United States Department of Agriculture
Natural Resources Conservation Service

CEAP Conservation Insight
Conservation Effects Assessment Project
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Wintering Waterfowl Respond to Wetlands Reserve Program Lands in the Central Valley of California

Summary Findings

Daytime use by wintering waterfowl at Wetlands Reserve Program (WRP) sites within the northern Central Valley of California (CVC) increased dramatically after wetland restoration and was sustained for up to 8 years post-restoration.

The magnitude of the increase in waterfowl density at WRP sites after wetland restoration was greater with greater densities of birds in the local area before restoration, lower amount of surrounding wetland habitat within a 1.5-km radius, greater increase in flooding after restoration, and closer proximity to flooded rice fields.

Estimates of waterfowl distribution within areas sampled by weather surveillance radar suggest that 18 percent of wintering waterfowl use the more than 67,900 acres of restored and unrestored land enrolled in the WRP. Restored wetland habitat within WRP sites made up about 8 percent (30,360 acres) of the total wetland habitat within the CVC in 2007.

Waterfowl use of flooded rice fields during the daytime and during wetter winters nearly tripled from 1995 to 2007 relative to use of natural wetland habitats.

Recommendations

An additional 104,000 acres of seasonal wetland restoration are needed to meet waterfowl conservation objectives in the CVC (Central Valley Joint Venture 2006). Active restoration of hydrology and moist-soil management on WRP sites can help meet this objective.

Waterfowl use of WRP sites can also be improved by locating sites close to flooded rice fields within local landscapes that have high pre-existing waterfowl abundance and relatively little wetland habitat.

The assessment team developed spatially explicit decision support tools for prioritizing future WRP enrollments. The tools map the predicted post-restoration magnitude of waterfowl use based on site and local landscape variables.

The Wetlands Reserve Program (WRP) aims to create quality habitat for wildlife by helping landowners protect and restore wetlands. Most WRP wetlands are concentrated within a few geographic regions, including the Central Valley of California (CVC). Within the CVC, 146 individual easements, primarily agricultural fields, were enrolled into the WRP between 1992 and 2005. These enrollments cover about 67,000 acres. As of 2007, wetland restoration had been completed at 106 of these sites (73 percent).

The CVC provides critical wintering habitat for many species of waterfowl in the Pacific Flyway. Agricultural and other human development has reduced the extent of the estimated 4 to 5 million acres of original wetlands in the CVC by more than 90 percent. However, many wetlands in the northern CVC were converted to rice, corn, or other grains that have high forage value to waterfowl, resulting in a landscape where waterfowl roost on wetlands during the day and feed in surrounding croplands at night. Wintering waterfowl, especially field-feeding species such as mallards (*Anas platyrhynchos*) and northern pintails (*A. acuta*), regularly engage in flights between habitats used mainly for resting and those used for feeding. Although there is interspecific, geographic, and intraseasonal variability in the exact timing of these feeding flights, these movements tend to occur at dawn and dusk as an abrupt *en masse* exodus and are closely synchronized to sun elevation.

The current network of weather surveillance radars (WSR-88D) within the United States readily detects flying birds and has proven to be a useful remote-sensing tool for ornithological study. For migrating land birds, their locations and relative densities for a given day are typically sampled using a single nearly instantaneous radar scan collected during the abrupt *en masse* exodus of birds at evening civil twilight. Radar measures of reflectivity are strongly correlated with ground observations of bird densities and provide relative bird density measures that can be quantitatively compared across the radar area after being adjusted for sampling biases (Buler and Diehl 2009). The evening e*n masse* exodus of wintering waterfowl between foraging and roosting habitats presents a similar opportunity to quantify bird distributions using weather surveillance radar observations. Additionally, data

Evening emergence of waterfowl from a WRP easement site in California

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from WSR-88Ds have been archived since the mid-1990's by the National Climatic Data Center and are freely available. Thus, the data archive allows for assessing the change in bird use at WRP sites before and after restoration across many years.

Evaluation Partnership

In 2007, a partnership was formed among the Natural Resources Conservation Service (NRCS), the U.S. Geological Survey (USGS) National Wetlands Research Center, the USGS Western Ecological Research Center, and the University of Delaware to use weather radar observations to evaluate wintering waterfowl response to WRP wetland restoration within the CVC and to identify habitat and landscape features that are most important in explaining the magnitude of waterfowl responses among individual WRP sites. This partnership was formed in support of the Wildlife Component of the Conservation Effects Assessment Project (CEAP). This *Conservation Insight* provides a synopsis of the WRP evaluation; full details are available from the final project report posted at www.nrcs.usda.gov/technical/nri/ceap.

Assessment Approach

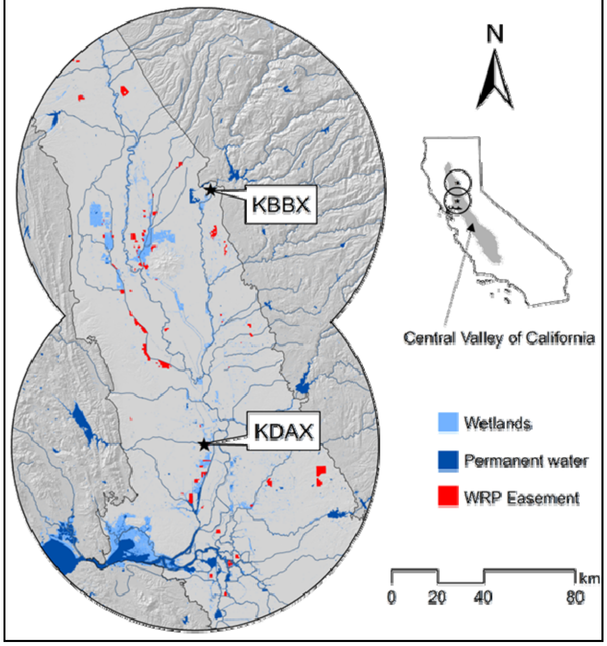
Quantifying wintering waterfowl distributions with weather surveillance radar. The first step was to develop and validate an improved approach for using weather surveillance radar to quantify wintering waterfowl distributions at the onset of evening feeding flights. Observations were studied from two WSR-88Ds (KDAX and KBBX) near Sacramento, CA, that provide radar coverage of the northern half of the CVC (fig. 1). Accuracy of radar measures collected during December and January 1998–2000 were validated using more than 8,000 locations of radio-marked waterfowl collected concurrently within 100 km of either radar site by Fleskes et al. (2007). The major source of bias in adjusting radar measures is due to the spreading of the radar beam as it travels away from the radar, which causes the radar to sample the airspace at different heights with distance from the radar. Bias-adjusted radar reflectivity (i.e., the amount of radio energy returned by targets in the sampled airspace) measured at the onset of waterfowl evening feeding flights was positively related to the observed diurnal density of radio-marked waterfowl locations at the ground. To improve the accuracy of reflectivity measures, the study team modified the algorithms of Buler and Diehl (2009) by interpolating reflectivity to a sun elevation angle of 5.0° below horizon (about 30 min after sunset). This time point occurs about 5 minutes after the mean onset of evening feeding flights and represented the sampling time point that optimized the correlation between radar and ground measures of bird density.

The software package BIRDS (Bias Improvement of Radar Data System) was written to facilitate and implement the radar data analysis approach. Users input native radar data from the NCDC archive and output bias-adjusted radar data in file formats easily imported into popular statistical or GIS software. The software enables non-technical users interested in processing WSR-88D data for mapping bird distributions to pursue their own management related research questions and analyses.

All available radar data collected during the period of peak wintering waterfowl population numbers (December – January) were obtained for KDAX (winters 1995 through 2007, $n = 13$ winters) and KBBX (winters 1996 through 1998 and 2004 through 2007, $n = 7$ winters). Data were screened to exclude sampling days when precipitation was present or there was anomalous propagation of the radar beam. Overall, one-third of all potential days were used for quantifying bird densities. For each winter, the geometric mean of reflectivity measured at the onset of evening feeding flight was calculated as a measure of mean relative bird density. Relative bird density measures at WRP sites were then standardized for a given winter to control for annual fluctuations in overall waterfowl populations by dividing the mean winter reflectivity at the site by the mean winter reflectivity observed across all wetland habitats. This produced a ratio of reflectivity where a value of 1 indicates bird density identical to that at existing wetlands.

The focus of this assessment was on waterfowl habitat use patterns during the winter season—specifically during December and January. This time period also coincides with the waterfowl hunting season in the CVC. Although hunting disturbance likely influences habitat use patterns, no attempt was made in this assessment to control for hunting disturbance effects.

Figure 1. Locations of two WSR-88D stations and their 80-km radius sampling areas within the Central Valley of California. The extent of wetlands and permanent open water during 2000, and Wetlands Reserve Program sites as of 2007 also displayed.



Compiling land cover and soil wetness data. The 1999 land cover dataset produced by Fleskes et al. (2005a) and derived from 30-m resolution Landsat Thematic Mapper (TM) data was used to determine the distribution of habitats within the CVC. This land cover dataset was chosen because rice is classified separately from other types of agriculture and the year of data collection is close to the middle of the time period of this study. At least one TM satellite image from each winter was used to quantify annual fluctuations in the extent of surface water and soil moisture. The mean soil wetness index was calculated within WRP site boundaries during each winter (fig. 2A). Integrating the map of classified surface water (fig. 2B) with the land cover map (fig. 2C) allowed for quantification of the extent of flooded rice during each winter.

Data Analysis. WRP sites with at least three winters of baseline radar data before enrollment and at least one winter of radar data after wetland restoration were assessed. Data from winters prior to enrollment of a WRP site, when active farming was being conducted, were classified as "pre-enrollment" years. Winters following the completion of micro-topography restoration efforts and active flooding management were classified as "post-restoration" years. Because some individual WRP sites are adjacent to other WRP sites or are spatially clustered into restored wetland complexes, WRP sites located within 4 km of each other were grouped into 19 independent sampling clusters.

Simple linear regression modeling within an information-theoretic approach was used to estimate the relative importance and effect size of variables in explaining variation of the mean standardized bird density during pre-enrollment and post-restoration years. Predictor variables included local site, landscape composition, and landscape placement characteristics. Local site characteristics analyzed for pre-

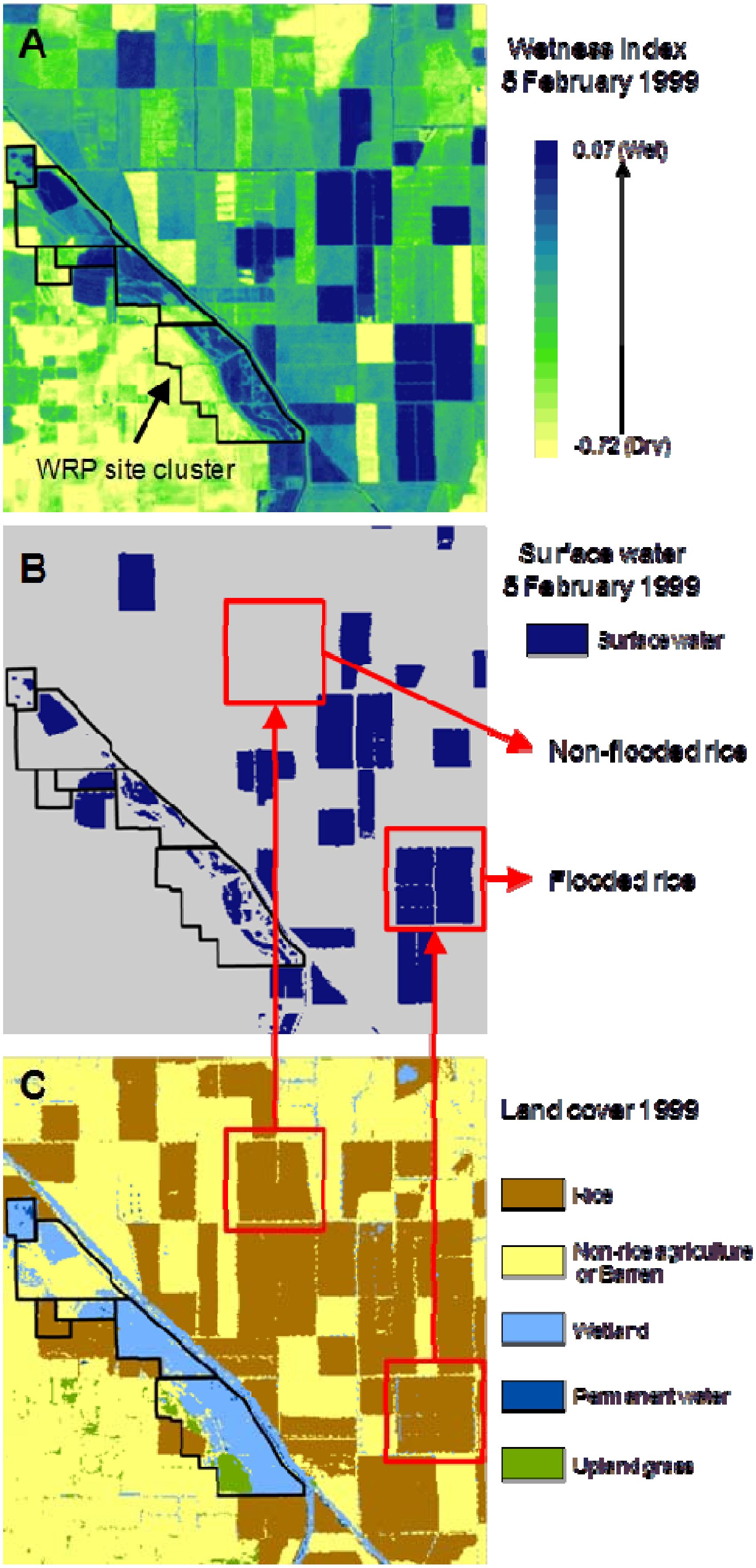


Figure 2. Example data layers of A) wetness index, B) surface water, and C) land cover. Red squares and arrows illustrate how surface water and land cover data were integrated to determine extent of flooded rice.

enrollment data included mean wetness index and site area. Local site characteristics analyzed for post-restoration data included mean standardized bird density during pre-enrollment years, change in mean wetness index before and after restoration (i.e., post-restoration mean wetness index minus pre-enrollment mean wetness index), restored wetland area, and the mean age of restoration. Landscape composition variables included the amount of wetland, flooded rice, and open water surrounding sites.

The study team also examined general patterns in the yearly variability of waterfowl populations and distributions. Data from 17 NCDC weather stations within the KDAX radar coverage area were used to calculate mean monthly precipitation of each winter. Linear regression analysis was used to test for relationships of yearly and mean monthly precipitation (independent variables) with seasonal mean radar reflectivity, and the ratio of reflectivity at flooded rice fields relative to wetland habitats (dependent variables).

Two maps were developed as decision support tools for prioritizing future WRP enrollments. The first is a map of the predicted post-restoration waterfowl density using important site and local landscape variables as determined from the regression modeling analysis. The second is a map of the magnitude of linear change in waterfowl densities over time. This map indicates where increases and decreases in waterfowl densities have occurred during the 13-year study period.

Findings

Wetlands and open water in the surrounding landscape influence radar measures of pre-enrollment bird densities. Before enrollment in WRP, sites were active agricultural fields with little expected diurnal use by roosting waterfowl. Accordingly, site characteristics had little importance in explaining bird density among site clusters before enrollment in WRP (table 1). Landscape composition and site placement variables, however, explained 72 percent of the variability in bird density during pre-enrollment years. Bird density increased with greater wetland and open water area in the surrounding landscape and with greater distance from the nearest wetland. These results may be because waterfowl dispersing from adjacent wetlands contaminated radar measures of the airspace over WRP sites. After controlling for the effects of the amount of wetlands and open water in the local landscape, sites immediately adjacent to wetlands had relatively lower pre-enrollment bird density than more isolated sites that were up to 1 km from a nearby wetland. Because waterfowl are gregarious during the winter and agricultural fields are less suitable than wetlands for roosting waterfowl, the relatively more isolated WRP sites may concentrate flocks of birds compared to sites adjacent to wetlands where birds may preferentially use nearby wetland habitat.

Waterfowl densities increased at WRP sites after wetland restoration. Weather surveillance radars detected a mean relative increase of daytime bird density of 469 ± 94 percent at nearly all WRP sites within the CVC after wetland restoration (16 of 19 site clusters or 84 percent). Bird density typically increased in the first winter after restoration and did not differ in the following winters for up to 8 years (the extent of data availability). Bird density at the remaining three site clusters decreased by 39 ± 11 percent on average. The WRP sites within these three clusters experienced extensive flooding during one or more pre-enrollment years that coincided with exceptionally high bird density. This increased the mean pre-enrollment bird density and explains the apparent decline in bird density after restoration.

Surrounding wetlands and rice fields and site water management influence the response of waterfowl to wetland restoration. After wetland restoration the overall mean standardized bird den-

Table 1. Relative importance and effect size of variables in explaining standardized bird density (ratio of reflectivity relative to that of wetland habitats) during pre-enrollment years among WRP site clusters (*n* = 19). Effect size is the standardized regression coefficient

Variable type	Explanatory variable	Effect size	Relative importance
Site characteristic	Site area	0.11 ± 0.20	0.15
	Site wetness index	0.23 ± 0.20	0.25
Landscape placement	Distance from wetland	**0.55 ± 0.18*** **	0.92
	Distance from flooded rice field	0.25 ± 0.22	0.28
Landscape composition	Wetland within 2.0 km	**0.70 ± 0.21*** **	0.96
	Flooded rice within 0.5 km	-0.27 ± 0.22	0.31
	Open water within 0.5 km	**0.41 ± 0.20*** **	0.66

*** Strong effect, ** Moderate effect, * Weak effect sity in site clusters was 3.79 ± 1.67—not significantly different from the density in existing wetlands because of large variability among clusters (range = 1.09 to 8.90). Eighty-one percent of the variability in bird density among all clusters was explained by site and landscape characteristics (table 2). Most importantly, pre-enrollment bird density was positively related to post-restoration bird density. Again, this relationship may largely represent measurement bias due to contamination caused by birds dispersing from the surrounding landscape. In addition, bird density after restoration increased with less wetland area in the landscape, greater increase in site wetness after restoration (i.e. active flooding), and closer proximity to flooded rice fields. The negative relationship between bird density and the amount of wetlands in the local landscape may indicate that WRP restored wetlands are relatively less attractive for diurnal use by waterfowl than are natural wetlands.

Most of the WRP sites in the CVC are under some degree of active moist soil management—the manipulation of water levels to mimic natural hydrology and stimulate production of plants and invertebrates that provide food for wintering waterfowl and other wetland wildlife (Baldassarre and Bolen 2006). Not surprisingly, the intensity of moist soil management had an important effect on wintering waterfowl response, as others have found for birds during spring and summer (Kaminski et al. 2006, O'Neal et al. 2008). WRP sites with the greatest increases in site soil wetness after restoration had the greatest post-restoration waterfowl use. Thus, active restoration of hydrology and intensity of moist-soil management is important for maximizing the benefit of WRP sites for supporting wintering waterfowl.

WRP sites closer to flooded rice fields had a greater increase in bird density after restoration. Rice fields, particularly flooded rice fields, are an important habitat used by feeding waterfowl within the CVC. Additionally, white-fronted geese, northern pintails, and mallards have increased their roosting use of agricultural fields relative to wetlands and shifted their winter distributions during the 1990s to track the increase in flooded rice area (Fleskes et al. 2005b, Ackerman et al. 2006). Radar observations corroborated these changes by revealing that diurnal bird use of flooded rice fields nearly tripled from 1995 to 2007 relative to bird use of wetlands, and also increased during winters with greater precipitation. Specifically, the ratio of mean radar reflectivity at flooded rice fields relative to wetlands increased positively in response to both year and the mean monthly precipitation ($r^2 = 0.798$, $F_{2,10} = 19.7$, $P < 0.001$; fig. 3). Additionally, relative waterfowl density changed over the 13-year time period with the strongest and most extensive trends of increasing bird density located within the Sutter, Colusa, and American basins. These basins contain an abundance of rice fields that have experienced increased winter flooding over time (fig. 4).

Future WRP sites in the CVC could be selected to maximize use by wintering waterfowl. Maximizing waterfowl use of restored WRP sites can be achieved by locating sites close to flooded rice fields within local landscapes that have high general waterfowl abundance and relatively little existing wetland area and by intensively managing moist soil at WRP sites. As a decision support tool, a map was developed for prioritizing future WRP enrollments. The tool maps the predicted post-restoration magnitude of waterfowl density based on the site and local landscape variables associated with relative waterfowl use (fig. 5). Additionally, changes in waterfowl distributions

Table 2. Relative importance and effect size of variables in explaining standardized bird density (ratio of reflectivity relative to that of wetland habitats) during post-restoration years among WRP site clusters (*n* = 19). Effect size is the standardized regression coefficient for each variable averaged across all models ± unconditional SE. Importance ranges from 0 to 1 with 1 being most important.

Variable type	Explanatory variable	Effect size	Relative importance
Site characteristic	Pre-enrollment bird density	**1.11 ± 0.21*** **	1.00
	Restored wetland area	0.09 ± 0.17	0.13
	Change in wetness index	**0.40 ± 0.14*** **	0.91
	Mean age of restoration	0.05 ± 0.15	0.11
Landscape placement	Distance from wetland	-0.24 ± 0.23	0.24
	Distance from flooded rice field	**-0.32 ± 0.17** **	0.51
Landscape composition	Wetland within 1.5 km	**-0.62 ± 0.21*** **	0.96
	Flooded rice within 1.0 km	0.18 ± 0.20	0.22
	Open water within 0.5 km	-0.02 ± 0.25	0.14

*** Strong effect, ** Moderate effect, *Weak effect

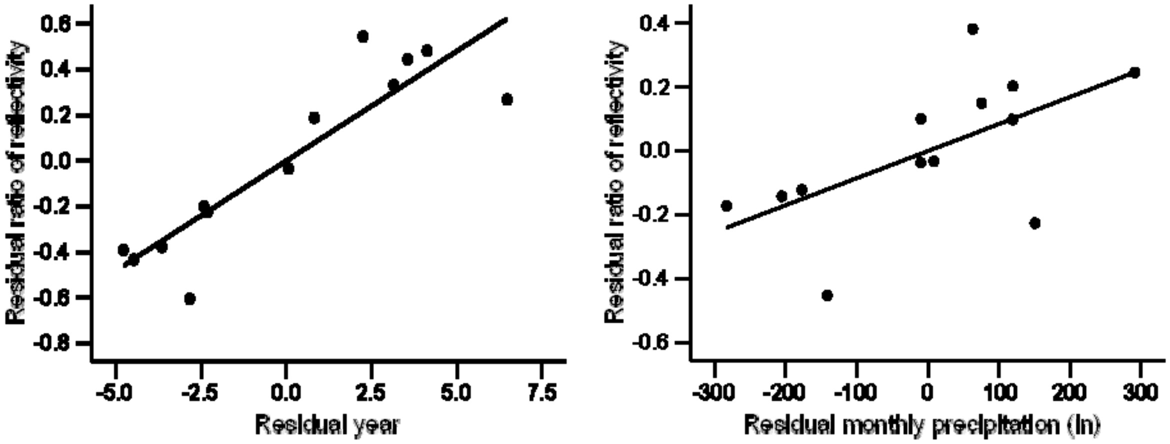


Figure 3. Partial regression scatterplots indicating increased diurnal bird use of flooded rice fields relative to wetlands from 1995 to 2007 (ratio of reflectivity x year) and during wetter winters (ratio of reflectivity x mean monthly precipitation)

Figure 4. Direction and magnitude of linear trends (i.e., standardized regression coefficients) of mean winter radar reflectivity from 1995 to 2007. Reds denote strongest increases and blues denote strongest decreases in bird density over time. Boundaries and names of ground water basins and the locations of rice fields are shown for reference.

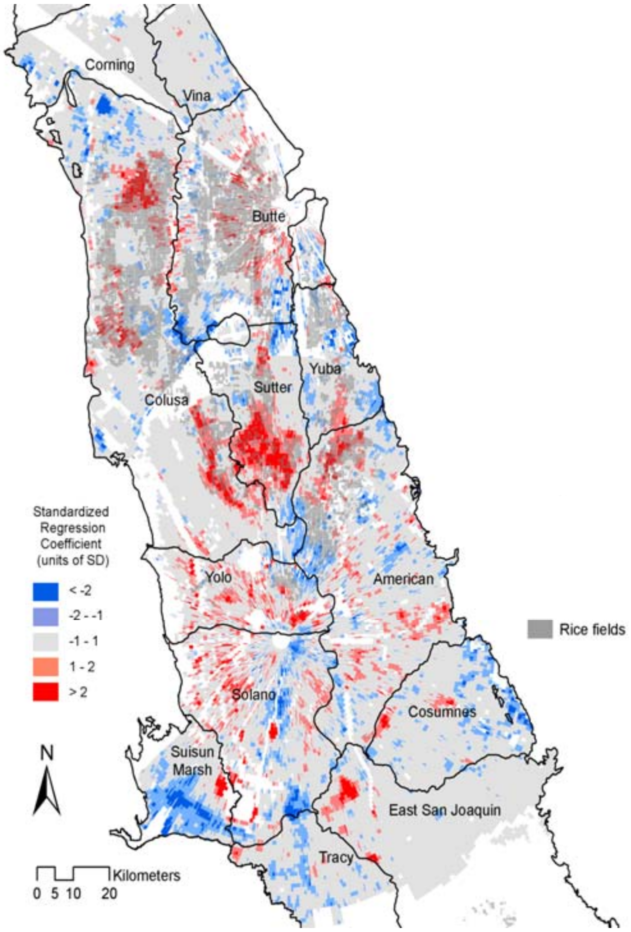
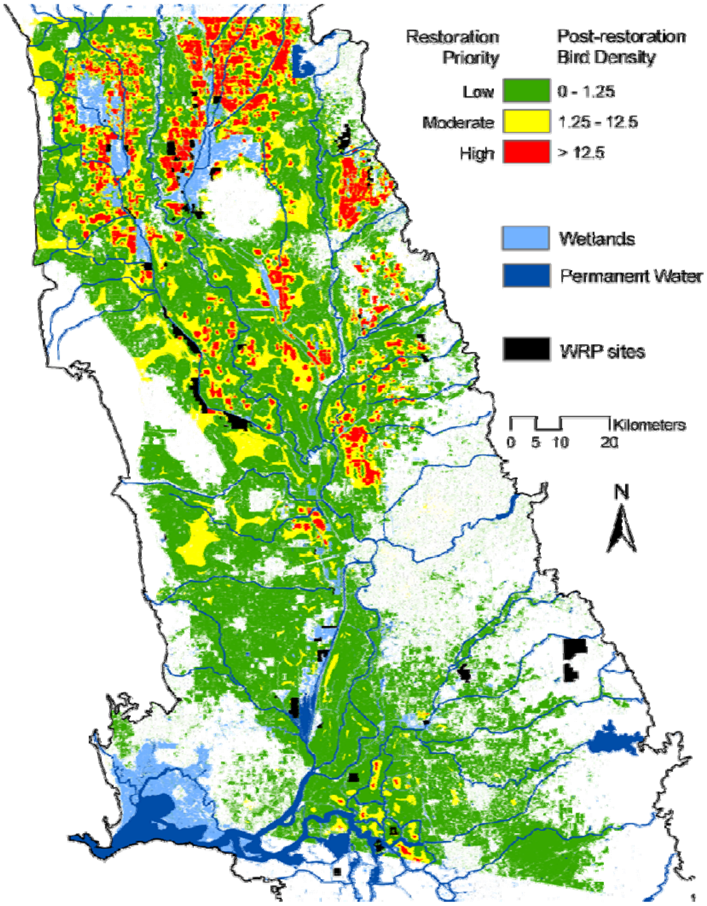


Figure 5. Predicted post-restoration standardized bird density (ratio of reflectivity relative to that of wetland habitats) and associated potential wetland restoration priority category on agricultural lands within the northern Central Valley of California based on 1999 land cover and winter surface water.



over the 13-year study period and the increasing importance of flooded rice for waterfowl should be considered for future WRP enrollment strategies. These types of tools would help prioritize future WRP wetland restoration efforts to provide the highest quality waterfowl habitat.

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The Conservation Effects Assessment Project: Translating Science into Practice

The Conservation Effects Assessment Project (CEAP) is a multi-agency effort to build the science base for conservation. Project findings will help to guide USDA conservation policy and program development and help farmers and ranchers make informed conservation choices.

One of CEAP's objectives is to quantify the environmental benefits of conservation practices for reporting at the national and regional levels. Because fish and wildlife are affected by conservation actions taken on a variety of landscapes, the wildlife national assessment draws on and complements the national assessments for cropland, wetlands, and grazing lands. The wildlife national assessment works through numerous partnerships to support relevant studies and focuses on regional scientific priorities.

This assessment was conducted through a partnership among NRCS Agricultural Wildlife Conservation Center, USGS National Wetlands Research Center, USGS Western Ecological Research Center, and University of Delaware (UD).

Primary investigators on this project were Jeffrey Buler (UD), Wylie Barrow (USGS), and Lori Randall (USGS).

For more information:
www.nrcs.usda.gov/technical/nri/ceap/