Surveys

Changes in Types and Area of Postharvest Flooded Fields Available to Waterbirds in Tulare Basin, California

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Abstract

Conservation efforts to restore historic waterbird distribution and abundance in the Central Valley of California require information on current and historic areas of waterbird habitat. To provide this information, we mapped the area of agricultural fields in the vicinity of the historic Tulare Lake Bed in the Tulare Basin, California, that were treated postharvest with two different flooding regimes that varied in depth and duration of water applied ($<$ 1 cm to 1.5 m water for longer than 1 wk [FLD]; $<$ 1 to 15 cm water for 1 wk or less [IRG]) during August–March 1991–1994 and 2005–2006. We compared our results with published estimates for 1976–1980 and 1981–1987. Area and crops treated postharvest with FLD or IRG flooding differed among years and months. Overall for August through March, weekly area of FLD fields averaged 1,671 ha in 1976–1980 but declined to about half that in later years; the decline was most severe during January–March. Cotton was primarily treated with IRG flooding and comprised 47–95% of the total IRG field area. Other crops were primarily treated with FLD flooding; tomato replaced safflower in 2005–2006. These documented declines since the 1970s in area of FLD fields and changes in crops being flooded postharvest reduce the carrying capacity of the Tulare Basin for waterbirds, a situation that will need to be reversed for restoration of historic waterbird distribution in the Central Valley to be viable. If maintaining agricultural production is a priority and agricultural drainage waters can be disposed of safely, then increasing the extent of FLD grain fields would provide the most benefit for wintering waterbirds; otherwise, restoring and providing adequate water supplies to managed wetlands would most benefit waterbirds.

Keywords: California; Central Valley; habitat; postharvest flooding; Tulare Basin; waterbirds; waterfowl

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Introduction

California's Central Valley is the focus of extensive waterbird habitat conservation efforts because millions of waterfowl, shorebirds, and other waterbirds still breed, migrate through, and winter in the region despite wide-scale wetland loss during the last century (United States Fish and Wildlife Service [USFWS] and Canadian Wildlife Service 1986; USFWS 2007; Fleskes 2012). Like in many regions important to waterbirds (Butcher et al. 2007; Audubon 2013), agriculture dominates the Central Valley's modern landscape and is an integral component of avian conservation planning. The Central Valley Joint Venture (CVJV; a partnership of nine conservation organizations, 11 state and federal agencies, and one corporation established under the North American Waterfowl Management Plan to help conserve the continent's waterfowl populations and habitats and which has expanded to include conservation of all birds), includes programs that focus on enhancing Central Valley agricultural lands for waterfowl and other waterbirds (CVJV 2006). In the northern Central Valley, the focus is on rice fields, which replaced many wetlands and provide valuable habitat for waterfowl and other waterbirds when properly managed (Elphick and Oring 1998; Eadie et al. 2008). Increases in postharvest flooding of northern California rice fields (Fleskes et al. 2005a) due to the Rice Straw Burning Reduction Act of 1991 (Bird et al. 2002) and conservation efforts (CVJV 2006) have further enhanced waterbird habitat value of rice and helped maintain and increase abundance of waterfowl and other waterbirds in northern California during winter (Fleskes et al. 2005b). Wetland loss in the Tulare Basin, comprising the southern third of the Central Valley (Figure 1), has been even more severe than in the northern Central Valley (Fleskes 2012). Nonrice agriculture replaced wetlands in the Tulare Basin and abundance of wintering waterfowl has declined more than in other Central Valley regions (Kirk 1994; Fleskes et al. 2005b).

Although rice is not grown in the Tulare Basin, some agricultural fields are flooded postharvest and provide valuable habitat for waterfowl and other waterbirds (Barnum and Euliss 1991; Fleskes et al. 2012). Water is applied postharvest to a portion of the Tulare Basin fields to remove salts accumulated during irrigations, control crop disease, facilitate conversion of alfalfa to a different crop, and provide soil moisture for the next planting (San Joaquin Valley Drainage Program Study Team 1990). Two different water regime treatments are used on fields, depending upon the treatment goal; these treatments differ by the depth and duration of the water applied. When the goal is only to remove salts and provide soil moisture, an irrigation flood treatment (hereafter, IRG) is used, in which water is applied sequentially to parts of the fields separated by levees (i.e., checks). Each check in IRG fields has water $<$ 1 to 15 cm deep for 1 wk or less before the water is drained or pumped to an adjacent check. Water is sometimes applied multiple times to IRG fields depending upon the crop. When control of a locally common fungal cotton pest is also needed in a field where cotton will be planted or alfalfa needs to be killed to facilitate planting a different crop, a deeper and longer duration flood treatment (hereafter, FLD) is used, in which water is applied to all, or nearly all, of the field to a depth of up to 1.5 m for more than 1 wk to many weeks by adding additional water as necessary. Water is then pumped off or drained by cutting through a levee. Water depth varies within FLD fields from $<$ 1 cm to about 1.5 m, depending upon field slope and the stage of the process (i.e., filling up, fully flooded, drawing down) but on average it is maintained deeper (e.g., at 20–40 cm) than on IRG fields. Water drained from many agricultural lands in the southern Central Valley contains elevated levels of salts, selenium, and other elements that can endanger fish and wildlife if not disposed of properly (Ohlendorf et al. 1986; Wu 2004).

Extensive habitat restoration and enhancement is planned for the Tulare Basin in an effort to restore historic waterbird distribution in the Central Valley (CVJV 2006; USFWS 2007). The CVJV and the Landowner Incentive Program (managed by the California Department of Fish and Wildlife) are both broadly supported cooperative efforts that include a focus on sustaining and enhancing agricultural lands for waterfowl and other waterbirds (CVJV 2006; USFWS 2012). The CVJV does not currently account for the habitat provided by postharvest-flooded fields in the Tulare Basin in its conservation planning (CVJV 2006) because frequent winter fog and clouds complicate use of remote sensing methods to track these ephemeral habitats, and when the latest plan was developed, data were lacking on field area, waterbird food densities, and whether IRG fields were used by waterbirds (M. Petrie, Ducks Unlimited, Inc., personal communication). Since the 2006 CVJV plan, data have been collected on waterbird food densities in FLD fields (J.P. Fleskes, unpublished data). Also, waterbirds have been shown to use not only FLD fields (Coe 1990; Barnum and Euliss 1991; Shuford et al. 1998; Fleskes et al. 2003) but also IRG fields, although the density of waterfowl was 108 times greater, and other waterbirds 11.8 times greater, on FLD than on IRG fields (Fleskes et al. 2012). Successful implementation of the CVJV and other conservation programs requires an understanding of flooded agricultural habitats that historically have been, and are currently, available to wintering waterfowl and other waterbirds in the Tulare Basin. Thus, to inform waterbird habitat conservation planning, we mapped the types, timing, and amounts of FLD and IRG fields in the Tulare Basin during 1991–1994 and 2005–2006 and compared our results with published (see Barnum and Euliss 1991) estimates for 1976–1980 and 1981–1987.

Study Site

We surveyed areas of FLD and IRG fields in and adjacent to the historic lake bed of Tulare Lake (hereafter, "Tulare Lake Bed") in the Tulare Basin of California (Figure 1). The 13,000-km^2 Tulare Basin is the southernmost and most arid part of the Central Valley (USFWS 1978; Fleskes 2012). Tulare Lake, once the largest freshwater lake west of the Mississippi River and the dominant feature of Tulare Basin, was drained by the early 1920s and converted into agricultural fields (Kirk 1994). Most agricultural flooding in the Tulare Basin occurs in the Tulare Lake Bed. In addition to postharvest-flooded agriculture, other wetland habitat in Tulare Basin includes approximately 2,946 ha of public and private wetlands, 1,951 ha of agricultural-drainwater evaporation ponds, and other habitats (0–1,374 ha of flood basins, 82 ha of sewage treatment ponds, and 390–742 ha of reservoirs; Fleskes 1999). The hydrologic index for the southern Central Valley, a measure of the water supply for agriculture and other users, varied among study years but each multi-year study interval included a mix of wet and dry water years (1976–1980: critically dry, critically dry, wet, above normal; 1981–1987: dry, wet, wet, above normal, dry, wet; 1991–1994: critically dry, critically dry, wet); 2005–2006 was classified as a wet water year (California Department of Water Resources 2013).

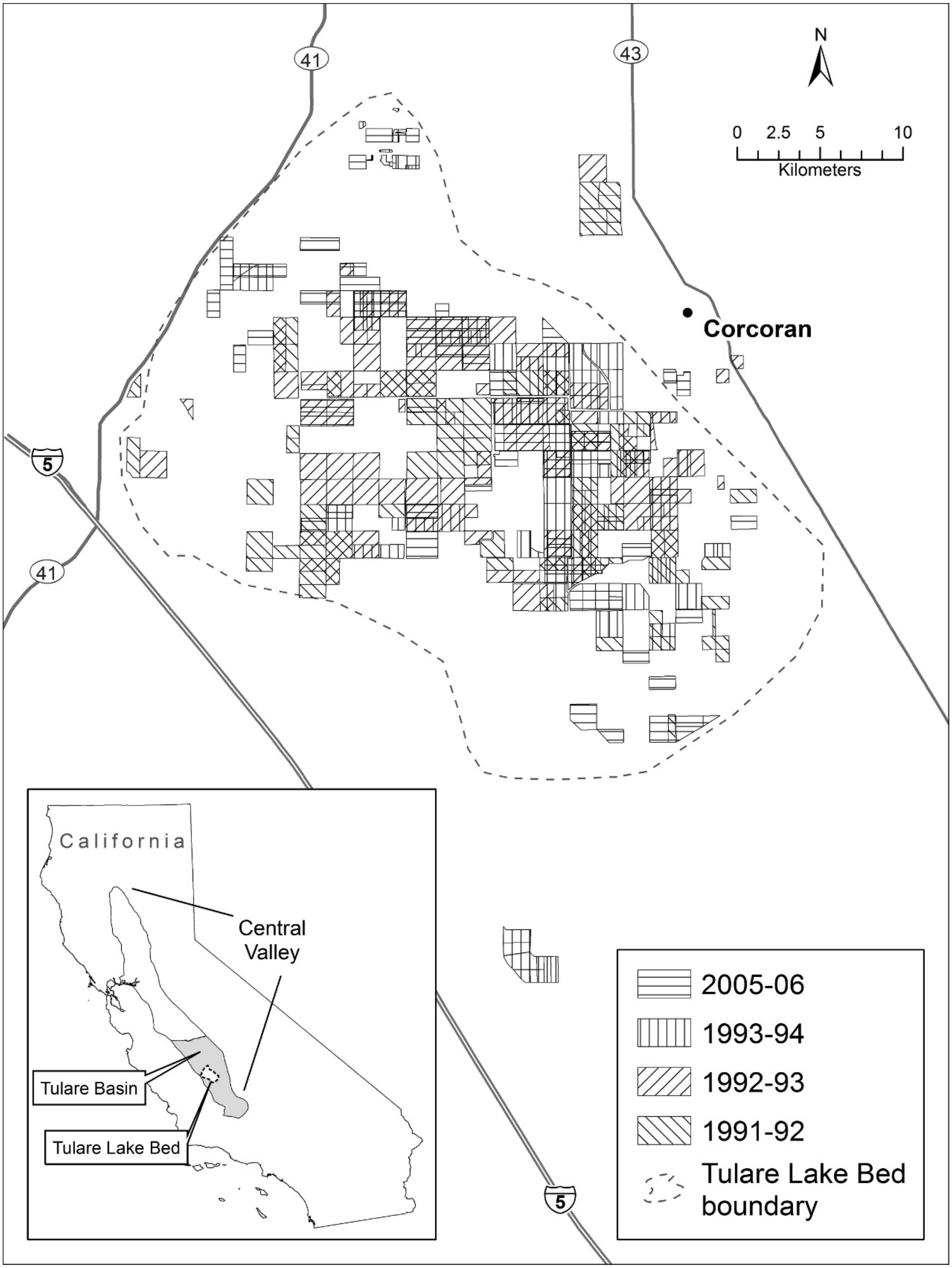

Figure 1. Tulare Lake Bed and vicinity study area in the Tulare Basin, California, showing locations of crop fields treated postharvest with two different flooding regimes during 1991–1992, 1992–1993, 1993–1994, and 2005–2006.

Table 1. Weekly mean ($\bar{x}$) hectares of crop fields treated postharvest with two different flooding regimes (< 1 cm to 1.5 m for longer than 1 wk [FLD]; < 1 to 15 cm water for 1 wk or less [IRG]) in the vicinity of the Tulare Lake Bed in the Tulare Basin, California, by month interval and year interval, August–March, 1976–2006.

		1976–1980[b]			1981–1987[c]			1991–1994			2005–2006		
Interval	Treatment[a]	n[d]	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
August–September	FLD	6	2,616	243	5	1,062	278	17	1,645	225	6	1,601	430
	IRG		0	0		0	0		0	0		212	87
	All		2,616	243		1,062	278		1,645	225		1,813	499
October–December	FLD	9	1,630	290	29	1,141	168	39	1,095	178	10	1,023	178
	IRG		0	0		0	0		561	101		763	233
	All		1,630	290		1,141	168		1,656	180		1,786	203
January–March	FLD	6	1,097	395	21	620	145	32	116	41	1	0	
	IRG		0	0		0	0		211	75		130	
	All		1,097	395		620	145		327	81		130	
Overall[e]	FLD	21	1,671	307	55	918	169	88	891	137	17	815	256
	IRG		0	0		0	0		283	72		390	175
	All		1,671	307		918	169		1,174	153		1,205	303

[a] Flooding regime treatment (All = FLD and IRG combined); treatment not specified during 1976–1987 but descriptions indicate all were FLD-treated fields.
[b] U. S. Fish and Wildlife Service (1985).
[c] Barnum and Euliss (1991).
[d] n = number of surveys.
[e] Overall means calculated by weighting August–September (9 wk), October–December (13 wk), and January–March (11 wk) means by the number of weeks in each interval.

Methods

Field surveys

We mapped the area of FLD and IRG fields in the vicinity of the Tulare Lake Bed (Figure 1) weekly during late summer through early spring of four study years: 26 August 1991–22 March 1992, 18 August 1992–12 March 1993, 29 August 1993–22 March 1994, and 1 August 2005–2 February 2006 (no surveys during 11 December 2005–31 January 2006) by driving all accessible public and main elevated levee roads in the region. These roads provided us complete coverage of the study area, as confirmed with aerial surveys conducted periodically during 1991–1994 (Fleskes 1999). We used a window-mounted 20–60 power × 80 mm spotting scope and 10 power × 42 mm binoculars at key elevated sites to aid our search for flooded fields. We sketched and subsequently digitized (ArcGIS, ESRI 2009) borders and inundated, mudflat, and dry parts of each FLD- and IRG-treated field each week on USGS 1:24,000 maps by using landmarks, a GPS, and the truck odometer. Fields tended to be divided into one-half, one-quarter, one-eighth, or one-sixteenth sections that facilitated mapping. To identify crops of FLD and IRG fields, we mapped crops of fields before harvest (in 1991), identified crop residue (2005–2006), and obtained crop information from County Agricultural Commissions (all fields 1991–1994 and eight fields in 2005 where crop residue was not present).

Data analysis

We compared locations of FLD and IRG fields within and among the four study years that we surveyed (i.e., 1991–1992, 1992–1993, 1993–1994, 2005–2006) and compared the areas of FLD and IRG fields during 1991–1994, 2005–2006, and two earlier intervals (1976–1980 [USFWS 1985], 1981–1987 [Barnum and Euliss 1991]). Because mudflats indicate very recent inundation, often contain water puddles, and are used as habitat by waterbirds (Fleskes et al. 2012), we included both inundated and mudflat sections when calculating areas of FLD and IRG fields. We report weekly averages with standard errors (SEs) calculated in R (R Core Team 2011) for areas of FLD and IRG fields by year interval (1976–1980, 1981–1987, 1991–1994, 2005–2006) and month interval (August–September, October–December, January–March, overall). We also report peak FLD and IRG field area by crop and total area of each crop that was FLD- or IRG-treated one or more times during a study year during 1991–1992, 1992–1993, 1993–1994, and 2005–2006.

Results

Temporal changes in weekly area of FLD and IRG fields

Average weekly area of FLD and IRG fields in the Tulare Lake Bed vicinity varied among year and month intervals (Table 1). Overall during August through March, the weekly average area of FLD fields in 1981–1987, 1991–1994, and 2005–2006 was about half (i.e., 49–55%) the 1976–1980 average (Table 1). The decline in average weekly FLD field area after 1976–1980 was similar among year intervals during August–September (percentage of 1976–1980 area: 41% in 1981–1987, 63% in 1991–1994, 61% in 2005–2006) and October–December (percentage of 1976–1980 area: 70% in 1981–1987, 67% in 1991–1994, 63% in 2005–2006), but during January–March it

Table 2. Total area (ha), percentage (%) of total area, and peak area (ha) of crop fields treated postharvest with two different flooding regimes (< 1 cm to 1.5 m for longer than 1 wk [FLD]; < 1 to 15 cm water for 1 wk or less [IRG]), by flooding regime and crop in the vicinity of the Tulare Lake Bed in the Tulare Basin, California, during 1991–1992, 1992–1993, 1993–1994, and 2005–2006.

	1991–1992			1992–1993			1993–1994			2005–2006		
Flood regime - crop	**Total**	**%**	**Peak**	**Total**	**%**	**Peak**	**Total**	**%**	**Peak**	**Total**	**%**	**Peak**
FLD												
Alfalfa	2,499	26.7	1,305	491	8.4	278	171	4.3	171	1,230	34.4	712
Barley or wheat	1,543	16.5	1,126	182	3.1	124	385	9.6	385	1,568	43.8	1,350
Safflower	3,573	38.2	1,783	3,246	55.4	2,150	2,232	55.5	1,782			
Cotton	1,683	18.0	897	1,937	33.1	876	439	10.9	240	259	7.2	259
Fallow	61	0.7	61				790	19.6	688			
Tomato							6	0.1	6	518	14.5	518
FLD total	9,358		4,073	5,856		2,515	4,022		2,419	3,576		2,839
IRG												
Alfalfa	187	8.2	187	266	2.4	266				202	3.1	129
Barley or wheat	257	11.3	257	0		0				518	7.9	259
Safflower	753	33.2	476	269	2.4	269	733	8.4	471			
Cotton	1,074	47.3	444	10,720	95.2	1,932	7,951	91.6	3,036	4,354	66.0	2,072
Fallow										129	2.0	129
Tomato										1,036	15.7	777
Corn										194	2.9	194
Oats										162	2.5	162
IRG total	2,271		522	11,255		1,932	8,684		3,507	6,596		2,072
FLD + IRG	11,629			17,111			12,706			10,172		

was much more severe in the later year intervals (percentage of 1976–1980 area: 57% in 1981–1987, 11% in 1991–1994, 0% in 2005–2006). The average weekly area of FLD fields was greater during August–September and October–December than during January–March in all year intervals. In contrast to FLD fields, average weekly area of IRG fields was greater in later year intervals than in earlier year intervals and was greater in October–December than in other month intervals (Table 1). No IRG fields were present during 1976–1980 or 1981–1987 (USFWS 1985; Barnum and Euliss 1991) but IRG fields comprised 0% (August–September), 34% (October–December), and 65% (January–March) of the total treated field area in 1991–1994, and 12% (August–September), 43% (October–December), and 100% (January–March) in 2005–2006.

Average weekly area of all FLD and IRG fields combined was similar among year intervals during October–December due to the increase in IRG fields after 1987; however, during other month intervals, differences among year intervals were similar to those for FLD fields. Overall during August through March, weekly average area of all FLD and IRG fields combined was 55% of the 1976–1980 area in 1981–1987, 70% in 1991–1994, and 72% in 2005–2006.

During the four study years when both FLD and IRG fields were present (i.e., 1991–1994 and 2005–2006), FLD fields occurred mostly during weeks 1–17 (1 August–30 November) and peaked at 2,419–4,073 ha during weeks 7–11 (15 September–19 October; Table 2 and S1, *Supplemental Material*; Figure 2). Area of IRG fields was greatest during weeks 12–33 (20 October–21 March) with no consistent peak (Figure 2). No IRG fields were present until week 12 in 1991–1994, but in 2005, < 100 to 600 ha were present during weeks 5–11.

Annual area treated with FLD or IRG flooding

The combined total area of cropland on which FLD or (one or more) IRG treatments were applied in 2005–2006 (10,172 ha) was less than during 1991–1994 ($\bar{x}$ = 13,815 ha, range = 11,629–17,111 ha; Table 2); total treated area before 1991 was not reported (Barnum and Euliss 1991). The total area treated in 2005–2006 was less mainly because the area treated with FLD declined (Table 2). Annual area treated with IRG ranged widely (2,271–11,255 ha) during 1991–1994 but averaged 7,403 ha, which was similar to the 6,596 ha treated with IRG in 2005–2006.

Most fields were treated postharvest with water during only one out of the three sequential years (1991–1992, 1992–1993, 1993–1994) that we studied. Of the 30,458 ha in the study area that were FLD- or IRG-treated during any of our three sequential study years, 70.5% was treated during only 1 y, 25.7% during 2 y, and 3.8% during all 3 y. The percentage of area treated multiple years was greater for IRG-treated fields (2 y: 21.6%, 3 y: 1.7%) than for FLD-treated fields (2 y: 5.2%, 3 y: 0.7%). Of the 10,172 ha treated with FLD or IRG in 2005, 54.8% was treated during at least one of the 3 y during 1991–1994. Both FLD and IRG fields occurred throughout the study area and were in similar locales each year (Figure 1).

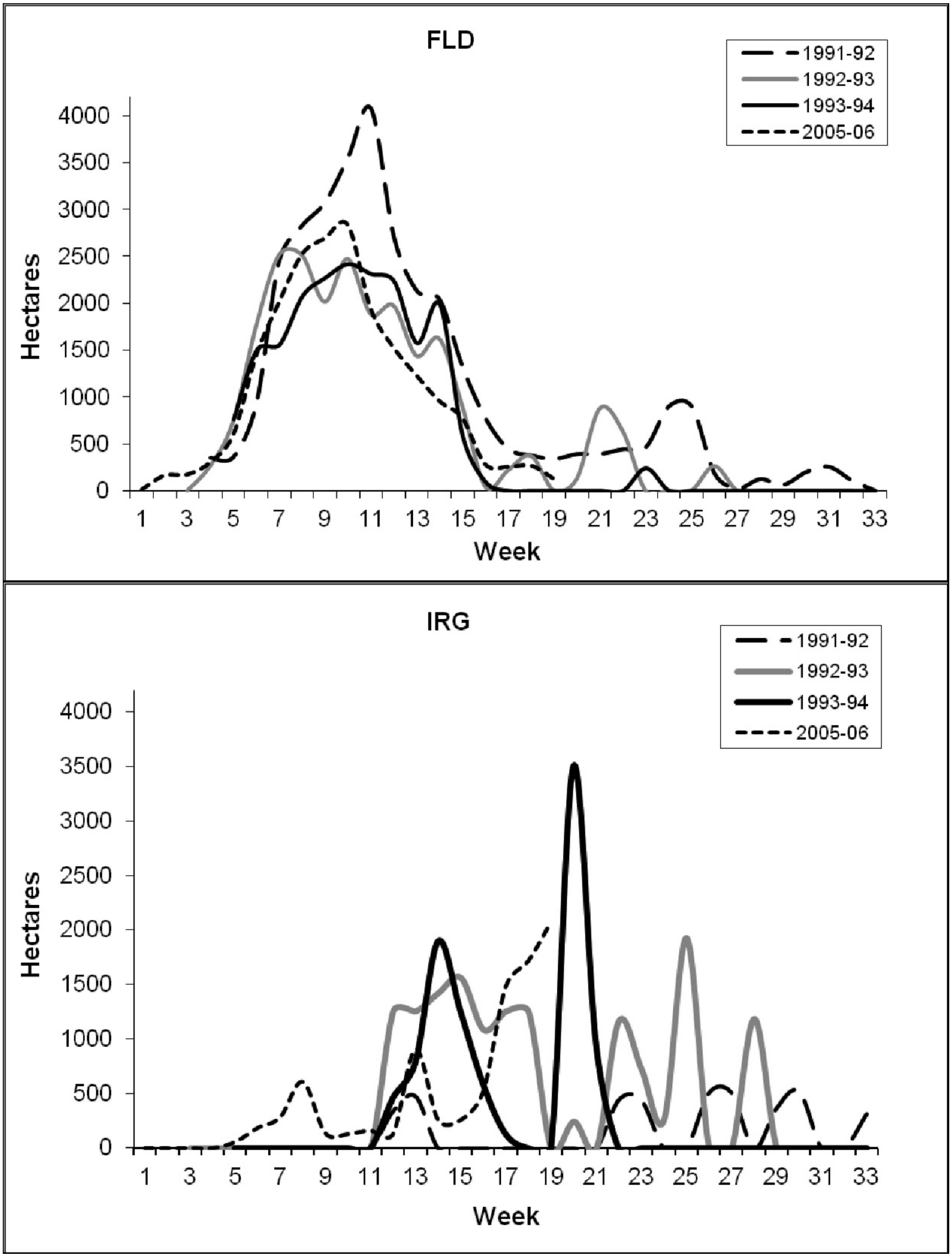

Figure 2. Weekly area of crop fields treated postharvest with two different flooding regimes ([top panel] < 1 cm to 1.5 m for longer than 1 wk [FLD]; [bottom panel] < 1 to 15 cm water for 1 wk or less [IRG]) by study year (1991–1992, 1992–1993, 1993–1994, 2005–2006) during 1 August (week 1) to 25 March (week 33) in the vicinity of the Tulare Lake Bed in the Tulare Basin, California. (In 2005–2006, surveys were not conducted in weeks 20–26 or 28–33).

Crops treated with FLD and IRG flooding

Area of each specific harvested crop receiving FLD or IRG treatment varied among and within years (Table 2; Figure 3). Safflower, a very common crop during 1976–1987 (Kings County Agriculture Commissioner 2012) and the most abundant crop receiving FLD treatments in 1991–1994 (38–55% of FLD field area and 2–33% of IRG field area) was absent in 2005–2006. In contrast, tomato fields were common only in 2005–2006, comprising 14% of the FLD field area and 16% of the IRG field area. Alfalfa, barley or wheat, and fallow fields were primarily FLD-treated but area varied greatly among years. Cotton was primarily IRG-treated and comprised 47–95% of the IRG field area; the area of IRG cotton greatly exceeded the area of FLD cotton after 1991–1992 (Table 2).

Discussion

Our study documents temporal changes in area, timing, and crops flooded postharvest in the Tulare Basin. Overall during August through March, the weekly average area of FLD fields in the Tulare Lake Bed vicinity during 1981–2006 declined to about half the 1976–1980 average; the decline was especially severe during January–March. The addition of IRG fields increased the combined average area of FLD and IRG fields after 1991 to about 70% of the 1976–1980 average but most IRG fields were cotton fields during October–December, which provide minimal habitat value for waterbirds (Fleskes et al. 2003; Taft and Elphick 2007).

Fleskes et al. (2012) described agronomic factors driving water management changes in the Tulare Basin. Before the 1980s, few fields were laser-leveled. Thus, water applied postharvest for any purpose (e.g., during late summer–fall primarily to flush salts or during winter–spring primarily to improve soil moisture for planting) resulted in water of variable depths, including some deep water, remaining on fields for extended periods of time (i.e., FLD fields). However, since laser-leveling of fields became prevalent in the 1980s, more precise water application was possible and the need for FLD treatment was reduced. Costs for levee construction and maintenance are greater for FLD fields than for IRG fields and reauthorization of the Central Valley Project Improvement Act in 1992 instituted tiered water pricing (U.S. Bureau of Reclamation 2013), providing additional monetary incentive to reduce water use, and thus, to create IRG fields rather than FLD fields. Therefore, when the goal is only to flush salts or improve soil moisture, IRG treatments are used. Although IRG treatments alone may not provide adequate soil leaching over the long term for moderately salt-tolerant crops such as wheat and safflower, they may be adequate for more salt-tolerant crops such as cotton (Food and Agriculture Organization of the United Nations 2013). The area of FLD fields during late summer and early fall was partially restored after the mid-1980s when farmers discovered that ambient temperatures $\geq 30^{\circ}$C (common locally in late summer and early fall) in combination with maintaining deep water on fields helped to control a prevalent fungal cotton pest (Rourke and Nehl 2001) in addition to removing salts. Thus, FLD fields are currently mostly restricted to late summer and fall for fungal control. In contrast, IRG fields are mainly present during winter and spring when cooler temperatures minimize evaporation and water applied most effectively increases soil moisture.

We documented a decline in area of FLD fields and changes in crops being flooded postharvest that (with all other factors held constant) translates to reduced carrying capacity of the Tulare Basin for waterfowl and other waterbirds. In addition to IRG fields retaining water and thus providing waterbird habitat for less time than FLD fields, densities of waterbirds, especially waterfowl, are much lower on IRG fields than on FLD fields (Fleskes et al. 2012). This likely occurs because densities of waterbird foods (i.e., invertebrates and seeds) are much lower on IRG fields. Most IRG fields are flooded for only a few days during cooler months, conditions less conducive for producing invertebrates than conditions in most FLD fields, which are flooded for a few weeks during warm months. For example, although production of invertebrates is very high in FLD-treated tomato fields (Moss et al. 2009), use of IRG-treated tomato fields by waterfowl is extremely low and use by other waterbirds only moderate (Fleskes et al. 2012). Crops such as wheat and safflower that produce seeds favored by waterfowl are only moderately salt-tolerant and mostly receive FLD treatment whereas cotton, which provides minimal food and habitat value for waterfowl (Fleskes et al. 2003; Taft and Elphick 2007), is relatively tolerant to salt and mostly receives IRG treatments. Safflower, almost completely replaced by tomato in 2005–2006, was the flooded agricultural habitat most highly selected by wintering northern pintails (*Anas acuta*) in 1991–1994 (Fleskes et al. 2003).

To restore historic abundance and distribution of waterbirds throughout the Central Valley, the carrying capacity of the Tulare Basin will need to be increased (Fleskes et al. 2002). Recovery of waterbird populations in other agricultural regions of North America have been linked to success of wetland and farmland conservation programs in restoring waterbird habitat and to increased food resources in crop fields (Butcher et al. 2007). The CVJV employs restoration, enhancement, and protection of both wetland and agricultural habitats to meet their goals (CVJV 2006); all these methods are possible in the Tulare Basin but need to be well designed to ensure maximum benefit to waterbirds. Although IRG fields, particularly grain fields, are used by waterbirds, increasing the extent of FLD fields, especially FLD grain fields, would provide the most benefit for wintering waterfowl and other waterbirds (Fleskes et al. 2012). Thus, if maintaining agricultural production is a priority and agricultural drainage waters can be disposed of safely, then increasing the extent of FLD grain fields would provide the most benefit for wintering waterbirds; otherwise, restoring and providing adequate water supplies to optimally manage wetlands would most benefit waterbirds. Moss et al. (2009) recommended maintaining most of the area of FLD fields at ≤ 30 cm with some deeper areas to promote both aquatic insect

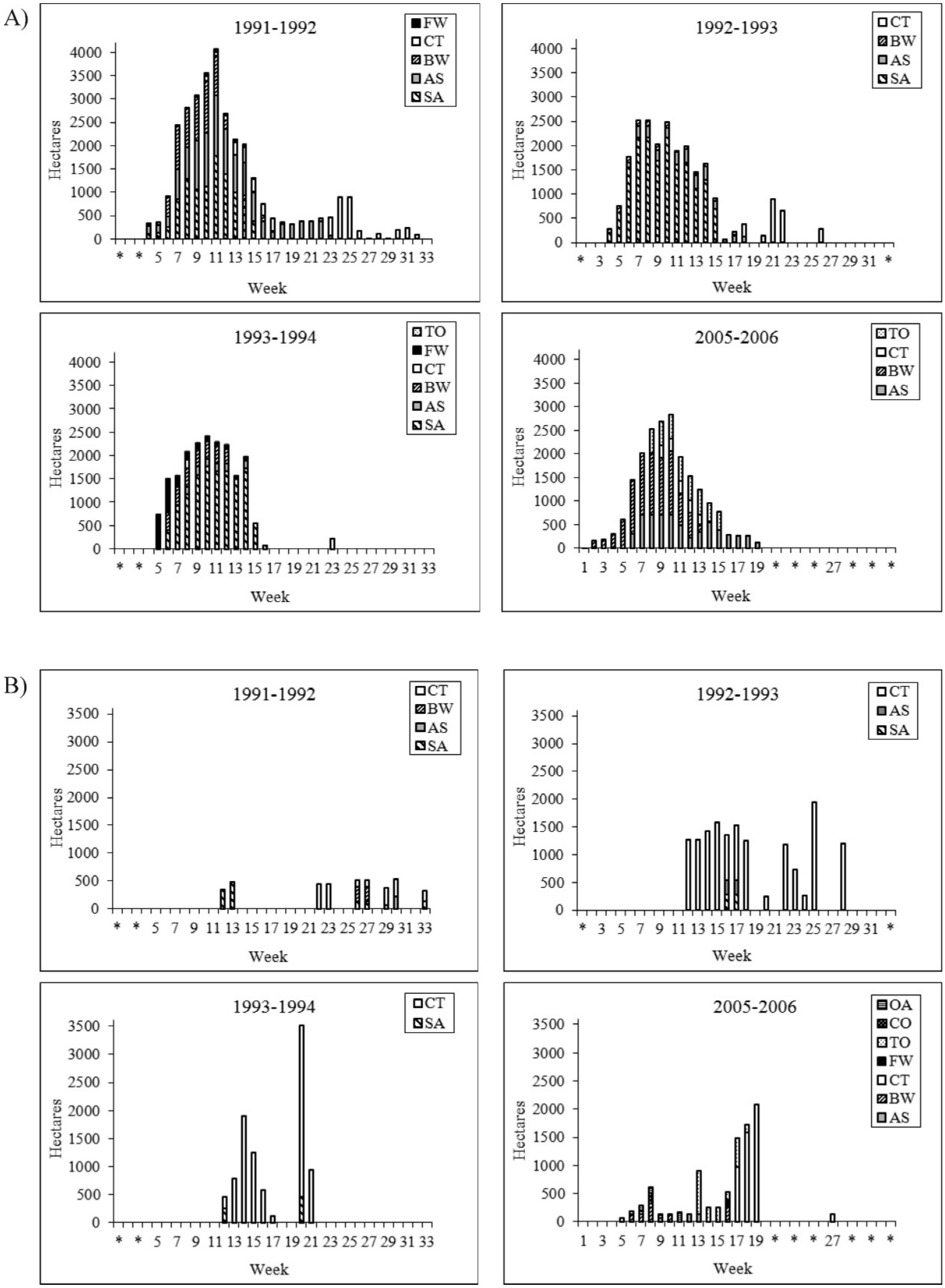

Figure 3. Weekly area of crop fields treated postharvest with two different flooding regimes ([**A**] < 1 cm to 1.5 m for longer than 1 wk = FLD; [**B**] < 1 to 15 cm water for 1 wk or less = IRG) by study year (1991–1992, 1992–1993, 1993–1994, 2005–2006) and crop (TO: tomato, FW: fallow weeds, CT: cotton, BW: barley–wheat, AS: alfalfa and alfalfa seed, SA: safflower, OA: oats, CO: corn) during 1 August (week 1) to 25 March (week 33) in the vicinity of the Tulare Lake Bed in the Tulare Basin, California. (*Indicates survey not conducted that week.)

production and waterbird foraging, but this recommendation has not been tested. In addition, fall and spring are critical migration periods for shorebirds (Shuford et al. 1998), which require shallower flooding than waterfowl (Isola et al. 2000), so flooding depths will need to be tailored to meet specific management objectives. Finally, periodically measuring the area of all habitats, including identifying crops of IRG and FLD fields, will be important for CVJV conservation planning and to track the success of waterbird habitat conservation programs in the region.

Supplemental Material

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Table S1. Microsoft Excel file containing data used in the analysis of area of agricultural fields treated postharvest with two different flooding regimes that varied in depth and duration of water applied ($<$ 1 to 15 cm water for 1 wk or less [IRG]; $<$ 1 cm to 1.5 m for longer than 1 wk [FLD]) in the vicinity of the Tulare Lake Bed in the Tulare Basin of California. Surveys were conducted during a 33-wk (1 August–22 March) interval in four study years (study years = 1991–1992, 1992–1993, 1993–1994, and 2005–2006). Data include field identification number, crop (TO: tomato, FW: fallow weeds, CT: cotton, BW: barley-wheat, AS: alfalfa and alfalfa seed, SA: safflower, OA: oats, CO: corn), flood type (FLD, IRG), field area (SqMeters), and weekly (wk1–wk33) fraction of the field that was flooded (0–1; "." indicates no survey conducted that week; includes both inundated areas and recently inundated mudflat).

Found at DOI: http://dx.doi.org/022013-JFWM-012.S1 (62 KB XLSX).

Reference S1. [CVJV] Central Valley Joint Venture. 2006. Central Valley Joint Venture implementation plan—conserving bird habitat. Sacramento, California: U.S. Fish and Wildlife Service.

Found at DOI: http://dx.doi.org/022013-JFWM-012.S2 (16.4 MB PDF).

Reference S2. Fleskes JP, Yee JL, Casazza ML, Miller MR, Takekawa JY, Orthmeyer DL. 2005b. Waterfowl distribution, movements and habitat use relative to recent habitat changes in the Central Valley of California: a cooperative project to investigate impacts of the Central Valley Habitat Joint Venture and changing agricultural practices on the ecology of wintering waterfowl. Published Final Report. Dixon, California: U.S. Geological Survey–Western Ecological Research Center, Dixon Field Station.

Found at DOI: http://dx.doi.org/022013-JFWM-012.S3 (10.1 MB PDF).

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