An Updated Management Plan For The Burrowing Owl Population At Naval Air Station Lemoore Lemoore, California

An Updated Adaptive Management Plan For The Burrowing Owl Population

At
Naval Air Station, Lemoore
Lemoore, California

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Executive Summary

Because of the large number of listed species, the San Joaquin Valley is one of the primary regions for conservation of biological diversity in California. A substantial proportion of the burrowing owls in California inhabit the San Joaquin Valley. The burrowing owl is considered a federal Species of Management Concern, formerly classified as a Category II species. The U.S. Fish and Wildlife Service reviewed the owl's status in 1998, following the listing of the burrowing owl in Canada as an endangered species. U.S. FWS did not believe listing was warranted and retained their status as a National Bird of Conservation Concern. In many western states, including California, burrowing owls are considered a species of special concern or endangered.

A relatively large population of burrowing owls occurs at Naval Air Station Lemoore (NAS Lemoore), located in the northern limits of the southern San Joaquin Valley. At NAS Lemoore, burrowing owls nest in established wildlife areas, runway buffer strips, and adjacent to runways. Owl conservation activities at NAS Lemoore have included an intensive demographic and space use research program that was part of a state-wide research effort, the protection of burrowing owls during construction activities at a landfill, and the attempted restoration of a native grassland designed to increase the number of burrowing owls nesting in the area. Further, mowing operations, prescribed burning, and the avoidance of discing grasslands has contributed to the large nesting population of burrowing owls at NAS Lemoore. To continue land management activities that are conducive to the protection of the burrowing owl at NAS Lemoore, the Department of the Navy requested we develop a plan for the management of the burrowing owl population at NAS Lemoore. This document represents an update of that original report, from the perspective of an additional decade of research and management experience.

We conducted surveys of burrowing owls at NAS Lemoore in 1997-2000, and again in 2008. We located 43 - 85 active nests each year. They were located in 5 primary areas clustered around the wildlife areas, runway strips in Air Operations, buffer strips near the runways, the capped landfill, and occasionally a nest was seen at the receiver or transmitter site. Many of the owl nest sites were located within 10 m of runways. With few owls likely to be nesting outside of the Station within 50 km, burrowing owls at NAS Lemoore seem to constitute a sub-population, although adult owls may move among populations and the juveniles frequently disperse off-station before breeding.

Factors potentially limiting the population size at NAS Lemoore include availability of nesting burrows, vegetation structure, food availability, and pesticide exposure. The high variability of the abundance of California ground squirrels at NAS Lemoore in some years restricts the number of natural burrows and the dense vegetation limits the ability of burrowing owls to utilize existing burrows. In 2008, California ground squirrels were very abundant throughout most of the areas where burrowing owls have nested and nest boxes were not used. Most of the nest boxes were in disrepair in 2008, but even those that were in good condition were not being used for nesting. We recommend maintaining ground squirrel populations at NAS Lemoore. If management actions are taken that result in sparse ground squirrel abundance where owls have nested, we recommend the system of artificial burrows be maintained to increase the availability of nesting burrows. We also suggest continuing to maintain a short vegetation height in grassland areas. Vegetation structure is determined largely by plant species composition and water availability. Most areas are dominated by dense stands of annual grasses. Currently, these areas are mowed 3-5 times annually to reduce hazards to Air Operations and to reduce fire hazards. However, burrows utilized by nesting burrowing owls have made mowing difficult because of the mounds that are often produced by burrowing owls. Through our discussions with Air Operations and Public Works Transportation Department in 1997, we recommend maintaining vegetation height in grasslands at <12", an increase from the previous guidelines of <6". This will facilitate mowing operations and the existence of natural burrows. Maintaining vegetation at <12" in height will also improve nesting and foraging habitat and will minimize production of seed thereby decreasing BASH in the area.

A large number of agricultural herbicides, insecticides, and other pesticides are used in the San Joaquin Valley. At NAS Lemoore, pesticides are used by local farmers on lands leased through the agricultural out-lease program, as well as in the Station's operations and grounds management. Pesticides that have demonstrated toxic effects to wildlife are discussed in detail in the plan. We provide a list of several pesticides currently used in the San Joaquin Valley and at NAS Lemoore that are particularly toxic to wildlife, including the burrowing owl. We recommend a thorough evaluation of alternative chemicals as well as an emphasis on Integrated Pest Management (IPM). Although DDE, created from the metabolism of DDT, has been banned for use in the United States for over 35 years, research conducted on burrowing owl exposure to contaminants at NAS Lemoore identified high levels of

DDE in some eggs and traces of DDE in all of them. Few other contaminants were identified in these samples. Since the publication of the first edition of this Management Plan, considerable research at NAS Lemoore has been conducted to better characterize the risks pesticides pose to burrowing owls. Although burrowing owls use agricultural fields extensively while foraging, they do not appear to track pesticide applications. In addition, newly fledged owls tended to remain in the fallow areas near their burrows. DDE occurred in some owls' eggs at levels of concern, but the pattern was not consistent from year to year nor among the owls each year. These patterns and prey sampling suggest that the majority of the DDE contamination is originating off-site.

Burrowing owls do not seem to pose a substantial risk to the safety of aircraft due to their small size and lack of flocking behavior. However, many owls live along the runway system at NAS Lemoore, and there are records of dead owls found along the runway that appeared to have died from collisions. We recommend ongoing monitoring of Bird Air Strike Hazards (BASH), and in particular, reporting of all known bird mortalities that resulted from aircraft collision to Public Works - Environmental Division. If research and monitoring results in a decision that burrowing owls pose a risk to aircraft and personnel, then their numbers near the airfields can be reduced by several non-destructive methods, including altering the habitat and blocking burrows that have developed near and adjacent to runways.

The population size of burrowing owls has fluctuated throughout the years at NAS Lemoore for reasons we believe are based on food supply and limited availability of burrows. Burrowing owls at NAS Lemoore have demonstrated a strong capacity to increase rapidly following decline. Because of both the variability of population size that was not directly related to management activities and the capacity to increase, we recommend a management trigger point of 32 pairs, which represents half of the average number of owl nests located during all surveys conducted to date throughout the Station. If the trigger point is met, we recommend a detailed evaluation of causative factors for the owls' decline and management actions to increase the population. Detecting this trigger point will require periodic monitoring. In the past, surveys were conducted to locate all active burrowing owl nests. We suggest developing a more efficient monitoring strategy to detect if the trigger population size is reached; we suggest an initial monitoring frequency of every 5-10 years if there are no changes to ground management.

Proactive steps to manage burrowing owls on public lands in California, such as those taken by NAS Lemoore, will be critical to averting the listing of the burrowing owl under the Endangered Species Act. The steps taken by the US Navy at NAS Lemoore to develop a management plan were some of the first in California. The large number of burrowing owls at NAS Lemoore suggests that this population is important regionally due to the few other known populations of burrowing owls in the northern San Joaquin Valley. This document represents an updated plan for the management of burrowing owls at NAS Lemoore. To be useful, this plan should be updated again in the future with results from ongoing research and monitoring activities. In this sense, this plan represents the next step in the development and use of an adaptive management strategy for burrowing owls at NAS Lemoore. Land management activities at NAS Lemoore may continue to serve as a model for conservation of burrowing owls in agricultural landscapes on private lands in the San Joaquin Valley. Regional efforts towards burrowing owl protection should ensure a safe future for the species and avert a need to formally list them under the Endangered Species Act.

NAS Lemoore has supported a large number of owls in part due to the agricultural activities while ensuring safe areas for nesting. The greatest change since 1997 to current conditions (2008) and that expected for the near- and long-term future is the loss of irrigation water from Westlands Water District. This will result in a major change in crop type and vegetative productivity, all of which will result in lower densities of burrowing owls. If fields are fallow and receive no irrigation water, we anticipate lower owl densities that approximate that found in non-irrigated grasslands. Lower population numbers, however, can still result in a healthy population and mimic that found in more natural grasslands. Appropriate management of the fallowed fields will be required to ensure the use of the fields for foraging and nesting by burrowing owls.

Acknowledgments

The work presented in the initial management plan and this updated version would not have been possible if it were not for the assistance of numerous talented professionals. Mr. John Crane, NAS Lemoore, was instrumental in furnishing us information on acreage estimates and pesticide use, as well as sharing the results of the soil samples which we presented in this report. Importantly, Mr. Crane provided logistical support which made our field activities possible. The staff at NASL also assisted in providing us information on mowing activities and BASH. Air Operations staff and security provided critical logistic support that allowed us to work safely near the runways. Mr. John Crane, Mrs. Noreen Roster (US Navy, EFA-West), and Mr. Richard Rugen (US Navy, EFA West), provided helpful comments that improved the initial management plan and assisted with directing the plan so that it would be most useful for managers at NAS Lemoore. Dr. Ellen Cypher provided us assistance with revegetation plans and helpful discussions on the vegetation at NAS Lemoore. Dr. Ted Donn, Tetra Tech, Inc., generously provided the digital GIS database that we used for mapping purposes. The Updated Management Plan was made possible by a grant from Naval Facilities Engineering Command, Southwest to Oregon Wildlife Institute, Cooperative Agreement No. N62473-07-2-0033. We thank Mr. John Crane and Mr. Rob Palmer for making this update possible and for their assistance throughout the project, from design to review.

SECTION 1

Introduction

1.1 Motivation for an Adaptive Management Plan

The western burrowing owl (*Speotyo cunnicularia*) is considered a National Bird of Conservation Concern, formerly classified as a Category II species when that classification existed. The U.S. Fish and Wildlife Service completed a status review in 2003 (Klute et al.2003), following the listing of the burrowing owl in Canada as an endangered species. In many western states, including California, burrowing owls are considered a species of special concern, critical concern, or endangered (Klute et al. 2003). The California Department of Fish and Game is developing a state-wide conservation strategy to prevent further declines (E. Burkett, California Dept. of Fish and Game, personal communication). In California, where large numbers of resident (breeding) and wintering owl populations exist, populations appear to have declined along the south coast in particular, but increased over historical levels in the Imperial Valley. Many of the remaining owls remain on private lands and thus are vulnerable to changes in land use and other pressures (Gervais et al. 2008). Because of these concerns, recent management and research efforts have been initiated to find ways to prevent further declines, and thus avert the need for federal listing of the species under the Endangered Species Act.

NAS Lemoore is located in the northern limit of the southern San Joaquin Valley. A large proportion (over 20%) of the breeding populations of burrowing owls in California exists in the San Joaquin Valley (DeSante et al. 2007). Most of the valley is in intensive agriculture, with few grasslands remaining. This has resulted in a large number of species listed as threatened and endangered (Williams et al. 1992; USFWS 1997). Because of the large number of listed species, the San Joaquin Valley is an area of concern and one of the target regions for conservation (Noss et al. 1995).

A relatively large population of burrowing owls inhabits NAS Lemoore. They are found in established wildlife areas, runway buffer strips, adjacent to runways, and in other areas where patches of grassy habitats exist, including the capped landfill and the transmitter and receiver sites. To continue land management activities that are conducive to the protection of the burrowing owl at NAS Lemoore, the Department of the Navy requested a management plan for burrowing owls. We completed the original management plan in 1998. This document represents an update of that plan.

Adaptive management plans assume that we will learn more about the system as we continue research and carefully monitor the effects of management practices. Plans are expected to be modified to take into consideration the new findings. Research on burrowing owls at NAS Lemoore and elsewhere during the last decade has provided information that can augment this plan. This type of strategy should prove to be effective and cost efficient. Under such an approach, we offer this document as an updated set of recommendations for the management of burrowing owls, while ensuring the national defense mission of NAS Lemoore.

1.2 Current Activities to Promote Owl Conservation

NAS Lemoore has one of the largest owl populations in the San Joaquin Valley. Understanding the factors that have resulted in such a large population will provide critical guidance for implementing science-based conservation strategies throughout the Valley. Much of the research conducted on burrowing owls in California has taken place at NAS Lemoore. The first toxicology study conducted on burrowing owls in California was supported, in part, by the Navy and conducted at NAS Lemoore. The burrowing owl demography and space use study was conducted at NAS Lemoore and three other study sites in California (Rosenberg et al. 2007). In 2006-2007, studies were conducted at NAS Lemoore and elsewhere to understand migration patterns (C. Conway, pers. Commun.). In addition, a native grassland restoration project on the capped landfill at NAS Lemoore was attempted. Within that area, six clusters of 3 artificial burrows were established to augment the owl population. Owls have successfully nested in most of these burrows. The activities conducted at NAS Lemoore to promote conservation of burrowing owls serve as a model example of efforts to promote the successful integration of agricultural production and wildlife conservation. These and similar efforts will assist in averting the need for the listing of the burrowing owl under the Endangered Species Act.

1.3 Land Use Patterns at NAS Lemoore

Based on discussions with Mr. John Crane (Public Works – Environmental Division, NAS Lemoore), land use of NAS Lemoore's 18,784 acres is allocated to five principle uses: (1) Air Operations, (2) Administration, (3) Housing, (4) Recreational and Wildlife, and (5) Agriculture. Approximately 75% of the land is allocated to agricultural production (14,119), the primary use of land in the San Joaquin Valley. During our studies from 1996-2001, cotton was the principal crop at NAS Lemoore, covering approximately 9,244 acres (1998 crop data, J. Crane, Lemoore, NAS), representing 65% of the area in agricultural production. As of the writing of this updated management plan, crop production has changed drastically since our studies, and due to limited availability of irrigation water, many acres are being fallowed (J. Crane, NASL, pers. commun.). Much of the Air Operation's buffer strips and uncultivated land in the receiver and transmitter areas provide potential nesting habitat to burrowing owls. In addition, approximately 50 acres provide habitat for burrowing owls and other wildlife at the grassland site created from capping the landfill and maintaining the area in grass and forbs (see also Section 4). Areas dedicated to wildlife habitat include approximately 406 acres, which includes both grasslands (200 acres) and wetlands (206). In addition, there is a total of approximately 846 acres in mowed grass areas surrounding air operations grasslands. From the information on grassland acreage in 1997 (J. Crane, personal communication), we estimate a total of 1,070 acres suitable as nesting habitat, not including the small patches of grass separating runways, taxiways, and buildings in Air Operations. Approximately 850 acres was fallowed following the fencing of Air Operations for security reasons; these acres can also be considered burrowing owl habitat both for nesting and foraging. Based upon our findings from the burrowing owl research program, crop fields, runways, taxiways, and roads are all used for foraging in addition to the grasslands. Thus, most of the base provides habitat for either nesting or foraging activities.

We have identified 8 areas in which burrowing owls nest at NAS Lemoore (Fig. 1). The North and South Airfields include large mowed grasslands within and adjacent to Air Operations. The area inside Air Operations contains relatively large patches of grasses where most of the burrowing owls nest. The receiver and transmitter sites are mowed grassland patches, totaling 130acres. The East Wildlife area contains small patches of grassland and wetland habitats. Tumble Weed Park is a medium sized grassland (86 acres) and serves as the primary site for the Fresno Kangaroo Rat, and is managed for native plant species. This site has had several prescribed burns and has been the most extensively studied site on the base in terms of the floral composition and response to treatments. Treatments have included grazing, fire, and establishment of native vegetation. The capped landfill now is dominated by introduced grasses and forbs. In 1998, native vegetation was established (see Section 4) although in subsequent years the invasive annuals prevalent in other areas of the station became dominant.

1.4 Overview of the Burrowing Owl Population at NAS Lemoore

A partial survey during the breeding season in 1991-1993 coordinated by The Institute for Bird Populations documented 9 pairs on the base (The Institute for Bird Populations, unpublished data; also reported in Morrison 1993a). These numbers were determined by surveys of areas of suspected occurrence, and were known as only a minimum number since the entire base was not surveyed. During fall 1993, Morrison (1993a) located 21 active burrow sites, and estimated there to be about 33 adults. Again, these estimates provided minimum numbers because the entire base was not surveyed. In 1996, 15 pairs of owls were located during the breeding season as part of the toxicology study conducted by Gervais et al. (1997). These numbers were again the minimum known, as only opportunistic surveys were conducted with a goal of finding a sufficient number of owls for a toxicological study (Gervais et al. 2000).

As part of the original management plan, we conducted what we believe to be a complete census of the breeding population of burrowing owls at NAS Lemoore in 1997. We found 54 active owl burrows in which nesting was attempted (see Section 3) in 1997. Subsequent censuses identified 63 nests in 1998, 85 nests in 1999, and 63 again in 2000. Most recently, 43 active nests were located during a census in 2008. Nests have been located at some point in all grassy areas of the Station, excluding only the ammunition area and the residential portion of the Station (Fig. 1). A proportion, if not all, of the breeding owls at Lemoore are year-long residents; we have resighted owls marked during the breeding season during following winters. We also found that young of the year may nest the following year at sites adjacent to their natal burrow. With few known clusters of owls located within 50 km of NAS Lemoore, burrowing owls at Lemoore likely constitute a sub-population. Immigration and emigration clearly occur, but the sub-population is large enough so that internal movements of young and adults strongly influence the population's dynamics Further, the large number of breeding pairs suggests that this population is important regionally due to the few other localized populations of burrowing owls in the northern San Joaquin Valley.

However, the NAS Lemoore population clearly does not exist in isolation from other sub-populations within the state. Experimental work in the Imperial Valley revealed that nest failure or loss of a mate was associated with movements of owls of greater than 400 meters (Catlin et al. 2005). It is worth noting that in the Imperial Valley, suitable habitat is essentially continuous. Movement in particular was associated with nest failure (Catlin et al. 2005, Catlin and Rosenberg 2008, Rosier et al. 2006). NAS Lemoore represents islands of suitable habitat in a largely unsuitable matrix. Owls dispersing away from either natal territories or from breeding territories following nesting failure are likely to leave the station entirely. Dispersal into other subpopulations was demonstrated in 2000, when an owl banded as a nestling at NAS Lemoore in 1999 was recaptured as a breeding adult at Carrizo Plain, approximately 130 km away (Rosenberg et al. 2007).

Nest burrows have been mapped each year fieldwork was conducted by researchers for the Burrowing Owl Research Project (Fig. 2). These maps indicate that owls are largely restricted to the area within and adjacent to Air Operations, and that the more distant wildlife areas including Tumbleweed Park are more variable in their use. Although some owls have utilized the artificial burrows that were placed in 1998 during the Eagle Scout project, many of these have remained empty. However, nearly every burrow, natural or artificial, was utilized during the 1999 breeding season, when ground squirrels were not as abundant and owls were at their peak abundance.

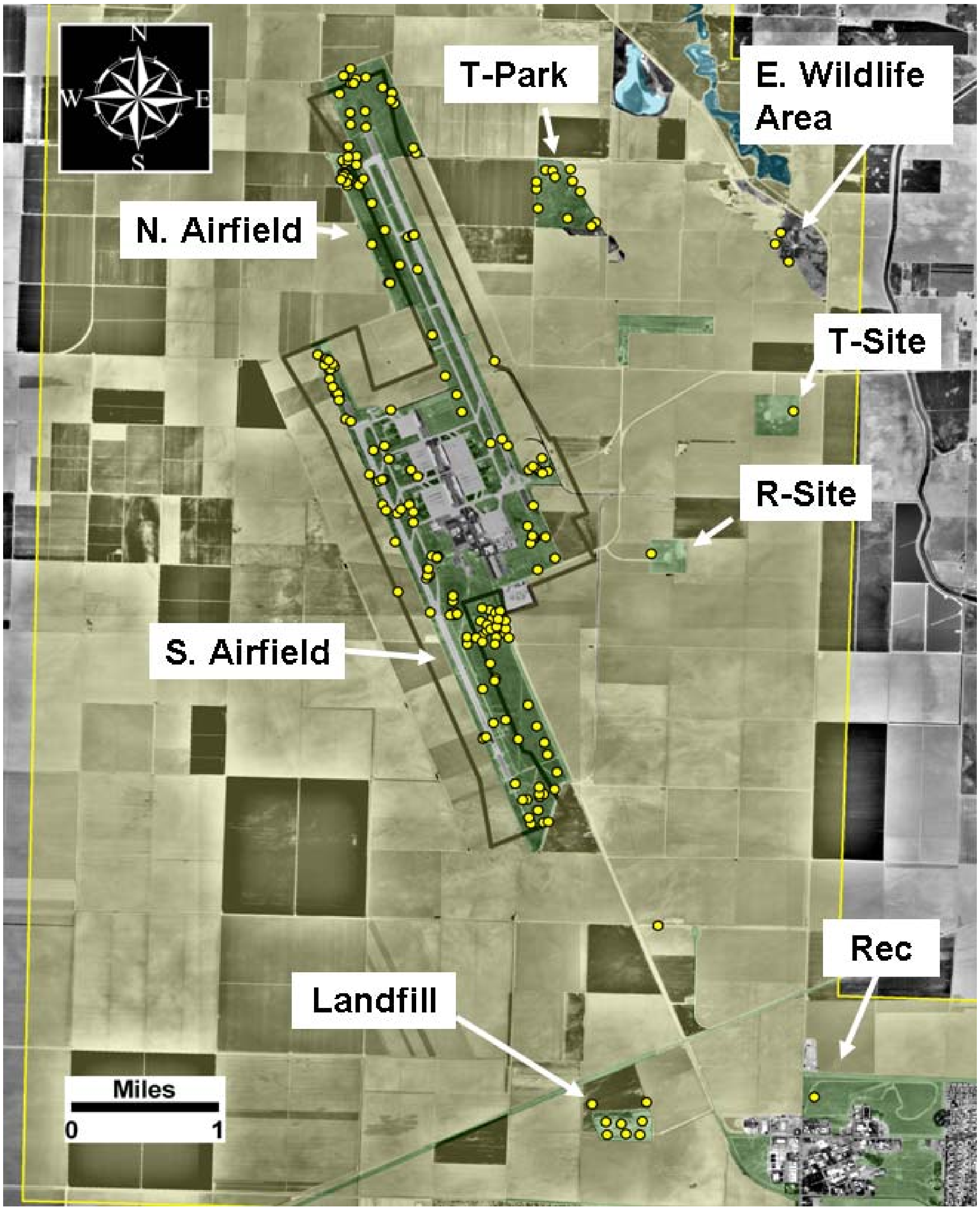
The 1999 breeding season was marked by an outbreak of California voles (*Microtus californicus*). Owls nested in parts of the station they had not used previously, and did not use again in at least two subsequent years. Nearly every known burrow was used either as a satellite burrow or for nesting. The abundant rodent prey led to very high numbers of fledglings that year as well (Gervais and Anthony 2003, Rosenberg et al. 2007). Vole numbers clearly contributed to the high productivity, as egg laying began in February, nest boxes were full of cached vole carcasses, owlets were heavier, and more fledged than previously (Rosenberg et al. 2007). In addition, pellets indicated that owls were consuming roughly double the biomass of voles than in previous years (Gervais and Anthony 2003). Although this population of owls lives in a very highly modified system, natural processes such as rodent outbreaks still exert strong influences on their demography and ultimately, population persistence.

These patterns highlight the importance of habitat that may remain unused in ordinary years, but is necessary to accommodate local population increases in response to particularly favorable conditions. Burrowing owls are relatively short-lived, and lay many eggs. Recruitment pulses resulting from good years may be critical for population persistence (Gervais et al. 2006). Therefore, providing habitat modifications to enhance acceptability to burrowing owls in areas that are only occasionally used may still be of great benefit, and may even be necessary for long-term conservation. This also suggests that suitable habitat may remain empty during some years but be critical to population maintenance during the very good years. The capped landfill, Tumbleweed Park, and the receiver and transmitter site may all be important to the population in this way.

1.5 Development of the Management Plan

This document was prepared with the goal of providing an initial plan for the management of burrowing owls at NAS Lemoore. We realize that the Navy's first concern must be national defense and that the agricultural out-lease program is an important component of the management of the land base at NAS Lemoore. Therefore, we have included only recommendations that we believed would accommodate these other critical objectives. Further, goals of land allocation on public lands may vary through time. As biological diversity increasingly becomes an issue in the San Joaquin Valley, and public lands are seen as a means to provide for this need (USFWS 1997), the allocation of lands devoted to agriculture versus wildlife may change. Economics may motivate a change in farming practices, for example, from high to low water use, with resulting changes in crops or even in the relation of crops to livestock. The result of changes of land allocation will alter the management of grassland species such as the burrowing owl. Additional research conducted locally and regionally should improve our knowledge of these systems. The knowledge gained at NAS Lemoore on the interplay between agricultural production and wildlife conservation should be of particular utility to the management of lands in the region. Conservation of grassland species in the San Joaquin Valley will be best served with a regional conservation strategy.

Figure 1. Active burrowing owl nests located from 1997-2008 surveys.



SECTION 2

Natural History of Burrowing Owls

2.1 Species Status

Burrowing owls were once widespread and fairly common over western North America. In recent decades, however, a number of populations appear to have declined or in some cases, disappeared altogether. Burrowing owls are now endangered in Canada (Klute et al. 2003), and have declined in many parts of the United States (James and Espie 1997; DeSante et al. 1997, 2007; Klute et al. 2003). The species is now a federal and California state species of concern, and listed as endangered or threatened in a number of other states (Klute et al. 2003). The US Fish and Wildlife Service has not listed the burrowing owl and the California Fish and Game Commission denied a listing petition to list the species under the California Endangered Species Act in 2003. However, concerns over the status of the species in California and elsewhere remain (Klute et al. 2003, Shuford and Gardali 2008), with the goal that voluntary management actions will alleviate the need to list the species under the Endangered Species Act.

Depending on the population, burrowing owls are either year-round residents or migratory. Migratory populations appear to be primarily from the more northern parts of the species' range, while owls in California and east through New Mexico remain throughout the winter (Brenkle 1936, Ligon 1961, Thomsen 1971, Haug et al. 1993, Rosenberg et al. 2007), or appear to wander within the region during the winter months (Coulombe 1971, Martin 1973, Botelho 1996). Little is known about the winter ranges of migratory populations (Haug et al. 1993), although migratory owls are thought to augment resident populations in California during the winter months (Coulombe 1971), and it appears that the owls breeding the furthest north migrate the furthest south (James 1992). Christmas Bird Count data indicate that California is by far the most important state for burrowing owls in winter (James and Ethier 1989). The burrowing owl population at NAS Lemoore is composed of year-round resident breeding pairs, with possible winter migrants from more northern populations. Recent research conducted at NAS Lemoore and elsewhere (C. Conway, personal communication) on migration using population genetics and isotope analysis may shed light on winter population composition at NAS Lemoore in the future.

2.2 Distribution in California

The range of the burrowing owl in California extends through the lowlands south and west from north central California to Mexico, with small, scattered populations occurring within the Great Basin and the desert regions of the southwestern part of the state (DeSante et al. 2007, Gervais et al. 2008). The breeding range is essentially similar to historical boundaries although local abundances have shifted considerably with land use changes and increasing urbanization along the California coast (DeSante et al. 1997, 2007; Gervais et al. 2008). Breeding populations appear to be extirpated from central and southern coastal regions. Agricultural conversion in the Imperial Valley has led to great increases in burrowing owl numbers over what was likely there when the region was still a non-irrigated desert (DeSante et al. 2004); this is likely to be the case in the Central Valley although to a lesser extent (Gervais et al. 2008 and references within). Statewide surveys including the Christmas Bird Count and the Breeding Bird Survey offer conflicting or inconsistent data on trends (Gervais et al. 2008). Future work will no doubt address these data gaps and inconsistencies.

2.3 Home Range, Site Fidelity, and Space Use

Home range size is variable both among individuals and between years (Haug and Oliphant 1990, Gervais et al. 2003). Haug and Oliphant (1990) estimated home ranges in Saskatchewan, Canada to vary from 0.14 km^2 to 4.81 km^2, with the largest ranges estimated for late June and early July. A resident population in southern California had much smaller home ranges (C. Winchell, USFWS, personal communication). Winter ranges for these owls were four times the size of breeding ranges, and territoriality appeared to be absent outside of the breeding season (C. Winchell, USFWS, personal communication). During previous studies, owls were detected up to 2.7 km from their burrows during nocturnal foraging in Saskatchewan (Haug and Oliphant 1990), and up to 400 m in California (C. Winchell, USFWS, personal communication). Our recent research at NAS Lemoore suggests that breeding home ranges tend to be quite large, with foraging trips extending beyond 3 km from the nest site. Mean home range sizes varied widely by individual owl even though only breeding males were radio tracked. Home range sizes based on 9 male owls averaged 177 hectares in 1998 (95% CI 52-302 hectares) using the minimum convex polygon method, and 189 hectares in 1999 based on 22 owls (95% CI 122-256 hectares) (Gervais et al. 2003). Owls range much more widely at night than during the day.

During the breeding season, the owls' activity is tightly centered around the nest burrow. Owls defend the area immediately around the nest burrow (Martin 1973, Zarn 1974; Gervais and Rosenberg, unpublished data). Defense of foraging areas is less clear, with some researchers indicating nonexclusive use of foraging areas (Thomsen 1971, Martin 1973, Zarn 1974), and others indicating some territoriality, such as the generally non-overlapping home ranges of owls in Saskatchewan (Haug and Oliphant 1990). Foraging activities at NAS Lemoore overlapped extensively (J. A. Gervais, unpublished data).

Although breeding season activities center around a nest burrow, owls will use additional burrows within their home range if available. Owlets will move from the natal burrow to others within the home range (Martin 1973, Thomsen 1971, Henny and Blus 1981, Ronan 2002, J. A. Gervais personal observation), and parents carry food to and perch at the auxiliary burrow containing some of the young (J. A. Gervais, personal observation). The use of numerous burrows by an owl family may be an anti-predation strategy; excavation of a burrow by a predator may not result in the loss of the entire brood. In the Carrizo Plain, we have noted that entire families moved from 25-120 m away from natal burrows, despite the existence of abundant ground squirrel burrows in the area (Ronan 2002).

Young owls are known to make forays away from their natal nest burrow prior to starting migration in North Dakota and Canada. In North Dakota, juvenile owls roosted away from their natal burrow before they could fly, but did not actually migrate until they were 68-108 days old. Prior to migration, these juveniles were located 20-300 m from their natal nest burrow (Davies and Restani 2006). In Canada, the habitat patch size containing the natal nest appeared to influence juvenile owl movements prior to migration, such that owlets in small patches moved less far than those from large patches (Todd et al. 2007).

Radio tracking and band resighting have revealed that burrowing owl juveniles at NAS Lemoore have dispersed from their natal nests by late August; one young owl was relocated at the opposite end of the station, territorial calling from a burrow that had been occupied by a nesting pair that had fledged young that year. Prior to dispersal, young owls were found primarily in grass habitat and only occasionally out in the agricultural matrix. This is consistent with findings that the owlets were reluctant to venture across unsuitable habitat (Todd et al. 2007). Finally, an owlet banded at Lemoore was recaptured the following year as a breeding adult at Carrizo Plain, approximately 130 km away (Rosenberg et al. 2007).

The management implications of this new information pertain primarily to the importance of tolerating ground squirrels when possible as these animals are the most effective means of providing the scattered burrows the young owls use on their way to full independence. In addition, surveying for owls in late summer will not be efficient, as it appears that even resident birds either temporarily range more widely, or otherwise become far less easy to detect. Surveys performed in late summer will severely undercount even the resident owls.

During the nonbreeding season, burrowing owls remain closely associated with burrows, as they continue to use them as refuges and roost sites throughout the year. Resident populations will remain near the previous season's nest burrow at least some of the time (Coulombe 1971, Thomsen 1971, Botelho 1996, LaFever et al. 2008). This is true of the burrowing owl population at NAS Lemoore (Rosenberg et al. 2007).

Research in the Imperial Valley in the non-breeding season revealed that resident owls spent considerable time roosting in their burrows, particularly the females (LaFever et al. 2008). Although technically burrows are legally protected only during the nesting season, disruption of any burrow should be done with great care at any season of the year if there is known or suspected owl use. Radio-tagged owls at NAS Lemoore appeared to range widely at the end of the breeding season, but then were seen at their nest burrows in winter (J. A. Gervais, unpublished data). Owls were also observed taking shelter in burrows that has served as nest burrows for other pairs, suggesting that territoriality and burrow defense are relaxed in the non-breeding season. Both male owls and female owls will retreat underground in the winter months at NAS Lemoore. Overall, burrows are clearly important at all seasons of the year and can never be assumed to be unoccupied.

Although natural burrow availability will vary depending on ground squirrel activity and the collapse of old burrows, reuse of nest burrows occurs in both migratory and resident owl populations. Owls in Idaho renested in the same burrow particularly if the previous year's breeding attempt was successful (Belthoff and King 1997); in other instances, migratory owls returning to the same breeding territories moved to nearby burrows (Belthoff and King 1997). Resident populations also appear to frequently reuse the previous year's breeding burrow. At NAS Lemoore, we have found that burrowing owls will reuse burrows that were formerly occupied by other pairs (Gervais and Rosenberg, personal observation). This is likely due in part to the scarcity of burrows in some areas of the Station during the years when reuse occurred. Females seem more likely to change territories than males in some populations (Botelho 1996, Belthoff and King 1997, Rosenberg and Gervais, unpublished data), but females exhibited more territory fidelity than males in Colorado (S. Lutz, Univ. of Wisconsin, personal communication). At Salton Sea National Wildlife Refuge and at NAS Lemoore, adult females have been found nesting in their natal burrows (Rosenberg and Gervais, unpublished data). The birds do not mate for life, although pairs will remain together for more than one breeding season in resident populations (Catlin et al. 2005, Rosenberg et al. 2007). Preliminary results of our research at NAS Lemoore suggest high breeding-site fidelity. Adults are likely to nest at or adjacent to their previous year's nest site and young from the previous year have established nest sites nearby (<300 m) their natal site.

More recent work in the Imperial Valley has indicated that although owls tend to remain in the same nest or at least on the same territory with the same mate, nest failure is likely to lead to dispersal of either the male or the female owl. In addition, owls were likely to disperse long distances following the loss of their mate (Rosier et al. 2006, Catlin et al. 2005). The Imperial Valley contains vast tracts of suitable habitat with high density of owls, and dispersing owls are not forced to travel long distances to find a new territory or mate. Conversely, the small habitat patches available at NAS Lemoore are likely to force dispersing owls to either remain close to their previous territory, or to disperse off station and out of the area. These findings have important management implications that will be discussed throughout the Plan.

2.4 Habitat

In their native environment, burrowing owls are restricted to grassland and desert ecosystems. They are found in open habitats with suitable nesting burrows, usually with short grasses and sparse shrubs, and will use washes and arroyos for nesting (Coulombe 1971, Zarn 1974, Rich 1985, Haug et al. 1993, Botelho 1996). Owls generally avoid thick, tall vegetation and brush (Rich 1986, Green and Anthony 1989, Plumpton and Lutz 1993a). They also appear to avoid areas near trees, perhaps because trees provide roosting and perching sites for other raptors, many of which will prey on burrowing owls (L. A. Trulio, personal communication).

Burrowing owls have proven to be quite adaptable, and have nested successfully at airports (Thomsen 1971) including military installations (e.g., NAS Lemoore and NAS North Island), and in areas adjacent to intense agricultural activity. Burrowing owls will readily adopt suitable nest boxes, and have also initiated nesting in irrigation pipes, dry spring boxes, and even the interior of a buried car (Green 1988). Burrow availability appears to be the major limiting factor in disturbed habitats within the species' range. Owls at NAS Lemoore have been found nesting in culverts, burrows of ground squirrels, abandoned coyote and badger dens, in piles of concrete rubble, and under runway equipment, as well as in artificial burrows (Rosenberg et al. 2007).

Foraging habitat includes agricultural fields, grazed pastures, and fallow fields within disturbed habitats (Haug and Oliphant 1990). Stomach contents indicate that owls will also use irrigation ditches and canals (York et al. 2003). At NAS Lemoore, breeding male owls foraged extensively in agricultural fields and in runway easements in addition to the wildlife areas. The best predictor of foraging location however was distance from the nest, with most time spent foraging within 600 m of their nest (Gervais et al. 2003), similar to foraging behavior in the agricultural Imperial Valley of California (Rosenberg and Haley 2004). This is not surprising given that burrowing owls take one prey item at a time back to the nest for their young. There was no apparent selection for grass habitat, nor avoidance of cropland, although individual owls' selection varied (Gervais et al. 2003). Owls were also frequently detected foraging within Air Operations, along Reeves Road and the jog path, and were also observed hawking insects at the security lights by the Air Operations main gate. The owls do not appear to be territorial while foraging, and clearly are highly opportunistic of sources of prey provided they are relatively close to the nest burrow, at least during the breeding season. In conclusion, the most specific habitat requirement for burrowing owls is the presence of a burrow that occurs in relatively short vegetation, away from obstructions or tall vegetation.

2.5 Diet

Burrowing owls are ideal examples of opportunistic generalists. Prey items include a staggering array of taxa, including mammals, birds, reptiles, amphibians, fish carrion, insects, spiders, centipedes, scorpions, crayfish, and molluscs, as well as prey items of large species that were scavenged. Pellets also contain inedible items such as sand, rocks, and fragments of glass and plastic (Gervais et al. 1997). Small mammals tend to dominate the diet in terms of biomass although insects make up the majority of individual prey items (Thompson and Anderson 1988, Green et al. 1993, Plumpton and Lutz 1993b). There appears to be a seasonal shift from mammals to insects throughout the spring, perhaps due to increasing insect abundance (Green and Anthony 1989, Haug et al. 1993).

We have documented burrowing owls at NAS Lemoore preying on a number of rodent species, including young pocket gophers (*Thomomys bottae*) and California voles (*Microtus californicus*), although we have never verified that burrowing owls prey on the endangered Fresno kangaroo rat (*Dipodomys nitratoides*). However, owls most certainly do prey on this species when available. Sparrows, horned larks, and meadowlarks were consumed, as were western toads. Insects in the diet were primarily grasshoppers and crickets (Orthoptera), and beetles (Coleoptera). We also found centipedes at burrow entrances on nights that farmers were conducting field operations and apparently driving the centipedes to the soil surface. Owls will also scavenge the carcasses of species too large to be prey, such as carp and large shorebirds (e.g., at the Salton Sea National Wildlife Refuge, Rosenberg and Gervais, unpublished data).

Owls have also been documented eating each other, in the form of adults preying upon chicks. One adult owl was videotaped killing one of its chicks and feeding it to the remaining young (Botelho 1996), and the bands of chicks have been recovered in owl pellets at Lemoore (D. K. Rosenberg and J. A. Gervais, unpublished data). It is not clear in these cases whether the young owls were scavenged or predated, but we suspect the latter when bands indicated that the chick was from another nest.

Biomass of rodents, particularly California voles, is linked to reproductive success and survival in burrowing owls (Gervais and Anthony 2003). These rodents underwent a population explosion in the winter and spring of 1999 following a prolonged wet spring the previous year. Owls clearly capitalized on this prey species when available, as biomass of voles in pellets doubled in 1999 relative to other years (Gervais and Anthony 2003). Nest boxes were found with up to a kilogram of freshly dead voles that spring (D. K. Rosenberg, unpublished data). The effects of this abundant, high-quality food source affected survival, reproduction, and the impact of contaminants, and are discussed in detail in the appropriate sections below.

2.6 Survival and Reproduction

Longevity in wild burrowing owls is essentially unknown. The record currently goes to one banded wild owl which survived to the age of 8 years 8 months (Kennard 1975). The oldest owl of known age during the Burrowing Owl Research Program's study was 6 years, which was the maximum possible given an adult was caught in the beginning of the study (Rosenberg et al. 2007).

Return rates of bands may be used to give conservative estimates of survival in the absence of other data. Return rates of banded birds varied from 33-58% for adult owls in Canada (Haug et al. 1993). Estimates of survival from band return rates for migratory populations in particular will be negatively biased, because birds may have returned to breed outside the study area and would therefore escape resighting efforts. Little band resighting had been done in the United States prior to the Burrowing Owl Research Project in California. Thomsen (1971) estimated adult survival rates of 81% in a resident population based on band resighting in an owl population numbering 21 adults, with chick survival roughly 30% based on 30 banded juveniles (Thomsen 1971). In central California, Johnson (1997) estimated an annual survival rate of 0.42 for adults based on band returns.

The Burrowing Owl Research Program estimated survival rates using both mark-recapture techniques and radio telemetry (Carrizo), including at NAS Lemoore (Rosenberg et al. 2007). Estimates of survival from mark-recapture are confounded by emigration. Reproductive estimates are hampered by the inability to count young precisely if the brood is not in an artificial burrow (Gorman et al. 2003). Research into dispersal was carried out in the Imperial Valley and Carrizo Plain (Catlin et al. 2005, Rosier et al. 2006), and a study of the bias involved in counting number of young seen above ground as an estimate of reproductive success was completed at NAS Lemoore (Gorman et al. 2003).

Survival rates uncorrected for emigration varied by site and year (Rosenberg et al. 2007). The only site with strong year effects was NAS Lemoore, where survival rates were estimated as 0.59 ± 0.18 in 1997, 0.65 ± 0.13 in 1998, 0.63 ± 0.12 in 1999, and 0.33 ± 0.12 in 2000. The peak in survival occurred over the beginning of the vole population peak and the very low rates were associated with the year following the vole population crash. Burrowing owls are more likely to move from their nesting territory following reproductive failure or the loss of their mate (Catlin et al. 2005). It is likely that the 2000 estimates are biased particularly low due to greater emigration that year. Distances traveled by dispersing adults varied, on the order of a few hundred meters to over 50 km (Catlin et al. 2005, Rosier et al. 2006). Given the relatively small size of the Station and relatively large owl population, dispersing adults are likely to move off-station. Clearly, an owl that disappears from a nest site between breeding seasons or after nest failure cannot be assumed to be dead.

Reproduction in burrowing owls begins the year after hatching (Haug et al. 1993). The onset of egg laying varies according to the geographic region, with clutch initiation occurring in mid-late March in New Mexico (Martin 1973) and in the San Joaquin Valley (Rosenberg and Gervais, unpublished data), early to late April in Oregon (Henny and Blus 1981) and northern California (Thomsen 1971), and mid-late May in Saskatchewan (Haug et al. 1993). Florida burrowing owls have been documented to raise more than one brood a year (Millsap and Bear 1990), but this does not appear common for the western burrowing owl (Gervais and Rosenberg 1999), although clutches destroyed early in the season will be replaced (Haug et al. 1993; Catlin and Rosenberg 2008). Two pairs of burrowing owls at NAS Lemoore have been documented to raise second broods (Gervais and Rosenberg 1999) but this occurred only in the year of very high vole densities and is not likely to be an important factor in population dynamics. The varied timing of egg-laying and courtship in the species has prompted the California Department of Fish and Game to consider February 1 to August 30 as the nesting season for burrowing owls in the state (California Dept. Fish and Game 1994). In 1999, back-dating of hatching eggs suggested that burrowing owls initiated clutches in early February (J. A. Gervais, unpublished data).

Burrowing owl nest burrows are often distinctive, due to the species' habit of lining the entrance and tunnel with cow manure (Green 1988), coyote dung, insect parts, cotton, dead toads, plastic, tin foil, and other rubbish (Rosenberg et al. 2007). Manure and dung may serve an anti-predatory function, perhaps by masking the owls' odor from mammalian predators such as badgers (Martin 1973, Green and Anthony 1989). The habit is so strong that when the dung is removed, the owls promptly replace it (Martin 1973, Smith and Conway 2007). Much of the material used in human-altered environments has little odor and is actually very conspicuous, such as cotton and foil bits. Although cotton was the most frequent nest decoration at Lemoore, this population of owls appears to be fairly safe from ground predators, since large snakes, weasels, and badgers are either very rare or absent. We never observed any sign of coyotes digging out occupied nests. Owls may decorate nests to indicate occupation of a burrow; initiation of nest decoration typically occurs after the owls begin nesting.

Other researchers have explored the function of nest decoration. Owls whose nests were marked by cow dung consumed many more dung beetles than owls whose nests had been stripped of manure. The authors suggested that the manure may be used to attract food. They found no support for the hypothesis that the nest decorations masked the nest from predators (Levey et al. 2004). A more thorough test of four alternative hypotheses found support for increased arthropod prey, although not all material placed at burrows was likely to be attractive (Smith and Conway 2007). Alternatively, the material may serve to warn neighboring owls that the burrow is an active nest. Nest decorations did not seem to camouflage the nests, nor attract mates (Smith and Conway 2007).

At NAS Lemoore, decorations became evident after egg-laying and neighboring owls were seen to avoid entering decorated entrances when flushed toward a neighbor's nest burrow, suggesting that the habit serves as an "unwelcome mat" for neighbors. At NAS Lemoore, dung is a frequent nest decoration, but cotton, tomatoes, aluminum foil, food wrappers, and other rubbish were also common. Burrows also accumulated dried toad carcasses as the season progressed. Owls consume toads by opening the carcasses at the throat and removing the entrails, leaving legs and skin of the body intact. Nest decoration can be very helpful to human investigators searching for nests, but burrows containing eggs were found that had no external decorations at all. Conversely, every decorated burrow found contained eggs, nesting material, or shells, suggesting that some of these nests had subsequently been predated but had once been active nest attempts. In summary, nest decoration is a very good indicator of a nesting attempt, but not all nesting attempts are so marked.

Females lay up to 12 or even 14 eggs, with average clutch size varying according to geographic region (Haug et al. 1993, Todd and Skilnick 2002), but ranging from 7-9 eggs (Ehrlich et al. 1988, Haug et al. 1993). Only females develop a brood patch and incubate; laying rate and the onset of incubation remain unclear, with some researchers documenting laying rates in excess of 1 egg a day (Henny and Blus 1981), and others documenting much lower rates (Olenick 1990). Incubation may begin with the onset of laying (Thomsen 1971, Martin 1973), or be delayed until the clutch is complete (Haug 1985, Henny and Blus 1981), but is more likely that incubation starts prior to clutch completion (Haley 2002, Rosenberg et al. 2007). Incubation lasts between 21 and 30 days (Ehrlich et al. 1988, Haug et al. 1993). Hatching success is variable, with rates between 55-90% recorded (Haug et al. 1993). Repeated examination of artificial burrows in the Imperial Valley revealed that one egg frequently did not hatch (Haley 2002). It seems likely that similar rates should occur at NAS Lemoore.

Young owlets are altricial, partially covered with down, and weigh between 6 and 12 grams at hatching (Haug et al. 1993). Females brood the young until they are capable of thermoregulating on their own (Haug et al. 1993). Young are fed within the burrow while they are still very young, and then move to the mouth of the burrow for food deliveries from their parents at about 10-14 days of age. Chicks have been known to move among burrows at this time (Henny and Blus 1981). They are capable of short flights by week 4, and fly well at week 6 (Haug et al. 1993), although chicks remain near the burrow at least until early September at NAS Lemoore (J. A. Gervais, personal observation).

Males feed females during incubation, and bring food for both the female and the chicks during the early nestling period (Haug et al. 1993). Thereafter, males bring food and present it either directly to the chicks (J. A. Gervais, personal observation), or to the female, who either consumes it herself or feeds it to the chicks. Both parents forage for the young in the more advanced nestling stage (Haug et al. 1993, J. A. Gervais, personal observation); the onset of this is probably dependent on food supply. Chicks will emerge from the burrow and mob the incoming adult for food (Botelho 1996, J. A. Gervais, personal observation); adult owls do not appear to discriminate among chicks for feeding purposes, with the first chick to reach the adult claiming the food (Botelho 1996). Brood reduction through selective feeding does not appear to occur in this species (Botelho 1996, Haley 2002), with nest abandonment attributed to the adults' inability to provide food for the entire brood (Green 1988). Food supply and predation are probably the most limiting factors affecting the number of fledglings.

Determining the number of fledglings in burrowing owl nests is difficult, because young frequently remain underground when not actively seeking food or practicing flying; at any given time, it is highly unlikely that all young will be at the burrow entrance and visible. The most common method of estimating fledging success has been to use the maximum number of emerged young as the estimate, although this will be biased low, and be very sensitive to the amount of time and effort exerted to watch the nest, as well as the density and height of vegetation around the burrow. Literature estimates of numbers of young fledged vary widely, no doubt partially as a result of these problems: 4.9 young per nest in a New Mexico study site (Martin 1973), 1.05 to 3.20 young in human-altered and natural environments in New Mexico, respectively (Botelho and Arrowood 1996), 5-7 fledglings in Oregon (Green 1988), and <3 in an urban site in California (Trulio 1997).

Formal evaluations of nest watches conducted at nests with known numbers of young in artificial burrows at three sites including NAS Lemoore revealed that repeated counts of maximum young visible yielded relative reproductive rates, but these estimates were consistently lower than the actual number of young known to be at the nest (Gorman et al. 2003).

Further work conducted during the Burrowing Owl Research Program revealed that in fact burrowing owl reproductive output is highly variable; although at least 60% of nests at NAS Lemoore produced at least one owlet to three weeks of age in each year of the study, the percent of successful nests ranged to 90% (Rosenberg et al. 2007) and the mean number of young per successful nest ranged from 1.6 ± 0.2 to 3.9 ± 0.3. A maximum of 10 young per nest survived to reach 21-28 days of age. The maximum number of young, and the greatest overall mean number of young per nesting attempt occurred during the spring of 1999, when vole populations were still very high. 1999 was the only year in which we documented every egg in a clutch surviving to at least 3 weeks post-hatch. In good years, the owls' large clutches of eggs can lead to high numbers of recruits into the population, although in average or poor years only a fraction of the hatchlings reach fledging. The role of food in limiting the number of young that fledge was experimentally confirmed at the Salton Sea burrowing owl study area (Haley 2002).

2.7 Factors Limiting Population Size

The major requirement of burrowing owls in all habitats is the availability of burrows suitable for roosting and nesting. In some environments, territoriality may limit the population size, as unused burrows will be too close to established nests (Green and Anthony 1989). Other factors such as food availability (Green and Anthony 1989) and pesticides (James and Fox 1987, Gervais et al. 2000) also may limit burrowing owl populations. In addition, predation by domestic dogs and cats may further compromise populations in more urban environments. At NAS Lemoore, we believe that the greatest limiting factors during our studies in 1997-2001 were the number of nest burrows followed by food availability.

In 1999, nearly every natural and artificial burrow was in use by a nesting pair of owls. In addition, nesting attempts were documented in culverts over 1 foot in diameter and in pipes with cables running through them, which suggested that owls were limited in good quality nesting sites. Owls were documented nesting in sections of the Station where they had not previously been recorded, such as the East Wildlife Area. The number of nesting pairs found that year exceeded the previous maximum by over 20, from 63 to 85. This corresponded to the peak densities of the California vole outbreak. Owls raised more young in that year, the owlets were heavier, and there was roughly double the amount of rodent biomass represented in the pellets. From these lines of evidence, food was a limiting resource and when food was abundant, nest sites also became limiting at NAS Lemoore, largely because of the few ground squirrels that occupied NAS Lemoore during our studies from 1997-2001.During our survey in 2008, ground squirrels were very abundant, and nest burrows were clearly not limiting the population. Rather, we suspected that food limited the population size, and the recent drought in the region is likely responsible. Further, food may be limited on an annual basis during winter at NAS Lemoore, when agricultural fields are usually without vegetation. We anticipate that population size will continue to be limited by food availability as the acreage of irrigated agriculture is reduced. Populations will be further limited by nest burrows if ground squirrels are reduced and nest boxes are not maintained. However, the reduction of irrigated agriculture may result in ground squirrel populations causing less economic damage.

2.8 Population Dynamics

Demographic work with the owls at NAS Lemoore led to estimates of survival and reproduction over the course of four years, 1997-2000, and these years represented a range of conditions including the peak and crash of the vole population in the region. We created a two-stage matrix model to represent the burrowing owl's life history and used the estimates of survival and reproduction to explore both the realized dynamics of the population and potential future dynamics based on changing conditions. The estimated population growth of the population, often called "lambda", was estimated as 0.866 in 1997, 0.842 in 1998, 1.320 in 1999 and 0.396 in 2000. A value of 1.0 indicates that the population is stable, values above 1.0 indicate growth, and values below 1.0 indicate declines. These values of lambda were not corrected for bias, are known to be biased low (Gorman et al. 2003, Rosenberg et al. 2007), and the bias is likely to vary among years. For example, it is reasonable to expect that greater levels of emigration by adults followed the greater levels of nesting failure in 2000, and survival would be correspondingly biased low, more so than the period 1998-1999. Although that estimate also is likely biased low, fewer owls would have been expected to emigrate because of the abundant local vole population. The fact that nest numbers were relatively stable also indicates that although population turnover occurs, there is sufficient recruitment to maintain population size. Clearly, however, NAS Lemoore does not exist in isolation, contributing emigrants to and receiving individuals from a regional recruitment pool.

SECTION 3

Distribution and Abundance of Burrowing Owls At NAS Lemoore

3.1 Population Abundance

The primary data-gathering effort for the original management plan was to identify all locations where burrowing owls were nesting in 1997 at NAS Lemoore. Two survey techniques were originally used to locate owls. The presence of owls was initially determined using nocturnal calling surveys (e.g., Fuller and Mosher 1987, Haug and Didiuk 1993) during April. Diurnal walking surveys were conducted from early April to mid May to locate nest burrows. Calling surveys were conducted from transects located along vehicle-accessible roads. Details of these surveys can be found in the first edition of this management plan. Although broadcast surveys have been effective in other locations (e.g., Conway and Simon 2003, Rosenberg et al. 2007), they did not work well at NAS Lemoore. Owls did not respond vocally to the call playback even though they moved, changed posture, or otherwise indicated that they had heard the recording (J. A. Gervais, personal observation). The very high densities of owls at NAS Lemoore may have caused them to be less responsive to territorial calling. In addition, high levels of ambient noise from the Air Operations area and from the surrounding agricultural fields made detection of any responses by the owls very difficult.

As a result, walking transect surveys were used exclusively to determine the precise location of potentially active owl burrows in 1997-2000 and again in 2008. All suitable habitats (uncultivated areas which were not also adjacent to residential development, wetland, or predominantly covered with brush) were censused by visual searches along transects with observers walking a uniform distance apart (between 7 and 20 meters depending upon vegetation height and density). Active burrows were defined by one or more of the following criteria:

1.) Pair of owls seen at burrow
2.) Nest decorations present
3.) Egg shells present at burrow entrance
4.) Chicks seen
5.) Owls' behavior at burrow during disturbance
    a) Alarm call given upon human approach
    b) Owl reluctant to flush, allows close approach
    c) Behaves defensively (aggression toward human)
    d) Owl retreats into burrow

3.2 Results

A total of 54 active burrowing owl nests were located at NAS Lemoore in 1997, 63 in 1998, 85 in 1999, 64 in 2000, and 43 in 2008. All nest locations are listed in the Appendix. Nest locations varied from year to year, with some areas consistently occupied (Air Operations) and others occupied only during some years (Tumbleweed Park and Landfill). The vast majority of nests were located within or adjacent to grassy areas in Air Operations (Fig. 1). The distribution of nesting burrowing owls from 1997-2008 demonstrates the dynamic nature of the burrowing owl population at NAS Lemoore, and elsewhere in California (Fig. 2).

The distribution of owls closely coincided with the availability of burrows. Nests were almost always located in natural burrows created primarily by ground squirrels and coyotes. Exceptions included a pair that nested in a culvert, in a cable slot in Air Operations, and owls that nested under signs along the runways. Most of the surveyed area did not contain burrows of any type in 1997; where burrows were abundant, owls were present. Our findings of ground squirrel evidence in 1997 suggested ground squirrels were not common at NAS Lemoore despite apparently suitable habitat (see Section 7). Populations of ground squirrels increased and in 2008 they were very abundant in most areas. Fields within which owl nests were absent typically did not have burrows. Installation of burrows by construction of artificial burrows (Section 8) was done to increase populations of burrowing owls. Maintaining suitable habitat including burrows in areas even when no owls are present is a vital component of long-term conservation. Owl numbers clearly increase when conditions are favorable, and maintaining habitat for these events will allow for maximum recruitment into the regional population.

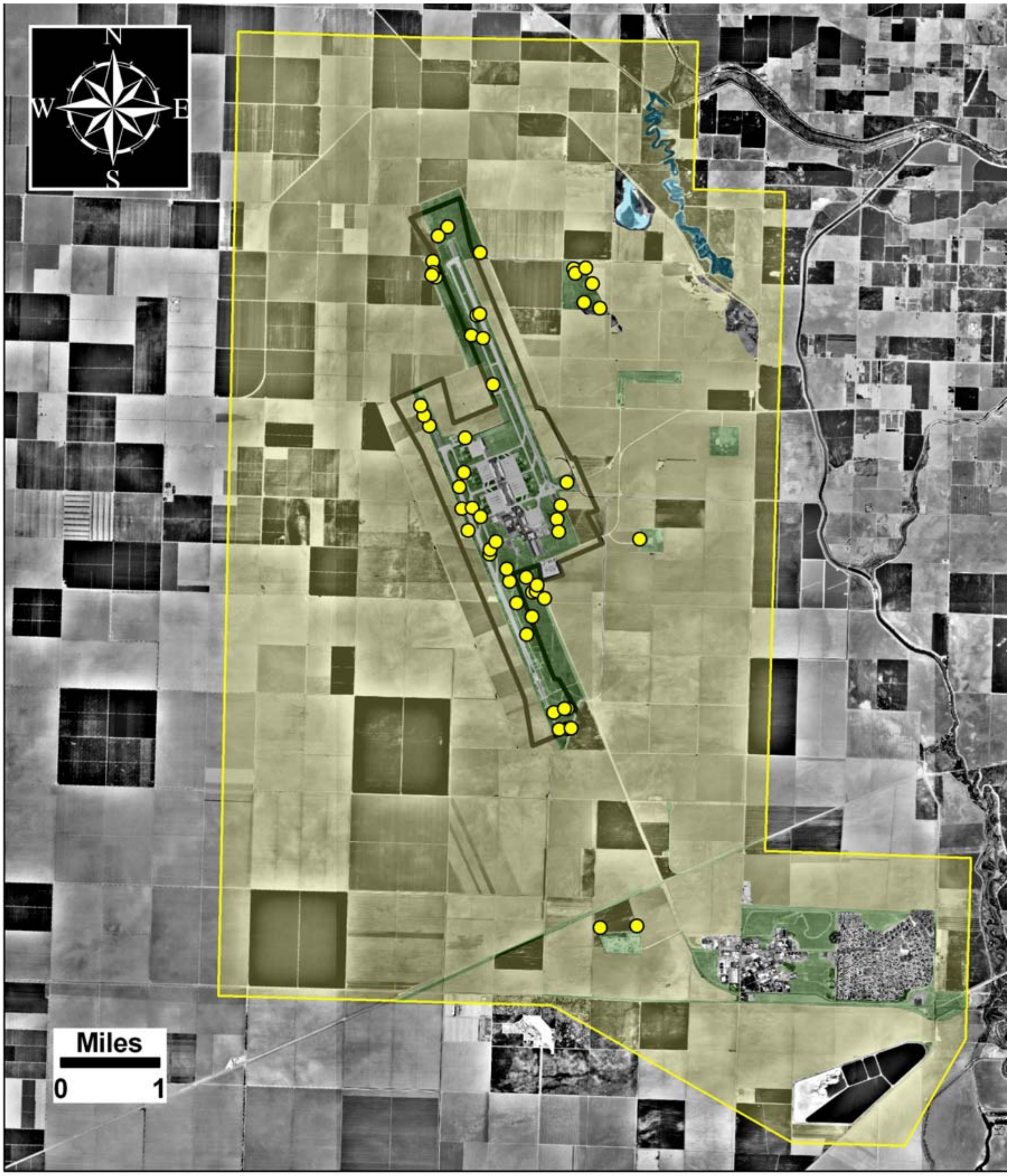
3.3 Future Monitoring and Surveys of Burrowing Owls

Additional evaluations of survey methods using point counts and call playback have been carried out for burrowing owls in eastern Washington and Wyoming (Conway et al. 2008). Factors affecting detection rates vary widely by region and frequently interact with each other. In general, however, owls were most likely to be detected either early in the morning after dawn or in the late afternoon prior to sunset, and detection probabilities increased with ambient temperature during these periods. The authors noted that high temperatures in the mid-day time period in hot weather may reduce detection as owls seek shelter underground; this appears to be true at NAS Lemoore (J. A. Gervais, personal observation). Owls were also most likely to be seen during the early nesting period, which at Lemoore NAS occurs from April through mid-May. Conway and colleagues recommended three surveys a year, corresponding to egg-laying and incubation, early nesting, and late nesting stages (Conway et al. 2008).

Other researchers have noted that owls will defend their nests more vigorously after eggs have hatched, although flushing versus allowing an approach by a person varied with ambient temperature and wind speed (Fisher et al. 2004). Overall, it appears that owls will be more easily detected at nest burrows during surveys after eggs have hatched, on somewhat cooler days, and when wind speeds are relatively low (Fisher et al. 2004). Burrow entrance decoration by both anthropogenic and natural objects is a fairly consistent indicator of the presence of a nest at NAS Lemoore, but not all nests are so marked. Behavior of the owls is then the only clue. Our earlier work at NAS Lemoore indicated that through our survey methods we detected nearly 100% of nests that were found throughout the breeding season (Rosenberg et al. 2007). We discuss alternative monitoring strategies for NAS Lemoore in Section 10.2.

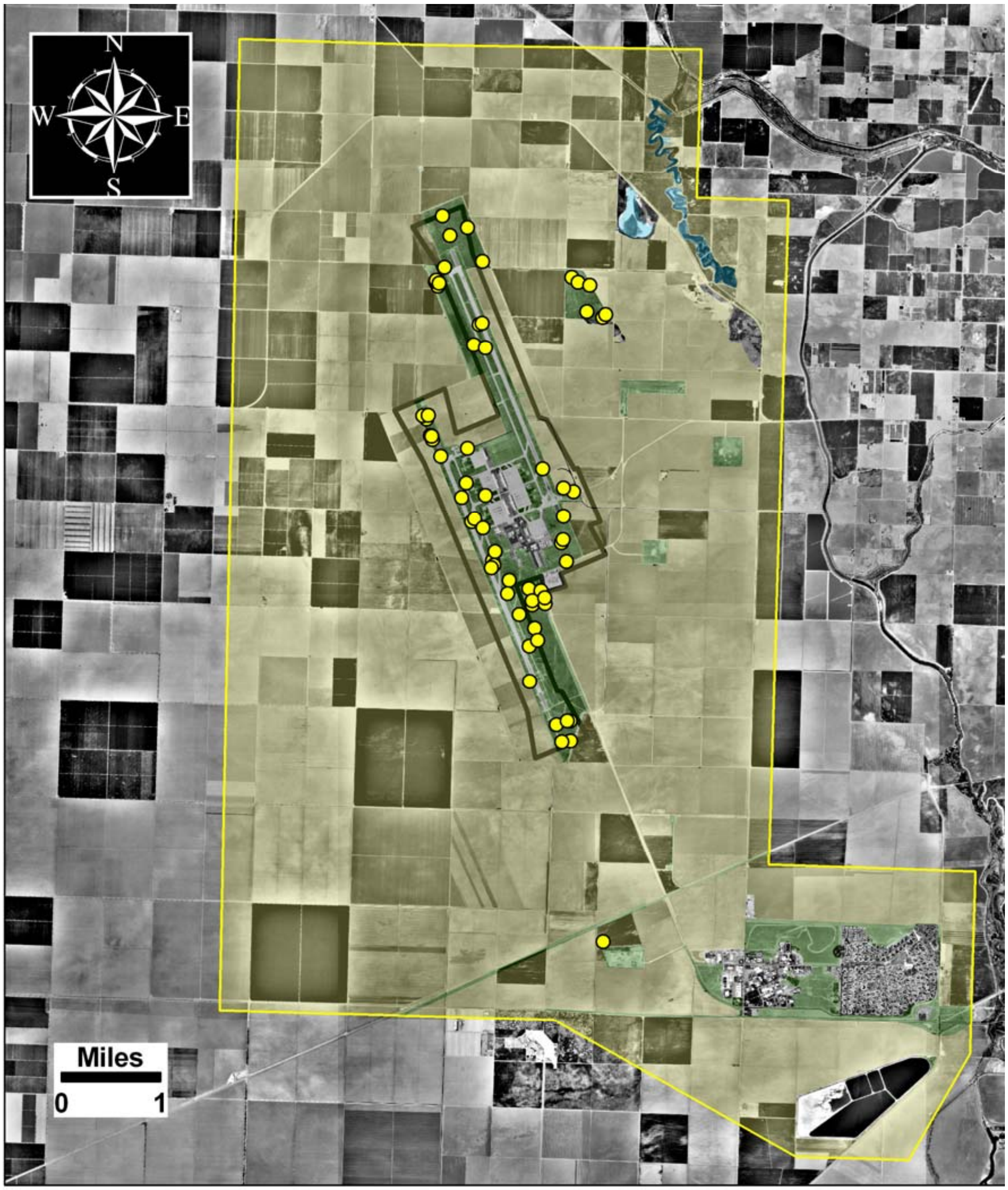
Figure 2. Locations of active burrowing owl nests for each year of field studies.

(a) 1997

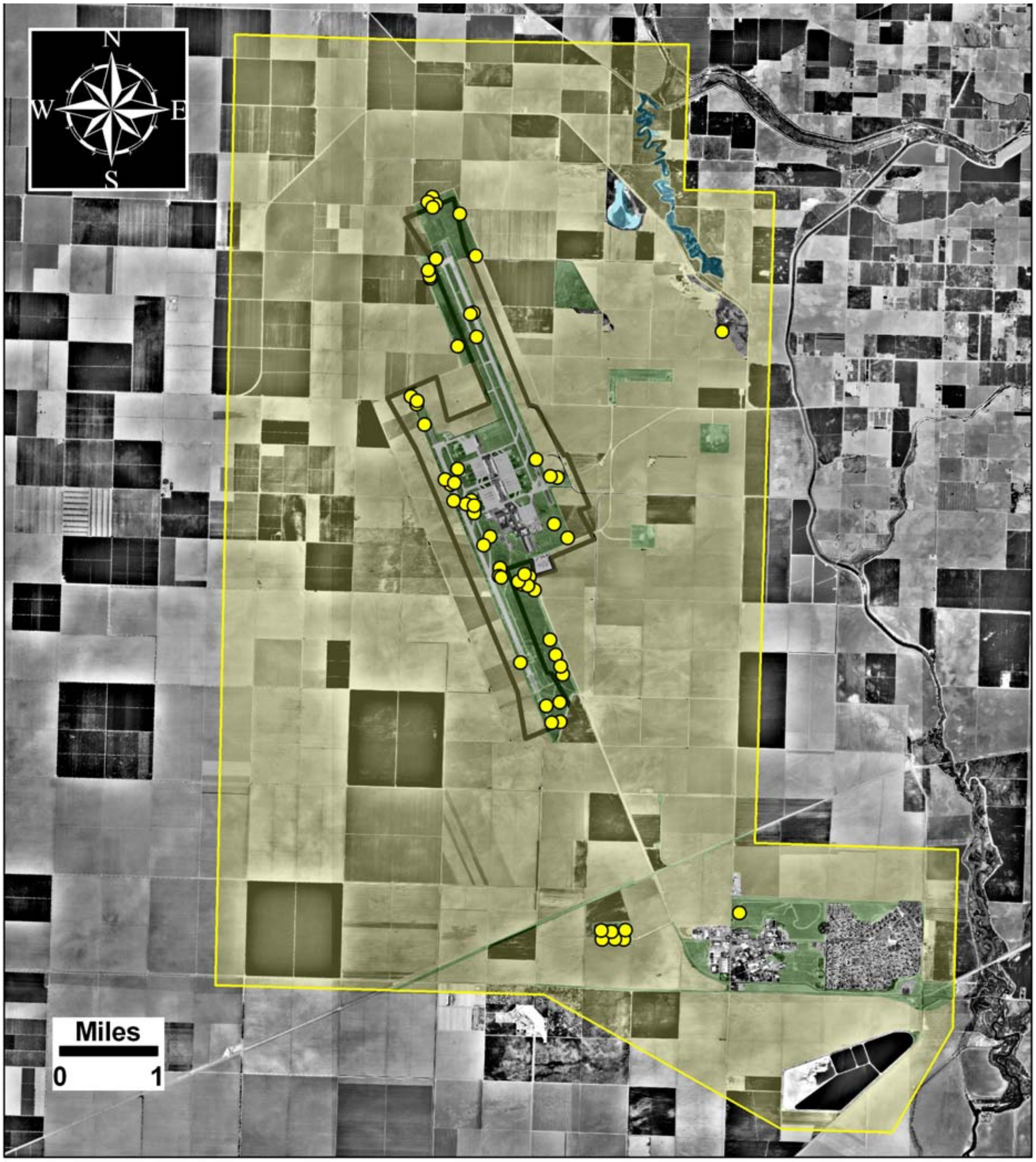


(b) 1998

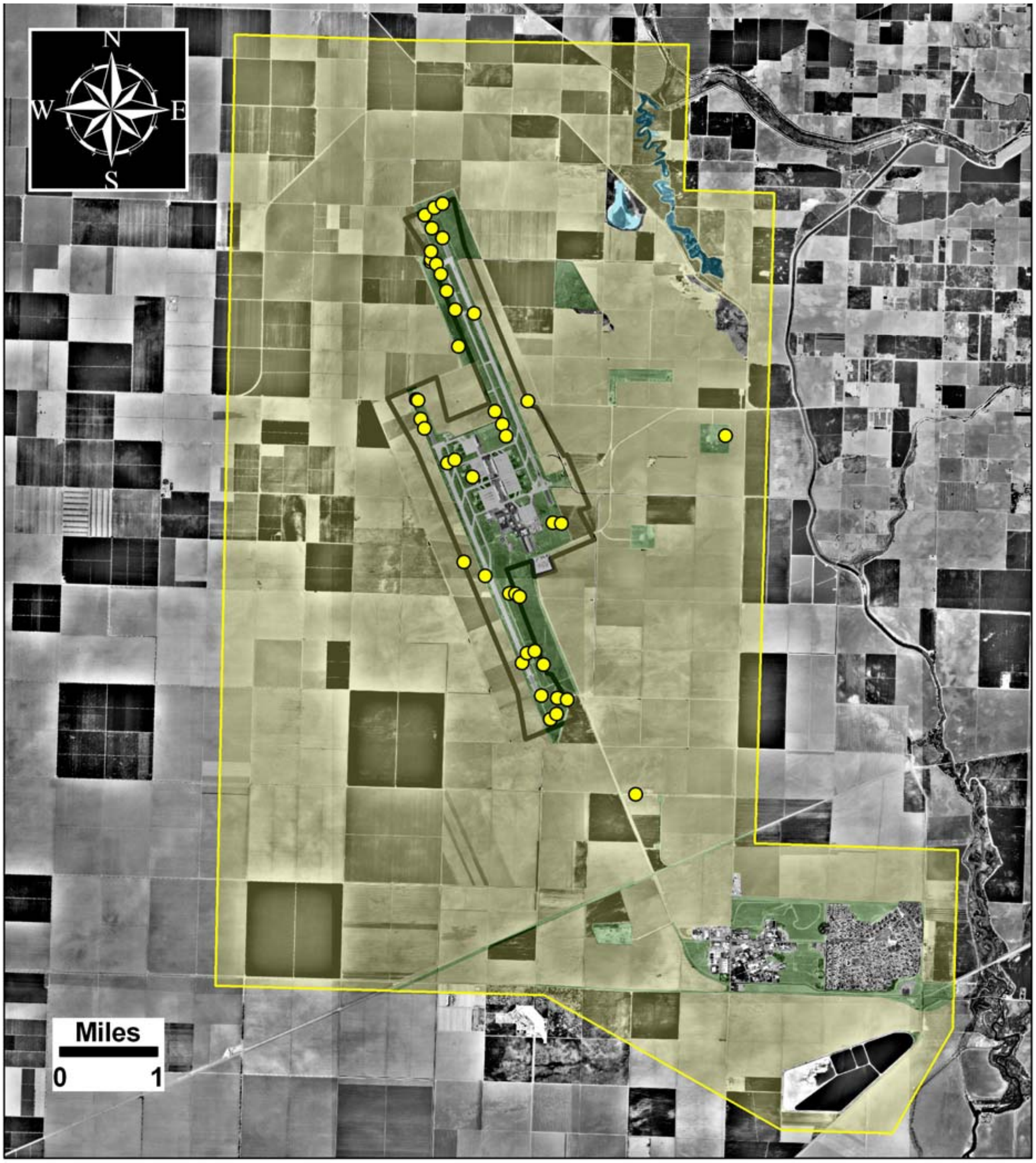
(c) 1999



(d) 2000



(e) 2008



SECTION 4

Managing Grassland Systems

4.1 Historical and Present Condition

The native vegetation of California were greatly altered as a result of European contact in the 1700's, reducing arid grasslands and scrublands from 8.9 million hectares to 800,000 hectares (Stromberg and Kephart 1996). The San Joaquin Valley contained much of California's arid grasslands and scrublands. Prior to the expansive growth of industrial agriculture following the construction of the California Aqueduct, the San Joaquin Valley was a productive area of arid grassland or scrubland vegetation. Current land use practices have further reduced California's lowland vegetation (Keeley 1990). Most grasslands remaining in the Valley are typically surrounded by intensive agriculture and comprised of predominantly introduced annual grasses (Germano et al. 2001). Alterations began so early in the historic period that the former condition of these grasslands will always be questionable (Wester 1981, Schiffman 2007). California grasslands and scrublands evolved under a regime of grazing by ungulates (Clark 1956). The area was not capable of withstanding the intensive cattle and sheep grazing that was followed by severe drought in the first half of the 19th century. The combination of these two factors was responsible for the transition from native grasslands/scrublands to non-native dominated grasslands (Burcham 1957, Dasmann 1966). Almost all of the native arid grasslands and scrublands have been eliminated by agriculture in the San Joaquin Valley. The parcels remaining have been degraded by the expansion of introduced Eurasion species of annual grasses. The vegetation is primarily dominated by foxtail barley, bromes, and fescues (CNLM 1994), often forming very dense stands that increase the likelihood of wildfire and certainly inhibit the use of these areas by native arid community vertebrates such as burrowing owls.

Several species of wildlife have been affected by the altered grasslands and current land use practices. In the San Joaquin Valley, the structure of the exotic grasses is unfavorable for a number of species (USFWS 1997), including the blunt-nosed leopard lizard (*Gambelia silus)*, kangaroo rats *(Dipodomys* spp.), San Joaquin kit fox (*Vulpes macrotis mutica*), and the burrowing owl. These species prefer the short stature and low density of vegetation that native perennial plants provide. The exotic grasses grow much taller than the native grasses, which restricts the movement and foraging abilities of many animal species.

4.2 Current Conditions of Grasslands at NAS Lemoore

The grasslands at NAS Lemoore are typical of areas that are dominated by introduced grasses throughout the San Joaquin Valley, and fall into the category of "Non-Native Grasslands" by the California Native Plant Society and Natural Diversity Data Base (Kelly and Allenger 1996). Within NAS Lemoore, Tumble Weed Park has perhaps the best remaining examples of native species; however, introduced species predominate and include red bromes *(Bromus madritensis* spp. *rubens*), Mediterranean barley (*Hordeum murinum*, a foxtail), prickly lettuce (*Lactuca serriola*), and Mediterranean grass (*Schismus arabicus*) (Kelly and Allenger et. al. 1996). Native species that predominate include saltgrass (*Dictichlis spicata*). Outside of Tumble Weed Park, the grasslands are much more dense and more homogeneous, and dominated by only a few species, such as wild oats (*Avena* spp.), foxtail (*Hordium murinum*), and Bromes (*Bromus* spp.).

The high water table created by the subsurface geology of the region and exacerbated by irrigation (INRMP 1990) is at least partly responsible for the proliferation of the exotic grasses at NAS Lemoore. During wet years, such as occurred in 1998, plant biomass reaches its highest levels. The vegetation in the grasslands often reach such high densities and biomass that they have been mowed 3-5 times per year at considerable expense (B. Fraley, NAS

Lemoore, Transportation, personal communication). Further, the large amount of biomass that has developed over the years is contributing to a high risk of wildfire.

4.3 Retaining and Restoring Native Grasslands

Natural succession to native perennial grasses is unlikely in most cases because the native grasses cannot survive the intense competition with exotic annuals (Stromberg and Kephart 1996). Exotics have immense seed banks and a diverse set of plant growth forms and phenologies causing fierce resource competition for light and water (Menke 1992). Upon establishment, perennials are very strong competitors (Menke 1992). Strategies are necessary to reduce the competitive edge of introduced species in order for native grasses to persist. Herbivory and periodic fire are natural and necessary processes in grasslands (Menke 1992) and can reduce or eliminate the competitive edge of exotic species. Fire and grazing can influence grasslands and in turn, wildlife (Ivey 1996) such as the species of interest found in the San Joaquin Valley (USFWS 1997). The response by wildlife is dependent on the timing and intensity of fire or grazing (Ivey 1996).

Fire--Natural fires have been suppressed in most of the United States (Forde et al. 1984). Sophisticated fire fighting equipment has reduced fire frequency in grasslands and scrublands, promoting invasion by a number of troublesome exotics (Hastings 1993). In recent years, improved understanding of natural functions of fires in ecosystems has increased the use of prescribed burning for resource management (Ivey 1996). Prescribed burning in late spring has been found to reduce exotic annual plant seed production and the resulting seed bank size. Prescribed fire lowers competition which increases perennial grass seedling establishment (Menke 1992). Summer burning causes substantial reductions in annual grasses and stimulates perennial bunch grasses to fragment into vigorous daughter plants (Menke 1992). Some perennials are lost in the fire. It is not clear if the benefits from greater native grass seedling establishment make up for this loss. Some authors have argued that it does (Menke 1992), whereas others argue that fire has long term negative effects on perennial vegetation in the San Joaquin arid vegetation (German et al. 2001). Kelly and Allenger (1996) reported a positive response with both native plant density and species composition at NAS Lemoore following experimental fire manipulations. Liability from escaped controlled burns, smoke restrictions and time required to get permits makes burning as a management strategy difficult to implement in many situations (Menke 1992). These issues became apparent during prescribed burns conducted at NAS Lemoore (J. Crane, NAS Lemoore, personal communication). There have been two prescribed fires at Tumbleweed Park at NAS Lemoore since we began our studies of burrowing owls. In each year, owls were nesting at the time of burning. In both cases, there were no negative effects evident to the owls or their chicks. The habitat conditions seemed much improved following burning. Therefore, evidence suggests that burning can be an appropriate management tool for improving and maintaining burrowing owl habitat, even when burning occurs during the nesting season. The timing and frequency of prescribed fire will be important aspects to evaluate at NAS Lemoore. Since the time of the original management plan, reintroduction of native perennial plants has been conducted in Tumbleweed Park. Results from these efforts and the prescribed fires should help guide future management. A combination of management tools including fire, grazing, and restoration planting may be useful. These issues should be addressed within an adaptive management framework.

Grazing--Historically, San Joaquin Valley grasslands were grazed in the winter and spring by large native ungulates. Today, used as an effective management tool, prescribed grazing can control the height and density of exotic grasses, reduce fire potential by reducing fuel volume, and promote the proliferation of some native species (CNLM 1994, Germano et al. 2001). These methods have been used at several sites within the San Joaquin Valley (CNLM 1994) and in the Carrizo Plain (Rosenberg et al. 2007).

Intense grazing by domestic livestock has been responsible for habitat degradation by disrupting the cryptogamic soil crust, compacting the soil, removing vegetative cover, destroying rodent burrows and trampling vegetation. Domestic livestock also forage on endangered plant species. On the other hand, invasion from introduced plants results from the discontinuation of grazing (CNLM 1994). Thus, grazing can be an effective management tool if carefully managed and monitored (Germano et al. 2001). Our observations of burrowing owl ecology in areas that are grazed suggest that grazing is a very useful management tool for providing high-quality nesting and foraging habitat for burrowing owls. One of the highest densities of burrowing owls we have found in the San Joaquin Valley occurred in a privately owned small grassland that was heavily grazed, although not to the point of exposure of bare soil. The burrowing owl is much more a species of disturbed environments than many of the other species that are vulnerable in the San Joaquin Valley.

Mowing--Mowing is an effective tool for the management of vegetation height for burrowing owl conservation as it does not typically disturb the structure of the nest. The use of large-tired mowers reduces the risk of nest damage, and the restricted use of mowing when young chicks emerge (May-June) prevents destruction of young. At NAS Lemoore, mowing appears to be an effective tool. The frequency and timing of mowing to control vegetation height, reduce seed production for reducing BASH, and to encourage native flora requires an active monitoring and research effort. Because mowing does not reduce residual dry matter, continued mowing without fire or grazing may increase risk of wildfire and limit opportunities for native plant establishment and maintenance. Therefore, mowing is a viable tool for vegetation control which is most useful when combined with fire and/or grazing. Mowing by itself does not reduce the density of grasses, which is important for species adapted to sparse vegetation. The burrowing owl, however, requires low vegetation height more than it does sparse vegetation, and in this sense, mowing is sufficient as a management tool for burrowing owl nesting habitat in agricultural areas.

Case Studies--Despite the clear importance of managing and restoring native grasslands in the San Joaquin Valley, there have been few studies conducted that provide management guidelines (USFWS 1997). Below, we discuss the few case studies we found in the literature. The studies by Kelly and Allenger (1996) at NAS Lemoore were discussed previously. Results from their study, and other experimental manipulations of vegetation, will be critical in designing site-specific vegetation management recommendations for NAS Lemoore. The height and density of vegetation will be critical parameters to estimate during the studies.

Ivey (1996) reported that burrowing owl densities were highest in heavily grazed sites in northern plains grasslands that supported high populations of Richardson's ground squirrels (*Spermophilus richardsonii*). From our experience at Carrizo Plain National Monument, and privately owned parcels in the San Joaquin Valley, livestock grazing and burrowing owls can be compatible. Obviously, the density of livestock will determine the likelihood of compatible management. We have also observed that burrowing owls, both adults and chicks, survive prescribed fire during the breeding season, and they clearly find recently burned areas to be suitable nesting habitat.

Hastings (1993) conducted burns at Sugarloaf Ridge State Park to control the invasive weed, yellow star thistle. Their results indicated that fire intensity was not a critical factor. Rather, burning during the appropriate stage of plant development to prevent seed production was important. Also documented during the study was an increase in the abundance and diversity of native plant species on burned sites. Cover by native species ranged from 11 percent on unburned sites to 25 percent on the site burned two consecutive years.

Hansen (1992) conducted three fall burns at The Nature Conservancy's Pixley Vernal Pools Preserve and four fall burns at the Creighton Ranch Preserve to compare the effects of fire and fire frequency on diversity, percent composition of grasses, legumes, and forbs, and percent composition of native and exotic species. Both preserves are located near NAS Lemoore. Diversity was increased by fire in 18 of 34 burn treatments. In 7 of the 16 burn treatments with reduced diversity, there was an increase in percent composition of natives. This is due to the fact that most native annual forbs are favored by fire; most introduced annual grasses are not fire adapted. Fire increased percent composition of natives in 24 of the 34 burn treatments.

In 1980, Forde et al. (1984) began a four-year study to evaluate the effects of a prescribed burning program in spring that was initiated at Wind Cave National Park, South Dakota. Immediate reductions in perennial species and the amount of dead material present were documented. Immediately after the fire, bare-ground coverage increased. The grassland species were historically subjected to fire and Wind Cave National Park was encouraged to continue its fire program using controlled burns.

An extensive research program on the effects of grazing and fire on plant and animal species has been completed in the San Joaquin Valley. Results from these experimental treatments of varying intensities of prescribed fire and grazing will be instrumental in determining appropriate vegetation management scenarios at NAS Lemoore. Investigators have not yet published results from the study regarding effects of grazing, but they may be made available via their website: http://www.csub.edu/~dgermano/GrazingWebSite.htm

4.4 Creation of Native Grasslands: Specific Recommendations for NAS Lemoore

Although restoration efforts including fire and grazing may be appropriate for sites with native plant species, such as Tumble Weed Park and the capped landfill, creation of grasslands should be attempted where and when it is feasible. The following are guidelines that were suggested for the creation of a native grassland as cover for the capped landfill at NAS Lemoore. The original plan was developed by Dr. Ellen Cypher as per a contract with The Institute for Bird Populations during the burrowing owl relocation work at the landfill. This plan was intended for both erosion control, use of native species favorable for grassland species such as burrowing owls, and as cover that minimizes depth of rooting material so to avoid penetration of the landfill barrier. Therefore, other mixes may be appropriate depending upon the conditions and objectives of the work.

Topsoil--Weed seeds must be killed before native species are hydroseeded onto a site to prevent the weeds from out-competing the natives. There are several options for killing the weed seeds. A common procedure is to apply a granular or liquid pre-emergent herbicide (for example, Amaze or Surflan). However, the following requirements must be met:

(1) the product used must control both grass and broad-leaf weed seeds.
(2) the treated soil must not be disturbed for at least 90 days after the pre-emergent is applied (longer if the label so indicates).
(3) native plant seed must not be sown for at least 90 days after the pre-emergent is applied (longer if the label indicates a greater duration of the herbicide).
(4) after the waiting period, the soil should be disced, then the native seed mixture may be sown

<u>Suggested Species</u> (percent composition in [])
dwarf goldfields [25](*Lasthenia chrysostoma*)
sky lupine [12] (*Lupinus nanus*)
plantain [50] (*Plantago insularis*)
pine bluegrass [12] (*Poa scabrella*)
nodding needlegrass [1] (*Stipa cernua*)
California buckwheat (*Eriogonum fasciculatum*) may be substituted for needlegrass.

<u>Suggested Species For Gently Sloped Areas</u>
white yarrow [18] (*Achillea millefolium*)
creeping wildrye[9](*Elymus triticoides*)
dwarf goldfields [9] (*Lasthenia chrysostoma*)
plantain[36] (*Plantago insularis*)
alkali sacaton [18] (*Sporobolus airoides*)
nodding needlegrass [10] (*Stipa cernua*)

<u>Additional species for gently sloped areas that can be used if rooting depth is not important</u>
California buckwheat [1] (*Eriogonum fasciculatum*)
Dwarf goldfields [25](*Lasthenia chrysostoma*)
Sky lupine[12] (*Lupinus nanus*)
Plantain [50] (*Plantago insularis*)
Pine bluegrass [12] (*Poa scabrella*)

The native seed mixtures should be sown during early fall to take advantage of natural rainfall. Seeds should be spread at a rate of 8 lbs per acre, approximately equal to 75 seeds per square foot, a rate that has been successful in the San Joaquin Valley. Seeds should be pure live seeds. Seed sources are best if local, but should always be from an area with <10 inches of rain per year and a Mediterranean climate. Fertilizer should not be used, as nitrogen promotes growth of exotic species. Use weed-free mulch (e.g., straw or hydromulch) to avoid introducing undesirable species. Using native, commercially available species, such as those suggested here, should not be more expensive than typically used exotic species such as brome, fescue, and rygegrass when applied at the proper rate. Note that sparse cover is desirable to create grasslands typical of the California grassland association. The lower application rate to achieve this condition requires fewer seeds/acre. This results in similar costs for using native species as compared to the non-native species. Estimated seed costs (1996) were approximately $212/acre.

Watering- Watering the surface after seeding will be necessary only if precipitation is considerably below average. The actual application rate (e.g., gallons per hour) will depend on soil permeability and must be adjusted accordingly by the operator of the water truck or other delivery system. Water should be applied at a rate that will allow it to soak in, rather than run off. If the Station has not received at least 1 inch of rainfall between 1 October and 1 December, apply 0.5 inch equivalent. After that, the revegetated area will need at least 0.5 inches of water every 2 weeks until 31 March. If this amount or greater falls naturally, no irrigation will be necessary. If less rain falls during any of the 2-week periods, apply enough additional water to bring the 2-week total to 0.5". No additional watering will be necessary after 31 March, regardless of rainfall.

4.5 Integrating the Needs of Air Operations, Ground Maintenance, and Burrowing Owls

Ground maintenance of vegetation, such as mowing operations, supports the needs of Air Operations by managing the vegetation for safe and efficient operations of the jets. This is the primary objective of vegetation management in areas near the runways. These same areas support many of the owls and other wildlife that are found at NAS Lemoore. Therefore, a secondary objective of vegetation management is to contribute to the Station's mission of natural resource management. On May 15, 1997, DKR met with staff of the Public Works Transportation Department to discuss vegetation management issues. Primary concerns of their Department were (1) the difficulty of mowing operations in areas inhabited by burrowing owls due to the raised ground at burrow entrances, (2) limitations placed on their ability to level fields by discing and thus facilitate mowing at a 4-6 inch height because of the presence of burrows occupied by burrowing owls, and (3) vegetation height management to provide for BASH and other Air Safety issues.

Currently, vegetation height in the grassy fields is kept to a maximum height of approximately 4-6 inches, as per guidelines (B. Fraley, NAS Lemoore, personal communication). Maintaining this short structure requires frequent mowing, resulting in high costs. This height restriction was due to the desire to meet Air Operations guidelines (B. Fraley, NAS Lemoore, personal communication). However, Air Operations staff believe that such a low height restriction is not necessary (finding from meeting with DKR and Air Operations staff, 1997). The primary concern of Air Operations regarding vegetation height is to minimize bird strikes. Because large agricultural fields near runways attract birds (Morrison 1993b), maintaining such a short vegetation structure is unlikely to reduce bird strikes. The primary need outside of agricultural fields would be to reduce the production of seed heads from non-native grain species, such as oats or foxtails. Maintaining vegetation heights at less than 12 inches should meet Air Operations safety needs. This height requirement would alleviate the difficulty mowing in areas with burrows, as this height can be safely achieved without damaging mowing equipment (S. Reinke, NAS Lemoore, personal communication). A 12" height maximum, if diversified by the presence of a species assemblage that consists of various heights and structures, should provide suitable nesting habitat for burrowing owls. It would be desirable for owl areas to be mowed by March 1, although rainfall may be too high during some years to allow this to occur. If mowing operations occur in owl areas during the early chick rearing period, May 20-July 1, then caution must be used to minimize accidental death to chicks that are outside of burrows and are not old enough to escape quickly. This has occurred once to our knowledge in the past three years.

We recommend that the maximum height of non-woody vegetation in grasslands be increased, thereby facilitating mowing operations where owls and their burrows are present. Under current conditions of dense, non-native grasses, vegetation height and density must not be allowed to achieve a level that will prohibit owls from nesting and foraging. It will be important to mow all areas including the areas adjacent to burrows. It is important to avoid creating small islands of tall vegetation that may act to attract predators near the nest. Mowing equipment should be able to mow over nests without destroying burrows. During our research at NAS Lemoore, there have been no burrows that have collapsed due to mowing operations. Note, however, that any discing operations are potentially harmful to burrowing owls, and should be avoided until staff of the Public Works – Environmental Division of NAS Lemoore is consulted regarding potential risk. Experimental research, such as has been carried out by Kelly and Allenger (1996) at NAS Lemoore and the Loekern grazing study in the southern San Joaquin Valley, will allow specific recommendations to be tested and modified for incorporation into management plans at NAS Lemoore. Based on the high density of nests of burrowing owls in Air Operations at NAS Lemoore, the current mowing procedures are at least adequate. During 2008, vegetation density and height at the capped landfill and at Tumbleweed Park were appropriate for burrowing owls for both nesting and foraging; the lack of nests at these sites in 2008 was clearly not due to vegetation composition nor structure.

SECTION 5

Pesticide Use at NAS Lemoore: Implications for Burrowing Owls

5.1 Overview of Regional Use and Effects on Wildlife

The southern San Joaquin Valley in particular encompasses some of the most intensively farmed agricultural lands in the US (Gilmer *et al*. 1982, Griggs 1992), and the agricultural out-lease areas at NAS Lemoore are similar in this respect. High agricultural contaminant levels continue to threaten many native species of plants and animals in the valley (Williams *et al*. 1992). Thus pesticide use at NAS Lemoore is a concern which should be addressed by the Management Plan. Our research group investigated contaminant exposure to burrowing owls at NAS Lemoore and elsewhere in California. Here we present an overview of pesticide effects to wildlife and a summary of our findings and implications to the management of owls at NAS Lemoore.

Many of the pesticides both currently in use and previously used in the southern San Joaquin and Imperial Valleys have been found as contaminants in many species of wildlife, and have been documented to have detrimental effects. Organochlorine compounds in particular are notorious for their effects on the survival and reproduction of birds, causing eggshell thinning and embryo toxicity (Wiemeyer *et al*. 1989), impaired development (Fry and Toone 1981, MacLellan *et al*. 1996), and impaired nervous system function (Yamamoto *et al*. 1996). DDT and its analogs continue to be detected in the soils of California (Mischke *et al*. 1984), including those at NAS Lemoore (Table 1), and remain widespread as contaminants in wildlife, particularly in birds. Although banned over 35 years ago, DDE has been documented in the eggs of Caspian terns, snowy egrets, black-crowned night herons, and Forster's terns in San Francisco Bay (Ohlendorf and Fleming 1988, Ohlendorf and Marois 1990, Hothem *et al*. 1995), and in black-crowned night-herons and great egrets in the Imperial Valley (Ohlendorf and Marois 1990). Ducks wintering in California also contained organochlorine residues, some of which were great enough to be potentially harmful (Ohlendorf and Miller 1984). Elevated levels of organochlorine compounds, including DDE, have been found in the eggs of prairie falcons in California's Pinnacles National Monument, and were associated with impaired reproduction (Jarman *et al*. 1996). Burrowing owls in Canada were contaminated with DDE (Haug 1985). Hunt and coworkers (1986) discovered DDE contamination in a number of other birds in California, including migratory short-billed dowitchers, western sandpipers, black-headed grossbeaks, violet-green swallows, and resident killdeer and starlings. The contaminant concentration at which these species' reproduction and survival are affected is not known, but in any case the concentrations found may bioaccumulate to dangerous levels in accipiters, falcons, and owls (e.g., Klaas *et al*. 1978).

Dicofol is another organochlorine compound that is used as a miticide in the San Joaquin Valley, primarily on cotton and citrus crops. In birds, exposure to dicofol can lead to eggshell thinning and embryo toxicity (Wiemeyer *et al*. 1989, Clark 1990, Schwarzbach 1991, Schwarzbach *et al*. 1991), and can therefore have effects on avian productivity. Organophosphorus and carbamate compounds have been implicated in the direct mortality of a number of wildlife species (Smith 1987, Mineau 1993). Burrowing owls in Canada disappeared from their breeding burrows following a nearby application of a carbamate insecticide (James and Fox 1987). The compound DEF (s,s,s-tributyl phosphorothithioate), a defoliant applied to cotton prior to harvesting, has the potential to bioaccumulate, and may cause neurotoxicity (Smith 1987). Other pesticides have been implicated in wildlife mortalities, as in the deaths of a number of red-tailed hawks in California following a winter dormant spray application (Hooper et al. 1989). These and other organophosphates (see "Local Use" below) are currently widely used in the San Joaquin Valley, including NAS Lemoore.

Table 1. Levels (ppb) of DDT, DDE, and the ratio DDT/DDE in soil samples collected from NAS Lemoore, December 1997[1]			
Site	DDT	DDE	DDT/DDE (%)
Cluster Samples			
NW-6	ND[2]	8.6	0
NDD	ND	4.2	0
TWP	ND	4.7	0
WL	ND	ND	0
EG	ND	4.7	0
KRT	ND	2.8	0
EAS	ND	2.3	0
GBP	2.2	6.2	35.5
EAN	2.6	4.2	61.9
Individual Samples			
GBP-1	ND	2.3	0
GBP-2	2.2	33.2	6.6
GBP-3	3.8	6.4	59.4
GBP-4	5.3	11.8	44.9
GBP-5	4.9	10.6	46.2
EAN-1	17.3	8.6	201.2
EAN-2	ND	4.1	0
EAN-3	ND	3.7	0
EAN-4	ND	7.2	0
EAN-5	7.2	12.4	58.1

[1] Samples collected and provided by J. Crane, Env Mgmt. Div., NAS Lemoore.
[2] ND; not detected.

The burrowing owl's diet includes aquatic organisms taken from agricultural drainage ditches (Section 2). This makes the species vulnerable to selenium, a naturally occurring element that is leached from soils through irrigation. Selenium has caused substantial damage to populations of other bird species (Ohlendorf *et al.* 1986, 1987, 1988). We are unaware of data on the level of selenium in the soils at NAS Lemoore.

5.2 Local Use

Large amounts of agricultural chemicals that are potentially harmful to wildlife are used in the San Joaquin Valley, and therefore at NAS Lemoore as well. Of particular concern are the following chemicals, all of which are applied at NAS Lemoore within 1 km of burrowing owl nest sites, and often much closer (Gervais et al. 1997): aldicarb, chlorpyrifos, def, dicofol, and metam sodium. In addition, diazinon, endosulfan, lindane, methidathion, and paraquat dicholoride fall into the same category; however, they were not sprayed at NAS Lemoore during our toxicology study in 1996. Large quantities of these chemicals are typically used in the San Joaquin Valley primarily for cotton production (Gervais et al. 1997). At NAS Lemoore, the rotation of cotton with grain crops for 2 of each of 5 years results in a lower use of most of these herbicides and pesticides than in the general region. As of the writing of this management plan, crop allocation is in a state of flux due to changes to allowable irrigation. A review of the crop allocation in the near future will be useful in reviewing issues related to pesticide use.

5.3 Summary of Pesticide Residue Study of Burrowing Owl Populations

Potential impacts from pesticides was of considerable concern a decade ago, due to preliminary findings of high levels of p,p'DDE in particular in owls' eggs and the presence of chlorpyrifos in footwash samples collected in 1996 (Gervais et al. 2000). Extensive radio-tracking of male burrowing owls during the breeding season suggested that they do not appear to track pesticide applications for potential pulses of dead prey, although owls do use recently treated agricultural fields (Gervais et al. 2003). Distance to nest was the greatest predictor of use, not cover type (Gervais et al. 2003). Although some radio-tagged owls died during the breeding season, none of the carcasses were recovered quickly enough for diagnostic testing to be feasible. The primary causes of mortality that were identified were predation and vehicle strikes on the access road to Air Operations. Although individual owls likely occasionally die from pesticide exposure, and exposure may contribute to predation risk or accidents, it is not currently possible to quantify these losses. Agricultural lands and fallow areas at NAS Lemoore consistently provide habitat to owls that consistently fledge young; in a region with little alternate nesting habitat, the risks of pesticide exposure may well be outweighed by increased food supply and reduced predation risks.

Contaminants in the owls' eggs varied widely, by several orders of magnitude. Most eggs contained relatively low residue levels, suggesting that the contaminant source is not local. It appears that highly contaminated eggs are laid by females whose body burdens are obtained off site; samples of prey revealed that only centipedes contained contaminant residues great enough to cause bioaccumulation to any degree, and these are only occasional prey items (Gervais 2002). However, even low concentrations of organochlorine pesticides, particularly p,p'DDE, were associated with reduced reproductive output if the adult owls were also subjected to food stress (Gervais and Anthony 2003). Ultimately, the effects of persistent contaminants in particular may be related to long-term habitat quality, particularly the availability of high-quality prey such as voles (Gervais et al. 2006).

Eggs contained none of the organophosphorus compounds tested for in 1996 (Gervais et al. 1997) and were not analyzed for these compounds in subsequent years (Gervais 2000). The majority of organochlorine compounds tested for were also not found within the eggs, but the notable exception was the para, para isomer of DDE, a metabolic product of DDT. All eggs in 1996 (n = 9 eggs from different nests) analyzed from NAS Lemoore had detectable levels of DDE ranging from 1.5 to 33 ppm. The eggs from NAS Lemoore showed a great amount of variability in DDE concentrations; the second, third, and fourth highest concentrations were 18 ppm, 17 ppm and 9.4 ppm, respectively; the remaining eggs contained 5 ppm DDE or less. Mean p,p'DDE concentrations at Lemoore was 10.91 ppm. BHC (ß-benzenehexachloride) was detected at 0.11 ppm in one egg, and mixed PCBs were detected in two eggs (1.6 ppm and 2.9 ppm). These same eggs contained 33 ppm, 4.8 ppm, and 4.8 ppm p,p'DDE respectively. Selenium was detected in most eggs, but in small quantities; these values were within the range considered normal for poultry eggs (California Veterinary Diagnostic Laboratory Service 1997). Mean eggshell thicknesses varied among our study sites, with the thinnest shells occurring at NAS Lemoore (Gervais et al. 2000).

Feathers did not contain any of the organophosphorus insecticides tested for in amounts greater than the minimum detectable levels (Gervais et al. 2000). Most of the samples from Lemoore had traces of p,p'DDE (mean detectable limits = 0.1 ppm, % of samples below MDL= 25%, $\bar{x}$ = 0.26 ppm, SE=0.075, range = 0.06-1.02 ppm, n = 12), but no traces were found in the Carrizo feather samples. DDE contamination in egg samples were correlated to feather samples collected from the same owls (r = 0.59, n = 10, P = 0.08); however this relationship was heavily influenced by the samples from one individual bird that had very high levels of DDE. When data from this owl were removed, there was no correlation between the remaining data (r = .27, n = 9, P = 0.48). Feathers were not sampled in subsequent years.

Footwash samples contained none of the organochlorine compounds in 1996. The only organophosphorus compound detected was chlorpyrifos (MDL = 10ng, % samples below MDL = 58.8%, $\bar{x}$ = 25.3 ng, SE = 4.46, range = 12.5-45.0, n = 7). We did not repeat footwash sampling in subsequent years.

Following our findings of high p,p'DDE exposure in 1996, staff at NAS Lemoore sampled soil in 10 areas using a composite sampling design in which subsamples of the areas were pooled for chemical analysis, then separated out upon finding high levels (J. Crane, NAS Lemoore, personal communication). Both DDT and p,p'DDE were found in most samples. Importantly, the ratio of DDT/DDE was fairly high in some samples, indicating either recent use or low metabolism of the existing DDT. This suggests that high levels of p,p'DDE will not be significantly reduced in the near future by natural mechanisms because the metabolism of existing DDT will contribute to further DDE levels.

These initial findings led to continued sampling of eggs from the NAS Lemoore burrowing owl population concurrent with the studies of survival and reproduction (Gervais 2002, Gervais and Anthony 2003, Gervais et al. 2006). A total of 92 eggs were collected over the period 1996-2001. Some females were sampled in more than one year, allowing us to assess changes in contaminants through time. Egg collections were made each year from all parts of the station. In nearly all cases, eggs were randomly removed from clutches once at least 3 eggs were present. In 1998, a number of clutches were initiated but subsequently abandoned apparently due to the extremely wet soil conditions. Eggs abandoned in burrow tunnels were collected on several occasions. One egg per nest was collected.

Levels of contaminants varied widely, although the pattern was one of declining residues overall. Although other contaminants were found (see Gervais and Anthony 2003), they occurred in low concentrations and were absent altogether from many of the eggs. We resampled eggs from 2 female owls in 3 consecutive years and 13 females in 2 consecutive years. Levels of p,p'DDE declined in nearly all owls over time, with a maximum decline of 7.04 µg/g to a gain of 0.52 µg/g in another. The annual mean change in p,p'DDE was -1.27 ± 0.04 µg/g, calculated using the mean annual decline for the two owls for which we had 3 eggs (Gervais and Anthony 2003). Despite the general decline in egg residues over the population, a few highly contaminated eggs were collected after 1996. There were no consistent geographic patterns in the occurrence of contaminated eggs (Gervais and Anthony 2003).

In an effort to determine whether the contamination was likely to be from a local source, we collected fresh prey items brought back to the nest by adults and submitted them for contaminants analysis. Prey taxa so examined were centipedes, windscorpions, spiders, crickets, western toads, California voles, western harvest mice, deer mice, house mice, and a pocket gopher. None of the samples contained detectable levels of organochlorine contaminants other than the two samples of centipedes; these contained 0.4 and 0.7 µg/g p,p'DDE, respectively (Gervais 2002). Experimental work with American kestrels indicated that overall dietary concentrations of this magnitude may result in residues of 0.5 to 2.1 µg/g wet weight (Lincer 1975), but centipedes made up only a small fraction of the owls' diets. In addition, these concentrations do not explain the occasionally very high residue levels in some of the eggs.

Interestingly, the second-most contaminated egg collected was taken from a female in 2000. She had been banded as a nestling on NAS Lemoore the previous year, and the egg taken from that nest contained only very low residue levels (Gervais and Anthony 2003). It seems unlikely that she began to accumulate a body burden sufficient to lay an egg containing 25 µg/g p,p'DDE until after fledging and dispersal from the station; none of the other females sampled in that year produced such contaminated eggs. In any case, it is clear that burrowing owls can accumulate substantial body burdens of contaminants in a relatively short time.

We also radio-tagged 33 breeding male owls in 1998 and 1999, and tracked them on their nocturnal foraging trips. Although we did not find evidence that burrowing owls tracked pesticide applications in search of dying prey, they did enter fields within 3 days of treatment with pesticides that could cause harm to wildlife at sufficient exposure levels.

We found no direct evidence that agricultural chemicals currently in use at NAS Lemoore affect burrowing owl survival or reproduction. However, all eggs sampled contained at least low levels of *p,p*'DDE. Although there was no direct relationship between egg contaminants and reproductive success, owls that laid eggs with moderate levels of p,p'DDE (≥ 4 µg/g) and that also had low levels of rodent biomass in their diet raised fewer young (Gervais and Anthony 2003).

A retrospective analysis to examine what factors were most responsible for observed patterns in changes in population growth rate revealed that the very high population growth rate observed in 1999 was due to the large increase in reproductive output more than the increase in adult survival. Conversely, the crash year population growth rate estimate was mostly due to declines in adult survivorship, and affected to a lesser extent by declines in reproduction over the average years of 1997 and 1998 (Gervais et al. 2006). This was despite the fact that the proportional decline in reproduction over that time period was greater than the proportional decline in adult survival.

We projected our models forward in time to explore the effects of the vole peak and crash on owl dynamics through time in conjunction with reproductive impairment from *p,p*'DDE. The crash effect outweighed the gains made in the peak year, but this is likely due to the fact that no attempt has yet been made to correct the estimates of survival and reproduction for relative bias. The general patterns however should still hold. When vole populations peak often, altering the frequency of a peak/crash event by one year affected population growth to a much greater extent than did the presence of low levels of *p,p*'DDE. However, the relative impact of contaminants on population growth increased as the length of time between vole peak/crash events increased (Gervais et al. 2006). This suggests that the effects of the legacy contaminant *p,p*'DDE on the NAS Lemoore owl population will depend in large part on the dynamics of their main prey species.

5.4 Implications to the Management Plan

Although we demonstrated that owls use agricultural fields for foraging, the most significant finding was the high concentrations of p,p'DDE at NAS Lemoore in the owls' eggs. Despite more than a quarter-century ban on its use in the United States, DDT and its metabolites remain available for uptake and bioaccumulation in wildlife species in the San Joaquin Valley. The source for the contamination is from both residues in the soil and in the food chain, although the geographic locations of the main sources are unknown. Burrowing owls appear to be less sensitive than other birds to the effects of DDE on reproductive success, as the levels of p,p'DDE detected in the eggs of this study would cause total reproductive failure in many other species of birds (Gervais et al. 1997). A small percentage of burrowing owls at NAS Lemoore are exposed to high levels of p,p'DDE and may suffer impaired reproduction or survival as a result.

DDT has not been legally applied in the United States since 1972 (Peterle 1991), and DDT contamination in dicofol was banned by 1989 (Clark 1990). North American wildlife may be exposed either by migrating abroad, where DDT use continues (Peterle 1991), or through residues that persist from past use in this country and which still are able to bioaccumulate. Burrowing owls are potentially exposed to both sources, although those breeding in the San Joaquin Valley appear to be year-round residents and their toxicant loads would be a result of regional contamination. DDT and its metabolites remain widely distributed in the agricultural soils of California statewide, particularly in the San Joaquin Valley. At NAS Lemoore, soil samples collected at 10 sites had DDE levels that ranged from 0 (not detectable) to 33.2 ppb and DDT from 0 to 17.3, with a ratio of DDT/DDE that ranged from 0 to 201%. The variability in egg samples may therefore be a result of differential use of patchily contaminated habitat. The results suggest that there are still "hot spots" of DDE contamination within the region beyond NAS Lemoore's boundaries.

We documented that burrowing owls entered agricultural fields soon after pesticide application, and although we did not confirm any negative effects following this exposure, it is possible that low levels of exposure affect the owls' ability to forage, avoid predators, or other hazards such as traffic. Owls selected foraging locations that were close to the nest regardless of habitat type during the breeding season (Gervais et al. 2003). Management options to reduce the risk of exposure to agricultural pesticides include placing artificial burrows or other habitat improvements away from grassland edges; however, such edges may be excellent foraging habitat and may outweigh the risks from contaminant exposure under current use.

5.5 Recommendations

Cotton is the primary crop grown in the southern San Joaquin Valley and at NAS Lemoore as well. Cotton production represents a threat to wildlife due to the large amount of pesticides and defoliants applied to conventionally grown cotton (CNLM 1994). In contrast to other cotton production sites in the Valley, cotton production at NAS Lemoore utilizes a rest from cotton for 2 of 5 years per field; this will reduce the levels of pesticides used in the area. Several of the pesticides deserve special attention as potentially negatively affecting wildlife, including burrowing owls. These are aldicarb, chlorpyrifos, def, diazinon, dicofol,endosulfan, lindane, metam sodium, methidathion, and paraquat dicholoride. We recommend developing a plan for reducing the above listed pesticides at NAS Lemoore. Identification of the pesticides of greatest concern and finding alternatives as part of Integrated Pest Management will be a positive step for the integration of agricultural production and wildlife conservation. With conversion to drought-adapted crop species, there will be dramatic changes to the pesticides used at NAS Lemoore. A review of currently used pesticides with the anticipated changes in crop production is warranted.

SECTION 6

Bird Air Strike Hazards

Birds pose a potential hazard to aircraft, threatening both human lives and aircraft. Incidents involving loss of lives are rare but do occur (Burger 1985); more common are incidents in which damage to the aircraft results. Most incidents (>75%) occur near airports during take-off and landing. Although only 5% of air strikes with birds may result in aircraft damage (Burger 1985), this results in over 10 million dollars in damage annually. The recognition of this has led to plans to reduce bird air strike hazards (BASH). At NAS Lemoore, an initial study was conducted on BASH that evaluated the abundance of birds common in agricultural fields and potential habitat factors related to their abundance (Morrison 1993b). Owls have been responsible for a small percentage of collisions of aircraft with birds. In New York, near a coastal airport, Burger (1985) reported owls (short-eared and barn owls) represented 3% of the strikes. Because owls are most active at night, they pose a threat difficult to anticipate and avoid (Burger 1985). Burrowing owls are further likely to interfere with jets because of their proximity to runways and the ability of the powerful jets to "inhale" the birds from some distance away. These factors suggest burrowing owls deserve consideration in any BASH plan at NAS Lemoore, but do not necessarily require active management at this time. In this section we evaluate the evidence for a potential problem with burrowing owls, given our recent understanding of their distribution at NAS Lemoore. From documented deaths of previously marked (banded) burrowing owls in 1997 and 1998 (J. Crane, NAS Lemoore, personal communication), we now know that collisions between aircraft and burrowing owls do occur at NAS Lemoore. The primary interest in this section is to discuss issues related to Air Operations safety rather than conservation of owls in Air Operations. However, meeting both the critical needs of Air Operations safety and conservation of owls is desirable.

On May 15, 1997 the senior author of this report met with Mr. John Crane (Public Works – Environmental Division) and Air Operations staff (Mr. Don Gibson, Lt. Robert Craig, Lt. Ron Segerstrin, and ACC Anthony Betonio). From this meeting, we learned that there have been no major bird air strike incidents, although possibly minor incidents may have damaged jets. Therefore, we were left with the impression that Air Operations staff does not believe there to be a high risk of notable bird strikes. However, staff made clear their concern with the issue in general. Unfortunately, there has been little information collected regarding bird collisions, especially regarding the species involved, so it was difficult to assess the situation with clarity. Air Operations staff suggested that Field Support Division notify the Public Works – Environmental Division upon finding bird bodies which can then be identified.

Burrowing owl nests located in Air Operations are as close as 3 m from runways, with many located within 500 m (Fig. 3), which is certainly within the home range of a nesting pair of burrowing owls (Section 2). One of the marked owls that died from collision with an aircraft nested 570 m from the runway where it was found. There are typically 20-30 nests each year located this distance from a runway, and owls are present in these burrows throughout the year. Given an average reproductive success rate of 3 chicks/nest and two adult owls/nest, there are likely a total of 160 owls within this distance of runways during late summer when chicks begin to fledge.

Research on burrowing owls has been conducted since 1996 at NAS Lemoore. Given the enormous effort in the study of burrowing owls and our frequent contact with Air Operations, there does not appear to be any conflict with burrowing owls and air operations safety. Despite the few reported incidents of finding dead owls that were likely either hit by aircraft on land or air, there have been no concerns over aircraft or personnel safety that we are aware of. This lack of incidents is consistent throughout the range of the Burrowing Owl, despite the large number of burrowing owls that occur at airports and adjacent to runways.

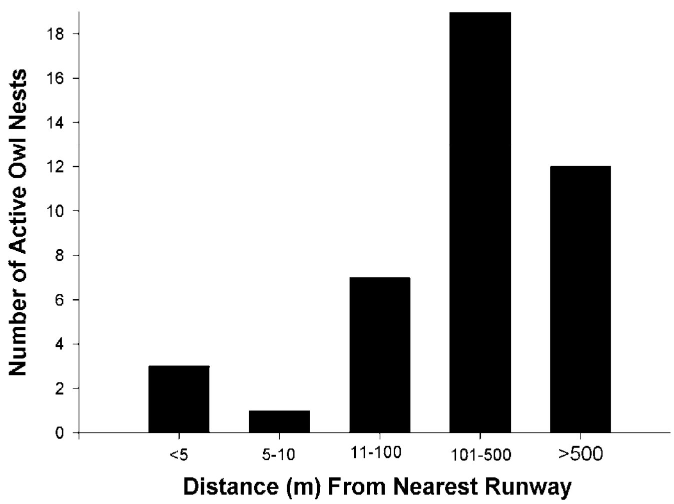


Figure. 3. Distance of nests to runways, 1997

SECTION 7

Relationship of California Ground Squirrels to Burrowing Owls

7.1 California Ground Squirrel Natural History

The distribution of burrowing owls in western North America coincides with that of ground squirrels and prairie dogs. Ground squirrels and prairie dogs provide excavations which the owls can modify into nest burrows. These mammals further alter the environment in the vicinity of holes by grazing vegetation near burrows, thereby increasing horizontal visibility which can increase the probability of nest use by owls (MacCraken et al. 1985, Green and Anthony 1989). The California ground squirrel is the primary species that creates burrows that owls use for nesting and year-round use at NAS Lemoore, and in the San Joaquin Valley in general (Rosenberg et al. 2007, Gervais et al. 2008).

Many other wildlife species utilize ground squirrel burrows. Mammals found in their holes include coyotes, badgers, foxes, skunks, cottontails, pocket gophers, kangaroo rats, white-footed mice, pocket mice, rock mice, brush mice, and woodrats. Reptile and amphibian species which sometimes occupy squirrel burrows include rattlesnakes, king snakes, racers, gopher snakes, lizards, skinks, whiptails, toads, and salamanders in addition to invertebrates (Loredo-Prendeville et al. 1994, Bangert and Slobodchikoff 2006). The only avian species that utilizes squirrel holes is the burrowing owl.

At NAS Lemoore, California ground squirrel abundance has dramatically changed during the years of our research and surveys of burrowing owls. In 2008, they were well distributed and generally very common, having expanded their presence since our initial surveys in 1997. Where ground squirrels are present at NAS Lemoore, their numbers were sparse initially and the densities were much lower than in other grassland areas in the San Joaquin Valley (D. K Rosenberg and J. A. Gervais, personal observations). Understanding the biology of the California ground squirrel and factors affecting their low numbers at NAS Lemoore are critical for properly managing the burrowing owl population at sites without artificial burrows.

7.2 Tolerance and Intolerance for California Ground Squirrels: Control Methods

As discussed, a healthy grassland and scrubland ecosystems in the San Joaquin Valley requires populations of fossorial mammals, such as ground squirrels. However, it will also be imperative to implement a control program to protect specific areas from California ground squirrel damage. Having an established plan for both retaining and controlling ground squirrels should reduce management conflicts.

California ground squirrels have long been thought of as a nuisance to farmers. The County Agricultural Commissioners Offices coordinated ground squirrel control programs in counties where these pests were a problem back in 1917. These findings resulted in extensive state-wide control programs (Marsh 1986, Marsh 1994). The objective of ground squirrel control programs is to reduce the population and maintain those lower numbers. Several methods which can be used for this purpose include shooting, trapping, poisoning with acute toxicants, poisoning with anticoagulants, and poisoning with fumigants (Salmon et al. 1982). In Kings County, anticoagulants and fumigants are usually used (L. Toss, Kings Co. Animal Control Office, personal communication).

Acute toxicants are compounds which are lethal in one dosage. Toxicants used to eliminate squirrels have included zinc phosphide, strychnine, and sodium fluoroacetate (Compound 1080), the latter of these no longer being registered for use for ground squirrel control (Marsh 1994). Current-use non-anticoagulant rodenticides are zinc phosphide, cholecalciferol, and bromethalin. Advantages to the use of acute toxicants include speed of effect, low cost, and minimal labor. One major disadvantage of this method is that animals may refuse to take bait after repeated applications, so the bait needs to be changed and/or baiting needs to be done intermittently. In addition, species other than squirrels may be adversely affected. At NAS Lemoore, the primary species of concern regarding non-target impacts is the endangered Fresno Kangaroo Rat.

Anticoagulants are agents which produce internal hemorrhaging by interfering with animals' blood clotting abilities. Compounds currently used for ground squirrel control include chlorophacinone, diphacinone, bromadiolone, and warfarin. Resistance to first generation anticoagulants such as warfarin led to the development of more effective second-generation anticoagulants, including brodifacoum, bromadiolone, difethialone, and difenacoum. These compounds are used primarily in bait forms. Their volatility is low and they have low solubility in water so concentrations in the air are low and the likelihood of water contamination is low. A study done by Odam et al. (1979) indicated that when wheat was treated with warfarin and kept in a bait box, there was no loss of warfarin after 12 months. The persistence of the poison when spread on the ground was variable and was determined by both soil conditions and rainfall. A further issue of concern is their effect on non-target species. Non-target species are at risk to poisoning in two ways. Primary poisoning through the direct consumption of bait is possible, particularly since small pellets and whole grain baits are attractive to birds and other non-target rodents. This is another reason that baiting in boxes is preferable to spreading over the ground, which is an application restricted in some areas. Secondary consumption through the ingestion of poisoned rodents is also possible. Given the delay between the ingestion of anticoagulant bait and the death of the rodent, predators have ample opportunity to feed on poisoned rodents that remain above ground. Second-generation anticoagulants provide a lethal dose with one feeding, but as with first-generation products, still require several days to take effect. During this time, animals may consume a supra-lethal dose that then may be passed on to predators or scavengers. In addition, second-generation anticoagulants may be retained in the bodies of predators for longer time periods, increasing the risk that cumulative exposure may lead to adverse effects (Erickson and Urban 2004).

Secondary toxicity has been studied both in the laboratory and in the field and much of this research has focused on owls. In an experiment in which mice killed by diphacinone were fed to owls death resulted (Mendenhall and Pank 1980). In the same study barn owls were fed rats poisoned with six different anticoagulants. Owls fed rats killed with diphacinone, fumarin, and chlorophacinone survived while all owls fed brodifacoum-killed rats and one of six fed bromadiolone-killed rats died. All owls that died suffered severe hemorrhaging. Birds subjected to a longer feeding regime of rats killed by difenacoum showed hemorrhage. Other studies have shown brodifacoum is more toxic to owls than difenacoum (Newton et al. 1990). Studies of wild owls have had similar results. Owls suffered high mortality when >20% of their home range was treated with brodifacoum (Hegdal and Colvin 1988). In observational studies, wild owls found dead often had difenacoum and/or brodifacoum residues in their tissues (Newton et al. 1990). In a recent assessment of the relative risks of anticoagulants on non-target species, brodifacoum and difethialone along with the non-anticoagulant zinc phosphide were considered to pose the greatest risk to non-target animals because of the toxicity of these compounds, such that consumption of a few bait pellets may be a lethal dose (Erickson and Urban 2004). Analysis of burrowing owl pellets at NAS Lemoore (Rosenberg et al. 2007) revealed that owls will consume items such as pebbles, bits of plastic, or glass, and so they may be at risk of consuming bait directly. Brodifacoum and difethialone were also considered to pose the greatest secondary risks to birds of all the current-use rodenticides (Erickson and Urban 2004). In general, the application of anticoagulants requires much care in chemical choice, dosage, placement, and in evaluating the effects to non-target species.

Fumigants are toxic gases released within blocked burrow systems. Gases used to control ground squirrel populations include aluminum phosphide, carbon bisulfide, and methyl bromide. This technique is highly effective. On the down side, the use of fumigants is costly, labor intensive, and several of these compounds are toxic to plants and several are extremely flammable. Great care must be taken to ensure that the burrow does not contain non-target species, which can be difficult given the large number of burrowing animals in the San Joaquin Valley that are either listed under the Endangered Species Act or are otherwise of conservation concern (USFWS 1997).

This section is intended as an overview. The development of a control program should include discussions with local animal-damage agencies. We recommend the preparation of a management plan for ground squirrels at NAS Lemoore. The management plan should emphasize both the maintenance of colonies in wildlife areas and control programs in areas that squirrels cannot be tolerated, such as ammunition bunkers and in areas with high densities of underground electrical cables. We believe the maintenance of California ground squirrels is critical to the long-term conservation of burrowing owls at NAS Lemoore.

SECTION 8

Mitigation Planning

Because of the burrowing owls' status as a National Bird of Conservation Concern federally (Klute et al. 2003), and as a Species of Special Concern in California, as well as its protection under the Migratory Bird Treaty Act, any disturbance to the owl's habitat that could result in harm must be planned with the appropriate state and federal agencies. Typically some type of mitigation is required or recommended in order to be in compliance with protective measures. Early actions will also avert the need to federally list this species under the Endangered Species Act. NAS Lemoore took such protective measures during the capping of the landfill in regards to burrowing owl protection. In this section, we discuss possible mitigation measures that can be taken to protect burrowing owls when actions affecting their habitat are scheduled.

If base activities disturb nest sites of burrowing owls, it may be necessary to relocate impacted owls or modify activities that would be likely to affect owls. If activities are likely to result in negative impacts to burrowing owls, the Public Works – Environmental Division must be notified, at which time their department would make these determinations during the NEPA phase of any action. If such disturbances are deemed possible, then it may be necessary to contact state and federal wildlife regulatory agencies to develop an acceptable plan of action. A plan of action may include passive relocation, such as was carried out at the now capped landfill at NAS Lemoore, or enhancement of existing potential habitat.

Passive relocation does not involve actual capture and removal. Rather, owls are enticed to artificial (or natural) burrows by providing such burrows and using one-way door "traps" that allow owls to leave the burrow of concern but will not let them reenter. Relocation is most successful if the added burrows are located nearby (e.g., < 200 m; Gervais and Rosenberg, personal observation). If such actions are taken, it will be useful to discuss intended management actions with US Fish and Wildlife Service and California Department of Fish and Game.

Other possibilities for mitigation would be the improvement and addition of owl habitat. Potential sites for native grassland restoration and inclusion of artificial burrows include the receiver and transmitter site. All of the grassland sites potentially could be improved for burrowing owls by tolerating ground squirrels that are already present, and by encouraging native plant species by biodiversity conservation in general. The most likely areas for mitigation or other protective measures for burrowing owls and other grassland species are the agricultural fields adjacent to Tumble Weed Park. Increasing the size of Tumble Weed Park and developing buffer strips adjacent to Tumble Weed Park would likely benefit many species that are dependent on arid grasslands and scrublands.

SECTION 9

Artificial Burrows

The availability of nesting burrows often limits the number of burrowing owls in grassland environments, particularly when ground squirrel numbers are low. Such was the case at NAS Lemoore during our research from 1997-2001. Burrowing owls readily nest in nest boxes constructed of wood or made of plastic, and buried in the ground or covered by a mound of soil. The use of artificial burrows at NAS Lemoore is particularly attractive because (1) concern exists over increasing ground squirrel numbers due to potential conflicts with base operations, including the agricultural outlease program, (2) artificial burrows facilitate monitoring owls, and (3) the number of nesting owls can be increased by the addition of artificial burrows because there are many locations where the boxes can be placed that do not have natural burrows but are adjacent to foraging areas.

9.1 Construction of Artificial Burrows

The original artificial burrow design we advocated using at NAS Lemoore was an inexpensive and easily assembled artificial burrow system constructed from a standard irrigation box (“christie box”) and a 4" diameter perforated drainage pipe. A hole was cut in the box to allow insertion of a 6' section of drainpipe. Dirt was then heaped over the box so it was well-covered, and the tube was buried. The tube was laid so that there was a 90' angle in it so light could not penetrate the nest box. A perch was also provided, either a wooden post or a metal t-post (Fig. 4a). The depth of dirt above the top of the box was initially at least12", to provide adequate protection from coyote excavation and insulation from heat stress.

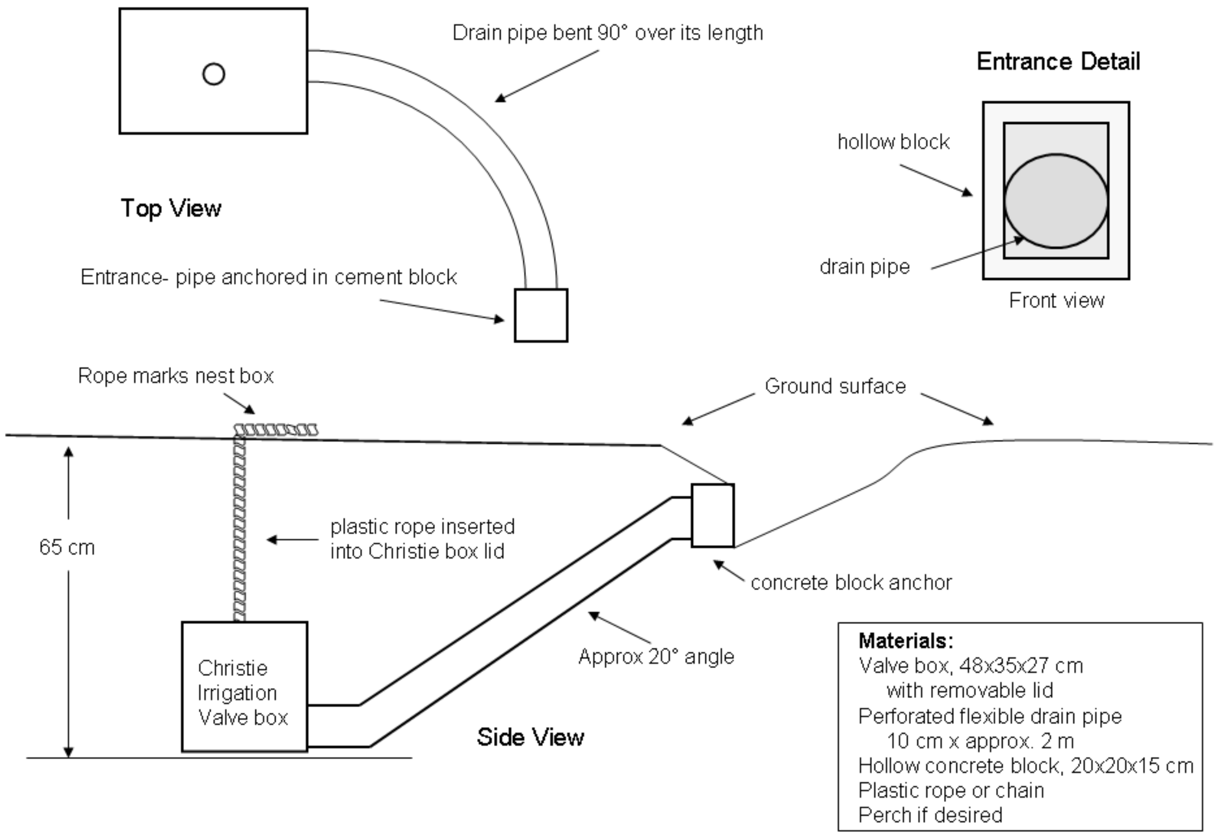
A cluster of two or three boxes was preferred over a single burrow, usually placed within the same mound to better imitate natural burrow systems (Fig. 4b). More soil is needed to adequately cover these systems, however. Young owls often move to nearby natural burrows soon after they emerge from the nest (Section 2). This may facilitate predator avoidance, nest overcrowding, or parasite loads. Although owls will successfully use a single box, a series of several boxes in the same mound may help increase survival and productivity. In locations where space is an issue, a single box can be used.

These boxes have been successfully used by burrowing owls at Lemoore, particularly in years of high food abundance and thus high numbers of nesting owl pairs. However, a decade of use has also revealed some design issues, and that frequently, the boxes are not used. We believe that the utility of these boxes is still great enough that they should continue to be installed where practical and maintained, and if natural burrows are limited.

The spacing of nest burrows influenced nesting outcome, in that nests that had more neighbors within 150 m had less success than nests with neighbors over 200 m away in South Dakota (Griebel and Savidge 2007). Although burrowing owls frequently nest in much greater densities at NAS Lemoore and seem to have adjusted to the local conditions, nests within 100 m of each other often failed (Rosenberg et al. unpublished data), although a formal assessment of the relationship between distance between nests and nest success has not yet been completed Artificial burrows placed within this distance to other burrows are not likely to be successfully used by another nesting pair, although they may function as satellite burrows for the fledging young. We consider burrows within 100 m of the nest burrow to function as satellite burrows (Ronan 2002).

Artificial burrows are an important management tool in conserving burrowing owls, but information gathered over the last decade provides better insight into their successful use. First, we note that maintenance of artificial burrows is necessary on an annual basis in order to keep them in good order. This maintenance requirement is obviously not present for natural burrows. Second, design modifications may be needed to facilitate mowing, reduce maintenance, and improve their attractiveness to owls. Maintenance issues for artificial burrows on NAS Lemoore include damage done by feral dogs, ground squirrels, and deer mice. Feral dogs can completely destroy an artificial burrow system, and apparently have done so at NAS Lemoore (see Final Report). Feral dogs are a threat to all wildlife species, possibly a

Figure 4: Artificial nest burrow setup. Modified from Barclay (2008).



threat to people, and a BASH issue. Ground squirrels were noted digging into the artificial burrow systems, filling nest chambers with dirt, and even uncovering sections of the Christie boxes or drain pipe entrance tunnels in several instances. This was particularly true when squirrels recolonized the area immediately adjacent to the nest box, or when nest boxes were installed in an area that already supported squirrels. Installing boxes where squirrels already exist is not likely to be useful, as owls at NAS Lemoore tended to use natural burrows over artificial ones if they were available (see Final Report), and having squirrels nearby greatly increases the likelihood that the box will be rendered uninhabitable by the squirrels because of the squirrels' behavior of filling the tunnels with soil. Given the maintenance challenges, boxes near active ground squirrel colonies might be better relocated to other areas or repaired when ground squirrels are not abundant and burrows may be limiting.

An alternative design has been used successfully in other locations in California, including Moffett Airfield (Barclay 2008). In this design, the nest chamber is buried two feet or more below the surface of the ground, and the tunnel entrance is held in place by a cement block fragment into which the tunnel is inserted (Barclay 2008). This was the design we used in 2008 along Reeves Road (see Rosenberg and Gervais 2009 [Final Report]). Research in Canada indicated that orientation of the entrance did not seem to affect owls' selection of the burrows (Poulin et al. 2005).

9.2 Maintenance

The most important maintenance requirement is to keep the vegetation around the burrows and on the mounds to a height of no more than 12", which still allows owls good visibility for predator avoidance. This is important because owls will abandon burrows that have become too overgrown. This has been successfully done at NAS Lemoore during 1996-2001 and observed again in 2008.

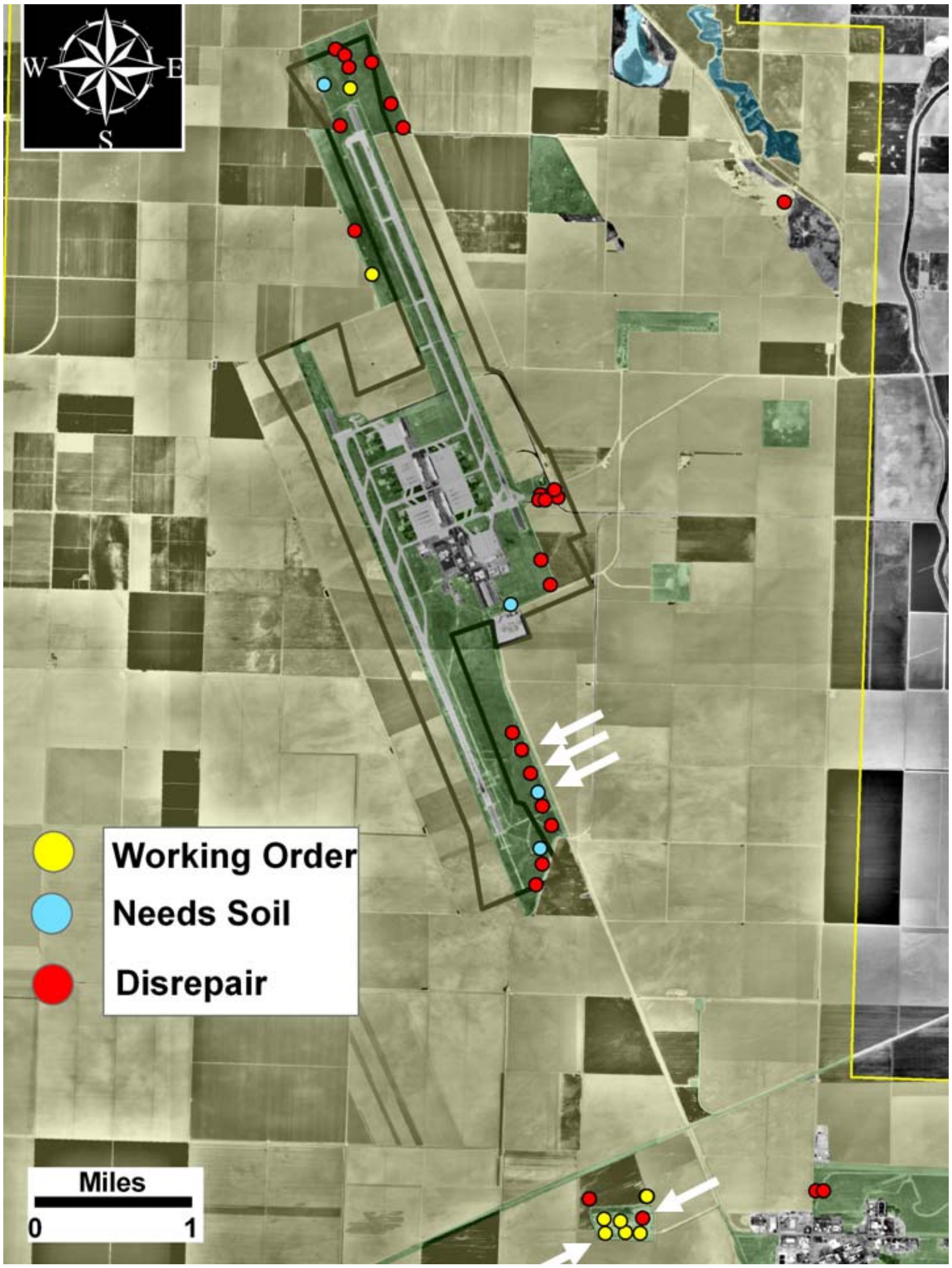
In addition, nest boxes should be checked before the owls begin breeding in early March to ensure that the drain pipes are not clogged or exposed by erosion, and that the mound is adequately covered and the perch post secure. Any necessary repairs can then occur before egg laying commences. Vegetation removal will need to be done later in the spring as the vegetation grows, but can be discontinued in late spring as the summer drought prevents further growth. Visits to manage vegetation will require some disturbance to individual burrows; however, the low level of disturbance is justifiable given the detrimental effect tall, dense vegetation has on owl survival and site occupancy.

9.3 Suggested Locations

Several considerations should guide placement of artificial burrows at NAS Lemoore. First, access for installation and maintenance must be a priority in the decision process. Heavy machinery is required to dig pits for the below-ground burrows, and large amounts of soil will need to be placed over surface burrows. All burrows must be maintained periodically. Thus, for logistic reasons alone, burrows should be placed in areas accessible to vehicles. Secondly, box location should ensure high survival rates of chicks and adults, and not be located in areas that might compromise this. Preferred areas are those that minimize disturbance. This would entail avoiding areas adjacent to busy roads, as vehicle collisions with owls, especially with recently fledged young owls, do occur (Rosenberg et al. 2007). We therefore recommend that boxes be placed at distances greater than 10 m from areas of frequent disturbance and from paved roads. Areas of frequent disturbance would include sites such as jogging paths. Third, artificial burrows should be placed at distances greater than 100 m from one another, thus increasing the likelihood of use; burrowing owls tend to nest more successfully if they are not very close to another nesting pair (Section 2). Fourth, burrows are more likely to be used if they are placed within one km of other active owl burrows because artificial burrows may provide nesting sites for dispersing young that are recruited into the population. Finally, sites that do not have natural burrows but that otherwise meet the needs for nesting burrowing owls should be candidate areas for inclusion into the network of artificial burrows at NAS Lemoore. The capped landfill is a good example of this because the gravel used during the capping of the landfill provides a barrier to ground squirrels, as it was intended to do. The site is otherwise suitable nesting habitat and in most years during our research efforts owls were nesting there.

Numerous sites fulfill the criteria for optimal locations of artificial burrows and a total of 41artificial burrows were installed since the original management plan and that remained on site in 2008. Many of these are now in disrepair (Fig. 5), and should be repaired and maintained annually if ground squirrel abundance is diminished. Five clusters were improved and repaired during the 2008 owl survey (Rosenberg and Gervais 2009).

Figure 5. Location and condition of nest boxes during 2008 field studies. White arrows indicate the 5 nest box clusters that were repaired in 2008.



SECTION 10

An Adaptive Management Plan

10.1 Goals

The success of a management plan must be based on its achieving a set of objectives or goals. In our initial management plan, we excluded Air Operations from contributing to the population goals because of the priority of national defense goals. We now view the ability to support a large burrowing owl population outside of Air Operations as unrealistic given the current distribution of nesting owls. During all of our surveys, from 1997-2001, and in 2008, almost all of the owl nests were within or adjacent to Air Operations as it is currently delineated with the new perimeter fence. We now view our initial population goal of 72 as unrealistically high, given only one population estimate since 1997 reached the population goal, despite no apparent changes to habitat quality via management activities. The average number of owl nests during our surveys since 1997 is 63. We suggest this number of nesting pairs as a management goal, recognizing the number of owl pairs will fluctuate due to factors unrelated to management activities at NAS Lemoore.

A reasonable management objective would be to ensure that the population remains no less than a specified level. There is often great variability of population size from year to year with burrowing owls in California (Rosenberg et. al. 2007), which may be due to large fluctuations in prey availability (Gervais and Anthony 2003, Gervais et al. 2006). For example, NAS Lemoore's breeding owl population size dropped from 85 to 64 nesting pairs from 1999 to 2000. In the initial management plan, we suggested that the population at any time should be no less than 50% of the 1997 number of nesting owl pairs. Given the larger number of surveys since the first management plan was written (1998), we recommend the trigger point be set at 50% of the average number of nesting owls during these surveys. The average number of pairs from 1997-2008 is 63 pairs, and thus we suggest a trigger point of 32 pairs of nesting owls. The 50% trigger point is one that is measurable, and maintains a reasonable number of owl pairs given the current habitat conditions and would allow for potentially rapid expansion of the population if management responds with appropriate actions. The trigger point does not require habitat expansion or additional efforts, other than maintaining current conditions. A goal to initiate management actions if there is a 50% or greater reduction of the average number of breeding pairs seems reasonable. Thus the trigger point would be 32 nesting pairs. It will be mutually agreed upon, funding and personnel resources available, that the Navy will initiate an investigation of the decline of burrowing owls once the trigger point is reached, with management actions put into an adaptive management framework.

10.2 Monitoring

In order to evaluate the success of management strategies, including steps taken to provide for burrowing owls, monitoring is required that is specific to NAS Lemoore and the burrowing owl management plan. The key objective will be to determine accurately if the number of nesting owl pairs (as estimated by the number of active nests) drops to 32 pairs. During our research activities from 1997-2000, and again during field work in 2008, we estimated the number of nesting pairs of owls using what we considered to be a complete census, that is, an attempt was made to find every nest during the study period. Earlier work at NAS Lemoore suggested our methods resulted in a detection probability of 1.0 for areas in which we searched for nests (Rosenberg et al. 2007). Such efforts are very time consuming, expensive, and potentially disruptive to air operations. We recommend a reconsideration of the census approach to monitoring owls at NAS Lemoore in favor of using a sampling approach to estimate the number of active nests, and more importantly, to determine if the number of owl pairs exceeds the trigger point of 32 nests. A frequency of 5-10 years for surveys to estimate population size may suffice if there are no changes in the management of the nesting and foraging habitat of the owls.

10.3 Recommended Management

Below, we summarize our recommendations for the initial and updated management plan for burrowing owls at NAS Lemoore. We expect research and monitoring of management activities to provide further insight that can be used to continually update these set of recommendations.

Table 2. Recommended management activities comparing initial and updated management plan

Resource/Objective	Current Activity	Recommended Activities	
		Initial Mgmt Plan	Updated Mgmt Plan (Section:Page)
Management Goal	none	72 owl pairs outside of Air Operations	63 (mean of surveys) owl pairs within NAS Lemoore **(10.1:45)**
Trigger Point	none	32 pairs or active nests (50% of average number of active nests during all surveys)	32 pairs or active nests **(10.1:45)**
Vegetation (Air Operations)	Frequent Mowing	Fire, Mowing	Mowing (4.5:29)
Vegetation (Outside Air Operations)	Frequent Mowing	Fire, Mowing	Mowing (4.5:29)
Tumble Weed Park	Fire and Grazing	Fire and Grazing; Research	Fire, Grazing, continued restoration activities (4.5:29)
Capped Landfill	None Planned	Grazing and Mowing; Research	Grazing and mowing (4.5:29)
Newly Created Areas	Mixed	Revegetation with Native Species	Revegetation with native species along with follow-up restoration work (4.4:28)
Ground Squirrels	None	Develop Management Plan	Develop management plan, with an emphasis on identifying management goals and approaches (7.2:38)
Nest Boxes		Landfill: Maintenance; Monitoring	Maintain landfill nest boxes (9.3:43)
		Areas Outside of OPS: Install and monitor nest boxes in selected sites; maintenance	If ground squirrel population is reduced such that burrows are not abundant, repair and maintain existing nest boxes (Fig. 5) (9.3:44)
		Public School: Locate and install burrow cluster	Adding a nest box at the school at NAS Lemoore would be a very good educational experience for students

Bird Air Strike Hazards	Veg. height 4" max.	Monitor strike incidents; mow to minimize seed heads (<12 inches)	Air Operations to develop policy statement regarding BASH risk from burrowing owls relative to other birds at NAS Lemoore. Risk is understood to be very low, but formal statement would facilitate owl management actions. (6:36)
Pesticides		Evaluate high DDE levels with continued research; evaluate use of alternative chemicals; target selected chemicals for reduction consistent with DoD policy goals; strive for higher efficiencies of applications by improved technologies.	Research completed; review current use of pesticides for use with anticipated changes in crops due to reduction in irrigation (5.2:32; 5.5:35)
Education	School field visits	Provide artificial burrow at public school and in other high profile site; Install infrared video cameras within these burrows when active; provide information brochures or posters/kiosks	No Change. We believe there is still a great opportunity for natural resource education using the burrowing owl as a mascot for conservation.
Public Relations	Incidental	Actively disseminate proactive actions taken by NAS Lemoore with burrowing owl conservation to public and conservation organizations	No Change; Distribute and use the burrowing owl videos funded by the Dept. of the Navy/NAS Lemoore.
Research	Demography and Space Use	Continue demography and space use study through 2000; augment with experimental vegetation research; DDE evaluation	Research completed; DDE evaluation completed; Primary gap in understanding burrowing owls is (1) how to attract burrowing owls to unoccupied sites, and (2) regional movement patterns and population structure regionally
Monitoring		Implement nest reuse monitoring	Develop efficient monitoring strategy to detect if trigger point is reached (10.2:45)

SECTION 11

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Appendix: Active nest site locations at NAS Lemoore.

based on UTM NAD27, Zone xx N

Note: 1997-2000 UTMs have a potential error of 100m due to GPS scrambling that occurred during those years.

I. 1997

Nest	XUTM	YUTM
1	237444	4023614
4	236261	4020494
5	236030	4020760
6	234053	4028184
9	234098	4027929
13	236259	4020825
14	236362	4028063
15	236388	4027991
16	236121	4020482
19	236526	4027510
20	236664	4027820
22	236787	4027420
23	234830	4028328
25	234300	4028753
27	234057	4027999
29	234035	4027960
30	234682	4026970
31	236315	4020501
32	236212	4020824
34	237394	4017248
35	236793	4017225
36	235040	4026158
37	234000	4025475
38	233912	4025645
40	233853	4025809
42	234531	4024119
43	234630	4023753
44	236088	4023936

Nest	XUTM	YUTM
45	236116	4023737
46	236249	4024550
47	235676	4022340
48	235424	4022566
49	235682	4022741
50	234877	4026919
51	234775	4027298
52	235593	4022046
53	235744	4022764
54	235762	4022858
55	235312	4022918
56	235585	4022984
58	234985	4023365
59	234993	4023441
61	234696	4024133
62	234486	4024476
63	234582	4025283
64	234561	4024717
65	234832	4023980
66	235089	4023573
67	235262	4023125
68	235879	4022641
72	236147	4024173
74	236557	4028080
75	234821	4027319
76	234142	4028600

II. 1998

Nest	XUTM	YUTM
4	236261	4020494
5	236030	4020760
8	234174	4029073
9	234098	4027929
11	236281	4028071
13	236259	4020825
15	236388	4027991
16	236121	4020482
19	236526	4027510
22	236787	4027420
23	234830	4028328
25	234300	4028753
26	234584	4028879
27	234057	4027999
28	234075	4028024
30	234682	4026970
32	236212	4020824
35	236793	4017225
39	233918	4025758
40	233853	4025809
45	236116	4023737
47	235676	4022340
48	235424	4022566
50	234877	4026919
51	234775	4027298
52	235593	4022046
54	235762	4022858
56	235585	4022984
59	234993	4023441
60	234652	4024082
61	234696	4024133
62	234486	4024476

Nest	XUTM	YUTM
63	234582	4025283
64	234561	4024717
65	234832	4023980
67	235262	4023125
69	235806	4024946
72	236147	4024173
75	234821	4027319
77	235635	4022724
78	235783	4022950
79	235820	4022783
80	235845	4022742
81	236578	4027942
82	233944	4025818
83	233975	4025491
84	236198	4023430
85	235014	4023370
86	234972	4023328
87	235033	4023591
94	236835	4027462
95	235639	4022791
96	235842	4022840
97	234121	4027973
98	235725	4022140
99	236143	4023792
100	234146	4025153
101	234878	4024514
102	235234	4022905
103	236310	4024572
104	236145	4024630
106	234208	4028231
107	234010	4025420
108	235597	4021469
37	234000	4025475

III. 1999

Nest	XUTM	YUTM
88	237318	4016871
89	237169	4016878
90	236958	4016869
91	237345	4017024
4	236261	4020494
5	236030	4020760
13	236259	4020825
16	236121	4020482
113	236091	4021861
114	236269	4021420
115	236408	4021080
121	236202	4027626
125	236218	4020793
126	236080	4020764
15	236388	4027991
22	236787	4027420
94	236835	4027462
122	236184	4027853
123	236185	4027933
163	235602	4021484
128	235798	4022831
52	235593	4022046
136	235731	4022169
47	235676	4022340
48	235424	4022566
95	235639	4022791
133	235740	4022646
73	235585	4022660
135	235838	4022696
132	235772	4022919
134	235727	4022564
127	235696	4022866
130	235672	4022961
129	235733	4022930
63	234582	4025283
64	234561	4024717
61	234696	4024133
60	234652	4024082
65	234832	4023980
138	234985	4023365
139	235099	4023584
162	234448	4024457

Nest	XUTM	YUTM
51	234775	4027298
75	234821	4027319
23	234830	4028328
25	234300	4028753
76	234142	4028600
131	234620	4028843
142	234201	4029128
143	234596	4028966
165	234493	4029030
170	234204	4028221
111	234374	4027211
112	234559	4026764
144	234076	4028150
145	234090	4028032
146	234060	4027998
9	234098	4027929
148	234054	4028033
149	234230	4027896
154	235263	4023064
161	235289	4022935
166	234088	4025181
151	234013	4025457
152	233978	4025480
153	233783	4025925
157	233864	4025878
160	233950	4025804
164	233963	4025787
45	236116	4023737
84	236198	4023430
118	236387	4023563
167	236150	4023796
79	235820	4022783
80	235845	4022742
104	236145	4024630
159	236101	4024590
158	236173	4024613
174	236242	4024727
171	238868	4027343
172	238807	4027213
173	238952	4027006
175	234351	4024536
71	235679	4024899
168	234985	4023341

IV. 2000

Nest	XUTM	YUTM	Nest	XUTM	YUTM
88	237318	4016871	170	234204	4028221
89	237169	4016878	17	234143	4029247
90	236958	4016869	143	234596	4028966
91	237345	4017024	142	234201	4029128
92	237116	4016995	207	234062	4029164
93	236944	4017016	228	234862	4028268
4	236261	4020494	75	234821	4027319
5	236030	4020760	51	234775	4027298
13	236259	4020825	50	234877	4026919
16	236121	4020482	64	234561	4024717
177	236186	4021612	65	234832	4023980
176	236306	4021284	218	234789	4024188
220	235714	4022779	61	234696	4024133
221	235755	4022915	139	235099	4023584
95	235639	4022791	59	234993	4023441
135	235838	4022696	141	239237	4017308
154	235263	4023064	163	235602	4021484
209	235247	4022922	162	234448	4024457
113	236091	4021861	187	234492	4024187
215	235727	4022769	175	234351	4024536
118	236387	4023563	173	238952	4027006
196	236164	4023798	210	235284	4022905
114	236269	4021420	227	235566	4022837
153	233783	4025925	225	235865	4024869
208	233883	4025799	199	236219	4024572
151	234013	4025457	159	236101	4024590
222	233889	4025851	223	234145	4029075
112	234559	4026764	216	234509	4024481
190	234105	4027892	217	234832	4024103
191	234098	4027929	130	235672	4022961
192	234071	4028030	219	234988	4023439

V. 2008

(note: these nest numbers were new assigned numbers that do not correspond to any earlier nest numbers)

Nest	XUTM	YUTM
28	233875	4025879
1	233901	4025863
24	233947	4025552
23	234014	4025397
30	234021	4028957
18	234116	4028179
19	234117	4028223
29	234118	4028346
31	234136	4028738
102	234175	4029078
17	234206	4028135
20	234282	4027970
32	234311	4028571
33	234312	4029147
16	234375	4027688
2	234391	4024817
27	234513	4024869
15	234518	4027374
37	234575	4026760
38	234663	4023171
26	234804	4024589

Nest	XUTM	YUTM
103	234837	4027317
13	235015	4022936
21	235183	4025678
22	235307	4025463
3	235365	4025263
14	235420	4022648
104	235520	4022639
12	235589	4022591
8	235628	4021486
9	235712	4021652
35	235723	4025851
10	235843	4021688
7	235948	4020945
11	235985	4021460
6	236100	4020552
100	236139	4023823
5	236199	4020636
4	236213	4020906
101	236282	4023809
25	236381	4020878
36	237517	4019298
34	239005	4025272