Modeling the Impact of Climate and Anthropogenic Change on Birds and Vegetation on Military Lands in California (Legacy 10-465)

Abstract

Global climate change will affect the landscapes and biological diversity of Department of Defense (DoD) lands. Our previous work on climate-related shifts in bird distributions in California suggests that these changes may be especially great on DoD installations relative to those on other Federally administered lands in the state. In addition, the effects of climate change may be amplified by the effects of land-use change in the vicinity of bases. Together, these changes could compromise natural-resource management and the sustainability of the military mission.

In order to assess the potential impacts of changes in climate and land-use (housing development) on military installations in California, we used a combination of downscaled climate models, species-distribution models, and projections of future changes in housing densities to project changes in broadly defined vegetation types and in the distribution and occurrence of 202 breeding landbird species. We also used multivariate clustering approaches and ecoregional analyses to group together installations with similar projected future changes in environmental factors or bird-community composition, under the premise that, regardless of their location or military branch, installations undergoing similar future changes might benefit by sharing approaches and plans for dealing with future changes.

The climate models suggest that climate changes may be especially large on some interior desert installations but much less severe in coastal regions of southern California. Climate-induced changes may affect as much as one quarter of the vegetation at some installations, while others experience little overall change. On average, climate-related shifts in the distribution of bird species is projected to be considerably greater on DoD installations than in other areas of California. However, the effects of changing land use, especially the growth of low-density suburban and exurban housing development, are projected to be greater than those of climate change for many species in the areas immediately surrounding DoD installations.

Our results indicate that the combined effects of climate change and land-use change on birds and environments on military lands in California may be substantial, but will not be the same everywhere. There would be considerable benefits if installations with similar environments or facing similar changes in the future were to collaborate on developing management plans to cope with those oncoming changes.

Project Specifics

Description of geographic setting: The analysis was conducted for the state of California, including all ecoregions in the state. The approach and conclusions may be more broadly applicable to other regions in the western United States.

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Partners: None.

Service branch: Army, Navy, Air Force, Marine Corps.

Project location: The analyses focused on 39 military installations in the state.

Installation size: The 39 installations ranged from 449,115 ha in size (NAWS China Lake) to 136 ha (Defense Fuel Support Point San Pedro).

Installation primary mission: N/A

Project dates: 7/20/10 – 7/19/11

Project point of contact: Thomas Smith at the Army COE

Purpose/Need:
Global climate change is projected to have major impacts on the environment. These changes will alter the distributions of plant and animal species and affect the environment of military installations, potentially eroding their capacity to support the military mission and creating new challenges to the management of species and ecosystems. Climate change and anthropogenic effects on areas surrounding military installations may change land uses and increase the threat of encroachment managing installations to ensure the long-term sustainability of the military mission and the effectiveness of natural-resource management will require an understanding of what changes the future may hold.

The purpose of our work is to assess how climate change, together with projected changes in land use, may affect the distributions of California bird species in relation to military lands in the state. Our objectives are to (1) summarize projected distributional changes for a broad array of bird species, emphasizing threatened, endangered, and at-risk species (TER-S) and species of special concern; (2) assess projected changes in general vegetation types; (3) evaluate how changes vary regionally and among installations; (4) determine the effects of changes in land use (housing development) on bird distributions in areas surrounding installations; (5) test the effectiveness of assessments of species vulnerability to climate change; and (6) summarize the findings that may help to inform forward-looking environmental management on DoD installations.

Approach

We included 39 military installations in California in our analyses. The largest was 449,115 ha (NAWS China Lake) and the smallest was 136 ha (Defense Fuel Support Point San Pedro); jurisdiction of these installations was under the Army, Navy, Air Force, or Marine Corps. Our modeling addressed distributional changes associated with climate change for 202 breeding landbird species, although we focused on broader changes in the overall species richness of bird communities and the occurrence of groups of species associated with major habitat types.

To model current and future bird species distributions, we use data collected at 23,064 locations in California, in conjunction with a distribution-modeling algorithm (Maxent 3.2.1). To improve the capacity of the species distribution models (SDM) to project

changes in habitat relevant to birds, we included vegetation distribution as an input to the models. Vegetation types were aggregated into 12 major vegetation classes and were modeled into the future based on observed relations with climate, solar radiation, soil, and topography.

Future climate conditions were summarized using projections from a regional climate model (RCM), RegCM3 at a 30-km resolution, with emissions trajectories taken from the Intergovernmental Panel on Climate Change (IPCC) SRES A2 scenario. Boundary conditions were based on output from two global climate models (GCMs): the National Center for Atmospheric Research (NCAR) Community Climate System Model (CCSM3.0) and the Geophysical Fluid Dynamics Laboratory (GFDL) GCM CM2.1. For the CCSM boundary conditions, the RCM was run from 2038-2069; for the GFDL boundary conditions, the run was 2038-2070. The 30-km resolution RCM results were then statistically downscaled to a 800-m resolution using change values relative to the 800-m PRISM grid representing contemporary climate.

To examine the potential combined impacts of climate change and future housing development, we compared current and future climate and housing development in three buffer zones (2 km, 5 km, and 10 km) surrounding individual installations. We considered three housing-density classes: >12.4 units/ha (high/urban), 2.47 – 12.4 units/ha (low/suburban), and 0.247 – 2.47 units/ha (very low/exurban). Figure 1 shows an example of the analysis.

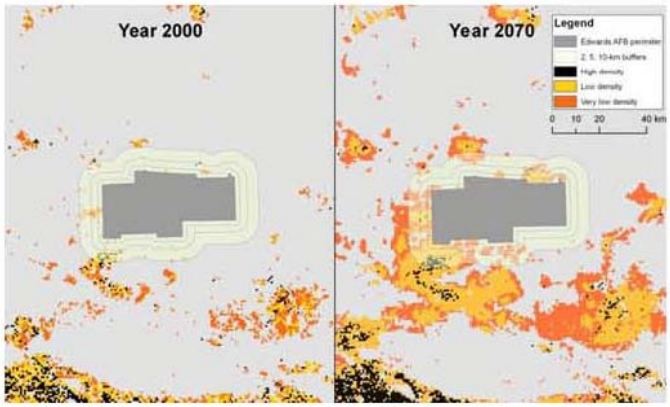

Figure 1. Detail of Edwards Air Force Base showing base area and perimeter with three buffer zones used for analysis (2, 5, and 10-km). Housing density classes are shown for the current period (year 2000) and projected future (year 2070).

Results

Climate change

In general, the two future climate models projected similar patterns in future climate change (Fig. 2). Both models projected substantial climate change in southeastern California, particularly in desert areas such as Death Valley and the Sonoran desert. DoD installations in desert regions, such as NAWS China Lake and Chocolate Mountain Air Gunnery Range are projected to experience high magnitude of climate change. Less change in climate was projected along the central and southern coasts.

Vegetation change

Based on our vegetation models, the current vegetation on the majority (74.0%) of military installations was classified as desert scrub, followed by chaparral/coastal scrub (6.1%), grassland (4.8%), desert wash (4.4%), barren (3.6%), urban (1.8%), eastside pine/piñon pine/juniper (1.7%), and blue oak/foothill pine (1.4%). Both future scenarios showed an increase in desert scrub habitat, a reduction in blue oak/foothill pine, and loss of all or almost all of eastside pine/piñon pine/juniper, redwood/closed-cone pine, and montane hardwood vegetation types on military installations in California. Eight installations are projected to experience major changes that affect over 27% of the vegetation, while five other installations are projected to experience changes in vegetation affecting 11.6% or less of the vegetation on that base.

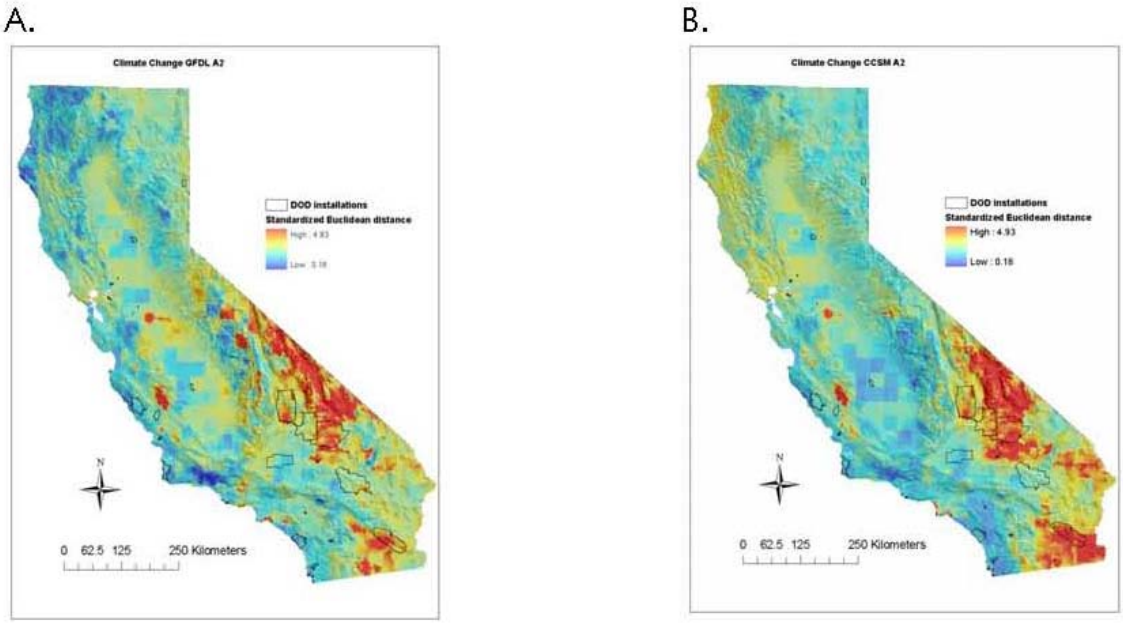

Figure 2. The magnitude of projected climate change, with warmer colors indicating a greater change from the current climate using the (A) Geophysical Fluid Dynamics Laboratory (GFDL) GCM CM2.1and (B) National Center for Atmospheric Research (NCAR) Community Climate System Model (CCSM3.0).

Changes in bird distributions

The mean percent change between current and future probability of occurrence for all bird species modeled over the state as a whole was -12.0% and -13.3% for the CCSM and GFDL future climate models, respectively (Fig. 3). However, the average decrease was much greater on DoD installations, with our models projecting a -34.2% and -28.7% change (CCSM and GFDL, respectively). Individual species varied in the projected response to climate change. For example, the California endangered Western Yellow-Billed Cuckoo is projected to decrease by -6.2% across the state while the decrease on DoD lands is projected to be -29.4% (based on the CCSM projections). On the other hand, some species that are projected to have declining probabilities of occurrence throughout the state, such as Hermit Thrush and Ruby-crowned Kinglet, are projected to have an increased probability of occurrence on DoD lands.

Areas in the foothills of the Sierra Nevada mountains though the north of the Central Valley are projected to have the highest levels of change in bird community composition with climate change (Fig. 4). In general, the areas of highest projected bird community turnover occur outside of DoD lands, although some installations, such as NAWS China Lake, do have areas with moderately high future turnover.

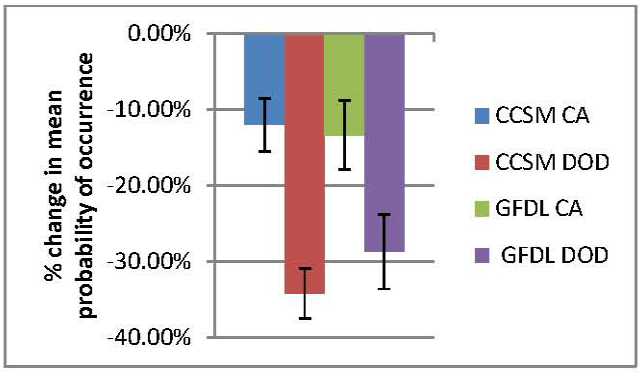

Figure 3. The percent change between current and future mean probability of occurrence across California (CA) and Department of Defense Installations (DOD) in California based on Maxent species distribution models for 202 bird species using two future climate projections.

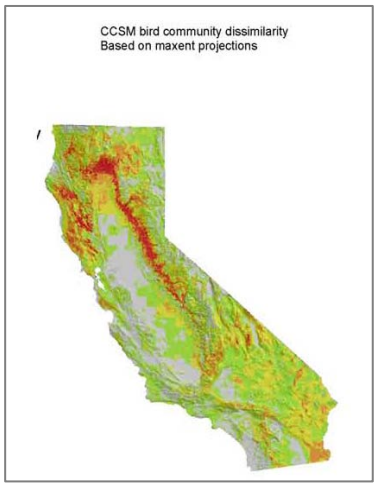

Figure 4. Dissimilarity between current and future bird communities under climate change. Red indicates large differences, gray indicates little change.

Grouping installations

Using the model results, we grouped installations into hierarchical clusters based on their similarities in environment or bird communities. The hierarchical clustering for current environmental conditions resulted in five main clusters of installations: installations along the south coast; inland bases, including installations bordering the Coast Range and the Central Valley; a third cluster of more central-coast installations; and two clusters containing installations located in desert areas, one with less topographic heterogeneity, the other containing some of the larger desert installations with greater topographic heterogeneity. The hierarchical models for future environmental conditions were generally similar to the current clusters.

Based on their current bird-community composition, DoD installations in California cluster into three main groups, one including desert installations, a south-coast cluster, and a cluster comprised of a mix of coastal and inland coastal installations. In the future projections, desert and non-desert installations are mixed among clusters, suggesting that

DoD installations across California may become more desert-like in their bird communities. This is not surprising, given the warmer, dryer California that the models project. Larger installations, which support a greater diversity of vegetation and bird communities, are also projected to experience a greater change in bird community composition; such installations are more likely to need adaptation plans that incorporate the possibility of novel community types than are smaller installations.

Land-use change

Climate change is only one of several environmental changes that will threaten species and biological communities in the future. Rapid changes in land use, particularly urban, suburban, and exurban housing development, may pose a more immediate threat to conservation and environmental management than climate change. These changes are of particular concern for management on military installations, where encroachment of development from "outside the fence" may compromise activities that are essential to meeting the military mission. When averaged across all installations, both climate scenarios showed potentially larger impacts from housing development on bird-species distributions than from climate change across all three buffer distances. In the GFDL scenario (the warmer of the two scenarios), the overall impacts of housing were greater than climate impacts, with high-density impacts varying little between buffers but suburban and exurban densities becoming more prominent at the 5-km and 10-km levels (Fig. 5).

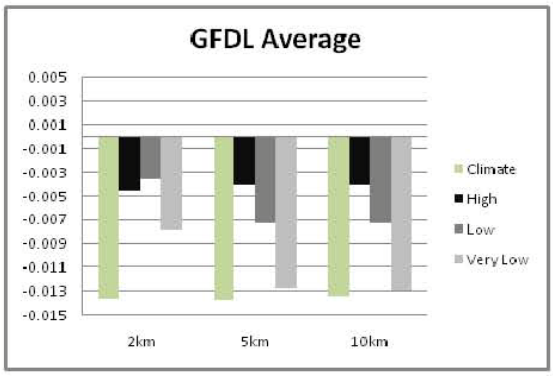

Figure 5. The effect of climate and high-, low-, and very-low-density housing on the projected distribution of bird species on and within 2-km, 5-km, and 10-km buffer zones averaged across DoD installations for the GFDL climate scenario. The Y axis is the mean change in the probability of occurrence between current and future climate given the climate or land-use scenario.

Of the 29 installations examined under the GFDL scenario, 23 had climate induced reductions in species occurrences, 10 of which had even larger reductions due to housing change. For this same scenario, 6 bases had climate related increases in species probabilities of occurrence, 5 of which had housing related reductions that were as great as or greater than the impacts of climate.

Benefit

Effective management of the environments of military installations in the future will require a consideration of the potential effects of changes in climate and land uses in the surrounding area. Our modeling results provide some preliminary guidance about the

potential consequences of these changes and where they may be most severe. For example:

- Climate change will affect most installations, but some more than others. Those responsible for managing natural resources on installations should consider the directions and magnitudes of change projected for the areas of their installations, while also recognizing the uncertainties inherent in model projections.
- Our projections can give managers an idea of whether or not they should continue to manage for the same sets of species or bird communities that they currently manage and whether species that do not currently occur at a particular installation are likely to occur there in the future.
- Our models of vegetation change may help managers plan for future shifts in the dominant communities that make up DoD installations. Shifts of vegetation types on DoD lands will not only change the habitat available for animal species but will also require managers to adapt to changing conditions, for example by modifying restoration techniques.
- The results of the cluster analyses can be used by resource managers on DoD installations to identify other installations that may have similar management issues with regard to the environment and bird communities. Installations with similar environments and/or similar bird communities could use this information to coordinate actions to most efficiently protect natural resources, for example developing regional plans that are coordinated within the clusters.
- Our modeling shows that bird species distributions along the periphery of DoD installations are sensitive to both the changes in climate and land use. This is relevant for DoD land managers in several ways. For example, increases in urbanization near DoD installations could result in species seeking refuge on DoD lands, potentially compromising DoD activities. Disturbance caused by habitat degradation can lead to the establishment of non-native or invasive species, which may further degrade habitat suitability or threaten the population viability of native species within installations. Loss of habitat in and around DoD lands could isolate populations, restricting their ability to move into or out of installations and making them more susceptible to rapidly changing climate.

Recommendations/Lessons learned

Although models of the future contain too much uncertainty to permit specific actions (particularly at the scale of 800-m pixels), there are several general recommendations from our work that could contribute to more effective and efficient environmental management on military installations in California.

- The effects of changes in climate and land use may appear suddenly. Consequently, it is important to monitor species or environmental attributes that can indicate oncoming changes so that management practices can be adjusted accordingly.
- Changes in climate or land use may affect some installations much more than others. Our results provide some suggestions about which installations those might be. Environmental managers on those installations should plan for the anticipated effects of climate or land-use change.
- Planning may be more effective if it is done collaboratively among installations with similar environmental or bird-community characteristics. Our cluster analyses help to identify installations that might benefit from such collaboration. It is not too early

for personnel at these installations to share their thinking about how they might adjust to future changes in climate and land use.

Communications

Two papers from this project were presented at the 2012 Annual Conference of the Western Section of The Wildlife Society in Sacramento, California in February, 2012:

- Birds and Buffers on Military Lands in California: The Impacts of Climate Change and Land-use Change. D. Jongsomjit, S. Veloz, and J. Wiens.
- Using Environmental Clustering to Examine the Potential Regional Effects of Climate Change on Birds on Military Lands in California. S. Veloz, D. Jongsomjit, and J. Wiens.