land uses for currently vacant and agricultural lands, from the city of San Jose. Projections were made about how habitat for Burrowing Owls could be increased in the northern portions of San Jose by mitigating development of open or agricultural land with Burrowing Owl habitat. Projected development throughout the study area was considered with respect to the impacts on Burrowing Owls in the future.

RESULTS

A visual analysis of the distribution change in Burrowing Owls over the study period showed a decrease in the number of owls and a concentration of the remaining owl locations. Nearly all of the Burrowing Owls currently residing in the study area can be found within a thin band around the south end of San Francisco Bay and in a ribbon of habitat running south, from the Bay through the San Jose airport. Moreover, owls are concentrated in habitat patches. The decline in owls and their habitat was confirmed by a ground inspection of all pre-1991 locations by Trulio and Buchanan in 1995. This inspection revealed that over 60 percent of the pre-1991 locations had been replaced by development. Conversion of dry grassland into developed land is the main reason for this population decline throughout the cities of San Jose, Santa Clara, Sunnyvale, Milpitas, and Mountain View.

Areas in which larger groups of owls are located can be considered protected habitat based solely on current land use and land management practices. For example, Burrowing Owls that reside on San Jose airport property, located mostly in San Jose, or Moffett Field Naval Air Station in Mountain View (the property includes an airfield), have a much greater chance of long-term survival because land utilization on these properties is not expected to change significantly in the future. The dry grass habitat at these locations is mowed several times per year, creating an environment that is conducive to a large number of Burrowing Owls. Management of the airport maintains nesting habitat away from runways, preserving both owls and public safety.

Owls located on public land, such as owls at Sunnyvale Baylands Park and Shoreline, are more likely to survive in the future, where both nesting and foraging habitat is actively protected.

RECOMMENDATIONS

Because Burrowing Owls are found in all cities in Santa Clara County, county action or collective city action is required to protect the owl population. There is no one single development project that will decimate the population, but incremental losses of habitat have a cumulative impact on the number of owls and will eventually result in a population too small for survival (Trulio, unpubl. data).

Compilation of information about Burrowing Owls in Santa Clara County using GIS creates a dynamic data set. Information about land use changes and new population census data can be added at any time, setting the stage for on-going analysis of population change. Utilization of remotely sensed data allows efficient evaluation of large land areas. This study has established a baseline of information about Burrowing Owls in this urban region and can be used to develop a conservation strategy that will protect the birds for the future. It is also a model for protection of Burrowing Owl habitat in other areas where urbanization is having an impact.

ACKNOWLEDGMENTS

This study was a Master's Thesis for the Environmental Studies Department at San Jose State University in San Jose, California, completed December 1996. The work was completed in the Ecosystem Science Division's GIS laboratory at NASA Ames Research Center. Future updates to the data in the GIS will be conducted by the author in order to continue the analysis of the Burrowing Owl population in Santa Clara County.

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