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CHANGE IN AREA OF WINTER-FLOODED AND DRY RICE IN THE NORTHERN CENTRAL VALLEY OF CALIFORNIA DETERMINED BY SATELLITE IMAGERY

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ABSTRACT

To understand possible factors impacting distribution of wintering waterfowl, we analyzed satellite imagery to estimate area of winter-flooded (flooded and saturated soil) and winter-dry harvested rice in Butte, Colusa, American, Sutter, Yolo, and Delta basins in the northern Central Valley of California. We compared our results for the 1999-00 winter with estimates that Spell et al. (1995) reported using identical methods for 1988-89 and 1993-94. Area of winter-flooded rice in the northern Central Valley in 1999-00 (78,841 ha) was 37% greater than in 1993-94 (57,702 ha) and 46% greater than in 1988-89 (53,816 ha). Winter-flooded rice increased an average of 3,253 ha per year between 1993-94 and 1999-00 compared to 777 ha per year between 1988-89 and 1993-94. The increase in flooded rice area was due to both an increase in total rice area (201,512 ha in 1999-00 vs. 171,918 ha in 1993-94 and 163,586 ha in 1988-89) and an increase in percentage of rice area that was flooded (39% in 1999-00 vs. 34% in 1993-94 and 33% in 1988-89). Change in winter-flooded rice area varied among basins. These results will help understand changes in distribution of wintering waterfowl among Central Valley basins during 1988-2000. The challenge for wildlife managers is to develop strategies that incorporate impacts of the increase in rice area in the northern Central Valley while recognizing that various factors could reduce rice area in the future.

INTRODUCTION

The Central Valley of California is a critical wintering area for many species of waterfowl and other wetland-dependent birds in the Pacific Flyway (Gilmer et al. 1982,

Heitmeyer et al. 1989). Once estimated at 1.6 - 2 million hectares, Central Valley wetlands were reduced by over 90% by the early 1900s (United States Fish and Wildlife Service 1978[1]). In the northern Central Valley, rice fields replaced many wetlands, and when flooded, maintain many of the same functions as wetlands they replaced (Elphick 2000). Both winter-flooded and winter-dry harvested rice fields are used heavily by waterfowl and other birds but species richness and use by ducks is greater in winter-flooded rice fields (Day and Colwell 1998, Elphick and Oring 1998).

Conservation programs such as the Central Valley Joint Venture that began in 1986 (Central Valley Habitat Joint Venture Implementation Board 1990[2]), the California Rice Straw Burning Reduction Act of 1991 (Assembly Bill 1378) that mandated the gradual phase-out of rice straw burning (Hill et al. 1999[3]), and changing agricultural practices and programs have impacted the amount of planted and winter-flooded rice. Tracking these changes is necessary to understand their impacts on ecology of wildlife that use rice fields. For example, information on change in area and distribution of winter-flooded rice fields is needed to understand factors related to wintering waterfowl distribution and aid the Central Valley Joint Venture in meeting its goal of providing habitat adequate to support and maintain historic distribution of wintering waterfowl.

To determine change in rice field habitats during 1988-2000, we analyzed late-summer satellite imagery to determine rice field area and mid-winter imagery to estimate area of winter-flooded (flooded and saturated soil) and winter-dry rice in Butte, Colusa, American, Sutter, Yolo, and Delta basins in the northern Central Valley of California during the 1999-00 season. We then compared our results with estimates that Spell et al. (1995) reported using identical methods for the 1988-89 and 1993-94 seasons.

STUDY AREA

The Central Valley of California (including the Suisun Marsh) is composed of nine basins (Fig. 1, United States Fish and Wildlife Service 1978[1]), but about 95% of the rice area is in the northern six basins (Butte, Colusa, American, Sutter, Yolo, and Delta) (United States Department of Agriculture 2004[4]) where we determined rice area present and flooded during mid-winter.

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[1]United States Fish and Wildlife Service. 1978. Concept plan for waterfowl wintering habitat preservation, Central Valley, California. United States Fish and Wildlife Service, Portland, Oregon, USA.

[2]Central Valley Habitat Joint Venture Implementation Board. 1990. Central Valley Habitat Joint Venture Implementation Plan, North American Waterfowl Management Plan, Portland, Oregon, USA.

[3]Hill, J. E., D. M. Brandon, and S. M. Brouder. 1999. Agronomic implications of alternative rice straw management practices. Agronomy Progress Report Number 264. University of California, Davis, California, USA.

[4]United States Department of Agriculture. 2004. NASS Agricultural Statistics Data Base: Crops county and district data. (http://www.nass.usda.gov:81/ipedbcnty/report2.htm).

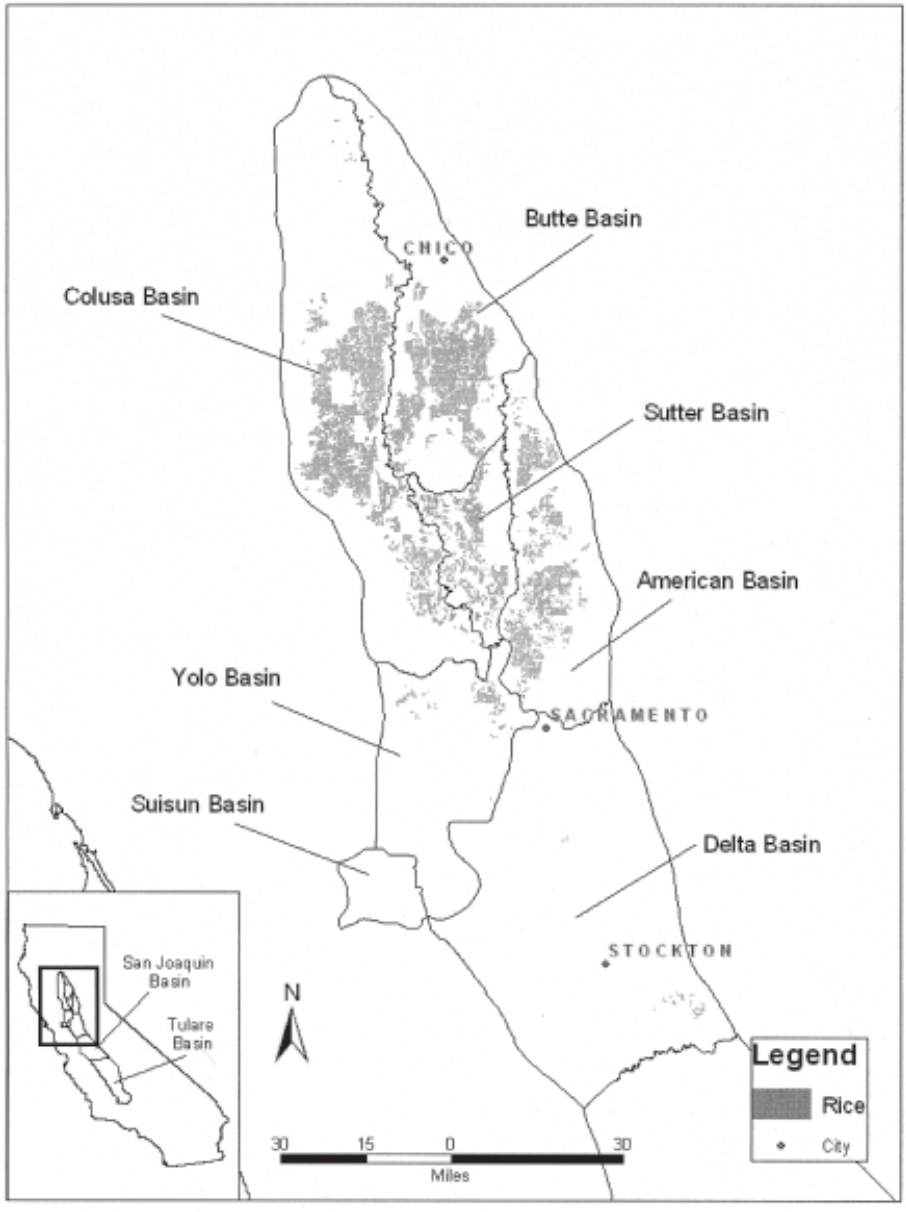

Figure 1. Basins in the north Central Valley where rice area was mapped from a 23 July 1999 satellite image and winter-flooded rice was mapped from a 30 December 1999 image.

Water availability and precipitation differed during 1988-89, 1993-94, and 1999-00. October – September water availability for the northern Central Valley, which varies with water supplies remaining from the previous year and current year precipitation, was "critical" (i.e., critically dry) in 1988-89, "above average" in 1993-94, and "wet" in 1999-00 (Gehrts 2002[5]). October-September rainfall at Sacramento Executive Airport was 42.6 cm during 1988-89, 30.8 cm during 1993-94, and 55.4 cm during 1999-00 (National Oceanic and Atmospheric Administration 2004[6]). However, precipitation was minimal before winter satellite imagery was collected each year with slightly less rain falling at Sacramento Executive Airport 0-3 days, 0-7 days, 0-14 days, and 0-30 days before 30 December 1999 (0.0, 0.0, 0.0, 0.15 cm, respectively) than before 24 January 1989 (0.33, 0.33, 0.33, 2.90 cm, respectively), and 6 January 1994 (0.15, 0.15, 0.28, 4.64 cm, respectively).

METHODS

We replicated methodology used by Spell et al. (1995) to process satellite imagery and estimate area of flooded (flooded and saturated soil) and non-flooded rice in Butte, Colusa, American, Sutter, Yolo, and Delta basins. Like Spell et al. (1995), in addition to flooded areas, we included areas of saturated soil in our winter-flooded estimate (<10% of total) to account for fields just beginning to flood or just after water was drained. The lack of rainfall for 2 weeks before winter imagery was collected eliminated the likelihood of misclassifying rain-wetted soils as soils that were saturated due to flooding. Our imagery covered the entire area of the six northern Central Valley basins whereas imagery used by Spell et al. (1995) did not include the northern 25% of Colusa (37 ha of rice present during our study) and Butte (300 ha of rice present during our study) basins, and the southern 48% of the Delta basin (1,292 ha of rice present during our study). Like Spell et al. (1995), we classified Landsat Thematic scenes acquired in late summer (23 July 1999) into rice and non-rice classes and scenes acquired in mid-winter (30 December 1999) to identify winter-flooded (flooded and saturated soil) and winter-dry areas.

We confirmed classification of areas using data provided by managers, aerial photographs, and site visits. We used a Geographic Information System (GIS) and ARC/GIS (ESRI, Redlands, California, USA) computer program to overlay a digitized basin coverage provided by the Central Valley Joint Venture on the classified imagery and derive basin estimates. We compared our 1999-00 results with estimates that Spell et al. (1995) reported for 1988(-89) using 1 August 1988 and 24 January 1989 imagery and for 1993(-94) using 30 July 1993 and 6 January 1994 imagery.

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[5]Gehrts, K. 2002. Water year hydrologic classification indices for the Sacramento and San Joaquin Valleys. IEP Newsletter: Interagency Ecological Program for the San Francisco Estuary 15:16-17. (http://www/iep.water.ca.gov/report/newsletter/2002winter/IEPNewsletterwinter2002.pdf).

[6]National Oceanic and Atmospheric Administration. 2004. Sacramento Executive Airport: Hourly/Daily Data, Local Climatological Data. (http://ols.ncdc.noaa.gov/cgi-bin/nndc/genOL-002.cgi).

RESULTS

Area of winter-flooded rice in the northern Central Valley in 1999-00 (78,841 ha) was 37% greater than in 1993-94 (57,702 ha) and 46% greater than in 1988-89 (53,816 ha) (Table 1). The increase in flooded rice area was due to both an increase in total rice area (201,512 ha in 1999-00 vs. 171,918 ha in 1993-94 and 163,586 ha in 1988-89) and an increase in percentage of rice area that was flooded (39% in 1999-00 vs. 34% in 1993-94 and 33% in 1988-89). The average annual increase in winter-flooded rice area in the northern Central Valley between 1993-94 and 1999-00 was 3,523 ha compared to 777 ha between 1988-89 and 1993-94.

Change in winter-flooded rice area varied among basins (Table 1). Between 1993-94 and 1998-00, winter-flooded rice area increased in Butte (+24%), Colusa (+78%), American (+28%), and Sutter (+22%) basins due to an increase in both rice area and the percent flooded but decreased in Yolo (-6%) due to an increase in rice area but decrease in percent flooded. In the Delta basin, rice area declined but percent flooded increased, resulting in little change (-2%) in winter-flooded rice area. Between 1988-89 and 1993-94, winter-flooded rice area increased in Butte (+30%) and Colusa (+16%) basins due to an increase in both rice area and the percent flooded but decreased in American (-11%), Sutter (-15%), Yolo (-33%), and Delta (-82%) basins because rice area (in Yolo), percent flooded (in American), or both (in Sutter and Delta) declined.

Table 1. Total area of rice and area and percentage that was winter-flooded in each northern Central Valley basin during 1999-00 vs. 1993-94, and 1988-89[a].

	1999-00			1993-94			1988-89		
Basin	Total ha	Flooded ha	Flooded %	Total ha	Flooded ha	Flooded %	Total ha	Flooded ha	Flooded %
Butte	54,669	30,659	56	47,408	24,718	52	45,399	18,977	42
Colusa	80,528	24,381	30	65,752	13,674	21	61,858	11,742	19
American	39,232	15,564	40	34,764	12,158	35	27,942	13,701	49
Sutter	20,956	6,624	32	18,374	5,444	30	18,442	6,399	35
Yolo	4,694	1,497	32	3,425	1,590	46	5,206	2,359	45
Delta	1,433	116	8	2,195	118	5	4,739	638	13
All	201,512	78,841	39	171,918	57,702	34	163,586	53,816	33

[a]Winter-flood values for 30 December 1999, 6 January 1994, or 24 January 1989. Values for 1999-00 from this study, values for 1988-89 and 1993-94 from Spell et al. (1995).

DISCUSSION

Our data indicate that both winter-flooded and total rice area in the northern Central Valley was greater in 1999-00 than in 1993-94, continuing an increase that occurred between 1988-89 and 1993-94. However, the increase in the area of winter-flooded rice

during the late 1990s was greater than during the previous five years because both the percentage of rice that was winter-flooded and the total area of rice increased. No rain fell during the two weeks prior to collection of the 1999-00 winter satellite image and rainfall was minimal before all the winter images. Thus, the greater percentage and area of winter-flooded rice in 1999-00 than earlier years was clearly due to an increase in flooding from delivered (i.e., managed) water rather than rainfall.

Improved rice farming economics due to improved rice prices and subsidies was probably the main factor for increased rice area (Childs 1997). We speculate that a number of factors resulted in a greater proportion and area of winter-flooded rice in the Sacramento Valley basins during 1999-00 than earlier years, including: (1) increasing restrictions on rice straw burning that started in 1992 (Hill et al. 1999[3]); (2) conservation payments for infrastructure allowing rice straw rolling and flooding that started in 1997 (Ducks Unlimited, Inc., 2004[7]); (3) new information showing utility of flooding and waterfowl presence for straw decomposition (Wrysinski et al. 1995[8], Bird et al. 2000); (4) increased opportunity for hunting revenue on flooded fields (Passaglia 1997[9]) due to greater hunter demand for leased blinds with improved waterfowl populations (e.g., 3.99 million waterfowl in 1993 vs. 6.95 million waterfowl in 1999 during Pacific Flyway midwinter survey; Trost and Drut 2003[10]) and more liberal harvest regulations (e.g., 59-day season and 5- duck daily bag limit in 1989 and 1993 vs. 100-day season and 7-duck daily bag limit in 1999; California Department of Fish and Game 1989[11], 1993[12], 1999[13]); and (5) better winter water availability (California Department of Water Resources 1991[14], Davis 1992, Gehrts 2002[5]).

Although Spell et al. (1995) did not study the northern 25% of the Colusa and Butte basins, while we included the entire area of both these basins, the 337 ha of rice we found

[7]Ducks Unlimited, Inc. 2004. Valley Bay CARE: CVPIA (b) (22) Private Land Winter Flooding. (http://www.ducks.org/conservation/valleycare.asp).

[8]Wrysinski, J. E., J. D. Garr, and M. A. Bias. 1995. Valley Habitats Number 1: Rice straw decomposition and development of seasonal waterbird habitat on rice fields. Ducks Unlimited Western Regional Office, Sacramento, California, USA.

[9]Passaglia, M. A. 1997. Ways to lease your land. Pages 3-4 *in* Anonymous, editor, Valley Habitats Number 16: Establishing a hunting program on your farm. Ducks Unlimited Western Regional Office, Sacramento, California, USA.

[10]Trost, R. E., and M. S. Drut. 2003. 2003 Pacific Flyway Data Book. United States Fish and Wildlife Service, Portland, Oregon, USA.

[11]California Department of Fish and Game. 1989. 1989 California hunting regulations: Parts II and III. Resident and migratory game birds. California Department of Fish and Game, Sacramento, California, USA.

[12]California Department of Fish and Game. 1993. 1993 California hunting regulations: Parts II and III. Resident and migratory game birds. California Department of Fish and Game, Sacramento, California, USA.

[13]California Department of Fish and Game. 1999. 1999 California hunting regulations: Parts II and III. Resident and migratory game birds. California Department of Fish and Game, Sacramento, California, USA.

[14]California Department of Water Resources. 1991. California's continuing drought, 1987-1991: A summary of impacts and conditions as of December 1, 1991. Sacramento, California, USA.

in this additional area represented only 0.2% (337 ha/135,197 ha) of the total rice area in these basins and accounted for only 1.5% (337 ha / [135,197 ha – 113,160 ha]) of the increase in total and flooded rice area between 1993-94 vs. 1999-00 in these basins. The 5.1% increase between 1988-89 and 1993-94 reported by Spell et al. (1995) and the 17.2% increase we found between 1993-94 and 1999-00 in total rice area in northern Central Valley basins based upon classification of satellite imagery is consistent with the increase in planted rice area reported for the Central Valley during those periods (2.5% increase between 1988-89 and 1993-94 and 15.9% increase between 1993-94 and 1999-00, United States Department of Agriculture 2004[4]).

The reason(s) that the area of rice grown in the Delta basin apparently decreased while rice area in most other northern Central Valley basins increased is unknown. Most rice we mapped in the Delta basin during 1999-00 was outside Spell et al.'s (1995) coverage, indicating that the decline of rice between 1993-94 and 1999-00 inside the Delta area covered by Spell et al. (1995) was even greater than what our estimate for the entire Delta basin shows. Perhaps the cooler Delta climate, along with other regional differences (e.g., soils), resulted in economics of rice being less favorable than other crops and conversion of rice fields to other agriculture (e.g., orchards, vineyards). Alternatively, the cooler climate and different rice varieties grown in the Delta (California Rice Research Board 2001[15]) may have resulted in different timing of rice planting, flooding, and growth, leading to us misclassifying some Delta rice as other crops or Spell et al. (1995) misclassifying some Delta non-rice crops as rice fields. Rice area planted in San Joaquin County, which encompasses most of the Delta basin and no other basin, reportedly ranged between about 1400 ha to 2000 ha each year during 1982-2000, with no obvious declining trend (United States Department of Agriculture 2004[4]).

We caution that our and Spell et al.'s (1995) estimates of total and winter-flooded rice area are single year estimates, and although total and winter-flooded rice increased between 1988-89, 1993-94, and 1999-00, changing economics, water availability, increased mosquito abatement costs (Lee 2004[16]), and other factors (e.g., water sales to southern California; Helton 2003) could quickly reverse this apparent trend. Further, each of our winter flooding estimates is based upon a single, mid-winter satellite image, and while representative of conditions during mid-winter, overlooks any differences in flooding occurring during early- and late-winter.

MANAGEMENT IMPLICATIONS

Waterfowl, like many other avian species, are highly mobile and can quickly respond to changes in distribution of preferred habitats (Heitmeyer et al. 1989, Fleskes

[15]California Rice Research Board. 2001. Annual Report: Rice Breeding Program-01. (http://www.syix.com/rrb/01rpt/Breeding.htm).

[16]Lee, M. 2004. The mosquito zone: Pressure on rice growers to help pay for fight against West Nile virus. Sacramento Bee, Business Section, Friday, July 23. (http://www.sacbee.com/content/business/story/10100327p-11021164c.html).

et al. 2002). Understanding how area of winter-flooded and winter-dry rice in the Central Valley, which are important habitats for waterfowl and many other birds (Miller 1987, Day and Colwell 1998, Elphick and Oring 1998, Elphick 2004), has changed during the 1988-2000 period will be useful for understanding changes in distribution of wintering waterfowl and other species during that interval. Historically, about 60% of the estimated 1.6 - 2 million hectares of wetlands originally in the Central Valley (United States Fish and Wildlife Service 1978[1], Gilmer et al. 1982) occurred in the Suisun, Delta, and other northern Central Valley basins (Colusa, Butte, American, Sutter, and Yolo), with the remaining 40% occurring in the San Joaquin and Tulare basins comprising the San Joaquin Valley. The conversion of wetlands in the northern Central Valley to rice fields, rather than to agriculture of less waterfowl value like occurred in the San Joaquin Valley, reduced the negative impacts of wetland loss in the northern Central Valley. Although nearly all winter-flooded rice is hunted for waterfowl (J. D. Garr, Ducks Unlimited, Inc., Sacramento, California, personal communication), thereby reducing its use as daytime waterfowl sanctuary to the degree it is hunted, all is fully available for nocturnal feeding. Thus, the increase in managed winter-flooding of rice that we report between 1988-89 and 1999-00 has increased the amount of feeding and loafing habitat available in the northern Central Valley landscape for most waterfowl and other wetland-dependent birds. Elphick (2004) reported that while winter flooding of harvested rice fields potentially has negative impacts for raptors and some other landbirds, it had no measurable impact on most species studied and possible benefit for some passerines. The increase in dry rice fields has increased the amount of foraging habitat available to some granivorous landbirds (Elphick 2004) and waterfowl such as geese that commonly use both flooded and dry rice fields (Elphick and Oring 1998). Given that birds are highly mobile and can respond to habitat changes over a wide range, we predict that unless area of wetland and agricultural habitats preferred by waterfowl and other birds increases at a similar scale in the San Joaquin Valley, the percentage of Central Valley waterfowl and birds that use agricultural fields will also increase in the northern Central Valley basins. The challenge for wildlife resource managers in the Central Valley is to develop management strategies that incorporate the current wildlife impact of the increase in total and winter-flooded rice area in the northern Central Valley while recognizing that changes in farm economics or other factors beyond their control could relatively quickly reduce area of planted and/or winter-flooded rice.

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