Surveys

Bird Use of Fields Treated Postharvest With Two Types of Flooding in Tulare Basin, California

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Abstract

We surveyed birds on grain and nongrain fields in the Tulare Basin of California treated postharvest with two types of flooding that varied in duration and depth of water applied (flooded-type [FLD] fields: $<$1 cm–1.5 m for $>$1 wk; irrigated-type [IRG] fields: $<$1–15 cm water for $<$1 wk at a time). Our goal was to compare use of these field types by birds to guide habitat conservation in the region. During 19 August–6 December 2005, we counted a total of 80,316 birds during 23 surveys of 5 FLD fields (four wheat, one alfalfa) and 8,225 birds during 38 surveys of 33 IRG fields (23 cotton, 4 tomato, 3 wheat, 1 alfalfa, 1 oat, 1 fallow). We recorded 14 waterfowl (13 duck, 1 goose), 29 other waterbird (coots, shorebirds, grebes, pelicans, herons, egrets, gulls, terns), and 14 nonwaterbird (passerines, raptors, and vultures) species on FLD fields compared to 5 duck, 14 other waterbird, and 9 nonwaterbird species on IRG fields. Species composition differed by field type; waterfowl comprised a greater percentage (FLD vs. IRG, 16.2% vs. 1.3%), other waterbirds a similar percentage (80.4% vs. 71.6%), and nonwaterbirds a lower percentage (3.5% vs. 27.1%) of birds on FLD than on IRG fields. The modeled density estimate of waterfowl was 108 times greater on FLD than IRG fields and 7.4 times greater on grain than nongrain fields. The density estimate of other waterbirds was 11.8 times greater on FLD than IRG fields and 4.4 times greater on grain than nongrain fields. The density estimate of nonwaterbirds was 14.3 times greater on grain than nongrain fields but did not differ by flood type. Long duration (i.e., $>$1 wk) flooding increased waterbird use of grain fields in the Tulare Basin more than in the northern Central Valley. Thus, even though water costs are high in the Tulare Basin, if net benefit to waterbirds is considered, management programs that increase availability of FLD fields (especially grain) in the Tulare Basin may be a cost-effective option to help meet waterbird habitat conservation goals in the Central Valley of California.

Keywords: agriculture; California; Central Valley; density; postharvest flooding; Tulare Basin; waterfowl

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Introduction

California's Central Valley is one of the most important areas in North America for waterfowl and other waterbirds despite extensive wetland loss and conversion to agriculture during the last century (Gilmer et al. 1982; United States Fish and Wildlife Service and Canadian Wildlife Service 1986; Heitmeyer et al. 1989). Wetland loss and decline in abundance of wintering waterfowl and other waterbirds have been greater in the Tulare Basin, comprising the southern third of the Central Valley, than in other Central Valley regions (Kirk 1994; Fleskes et al. 2005b). Extensive habitat restoration and enhancement is planned for the Tulare Basin in an effort to restore waterbird populations and distribution in the Central Valley (Central Valley Joint Venture [CVJV] 2006; The Outdoor Wire 2009). The CVJV and the Landowner Incentive Program (United States Department of Interior 2004) are both broadly supported cooperative efforts that include a focus on sustaining and enhancing agriculture for waterfowl and other waterbirds. Successful implementation of these programs requires understanding the relative habitat value of agricultural crops and field treatments to wintering waterfowl and other waterbirds.

Each year, farmers apply water to a portion of Tulare Basin fields after harvest to remove salts accumulated during irrigations, control crop disease, and provide soil moisture for the next planting (San Joaquin Valley Drainage Program Study Team 1990). Two types of flooding are used, which differ in duration and depth of applied water. We term the first type of flooding, in which relatively shallow water is applied sequentially and relatively briefly to parts of the field separated by levees (i.e., checks) as irrigated-type (IRG) flooding. Each check in IRG fields usually has water less than 1 cm to 15 cm deep for less than 1 d to less than 7 d before the water is drained or pumped to an adjacent check. Water is sometimes applied multiple times to IRG fields depending upon the crop. We term the second type of flooding, in which relatively deep water is applied for a week or longer as flooded-type (FLD) flooding. In FLD fields, water is usually applied to all or nearly all of the field to a depth of up to 1.5 m and maintained for more than 1 wk to many weeks by adding water as necessary. Water is then pumped off or drained off. Although water depth varies within FLD fields from less than 1 cm to about 1.5 m, depending upon field slope and the stage of flooding (i.e., flooding up, fully flooded, drawdown), it is generally deeper than in IRG fields.

Relative availability of IRG and FLD fields has changed over time and varies among seasons and crop types. Before precise laser leveling of fields became prevalent in the 1980s, application of water during late summer–fall (primarily to flush salts) and during winter–spring (primarily to improve soil moisture for planting) resulted in water of variable depths remaining on portions of the treated fields for extended periods of time. Thus, nearly all postharvest flooding used to create at least some FLD fields. However, now nearly all fields are laser leveled and water can be applied more precisely. Thus, when the goal is only to flush salts or improve soil moisture, application of water creates only IRG fields. Availability of FLD fields during late summer and early fall was restored somewhat after the mid-1980s, when farmers discovered that maintaining deep water on fields when ambient temperatures are 30°C or more (common locally in late summer and fall) helps control black root rot (caused by *Thielaviopsis basicola*), a naturally occurring fungal cotton pest that is prevalent in Tulare Basin soils and can reduce cotton yields by as much as 50% (Rourke and Nehl 2001). Shortly after harvest, an earthen border is placed around fields to be flooded and water is pumped to an approximate depth of 1 m to 1.5 m and maintained for several weeks. Nearly all fields selected for this extended, late summer–fall fungal control flooding are noncotton rotation crops such as wheat, safflower, tomato, or alfalfa that will be planted with cotton the following year. Hydrostatic pressure from the water also drives the accumulated salts down through the soil into underground drainage tiles. Also, even in late summer, flooding helps provide subsurface soil moisture, improving the seedbed for planting cotton in spring. However, preparing fields for deep flooding requires significant manpower and maintaining deeply flooded fields is costly because the Tulare Basin is the driest region of the Central Valley and water costs are high (e.g., $15–$118/acre-foot in Tulare Basin vs. $2–$37/acre-foot in the northern Central Valley; Department of Water Resources 2005). Thus, availability of FLD fields is currently restricted almost completely to late summer and fall for fungal control; whereas, IRG fields are mainly available during winter and spring when water to increase soil moisture is best retained.

Tulare Basin fields flooded after harvest for several weeks (i.e., FLD fields) receive extensive use by waterfowl and other waterbirds for both feeding and roosting (Barnum and Euliss 1991; Shuford et al. 1998; Fleskes et al. 2003). However, bird use of IRG fields has not been studied. Detecting and measuring area of briefly available habitats such as IRG fields is difficult, especially in the Tulare Basin where frequent dense fog often prevents collection of landscape information via satellite imagery, aerial surveys, or aerial photography. The CVJV currently does not account for IRG fields in their conservation planning (CVJV 2006) because bird use of IRG fields is unknown and tracking of the habitat is difficult (M. Petrie, Ducks Unlimited, Inc., personal communication). We surveyed and compared bird use of IRG and FLD fields to determine whether IRG fields are important habitats whose availability should be tracked and included in conservation planning in the region.

Study Site

The 13,000-km^2 Tulare Basin of California is the southern and most arid part of the Central Valley (United States Fish and Wildlife Service 1978, *Supplemental Material*, Reference S2; http://dx.doi.org/10.3996/092011-JFWM-056.S2; Figure 1). Most postharvest flooding of agricultural fields in the Tulare Basin occurs in the Tulare Lake Bed. Tulare Lake, once the largest freshwater lake west of the Mississippi River and the dominant feature of the basin, was drained by the early 1920s. The Tulare Lake Bed was converted to agriculture with cotton, grain (mainly barley or wheat), safflower, alfalfa, and tomatoes as important crops; tomatoes supplanted safflower in importance during our study. In addition to the 10,000–17,000 ha of IRG or FLD fields each year, about 2,946 ha of public and private wetlands, 1,951 ha of agricultural drainwater evaporation ponds, and other waterbird habitats (0–1,374 ha of flood basins, 82 ha of sewage treatment ponds, and 390–742 ha of reservoirs each year; Fleskes 1999; J.P. Fleskes, U.S. Geological Survey [USGS], unpublished data) are present in the Tulare Basin, mostly outside the Tulare Lake Bed (Fleskes et al. 2003). During 2005, IRG fields did not become common until late September but by November were the predominant type. Thus, in 2005, most IRG fields were tomato or cotton fields (J.P. Fleskes, USGS, unpublished data).

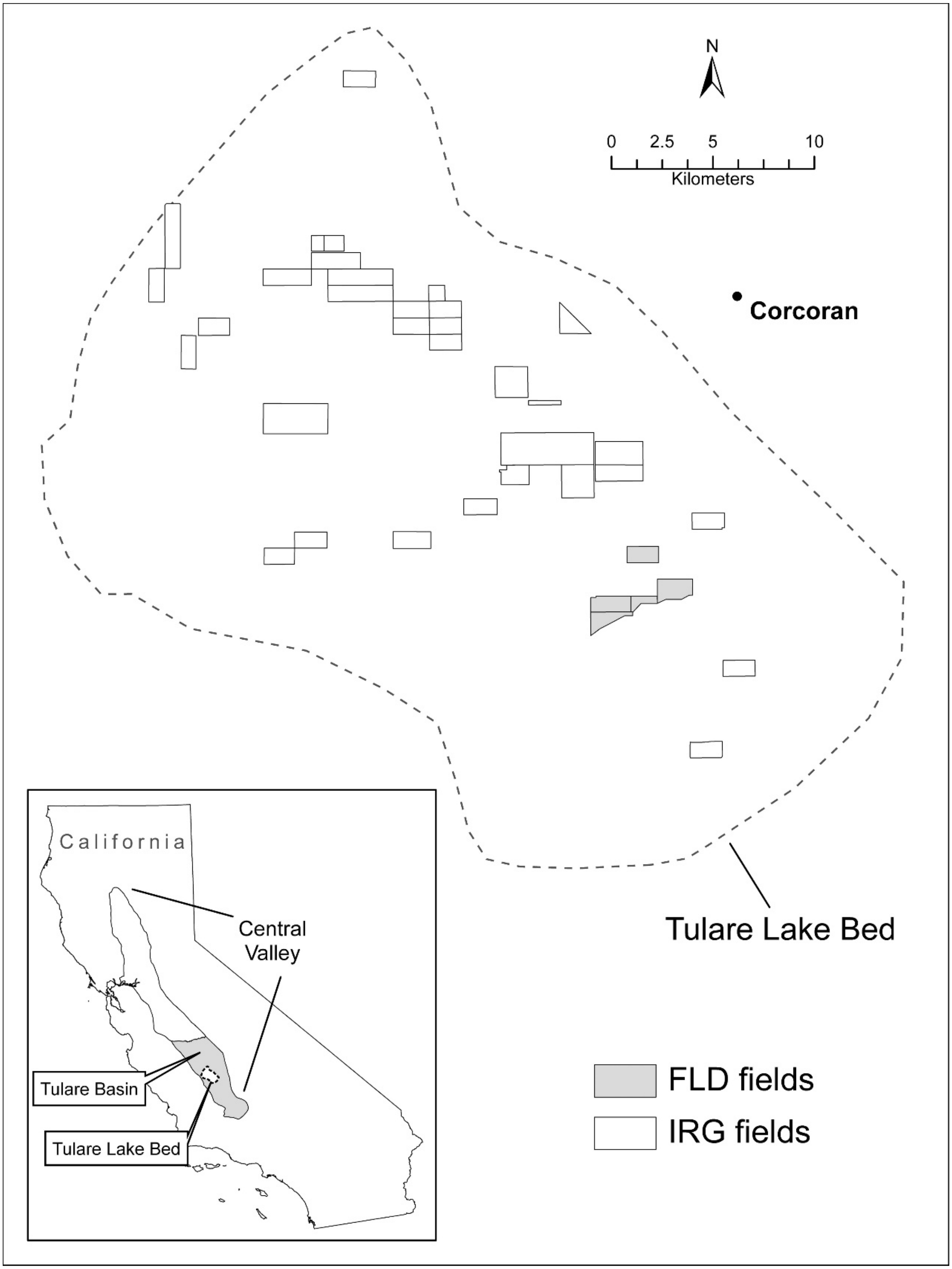

Figure 1. Tulare Lake Bed study site in the Tulare Basin of California showing fields that were treated postharvest with two types of flooding that varied in duration and depth of water applied (flooded-type [FLD] fields were flooded with <1 cm–1.5 m water for >1 wk; irrigated-type [IRG] fields were flooded with <1 cm–15 cm water for <1 wk) that were surveyed for birds during 19 August–6 December 2005.

Methods

Field surveys

We located and mapped FLD and IRG fields in the Tulare Lake Bed by driving all accessible public and main elevated levee roads weekly during 19 August–6 December 2005. These roads provided a view of the entire Tulare Lake Bed. We surveyed birds on 5 FLD fields and on 33 IRG fields that we encountered; additional IRG and FLD fields were mapped but not surveyed due to access or time limitations. We used a window-mounted 20–60× 80-mm spotting scope and 10× 42-mm binoculars at key elevated sites to aid our search for IRG and FLD fields and to identify and count birds. We conducted bird surveys during daylight hours between 0638 and 1640 hours from a pickup truck. Surveys took from 5 to 106 min to complete depending on field size, accessibility, and number of birds present. We tallied bird counts onto forms on which we recorded survey date and time and field information (flood type, crop, Township-Range-Section, percent flooded, percent mud-flat, percent dry, vegetation description). We mapped field location and sketched flooded and mud-flat areas on USGS 1:24,000 maps by using landmarks, a GPS, and the truck odometer. We used residual field vegetation to identify crops and obtained crop information from Kings or Tulare County Agricultural Commission for eight fields where residual vegetation was not visible.

We surveyed birds on 5 FLD fields (four wheat and one alfalfa) during 19 August–29 November 2005 and on 33 IRG fields (23 cotton, 4 tomato, 3 wheat, 1 alfalfa, 1 oat, and 1 fallow) during 2 October–6 December 2005 throughout the Tulare Lake Bed region (Figure 1). The FLD wheat fields that we surveyed shared at least one common border and were 4.8 km or less apart; the FLD alfalfa field was 4.8 km or more away. All FLD fields that we surveyed were owned by the same entity. We surveyed each FLD field every 12–16 d during the 45–56 d each was flooded. Thus, we surveyed each FLD field four or five times, conducting a total of 23 surveys on FLD fields. We conducted a total of 38 surveys of IRG fields. We surveyed most IRG fields only once because water was applied for a shorter duration, except two tomato, one wheat, and one cotton IRG field, which had repeated water application and we surveyed two or three times. All FLD fields that we surveyed were also part of a duck food habits study from which ducks were periodically shot. We surveyed these fields no sooner than 24 h after any collection attempt to minimize any impact of collection activities on bird abundance. The FLD fields were 76–167 ha and averaged 89% flooded and 11% mudflat at the time of our surveys. All FLD fields were at least 80% flooded when we surveyed them except for two instances when the fields were mostly (61%, 99%) mudflat at the time of our survey. The IRG fields were 13–466 ha and, because of shallower water and rapid dewatering, averaged only 38% flooded (62% mudflat) at the time of our survey; only 10 of our 38 surveys of IRG fields occurred when the field was more than 50% flooded.

Data analysis

We used chi-square tests to compare species composition for IRG and FLD fields. We estimated densities for waterfowl (includes Anseriformes [ducks and geese]), other waterbirds (includes Gruiformes [coots], Podicipediformes [grebes], Pelecaniformes [pelicans, ibis, herons, and egrets] and Charadriiformes [shorebirds, gulls, and terns]), nonwaterbirds (includes Passeriformes [sparrows, blackbirds, phoebes, ravens, swallows, pipits], Accipitriformes [hawks and vultures], and Falconiformes [falcons]), and the total of all birds. Because birds used both the flooded and mudflat areas of fields, we estimated bird density as the number of birds seen on the field divided by the sum of the field's flooded area and mudflat area at the time of the survey.

We used generalized linear mixed-effects models to examine effects of flood type (i.e., IRG vs. FLD) and crop type (i.e., grain [wheat or oats] vs. nongrain [alfalfa, fallow, cotton, tomato]) on bird density. To account for possible effects of unequal sampling of field types by survey date interval (i.e., 4-wk intervals from 15 August to 15 December) and time of day interval (i.e., early-day [$\leq$4 h post sunrise], midday [$>$4 h post sunrise and $>$4 h before sunset], and late-day [$\leq$4 h before sunset] surveys), we included these nuisance variables in the fixed effects component of all models. Waterfowl, other waterbirds, nonwaterbirds, and total birds were modeled separately. The most heavily parameterized model for all analyses included the fixed effects of crop type and flood type and their two-way interaction. Areas (flooded and mud flat total) of sampled fields were log transformed and included as an offset to model bird density independent of field size (Zuur et al. 2009). To control for multiple samples taken within the same field over time, fields were included as a random effect. Models were evaluated using R (R Development Core Team 2009) with the glmmPQL function (Venables and Ripley 2002). The quasi-Poisson error distribution was specified to account for overdispersion (Ver Hoef and Boveng 2007; Bolker et al. 2008; O'Hara and Kotze 2010). Parameters were removed in a backward-stepwise procedure from the most heavily parameterized model based on Wald *t*-tests (α = 0.05). The final model was used to generate density estimates for the median survey date interval (mid-October to mid-November) and most common time of day interval (early day). Surveys provided replication across factors by crop type (i.e., grain vs. nongrain) but not for all specific crops; thus, modeling was conducted by crop type but not by specific crop. To provide insight into bird use by specific crop, we calculated mean bird densities for IRG fields by crop, assuming survey independence and ignoring survey date and time of day intervals.

Results

Species composition

We counted a total of 80,316 birds during 23 surveys of 5 FLD fields and 8,225 birds during 38 surveys of 33 IRG fields, 19 August–6 December 2005 (Archived Material in Dryad, Table S1; http://dx.doi.org/10.5061/dryad.9b6qj34p). We observed 14 waterfowl (13 duck, 1 goose), 29 other waterbird, and 14 nonwaterbird species on FLD fields. We observed 5 duck, 14 other waterbird, and 9 nonwaterbird species on IRG fields (Table 1). Nearly all (99.2%) of the 13,030 waterfowl, 91.7% of the 70,505 other waterbirds, and 55.5% of the 5,006 nonwaterbirds that we counted were on FLD fields.

Bird species composition differed by flood type (χ^2 = 5253.8, 2 df, $P < 0.001$) with waterfowl comprising a greater percentage (FLD vs. IRG, 16.2% vs. 1.3%, χ^2 = 12.69, df = 1, $P < 0.001$), other waterbirds comprising a similar percentage (80.4% vs. 71.6%, χ^2 = 0.51, df = 1, P = 0.48) and nonwaterbirds comprising a lower percentage (3.5% vs. 27.0%, χ^2 = 11.61, df = 1, $P <$ 0.001) of birds on FLD than on IRG fields (Table 1). The largest differences for individual species by flood type were that northern shoveler *Anas clypeata* (12.2% vs. 0.2%), American avocet *Recurvirostra americana* (14.3% vs. 0.01%), and dowitcher species *Limnodromus* spp. (28.8% vs. 2.3%) comprised a greater percentage; whereas, western sandpiper *Calidris mauri* (1.3% vs. 8.6%), great blue heron *Ardea herodias* (0.05% vs. 2.8%), great egret *Ardea alba* (0.2% vs. 4.4%), ring-billed gull *Larus delawarensis* (2.2% vs. 26.6%), and Brewer's blackbird *Euphagus cyanocephalus* (0.07% vs. 24.4%) comprised a lower percentage of the birds on FLD than on IRG fields (Table 1).

Bird density

Modeled density estimates of waterfowl, other waterbirds, and total birds varied between flood and crop types with no interaction (FLD grain > FLD nongrain > IRG grain > IRG nongrain; Table 2). Nonwaterbird density estimates varied only by crop type with densities in FLD grain and IRG grain greater than in FLD nongrain and IRG nongrain (Table 2). The density estimate of waterfowl was 108 (95% CI = 14.1–826.3, t_{35} = 4.35, $P < 0.001$) times greater on FLD than IRG fields and 7.4 (95% CI = 1.5–37.1, t_{35} = 2.37, P = 0.02) times greater on grain than nongrain fields. The density estimate of other waterbirds was 11.8 (95% CI = 4.6–30.5, t_{35} = 4.92, $P <$ 0.001) times greater on FLD than IRG fields and 4.4 (95% CI = 1.8–10.7, t_{35} = 3.18, P = 0.003) times greater on grain vs. nongrain fields. The density estimate of nonwaterbirds was 14.3 (95% CI = 3.9–52.5, t_{35} = 3.91, $P < 0.001$) times greater on grain than nongrain fields but did not differ by flood type (t_{35} = 0.42, P = 0.68). The density estimate of total birds was 10.5 (95% CI = 5.0–22.1, t_{35} = 5.94, $P < 0.001$) times greater on FLD than IRG fields and 5.5 (95% CI = 2.7–11.1, t_{35} = 4.57, P $<$ 0.001) times greater on grain than nongrain fields.

Among IRG nongrain fields, all crops had low waterfowl density (cotton: $\bar{x}$ = 0.5/km^2, SD = 2.0, n = 24; tomato: $\bar{x}$ = 0.3/km^2, SD = 0.8, n = 7; alfalfa: 0/km^2, n = 1; fallow: 0/km^2, n = 1) and moderate density of other waterbirds (cotton: $\bar{x}$ = 147/km^2, SD = 157, n = 24; tomato: $\bar{x}$ = 124/km^2, SD = 148, n = 7; alfalfa: 166/km^2; fallow: 71/km^2); density of nonwaterbirds varied by crop (cotton: $\bar{x}$ = 3/km^2, SD = 10, n = 24; tomato: $\bar{x}$ = 11/km^2, SD = 21, n = 7; alfalfa: 0/km^2; fallow: 232/km^2). Among IRG grain fields, IRG wheat had low density of waterfowl ($\bar{x}$ = 16/km^2, SD = 32, n = 4) and moderate density of other waterbirds ($\bar{x}$ = 281/km^2, SD = 392, n = 4) and nonwaterbirds ($\bar{x}$ = 364/km^2, SD = 322, n = 4) whereas IRG oats had moderate density of waterfowl (107/km^2, n = 1) and other waterbirds (429/km^2, n = 1) but no nonwaterbirds.

Discussion

Our surveys showed that IRG fields did receive some use by waterbirds. However, densities, especially for waterfowl, were much lower than on FLD fields; nongrain IRG fields received almost no use by waterfowl and had low densities of other waterbirds. Waterbirds use postharvest flooded fields in the Tulare Basin for both roosting and feeding (Fleskes et al. 2003), and availability of suitable roost sites and preferred foods likely both impact waterbird use. When not forced to leave due to hunting or other disturbance, waterfowl and other waterbirds will often remain to roost in foraging fields (Fleskes et al. 2003), unless conditions are not adequate (e.g., water dries up or is too shallow to impede mammalian predators). Fields we surveyed were never or only rarely hunted and, based on our observations, had similarly low levels of disturbance. Thus, we suspect that the differences in densities of waterfowl and other waterbirds that we observed among fields primarily reflect differences in availability of preferred foods and suitable roosting sites. Aquatic insects (especially midges [Chironomidae]) and earthworms (Lumbricidae) are important foods in Tulare Basin fields for both waterfowl (Fleskes 2007, *Supplemental Material*, Reference S1; http://dx.doi.org/10.3996/092011-JFWM-056.S1) and other waterbirds (Baldassarre and Fischer 1984; Skagen and Oman 1996; Davis and Smith 2001). However, whereas waterfowl feed extensively on grain and other waste crop seeds, among "other waterbird" species that we most commonly observed (i.e., dowitchers *Limnodromus* spp., American avocets *Recurvirostra americana*, black-bellied plover *Pluvialis squatarola*, western sandpipers *Calidris mauri*, ring-billed gull, Table 1), only the ring-billed gull commonly consumes grain (Welham 1987).

Bird densities in FLD vs. IRG fields

The greater densities of waterfowl and other waterbirds on FLD than IRG fields that we observed indicate availability of preferred foods and suitable roost sites were greater in FLD than in IRG fields. Although loss of seeds to decomposition increases with flooding (Foster et al. 2010), ducks and most other waterbirds do not regularly feed in dry fields in the Tulare Basin (Fleskes et al. 2003). Thus, flooding of any duration and depth obviously facilitates access by ducks and other waterbirds to seeds. Abundance of aquatic invertebrates is related to duration and depth of flooding (Moss et al. 2009) and is probably much greater in FLD than in IRG fields. Water supplies used to flood fields often contain larvae and eggs of aquatic invertebrates (Euliss and Grodhaus 1987), but even chironomids, which develop rapidly in warm climates, require more than a week to develop from eggs to adult (Gray 1981; Hauer and Benke 1991). Also, temperature fluctuation in the range observed in shallow water has a strong negative impact on invertebrate production (Moss et al. 2009). Thus, the

Table 1. Species composition (%) of 80,316 birds observed on flooded-type (FLD) fields and 8,225 birds observed on irrigated-type (IRG) agricultural fields in the Tulare Basin of California, 19 August–6 December 2005.[a]

Species or species group	FLD	IRG
Waterfowl	16.17	1.33
Canada goose *Branta canadensis*	0.26	0
Gadwall *Anas strepera*	0.08	0
American wigeon *Anas americana*	0.02	0
Mallard *Anas platyrhynchos*	0.57	0.94
Cinnamon teal *Anas cyanoptera*	0.08	0
Northern shoveler *Anas clypeata*	12.24	0.22
Northern pintail *Anas acuta*	0.56	0.11
Green-winged teal *Anas crecca*	0.50	0.07
Canvasback *Aythya valisineria*	0.02	0
Redhead *Aythya americana*	0.02	0
Ring-necked duck *Aythya collaris*	0.005	0
Lesser scaup *Aythya affinis*	0.009	0
Bufflehead *Bucephala albeola*	0.002	0
Ruddy duck *Oxyura jamaicensis*	1.47	0
Unknown waterfowl species Anatidae	0.26	0
Other waterbirds	80.40	71.56
Pied-billed grebe *Podilymbus podiceps*	0.005	0
Eared grebe *Podiceps nigricollis*	0.09	0
Western grebe *Aechmorphorus occidentalis*	0.002	0
Clark's grebe *Aechmophorus clarkii*	0.001	0
American white pelican *Pelecanus erythrorhynchos*	0.03	0.96
Great blue heron *Ardea herodias*	0.05	2.80
Great egret *Ardea alba*	0.24	4.39
Snowy egret *Egretta thula*	0.12	0.17
Cattle egret *Bubulcus ibis*	0.02	0
Black-crowned night-heron *Nycticorax nycticorax*	0.02	0
White-faced ibis *Plegadis chihi*	0.43	0
American coot *Fulica americana*	2.70	0.06
Black-bellied plover *Pluvialis squatarola*	7.96	10.30
Semipalmated plover *Charadrius semipalmatus*	0.001	0
Killdeer *Charadrius vociferous*	0.04	0.04
Black-necked stilt *Himantopus mexicanus*	1.70	0.15
American avocet *Recurvirostra americana*	14.26	0.01
Greater yellowlegs *Tringa melanoleuca*	0.11	0.03
Lesser yellowlegs *Tringa flavipes*	0.001	0
Whimbrel *Numenius phaeopus*	0.05	0
Marbled godwit *Limosa fedoa*	0.38	0
Western sandpiper *Calidris mauri*	1.34	8.58
Dowitcher *Limnodromus* spp.	28.77	2.27
Wilson's phalarope *Phalaropus tricolor*	0.04	0
Red-necked phalarope *Phalaropus lobatus*	0.10	0
Ring-billed gull *Larus delawarensis*	2.25	26.59
Caspian tern *Hydroprogne caspia*	0.28	0.01
Forster's tern *Sterna forsteri*	0.02	0
Nonwaterbirds	3.50	27.0
Turkey vulture *Cathartes aura*	0.001	0
Northern harrier *Circus cyaneus*	0.01	0.01
Red-tailed hawk *Buteo jamaicensis*	0.005	0.02
American kestrel *Falco sparverius*	0.001	0.01
Peregrine falcon *Falco peregrinus*	0.01	0.01
Black phoebe *Sayornis nigricans*	0.001	0
Common raven *Corvus corax*	0.05	0.04
Cliff swallow *Petrochelidon pyrrhonota*	2.63	2.43
American pipit *Anthus rubescens*	0.42	0.06
Song sparrow *Melospiza melodia*	0.02	0
Unidentified sparrows	0.04	0
Red-winged blackbird *Agelaius phoeniceus*	0.17	0.12
Brewer's blackbird *Euphagus cyanocephalus*	0.07	24.39

[a] FLD fields were flooded with <1 cm–1.5 m water for >1 wk; IRG fields were flooded with <1 cm–15 cm water for <1 wk.

brief and shallow flooding of IRG fields likely results in fewer aquatic invertebrates, lower overall waterbird food availability, and lower use by waterfowl and other waterbirds than FLD fields. Further, we observed waterfowl almost exclusively on or near the portions of IRG fields that had standing water. Because standing water was present relatively briefly and on a much smaller portion of the field on average than for FLD fields, waterfowl density on IRG fields was low. Other waterbirds (especially shorebirds) readily used both the standing water and mudflat portions of IRG fields and their density on IRG fields was higher than for waterfowl. Fleskes et al. (2003) reported that postharvest flooded fallow fields were selected by pintails, but those were all FLD fields. The fallow field we surveyed was only briefly flooded and received very little use by waterbirds.

Bird densities in grain vs. nongrain fields

Greater densities of waterfowl and other waterbirds on grain fields than on nongrain fields also indicate availability of preferred foods was greater in grain than in nongrain fields. Waste grain provides an abundant, high-energy food that can be quickly consumed (Ringelman 1990), and although waterfowl will consume nongrain crop seeds including tomato (Miller et al. 2009) and alfalfa (Fleskes 2007, *Supplemental Material*, Reference S1; http://dx.doi.org/10.3996/092011-JFWM-056.S1), they most commonly select grain seeds (Miller 1987; Ringelman 1990). Thus, densities of waterfowl during our study were greater on grain (wheat and oats) than on tomato, alfalfa, and other nongrain (cotton, fallow) fields even though total biomass of waste crop seeds in the fields was likely similar (Moss et al. 2006). Fleskes et al. (2003) also reported that postharvest flooded grain fields (wheat or barley) usually ranked above alfalfa and cotton fields in selection by northern pintails *Anas acuta* in the Tulare Basin, although selection ranking of grain vs. alfalfa was more consistent than grain vs. cotton. Grain is

Table 2. Model-predicted estimates of the density (birds/km^2) of waterfowl, other waterbirds, nonwaterbirds, and total birds for grain and nongrain fields treated with two types of postharvest flooding that differed in depth and duration in the Tulare Basin of California, 19 August–6 December 2005.[a,b]

Field type[c]	Waterfowl[d]		Other waterbirds		Nonwaterbirds		Total birds	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
FLD grain	659.7	443.2–981.9	3,885.7	2,835.1–5,325.6	167.6	79.1–355.2	4,831.7	3,776.2–6,182.2
FLD nongrain	88.6	37.9–206.8	880.6	551.9–405.2	11.7	5.9–23.1	879.3	605.9–1,276.2
IRG grain	6.1	2.1–17.9	328.8	199.1–542.9	167.6	79.1–355.2	461.6	310.9–685.3
IRG nongrain	0.8	0.1–5.6	74.5	28.3–196.3	11.7	5.9–23.1	84.0	39.0–181.0

[a] Models accounted for survey repeated measures, and assumed the median survey date interval (mid-October to mid-November) and the most common survey time interval (early day). For nonwaterbirds, flood type was not in the final model.
[b] FLD fields were flooded with <1 cm–1.5 m water for >1 wk; IRG fields were flooded with <1 cm–15 cm water for <1 wk.
[c] Field type (number of surveys conducted by crop): FLD grain (17 wheat); FLD nongrain (6 alfalfa); IRG grain (4 wheat, 1 oat); IRG nongrain (24 cotton, 7 tomato, 1 alfalfa, 1 fallow).
[d] See Table 1 for listing of species included in waterfowl, other waterbirds, and nonwaterbird groups.

not a regular component of the diet of most ''other waterbirds'' but we suspect that availability of earthworms and other invertebrates important in the diet of many waterbirds (Skagen and Oman 1996) is greater in grain than nongrain fields. Abundance of earthworms varies greatly by field soil type, crop, tillage practices, and applied chemicals (Kladivko 1993). Relative abundance of earthworms in grain and nongrain fields in Tulare Basin has not been studied. However, cotton fields, the most common nongrain field type in our study, regularly undergo multiple applications of pesticides, some of which are lethal to earthworms and other invertebrates (Taft and Elphick 2007). Moss et al. (2009) found that aquatic insect production in FLD wheat fields was similar to production in FLD alfalfa fields but less than in FLD tomato fields; however, the effect of crop type interacted with flood duration and depth. Variability in relative importance of various crops to waterbirds could also be due to variation in factors unrelated to crop type such as harvest efficiency, postharvest tillage (Miller et al. 1989; Elphick and Oring 1998), water depth (Elphick and Oring 1998; Isola et al. 2000), weed management practices, and disturbance levels that impacts availability of waterbird foods or suitable roosting sites.

Bird densities in Tulare Basin vs. other areas

Tulare Basin FLD fields supported a greater density of nonwaterfowl waterbirds (especially shorebirds) during our study than reported for flooded agriculture in other regions. The density of nonwaterfowl waterbirds on Tulare Basin FLD grain fields (3,886/km^2) exceeded that on intentionally flooded harvested rice fields in the northern Central Valley (840/km^2; Elphick and Oring 1998) and managed-flooded rice, soybean, and moist soil fields in the Mississippi Alluvial Valley (59/km^2; Twedt and Nelms 1999). Density of waterfowl on FLD grain fields during our study (660/km^2) was similar to that on intentionally flooded harvested rice fields in the northern Central Valley (740/km^2; Elphick and Oring 1998) and greater than on managed-flooded agricultural fields in the Mississippi Alluvial Valley (rice: 260/km^2, soybean: 430/km^2; Twedt et al. 1998). In contrast, Tulare Basin IRG grain fields supported a lower density of waterfowl (6/km^2 vs. 380/km^2) but about twice the density of other waterbirds (329/km^2 vs. 166/km^2) than harvested rice fields in the northern Central Valley that were not intentionally flooded (i.e., dry or rain-puddle flooded; Elphick and Oring 1998). Geese are abundant during winter in the northern Central Valley (United States Fish and Wildlife Service 2006, *Supplemental Material*, Reference S5; http://dx.doi.org/10.3996/092011-JFWM-056.S5) and comprised 81% of the waterfowl counted on harvested rice fields that were not intentionally flooded (Elphick and Oring 1998). Few geese winter in the Tulare Basin (United States Fish and Wildlife Service 2006, *Supplemental Material*, Reference S5; http://dx.doi.org/10.3996/092011-JFWM-056.S5) and this reduced waterfowl density on IRG fields. In contrast, the Tulare Basin is an especially important region for shorebirds (Shuford et al. 1998), and with less flooded habitat available than in the northern Central Valley (Fleskes et al. 2005b), density of other waterbirds on IRG fields was greater than in the northern Central Valley.

Bird densities in Tulare Basin 2005 vs. 1982–1984

Coe (1990) reported waterfowl densities on postharvest flooded fields in the Tulare Basin during 1982–1984 (2,500/km^2) that were 3.8 times greater than what we observed for FLD grain (660/km^2) and about 28 times greater than on our FLD nongrain fields (89/km^2); northern pintails comprised 80% and northern shovelers 16% of the waterfowl use during Coe's study compared with 3% pintails and 76% shovelers during our study. Pintails were much less abundant and northern shovelers more abundant in the Tulare Basin during our study than during Coe's study (e.g., early January abundance of pintails declined 57% and northern shoveler abundance increased 262% from 1984 to 2006; United States Fish and Wildlife Service 1983, *Supplemental Material*, Reference S3; http://dx.doi.org/10.3996/092011-JFWM-056.S3; 1984, *Supplemental Material*, Reference S4; http://dx.doi.org/10.3996/092011-JFWM-056.S4; 2006, *Supplemental Material*, Reference S5; http://dx.doi.org/10.3996/092011-JFWM-056.S5). The decline of pintails in the Tulare Basin reflected the overall decline of North American pintail populations (Miller and Duncan 1999) but also a decline in the proportion of the

Central Valley's pintail use days occurring in the Tulare Basin due to reduced fall flooding in the Tulare Basin and improved habitat conditions in the northern Central Valley (Barnum and Euliss 1991; Fleskes et al. 2005a). Disturbance from the study of waterfowl food habits may also have reduced waterbird density on the FLD fields that we surveyed. However, collection activities were halted for at least 24 h before each of our surveys and we observed waterfowl quickly returning and other waterbirds usually remaining on fields even during collections.

Costs and benefits of flooding

The Tulare Basin is a critically important region for shorebirds and other waterbirds and once supported an even larger portion of the Central Valley's wintering waterbirds (Shuford et al. 1998; Fleskes et al. 2002). About 20–50% of shorebirds counted in the Tulare Basin during 1992–1995 (Shuford et al. 1998) and 59–74% of the waterfowl counted in the Tulare Basin during 1980–1987 (Barnum and Euliss 1991) were on postharvest flooded agricultural fields. Flooded agriculture is especially critical for waterbirds in the Tulare Basin during August–October, when few wetlands are available (Fleskes 1999).

Programs that increase the extent and duration of FLD grain fields in the Tulare Basin during the fall and winter may be a cost-effective way for the CVJV to help meet their conservation goal of providing habitat to maintain distribution of waterfowl and other waterbirds throughout the Central Valley (CVJV 2006). Managed, extended (i.e., $>$1 wk) flooding of grain fields in Tulare Basin increased use by 654 waterfowl/km^2 (660/km^2 in FLD grain vs. 6/km^2 in IRG grain; Table 2) and 3,557 other waterbirds/km^2 (3,886/km^2 in FLD grain vs. 329/km^2 in IRG grain; Table 2) compared with an increase in the northern Central Valley of 357 waterfowl/km^2 (737/km^2 in rice fields intentionally vs. 380/km^2 in rice fields not intentionally flooded after harvest) and 677 other waterbirds/km^2 (843/km^2 in rice fields intentionally vs. 166/km^2 in rice fields not intentionally flooded after harvest; Elphick and Oring 1998). Thus, managed, extended flooding of grain fields increased total waterbirds by 4,211/km^2 in Tulare Basin vs. 1,034/km^2 in northern Central Valley. Water costs \$15–\$118/acre-foot in the Tulare Basin vs. \$2–\$37/acre-foot in the northern Central Valley (Department of Water Resources 2005). The additional amount of water used to create and maintain FLD rather than IRG fields in Tulare Basin has not been reported. However, the amount of water required per acre to maintain wetlands during fall and winter is similar in Tulare Basin and northern California (CVJV 2006). Therefore, if we assume the 1.5 acre-foot per acre average amount of water required for postharvest rice field flooding in the northern Central Valley (Department of Water Resources, unpublished data) also is adequate to create and maintain FLD rather than IRG fields in Tulare Basin, and fields in both regions are assumed to maintained as flooded for 1 mo with the rate of bird use remaining constant, then the cost (per increased bird use-day) ranges (with range in cost of water) from about \$0.28–\$2.23 for waterfowl, \$0.05–\$0.41 for other waterbirds, and \$0.04–\$0.35 for total waterbirds in the Tulare Basin vs. \$0.07–\$1.28 for waterfowl, \$0.04–\$0.68 for other waterbirds, and \$0.02–\$0.44 for total waterbirds in the northern Central Valley. Thus, based on incremental increase in bird use-days, and depending upon the actual cost of water, flooding and maintaining water for several weeks on Tulare Basin grain fields after harvest may be relatively cost effective compared to flooding agriculture in the northern Central Valley.

Data limitations

We caution that timing of the studies on which the above comparisons are based differs (i.e., November–March 1993–1995 for northern Central Valley bird use in Elphick and Oring [1998] vs. August–December 2005 for our study), and estimates of water requirements and cost are somewhat tenuous. Thus, additional research is needed to more definitively determine relative costs and benefits of agricultural flooding in the Tulare Basin vs. other Central Valley regions. Also, our study was limited by the unbalanced availability of field types and different (though overlapping) timing of our surveys of field types. Although we accounted for these factors, our analysis should be considered exploratory. Unlike the IRG fields, FLD fields we studied had clumped distribution and the same landowner. We doubt this biased our results because others have also reported high use of FLD fields in the Tulare Basin by waterfowl and other waterbirds (Barnum and Euliss 1991; Shuford et al. 1998; Fleskes et al. 2003); however, densities of birds on FLD fields elsewhere in the Tulare Basin managed by other farmers may differ from what we report for the fields we surveyed. We conducted all our surveys during the day and did not measure waterbird use at night. Waterfowl and other waterbirds regularly fly from diurnal roost sites to feed in flooded agriculture fields at night (McNeil 1990; Owen 1990; Fleskes et al. 2005b), and feeding fields that lack suitable secure day roost sites or receive high daytime disturbance (e.g., hunting) may have much higher nocturnal than diurnal density (e.g., 10.5 times higher reported for Texas playas; Anderson and Smith 1999). However, we observed very little hunting activity on the fields we surveyed and radio-tagged northern pintails showed only minor differences in their selection of fields, and often remained in the same fields, during day and night (Fleskes et al. 2003). Thus, we doubt waterbird selection of field types or waterbird densities on the fields at night differed much from what we observed during the day.

Management recommendations

Along with restoring wetlands, management programs that increase duration and extent of postharvest flooding of grain fields in the Tulare Basin could help increase pintail abundance in the Tulare Basin, restore historic waterfowl distribution (Fleskes et al. 2002), and may be a cost-effective option to help meet waterbird conservation habitat goals (CVJV 2006) in the Central Valley. Moss et al. (2009) reported that aquatic invertebrate production increased with flooding duration

(10–50 d) in alfalfa and tomato fields and was greater in long-term flooded tomato fields than in alfalfa or wheat fields. Thus, in addition to targeting grain fields, long-duration flooding of tomato fields might provide valuable invertebrate resources for waterbirds in the Tulare Basin and elsewhere; further study would be needed to determine waterbird response. Also, FLD fields supported more species and greater density of waterfowl and other waterbirds than IRG fields during our study, but IRG grain fields did support moderate densities of other waterbirds and nonwaterbirds and IRG nongrain fields did receive use by low densities of other waterbirds. Thus, the available area and amount of waterbird foods available in both FLD and IRG fields should be considered when planning waterbird habitat conservation in the region.

Supplemental Material

Please note: The *Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Reference S1. Fleskes JP. 2007. Food habits of northern pintails and other ducks on post-harvest flooded fields in the Tulare Basin-Annual Update, January 2007. 2007 Data Summary. U.S. Geological Survey, Western Ecological Research Center, Sacramento, California.

Found at DOI: http://dx.doi.org/10.3996/092011-JFWM-056.S1 (234 KB PDF).

Reference S2. 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.

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Reference S5. United States Fish and Wildlife Service. 2006. Winter waterfowl survey, Pacific Flyway-2006. United States Fish and Wildlife Service. Portland, Oregon.

Found at DOI: http://dx.doi.org/10.3996/092011-JFWM-056.S5 (284 KB PDF).

Archived Material

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Fleskes JP, Skalos DA, Farinha MA. 2012. Data from: Bird use of fields treated postharvest with two types of flooding in Tulare Basin, California. Journal of Fish and Wildlife Management 3(1):164–174. Archived in Dryad Digital Repository: http://dx.doi.org/10.5061/dryad.9b6qj34p

Table S1. Microsoft Excel file containing data used in the analysis of bird use of grain and non-grain fields treated with two types of postharvest flooding that differed in depth and duration (flood-type [FLD] fields were flooded with <1 cm–1.5 m water for >1 week; irrigated-type [IRG] fields were flooded with <1–15 cm water for <1 week) in the Tulare Basin of California, 19 August–6 December 2005. Surveys were grouped by time of day into early-day (<4 hours post sunrise), mid-day (>4 hours post sunrise and >4 hours before sunset) and late-day (<4 hours before sunset) periods. Counts for each survey are presented by species and for waterfowl (includes ducks and geese), other waterbirds (includes coots, shorebirds, grebes, pelicans, herons, egrets, gulls, and terns), non-waterbirds (includes passerines, raptors, and vultures), and total birds (see Table 1 for species).

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