Slow and Steady: Gradual Drawdown of Private Wetlands Supports Shorebirds During Northbound Migration.

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Abstract

The Grasslands Ecological Area is the largest contiguous wetland complex in California's Central Valley and is a stronghold for hundreds of thousands of waterbirds. Primarily managed for waterfowl habitat and forage production, privately-owned seasonal wetlands in the Grassland Ecological Area are typically flooded in fall and dewatered the following spring in February and March. These wetlands support large populations of nonbreeding shorebirds and other waterbirds in winter. When the number of migratory shorebirds using the region peaks in mid-April, most wetlands have already been dewatered. The mismatch in the timing of available habitat and the habitat needs of migrating shorebirds contributes to the observed deficit of shorebird habitat in the Central Valley in spring. Working with private landowners, we developed and tested a wetland management practice designed to increase the amount of shallow water habitat available to shorebirds in April by delaying the drawdown and reducing water levels more slowly (gradual drawdown) relative to the traditional management practice. On average, we found that wetlands managed with gradual drawdown provided over twice as much shorebird habitat, contributing up to 26% of the overall shorebird habitat objective for the Central Valley. Wetlands managed with gradual drawdown supported up to 21 times more migratory shorebirds during peak migration and a greater number of shorebird species than traditionally-managed wetlands. Our results demonstrate the potential of working with private landowners to implement small changes in wetland management that can have a large impact in meeting regional conservation objectives for migratory shorebirds.

Key words**:** Grasslands Ecological Area, managed wetlands, shorebirds, migration, drawdown, spring

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Introduction

Prior to the mid-1800s, the Central Valley of California contained more than 1.6 million ha of wetland habitat (Frayer et al. 1989). Despite the loss of over 90% of this natural wetland habitat, the Central Valley continues to support millions of migratory waterbirds in the region's managed wetlands and compatible agricultural lands. Each year, nearly five million waterfowl use this area in winter, September through March (Olson 2019) and over 500,000 shorebirds rely on the Central Valley during spring migration from April through May (Shuford et al. 1998).

Over 30 species comprise these half a million shorebirds, including plovers *Charadriidae*, dowitchers and sandpipers *Scolopacidae*, and stilts and avocets *Recurvirostridae* (Shuford et al. 1998). Water depth is an important driver of habitat use for shorebirds; bill and leg length determine the range of water depths used by each species (Elphick and Oring 1998; Isola et al. 2000). Sandpipers are known to select for wetlands with more shallow water and mudflat and less vegetation (Skagen and Knopf 1994; Gillespie and Fontaine 2017). These conditions allow access to invertebrates in the water column and in the soft, bottom substrates by species with the shortest bills and legs (Isola et al. 2000; Taft et al. 2002; Strum et al. 2013). In the Central Valley, resources are available within a landscape matrix dominated by private agricultural lands including corn and rice field that are flooded post-harvest (Stralberg et al. 2011; Dybala et al. 2017).

Migration is energetically taxing and requires access to consistent and reliable resources and habitats. Shorebird abundance and richness are positively associated with the density of nearby wetlands at stopover sites (Albanese and Davis 2015) and in the Central Valley, managed wetlands are one of the most reliable and important sources of flooded habitat (Reiter et al. 2018; Shuford et al. 2019). Because the primary objective of managed wetlands is provisioning waterfowl habitat, most seasonal managed wetlands are flooded beginning in October and drained in February and March (Dybala et al. 2017) before the peak of northbound shorebird migration in mid-April. The dewatering of seasonal wetlands prior to this time reduces the amount of available habitat and related food resources that are available to shorebirds creating habitat shortfall (Dybala et al. 2017; Schaffer-Smith et al. 2017). As a result, the Central Valley Joint Venture, a Congressionally designated consortium of state and federal agencies and conservation non-profits responsible for setting habitat objectives for migratory shorebirds and other waterbirds in the Central Valley, created a habitat objective of an additional 4,692 ha of shorebird habitat on the landscape in spring (mid-March–late April; Dybala et al. 2017).

The Grasslands Ecological Area (GEA; Figure 1) contains 38% of the Central Valley's privately-owned managed wetlands (CVJV 2006). These wetlands provide an opportunity to work with private landowners, in one of the most important wetland habitats in California, toward a common goal of conserving and creating shorebird habitat during a period when it is scarce on the landscape. Together, we developed and implemented a practice to create and extend the availability of shallow water habitat by delaying and slowing the drawdown of water on seasonal wetlands over four to six weeks (gradual drawdown). Our goal was to determine if seasonal wetlands managed with a gradual drawdown would provide more habitat for migratory shorebirds than is usually available and thus contribute to the overall habitat objective for non-breeding shorebirds in the Central Valley. To evaluate our success, we monitored shorebird use of both traditionally-managed wetlands and wetlands implementing gradual drawdown during northbound migration in the springs of 2015–2017. If successful, we hypothesized that wetlands with gradual drawdown would support migratory shorebirds more often (a higher proportion of sites with detections) and in greater abundance than traditionally-managed wetlands during spring migration. We also hypothesized that gradual drawdown wetlands would support a greater diversity of migratory shorebird species during spring migration.

Study Site

The GEA is located in the San Joaquin River basin of California (37°03′30″N 120°51′00″W; Figure 1). This area is characterized by a Mediterranean climate with hot, dry summers and mild, wet winters. Precipitation varies from year to year with average annual rainfall of 23 cm, two-thirds of which falls between October and April (WRCC 2018), influencing the amount and quality of habitat on the landscape. The GEA encompasses nearly 73,000 ha of managed wetlands, vernal pools, riparian habitat, rangeland, grassland and farmland (Rahilly et al. 2010) including over 21,000 ha of private wetlands and 6,300 ha of public wetlands (CVJV 2006). The GEA is a Wetland of International Importance (Ramsar 2019) and a site of International Importance to shorebirds, supporting at least 100,000 shorebirds annually (WHSRN 1992).

Managed wetlands in the GEA are flooded using annual water supplies allocated to the region as part of the Central Valley Project Improvement Act and delivered via a network of canals. Wetlands consist of leveed units in which water levels are managed by means of water control structures at inlets and outlets. Most of the private managed wetlands in the GEA are managed to provide habitat to waterfowl, produce forage for waterfowl and contribute to recreational hunting opportunities in winter and are hereafter referred to as 'duck clubs'. Water allocations for flooding and irrigating wetlands for these purposes can be restricted in drought years.

Methods

Wetland management practices

We sought to determine if seasonal wetlands managed with a delayed and gradual drawdown (GD) would provide more habitat for migratory shorebirds in the GEA than traditionally-managed (TM) wetlands. To implement the GD practice, wetland owners participated in a reverse auction similar to Reynolds et al. (2017) where landowners submitted their expected cost to implement this practice as a bid. Bids were selected to maximize the amount of habitat provided at the lowest cost. Each GD wetland unit began fully-flooded on April 1, either through maintenance of winter flooding (most common) or re-flooding after an earlier drawdown event. We then reduced water levels gradually over a four or six week period such that flooded habitat was still available until at least April 29 or May 13, respectively. Landowners monitored water levels on a weekly basis to ensure compliance.

To understand how shorebird response to GD wetlands compared to what is typically available on the landscape and help us understand the contribution of an incentivized practice, we also studied TM wetlands adjacent or close to the GD wetlands on the same or adjacent duck club (Table 1). The speed of the drawdown on TM wetlands was more rapid, usually occurring over 1-3 weeks. Habitat conditions of the TM wetlands varied, largely due to the variation in the start of each unit's drawdown which could have happened anytime from February to April. This variation in timing of drawdown, and thus, available flooded habitat during our study, reflects the broad range of habitat conditions typically provided by seasonal wetlands in the GEA. While variation in physical attributes (e.g. vegetation type and density, topography, etc.) among wetlands in this study existed, there were no other physical differences between the GD and TM wetlands prescribed as part of this study.

Study design

We selected 7 duck clubs in 2015, 10 in 2016 and 9 in 2017 to participate in this study based on their willingness to submit a bid and the cost-effectiveness of that bid. Wetland units implementing gradual drawdown were chosen by the landowners; 12 wetland units implemented gradual drawdown in 2015, 28 in 2016, and 21 in 2017 (Table 1). For each wetland unit (both GD and TM) on the selected duck clubs, we generated random survey points, at least 400 m apart, along the unimproved roads adjacent to the wetland units using ArcMap version 10.2.2 (ESRI 2014). From each random point, we defined an area from the edge of each wetland unit, bounded by a 200 m fixed-radius and/or the levees separating units (whichever was closer) as the survey area. Survey areas were limited to a maximum distance of 200 m from the observer to ensure a high probability of detecting birds (Shuford et al. 2019). Many survey areas had poor visibility due to tall emergent wetland vegetation, usually cattails *Typha* spp. and tules *Schoenoplectus acutus*. On our initial visit, we estimated the proportion of the survey area that was visible (area able to be seen and subsequently surveyed for birds). We then retained only those survey areas that had at least 20 percent visibility for inclusion in the remainder of the study. To estimate the area surveyed, we calculated the area (ha) of each survey unit using ArcMap, then multiplied that area by the proportion of the survey area that was visible as estimated during the initial visit (a factor that was unchanged over the course of the study). Some wetland units, in both GD and TM wetlands, had more than one survey area. Within the same wetland unit, and thus within the survey areas themselves, water depth and vegetation structure and abundance varied.

From April 1 through mid-May of each year, we conducted surveys of shorebirds in each survey area once per week during daylight hours. We counted all individual shorebirds and identified them to species with the exception of dowitchers *Limnodromus* spp. and in some cases, yellowlegs *Tringa* spp. and calidrine sandpipers *Calidris* spp. All survey areas were scanned for a minimum of two minutes and until all birds present were counted; there was no maximum length of time for completing a survey. Only birds that were using (foraging, roosting, etc.) or landed in the survey area were counted; we did not count birds that flew over the survey area. Counts were not conducted in inclement weather (winds > 40 km/h, fog, or heavy rain). We also estimated the percent of the survey area that was covered in water (flooded) as an indication of shorebird habitat.

Data analysis

This study occurred during and after an extreme drought in California (2012-2016), thus the amount of flooded habitat on the landscape varied from year to year. We characterized the amount of open water on the landscape by including the water year information in our comparisons. In California, the water year is defined as the 12-month period from October 1-September 30. We used California Department of Water Resources' Water Year Index as calculated from the unimpaired runoff (million acre-feet) for the San Joaquin River basin to categorize the water year type of the San Joaquin Valley for the three years of the study (DWR 2018). The amount of precipitation recorded in a given water year determines regional water management decisions in the following spring thus influencing the flooded habitat available on the landscape.

To understand the habitat made available through the GD practice, during birds surveys we also estimated the percent of each wetland unit that was flooded. The data on percent flooding were not normally distributed and we used bootstrapping and the percentile method to estimate the 95% confidence intervals for the weekly mean shorebird density estimates (Manly 2007). Specifically, we used the 2.5 and 97.5 percentiles of the weekly means calculated for each of 10,000 bootstrap iterations (random resample with replacement) to compare the weekly mean percent flooded between GD and TM wetlands in each year of the study. We also calculated the percent of the Central Valley Joint Venture's non-breeding shorebird habitat objective (Dybala et al. 2017) that was met by implementing gradual drawdown as part of this project by dividing the total acres enrolled in the gradual drawdown practice summed over all clubs by the overall habitat objective for spring. This estimate is an upper bound and does not account for variation in water depth or the presence of emergent vegetation, which would reduce the area available to shorebirds. We used R v.3.2.4 (R Core Team 2016) in RStudio (RStudio, Inc. 2009-2018) for all statistical analyses, and specifically the 'boot' package version 1.3-11 for bootstrapping analyses (Canty and Ripley 2017).

Our objective to understand how the GD practice can contribute to CVJV habitat objectives for non-breeding migratory shorebirds (Dybala et al. 2017) led us to combine all relevant species for our comparisons between GD and TM wetlands. We pooled the detections for all *Calidris* sandpipers, dowitchers, yellowlegs, *Numenius* spp., spotted sandpiper *Actitis macularius*, and plovers (with the exception of killdeer *Charadrius vociferus*), hereafter ‘migratory shorebirds’ (Table 2). Non-migratory shorebirds (primarily stilts, avocets, and killdeer) were present in comparatively low abundances and were excluded from these analyses.

To characterize differences in migratory shorebird use between GD and TM wetlands, we compared mean migratory shorebird density (birds/ha) for each week of the study to elucidate changes in abundance over time and separately for each of the three years. The number of survey areas in each wetland unit varied. To reduce autocorrelation from repeated visits to each wetland unit, we pooled all the survey areas for each wetland unit and we performed all analyses at the level of wetland unit. Due to the large number of surveys with zero shorebirds detected (70-76% of surveys each year) and non-normal distribution of bird counts and subsequent bird density estimates, we again used bootstrapping with 10,000 iterations to estimate the 95% confidence intervals for the weekly mean shorebird density estimates. We calculated density estimates independently for each week of each year to assess within- and among-year variation. We considered non-overlapping 95% confidence intervals to provide evidence of a difference in bird use. As another method of assessing the effectiveness of the GD practice that is less influenced by total abundance, we also calculated the percent of individual GD and TM wetland units where we detected at least one migratory shorebird each week of each year. Finally, we compared the mean (± SE) species richness of migratory shorebirds between GD and TM wetlands across all 3 years combined for each week of the study. Species richness data were normally distributed and followed the same pattern year to year, thus we combined years.

Results

Each of the water years (WY) in this study was categorized differently by the Department of Water Resources; 2015 was “Critically Dry”, 2016 was “Dry”, and 2017 was “Wet”. Over the three years of this study (2015-2017), we monitored a total of 107 survey areas with GD and 73 survey areas with TM and completed 1,245 surveys (Table 1, Table S1). The GD practice was implemented on a total of 617 ha in 2015, 1,211 ha in 2016 and 1,163 ha in 2017. These acres represent up to 13%, 26%, and 25% of the CVJV short-term habitat objective for nonbreeding shorebirds in the Central Valley in spring (Dybala et al. 2017), respectively.

When we looked at how available shorebird habitat compared between GD and TM wetlands, we found that for the first three weeks of April in all years, GD wetlands had a higher percent of the wetland unit flooded compared to TM wetlands (Figure 2, Table S2). Percent flooded between GD and TM wetlands in the last week of April was similar in 2015, higher in

GD wetlands but with overlapping confidence intervals in 2016, and higher in GD wetlands without overlapping confidence intervals in 2017. There was no evidence of a difference in percent flooding of GD and TM wetlands in May in 2015 and 2016, while percent flooding remained higher in GD wetlands during the first week of May in 2017 (Figure 2, Table S2). In 2015, four TM wetland units at two duck clubs received irrigations in late April, resulting in an increase in the percent of the wetland unit that was flooded during the last week of April while GD wetlands continued to drawdown over the same timeframe (Figure 2, Table S2). Minor irrigation events were also documented in both 2016 and 2017 on three and two survey areas, respectively; however these events did not increase the mean percent flooding compared to the previous week.

We observed a total of 17 shorebird species during this study and counted nearly 42,000 individuals. The most abundant species were dunlin *Caldidris alpina*, dowitchers *Limnodromus* spp. and western sandpiper *Calidris mauri*, and the most often encountered species were American avocet *Recurvirostra americana*, killdeer and dunlin (Table 2). Ninety-six percent of shorebirds observed during the study were using GD wetlands. We detected migratory shorebirds on a greater proportion of GD compared to TM wetland units in all weeks of the study in all three years except the last week of May (Figure 2, Table S2). Average species richness across all years was higher in the GD wetlands for the entire survey period except the last week of May (Figure 3, Table S3) and the number of migratory shorebird species detected during any one survey ranged from zero to five.

Overall, we found higher migratory shorebird densities on GD wetlands compared to TM wetlands (Figure 2, Table S2). In 2015 and 2017, migratory shorebird density was higher on GD than TM wetlands with no or marginal confidence interval overlap during all weeks of April and the first week of May—the period in which migration was concentrated. We also found the maximum mean shorebird densities were much higher on GD wetlands than TM wetlands in those years (21x higher in 2015; 6x higher in 2017). Results from 2016 were less distinct, when GD wetlands had higher densities only in the first and third week of April, with a maximum mean density of only 2 times that of TM densities (Figure 2, Table S2).

Migratory shorebird densities varied by week and the timing of peak shorebird migration varied among years. In all years of the study, the highest mean migratory shorebird densities occurred from the second through the fourth week of April. There was a single peak in shorebird density in 2015 (36.5 birds/ha). In 2016, shorebird densities remained at high levels (> 25 birds/ha) for the last two weeks of April. No clear peak was exhibited in 2017, though densities were slightly elevated for the last three weeks of April (Figure 2, Table S2). In all three years of the study, shorebird densities were lowest at the end of the study period—the second and third weeks of May.

Discussion

In this study, the gradual drawdown of private duck clubs in the GEA provided over twice the amount of shorebird habitat and supported shorebirds densities from 2 to 21 times more than TM wetlands during peak migration, a time of habitat shortfall as identified by the CVJV (Dybala et al. 2017). These benefits were realized by delaying and slowing the rate of drawdown of seasonal wetlands, thus extending the timeframe during which a range of shallow water habitat was available to migrant shorebirds. Our results demonstrate that collaborations with private landowners to implement small changes in spring water management can have potentially large impacts on conservation outcomes.

The GD practice contributed up to one quarter of the habitat objectives for nonbreeding shorebirds for the entire Central Valley during spring migration (Dybala et al. 2017). In this highly managed landscape, there are opportunities to scale-up this or similar practices to provide additional habitat where and when it is needed most. This practice can be applied to other flooded land cover types and be managed to provide habitat and resources to shorebirds and other waterbirds, including private and public wetlands, flooded cropland (e.g. Strum et al. 2013; Sesser et al. 2016), floodwater holding basins, or groundwater recharge basins. In addition, this practice or one that creates similar habitat could be implemented during other times of limited habitat such as southbound migration (Golet et al. 2018). Our study only assesses the response of shorebirds to additional shallow-water habitat, however the quality of this habitat is also an important factor. Further research on the available food resources and subsequent benefits to body condition and survival for migratory shorebirds would be greatly informative.

We detected just over half (17 species, 56%) of the 30 shorebird species known to migrate regularly through the Central Valley. This is lower than Shuford et al. (1998) who conducted extensive surveys of the entire Central Valley but comparable to studies with a more localized geographic focus such as the recent work in the rice fields of the Sacramento Valley (Strum et al. 2013; Sesser et al. 2016; Golet et al. 2018) and other studies conducted in the GEA

(Rahilly et al. 2010; Taft et al. 2002). Of those 17 species, most were detected on both GD and TM wetlands but mean species richness was higher on GD wetlands for all but the last week of the study. During peak migration, the four weeks in April, mean species richness on GD wetlands was 2.1 to 3.6 times greater than TM wetlands.

Patterns in migratory shorebird density were largely driven by sandpipers and dowitchers. which comprised 78% of all migratory shorebirds counted in this study. *Calidris* spp. sandpipers are small and numerous and comprised the largest proportion of northbound migrants in other studies conducted in the Central Valley (Shuford et al. 1998; Sesser et al. 2016; Golet et al. 2018). Despite their apparent abundance in this study, western sandpipers, dunlin, and long-billed dowitchers are species of moderate conservation concern due to climate change (USSCP 2016). An additional five of the 13 migratory species in this study are of highest conservation concern (USSCP 2016), reinforcing the importance of providing habitat for shorebirds during migration.

Shorebirds are highly mobile species and tend to aggregate in flocks. Thus, means used to compare practices were affected by high variation in flock size. This, coupled with our modest sample sizes, led us to employ bootstrapping methods to estimate variance as used in other studies with similar data structure (Strum et al. 2013; Sesser et al. 2018). The differences in the mean and variance detected between GD and TM wetlands in multiple years ranging from critically dry to wet provides evidence that gradual drawdown is an effective approach to provide shorebird habitat for northbound migrants. The higher density of shorebirds using GD wetlands as seen in this study also reflects a pattern seen in other studies conducted in the GEA (Taft et al. 2002; Rahilly et al. 2010). Even when shorebird densities overlapped, such as in the second week of April in 2016 when one flock of over 1,000 shorebirds was detected in a TM wetland, shorebirds were detected on GD wetlands more often than TM wetlands.

Peak shorebird density varied within and among years similar to Taft et al. (2002) likely owing to the highly transient nature of migratory shorebirds. Peak mean density of shorebirds in 2017, a wet year, was 67% lower than the previous two years, which were dry and critically dry water years. We suspect that the greater amount of precipitation created additional flooded habitat on the landscape and migratory shorebirds were more dispersed as they exploited the additional available resources. We recommend that future studies examining wetland management also take into account the extent of open water on the surrounding landscape to provide greater context (Reiter et al. 2018; Golet et al. 2018). Despite the potential for rainfall to create additional habitat in TM wetlands in 2017, GD wetlands still supported 11 times more shorebirds during peak migration that year compared to TM wetlands.

Despite significant benefits for shorebirds, there are potential tradeoffs that should be considered when implementing this practice. Rahilly et al. (2010) highlighted the reduced production of swamp timothy *Crypsis schoenoides*, an important waterfowl food, in wetland units with a similar practice implemented. We did not quantify seed production, however, wetland managers and owners in this study did not observe reduced waterfowl use of wetland units following implementation of GD and were willing to continue implementation of the practice. To ensure the health of wetland units and continued forage production, we recommend rotating GD units every two to three years to ensure salt accumulation remains low and implementing GD on units where other waterfowl food crops are being grown that are more compatible with a later drawdown (e.g. watergrass *Echinochloa crusgalli*). Depending on the time of year and the distance to population center when implementing this or similar practice, it may be necessary to coordinate with local mosquito and vector control districts to ensure no risk to human health and safety from the creation of this habitat. Further, the creation of this habitat coincides with the onset of nesting for local migrants and resident species like American avocet and black-necked stilt that prefer to nest near shallowly flooded areas. As water levels draw down, nests can become more susceptible to depredation by terrestrial predators and continued surveillance and study of the impacts to breeding shorebirds is recommended.

Private and working lands are an important part of bird and wildlife habitat in the Central Valley of California. While permanently protected wetland refuges provide important habitat, migrants are also reliant on the availability of flooded habitat on agricultural land and privately managed wetlands (Reynolds et al. 2017) such as those in this study. Incentive programs supporting landowners to flood agricultural land provide a significant proportion, sometimes up to 100%, of the available flooded habitat in the Central Valley (Reiter et al. 2018). This, along with the success of our work on private wetlands highlights the importance of working with private landowners to enhance their habitat for birds and other wildlife. Our results demonstrate how this type of collaboration can benefit migratory shorebirds navigating a landscape impacted by drought and water uncertainty.

Supplemental Material

Table S1. Data collected during shorebird surveys of duck clubs in the Grasslands Ecological Area, California from April to May 2015–2017.

Table S2: Mean weekly migratory shorebird density and bootstrapped 95% confidence intervals in gradual drawdown and traditionally-managed seasonal wetlands from surveys conducted in the Grasslands Ecological Area, California from April to May, 2015–2017.

Table S3: Mean weekly migratory shorebird species richness across all years in gradual drawdown and traditionally-managed seasonal wetlands from surveys conducted in the Grasslands Ecological Area, California from April to May, 2015–2017.

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Table 1. Total number of wetland units, total number (and area [ha]) of survey areas monitored, and dates for weekly surveys conducted on duck clubs in the Grasslands Ecological Area, California during northbound shorebird migration 2015–2017.

Year	2015	2016	2017
Wetland units	28	43	45
Gradual Drawdown	12	24	21
Traditionally-managed	16	19	24
Survey Areas	51 (327)	62 (282)	67 (516)
Gradual Drawdown	31 (197)	37 (182)	39 (295)
Traditionally-managed	20 (130)	25 (100)	28 (221)
Dates	4/6–5/20	4/4–5/17	4/3–5/16

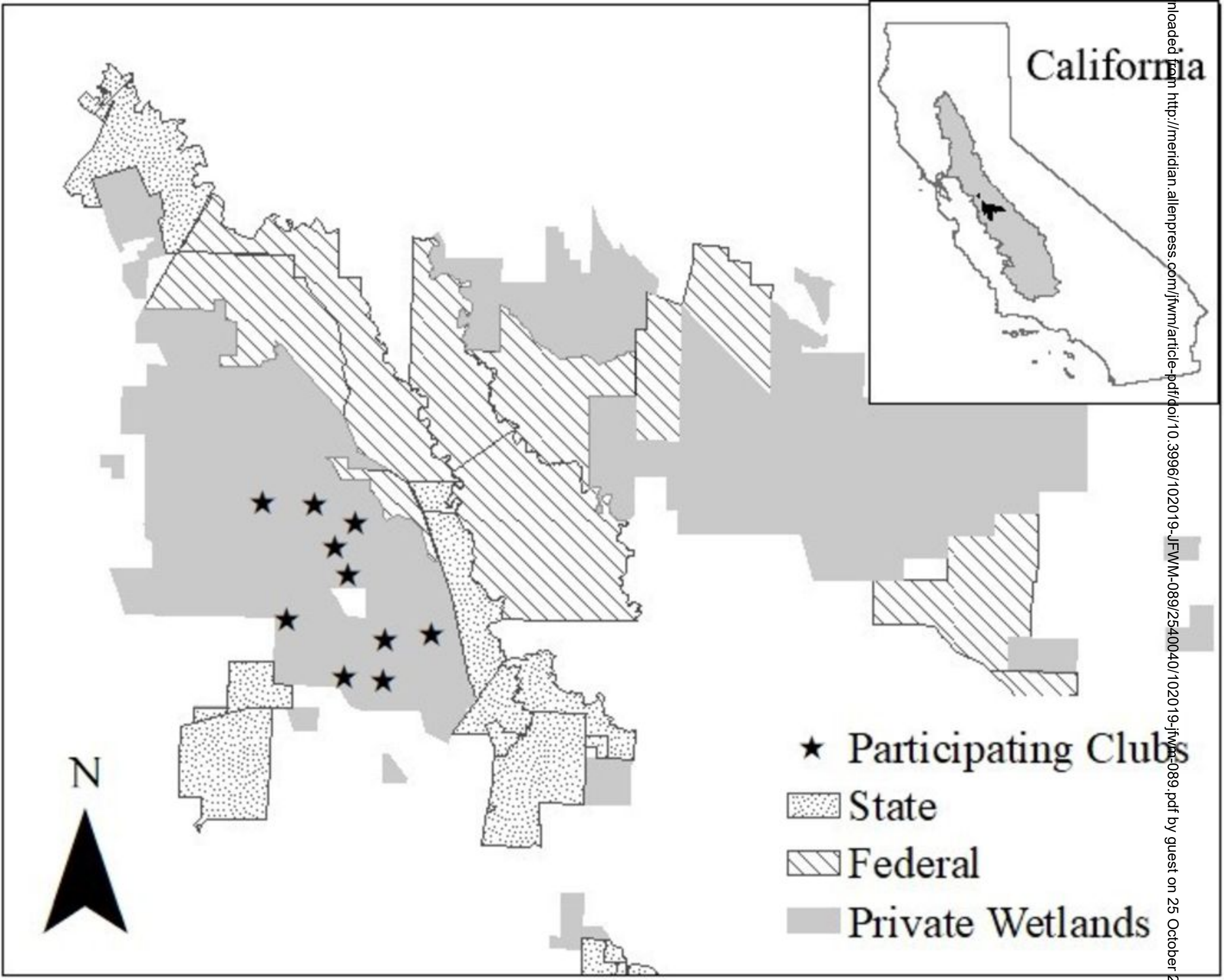
Table 2. Frequency of occurrence (percent of surveys species was detected), total abundance, and percent of total abundance for 17 species of shorebirds recorded in gradual drawdown and traditionally-managed wetlands as detected on surveys conducted in the Grasslands Ecological Area, California during northbound shorebird migration 2015–2017. * indicates the species was considered a migratory shorebird for the purposes of statistical analysis.

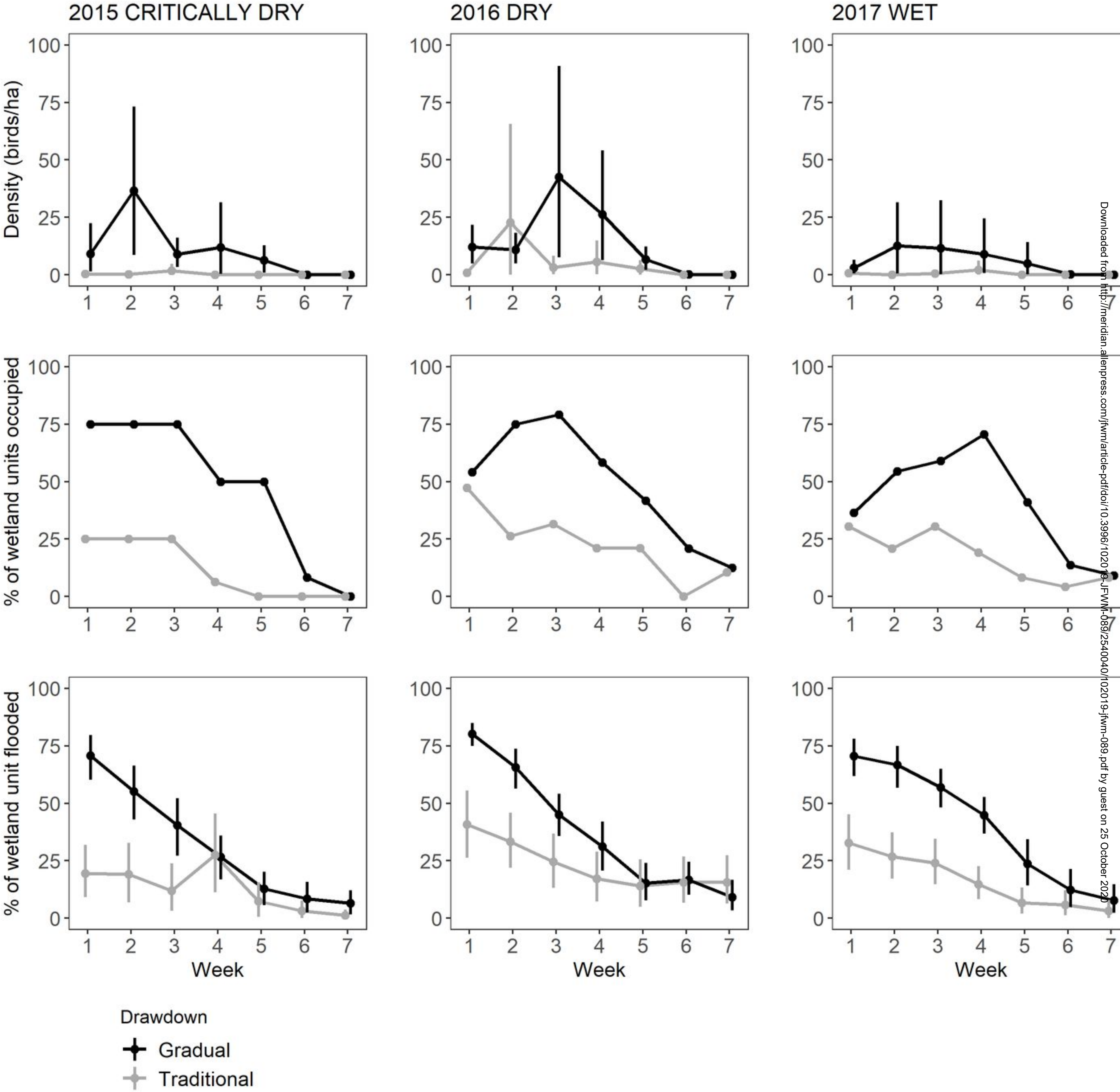
		Gradual Drawdown			*Traditional Drawdown*		
Species	Scientific Name	Freq. of Occ.	Total Abun	% Total	Freq. of Occ.	Total Abun	% Total
Charadriidae							
Black-bellied plover *	*Pluvialis squatarola*	0.9	149	0.3	0.0	0	0.0
Killdeer	*Charadrius vociferus*	15.2	212	0.5	13.2	94	0.2
Semipalmated plover *	*Charadrius semipalmatus*	4.5	173	0.4	0.9	44	0.1
Snowy plover *	*Charadrius nivosus*	0.4	5	<0.1	0.0	0	0.0
Recurvirostridae							
Black-necked stilt	*Himantopus mexicanus*	11.7	868	2.0	2.2	39	0.1
American avocet	*Recurvirostra americana*	24.7	919	2.1	8.6	76	0.2
Scolopacidae							
Whimbrel *	*Numenius phaeopus*	1.2	46	0.1	0.9	14	<0.1
Long-billed curlew *	*Numenius americanus*	2.3	252	0.6	0.6	18	<0.1
Dunlin *	*Calidris alpina*	12.0	14,069	32.2	1.9	903	1.2
Least sandpiper *	*Calidris minutilla*	10.5	2,137	4.9	2.2	182	0.4
Pectoral sandpiper *	*Calidris melanotos*	0.1	1	<0.1	0.0	0	0.0
Western sandpiper *	*Calidris mauri*	5.0	2,335	5.4	0.9	129	0.1
Western/Least/Dunlin *	*Calidris spp.*	8.5	14,007	32.1	3.0	1,230	1.5
Short-billed/Long-billed dowitcher *	*Limnodromus griseus/ scolopaceus*	9.0	6,528	15.0	0.2	243	0.1
Wilson's snipe	*Gallinago delicata*	0.9	20	<0.1	0.9	7	<0.1
Spotted sandpiper *	*Actitis macularius*	0.0	0	0.0	0.2	1	<0.1
Lesser yellowlegs *	*Tringa flavipes*	0.7	7	<0.1	0.2	1	<0.1
Greater yellowlegs *	*Tringa melanoleuca*	9.9	125	0.3	8.4	48	0.1

Figure 1. The northern portion of the Grasslands Ecological Area, California showing the general locations of shorebird surveys conducted on private duck clubs during northbound shorebird migration 2015–2017.

Figure 2. Mean and 95% confidence intervals (whiskers) for migratory shorebird density (top), percent of wetland units with 1 or more shorebird(s) detected (middle), and mean and 95% confidence intervals for percent of surveyed wetland unit flooded (bottom) in gradual drawdown (black line) and traditionally-managed (grey line) wetlands from surveys conducted on duck clubs in the Grasslands Ecological Area, California during northbound shorebird migration 2015–2017, including water year designation. Weeks 1 through 4 correspond to the four weeks of April and weeks 5 through 7 correspond to the first three weeks of May.

Figure 3: Mean species richness (+/- SE) of migratory shorebirds in gradual drawdown (black) and traditionally-managed (grey) seasonal wetlands from surveys conducted on duck clubs in the Grasslands Ecological Area, California during northbound shorebird migration 2015–2017. Weeks 1 through 4 correspond to the four weeks of April and weeks 5 through 7 correspond to the first three weeks of May.


California
Participating Clubs
State
Federal
Private Wetlands
N


2015 CRITICALLY DRY
2016 DRY
2017 WET
Density (birds/ha)
% of wetland units occupied
% of wetland unit flooded
Week
Drawdown
Gradual
Traditional

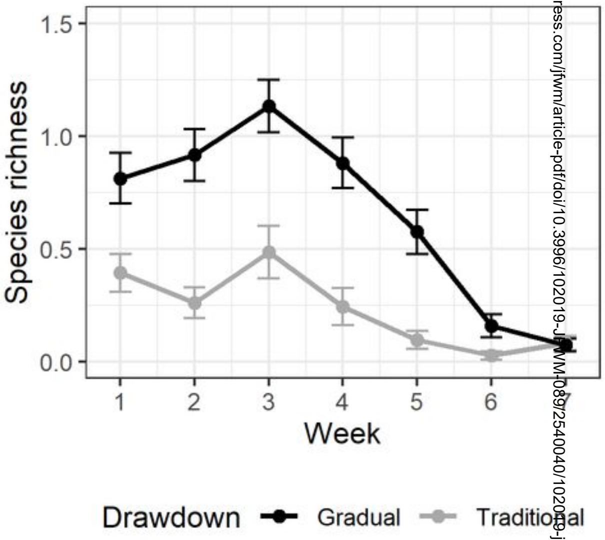

Species richness
1.5
1.0
0.5
0.0
1
2
3
4
5
6
7
Week
Drawdown
Gradual
Traditional

Table 1. Number of wetland units surveyed (no.), total number and area (ha) of survey areas monitored, and dates when weekly surveys were conducted for each year of the study in the Grasslands Ecological Area, California 2015–2017.

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