LMVJV Shorebird Plan

Mississippi Alluvial Valley and West Gulf Coastal Plain/Ouachitas

The Mississippi Alluvial Valley and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions serve as a migratory corridor for 28 species of shorebirds and a breeding/wintering location for three additional species. Migrant shorebird populations typically stopover from July through October, with a peak in late August/early September for fall migration, and from April to mid-May with a peak in mid-April for spring migration. During migration, shorebirds occur primarily in shallowly flooded freshwater wetlands. Shorebirds prefer water depths of <10cm or mud flats, and areas with less than 25% vegetation cover. Fall habitat (July to October) is the most limiting to shorebirds in this region. We used a bioenergetic model to estimate habitat requirements to support a fall migrating shorebird population. Results of the modeling predicted an average of 3,190ha ± 84ha (7,883ac ± 208ac) of shorebird habitat is needed in the fall to support shorebird populations that migrate through the region. Approximately 98-100% of the LMVJV habitat objective could be met on public managed lands based on survey responses. However, providing the necessary mix of water depth and vegetative structure at the appropriate times is the single most important management issue in the region. The LMVJV partnership must continue to promote management for high quality shorebird habitat in the region and evaluate effectiveness of those management actions.

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Acknowledgements
The Lower Mississippi Valley Joint Venture (LMVJV) Shorebird Working Group members and other LMVJV partners have contributed significantly to the formulation of this plan, provision of data, and promoting the delivery of shorebird habitat within the Lower Mississippi Valley Joint Venture geography. Dr. Anne Mini, LMVJV Science Coordinator, coordinated and compiled input from partners in the development of this document. Reviewers and their organizations include: Becky Rosamond, US Fish and Wildlife Service; Bill Vermillion, Gulf Coast Joint Venture; Brad Andres, U.S. Shorebird Conservation Plan Partnership; Cliff Shackelford, Texas Parks & Wildlife Department; Chuck Hunter, US Fish and Wildlife Service ; Darrin Unruh, US Fish and Wildlife Service ; David Breithaupt, Louisiana Department of Wildlife and Fisheries; David Hanni, Tennessee Wildlife Resources Agency; Dave Holdermann, Texas Parks & Wildlife Department; Doreen Mengel, Missouri Department of Conservation; Erik Johnson, Audubon Louisiana; Gypsy Hanks, US Fish and Wildlife Service ; Heath Hagy, US Fish and Wildlife Service; Houston Havens, Mississippi Department of Wildlife, Fisheries and Parks; Jamie Fedderson, Tennessee Wildlife Resources Agency; Jason Hoeksema, Delta Wind Birds; Jason Olszak, Louisiana Department of Wildlife and Fisheries; Jay Hitchcock, US Fish and Wildlife Service ; Jeffrey Gleason, US Fish and Wildlife Service; Jesse Burton, US Fish and Wildlife Service; Jimmy Laurent, US Fish and Wildlife Service; John Dickson, US Fish and Wildlife Service; Josh Richardson, Oklahoma Department of Wildlife Conservation; Karen Rowe, Arkansas Game and Fish Commission; Keith McKnight, LMVJV; Lamar Dorris, US Fish and Wildlife Service; Monica Iglecia, Manomet; Paige Schmidt, US Fish and Wildlife Service; Richard Crossett, US Fish and Wildlife Service; Tom Edwards, US Fish and Wildlife Service.

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Lower Mississippi Valley
JOINT VENTURE
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Description of the Region

The Mississippi Alluvial Valley and West Gulf Coastal Plain/Ouachitas planning regions (Figure 1), which comprise the Lower Mississippi Valley Joint Venture (LMVJV), include portions of Arkansas, Kentucky, Louisiana, Mississippi, Missouri, Oklahoma, Tennessee, and Texas, and consists of two Bird Conservation Regions (BCR): The West Gulf Coastal Plain/Ouachitas (WGCPO; BCR 25) and the Mississippi Alluvial Valley (MAV; BCR 26). The dominant vegetative component of the WGCPO is forest, principally loblolly and shortleaf pine in the north, longleaf pine in the south, and hardwood dominated systems in the river bottoms and floodplains. This is a relatively heavily populated region, with present rural land use dominated by pine silviculture and hayed/grazed pasture. The MAV is an alluvial floodplain, which was mostly hardwood forest prior to European settlement. Today, roughly 75% of the forest has been cleared and replaced by other land uses, predominantly row crop agriculture. Dominant crops include soybeans, corn, cotton, grain sorghum, and rice.

Historically, there likely was substantial shorebird habitat within the extensive mudbars, sandbars, and drying oxbows and sloughs of the major rivers (e.g., Arkansas River, Red River, Sabine River, Mississippi River). However, construction of levees, wingdams, reservoirs, and other changes to the hydrology of these systems has seriously altered their natural functions. Whereas the forest-dominated systems of this region probably offered limited habitat value for most shorebirds (Twedt et al. 1998), clearing of much of the Mississippi Alluvial Valley, with resulting open agricultural fields, has increased this region's potential for providing shorebird habitat. Water management capability on agricultural fields (particularly rice fields) and aquaculture facilities, along with frequent inundation of fields by spring floodwater further enhance this region's value to shorebirds. ***Providing the necessary mix of water depth and vegetative structure at the appropriate times is, perhaps, the single most important management issue in this region.***

Figure 1. Geographic scope of the Lower Mississippi Valley Joint Venture includes the Mississippi Alluvial Valley and West Gulf Coastal Plain/Ouachitas Bird Conservation regions

Shorebirds in the Mississippi Alluvial Valley and West Gulf Coastal Plain/Ouachitas

The Mississippi Alluvial Valley and West Gulf Coastal Plain/Ouachitas serve as a migratory corridor for 28 species of shorebirds and a breeding/wintering location for three additional species.

According to the U.S. Shorebird Conservation Plan (2016), Piping Plover, Eskimo Curlew, and Red Knot (*rufa* subspecies) are the only species in the region that are listed under the U.S. Endangered Species Act. Because the Piping Plover is listed as Threatened by the U.S. Fish and Wildlife Service (USFWS 2016), this plan will not address their conservation needs in detail. Eskimo Curlews are Federally Endangered and thought to be extinct (BirdLife International 2016). Red Knot was listed as threatened in 2015 (USFWS 2014); the MAV and WGCPO geography is not a major migration route for this species. Similar to Piping Plover, this plan will not address their conservation needs in detail.

Shorebirds in the Greatest and High Conservation Concern categories include: Snowy Plover, American Golden-Plover, Ruddy Turnstone, Whimbrel, Long-billed Curlew, American Woodcock, Buff-breasted Sandpiper, Short-billed Dowitcher, Pectoral Sandpiper, Dunlin, Semipalmated Sandpiper, Marbled Godwit, Hudsonian Godwit, Willet and Lesser Yellowlegs (USSCP 2016). Of those, the MAV/WGCPO is an important migration pathway for **American Golden-Plover**, **Pectoral Sandpiper**, **Dunlin**, **Semipalmated Sandpiper** and **Lesser Yellowlegs**. Other species listed in this category also migrate through the MAV/WGCPO, but only in small proportions of their populations. These BCRs are the most important wintering sites for **American Woodcock**, which is a hunted species across its migration and wintering range (McAuley et al. 2013), and one of only two shorebirds, along with Wilson's Snipe (Mueller 1999) in North America that are harvested.

Species of Moderate Conservation Concern include Black-bellied Plover, Killdeer, Sanderling, Western Sandpiper, Long-billed Dowitcher, and American Avocet. The MAV and WGCPO serve as an important migratory corridor for **Long-billed Dowitcher** and is important to **Killdeer** year-round.

Species of Least Concern include Semi-palmated Plover, Spotted Sandpiper, Upland Sandpiper, Baird's Sandpiper, White-rumped Sandpiper, Wilson's Snipe, Least Sandpiper, Stilt Sandpiper, Wilson's Phalarope, Greater Yellowlegs, Solitary Sandpiper, and Black-necked Stilt. The MAV and WGCPO are important for migration of **Least Sandpiper**, **Wilson's Phalarope**, and **Greater Yellowlegs**, and wintering for **Wilson's Snipe**.

Migrant shorebird populations typically move through the LMVJV from July through October, with a peak in late August/early September, and from April to mid-May with a peak in mid-April (Figure 2).

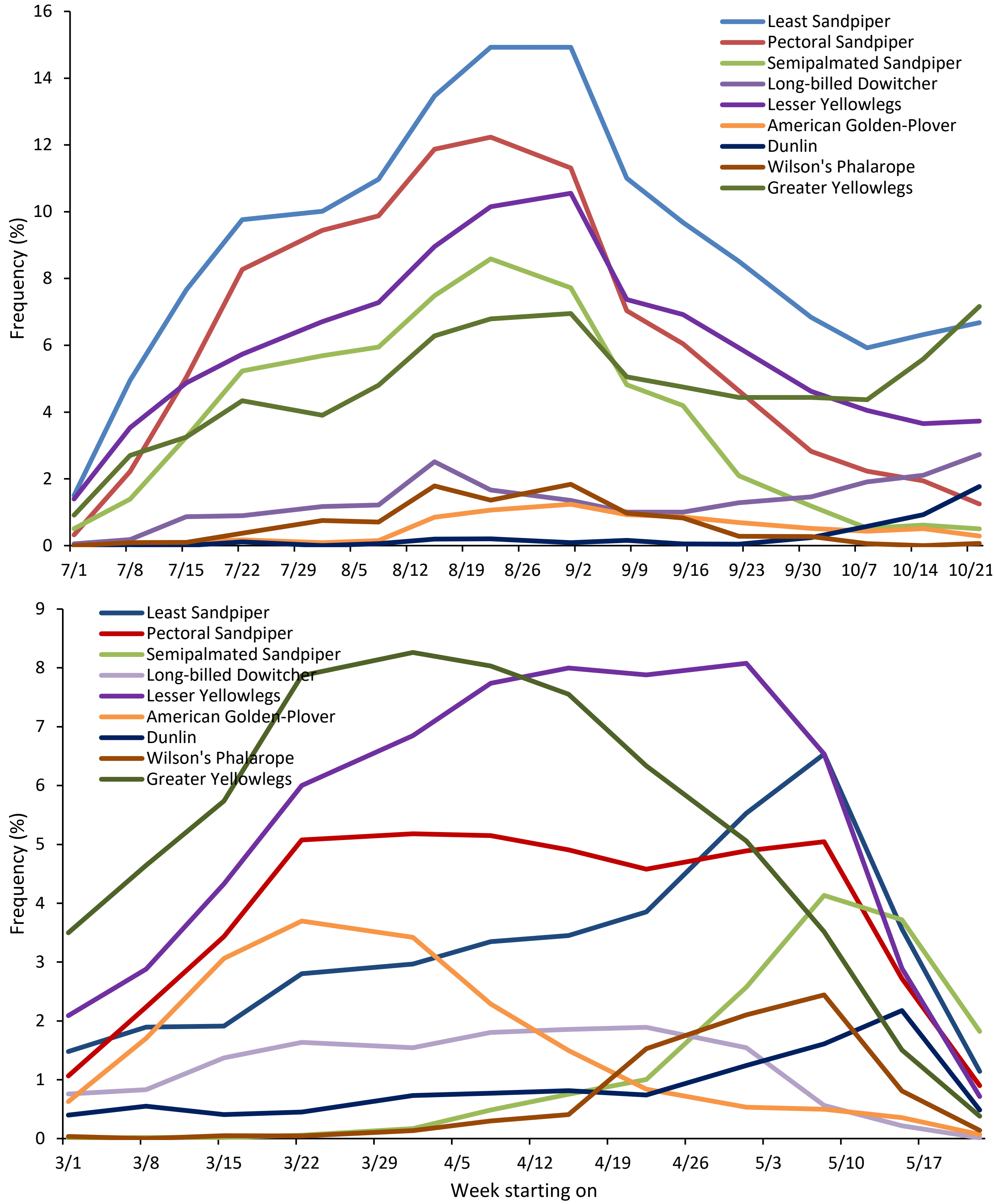

Figure 2. Example fall and spring migration periods for nine important shorebird species in the Lower Mississippi Valley Joint Venture based on eBird checklist frequencies.

Shorebird Habitats in the LMVJV

Types and Quality of Shorebird Habitat

During migration, shorebirds occur primarily in shallowly flooded freshwater wetlands. Most shorebirds either prefer water depths of <10cm (range = 0-18cm) or mud flats, and areas with less than 25% vegetation cover (range = 0-75%). Habitat types include inland riverine sandbars, freshwater wetlands, shallowly flooded agricultural fields or impoundments, and dry grasslands. Roosting habitats include sandbars, spits; and shallowly flooded areas, furrowed agricultural fields with crop stubble and large soil clods, or islands free of vegetation at noncoastal sites.

Habitat quality is determined by water depth (Figure 3), vegetation structure (in and adjacent to the wetland; Table 2), and food composition & availability, and the ideal conditions of these are not the same for all shorebird species.

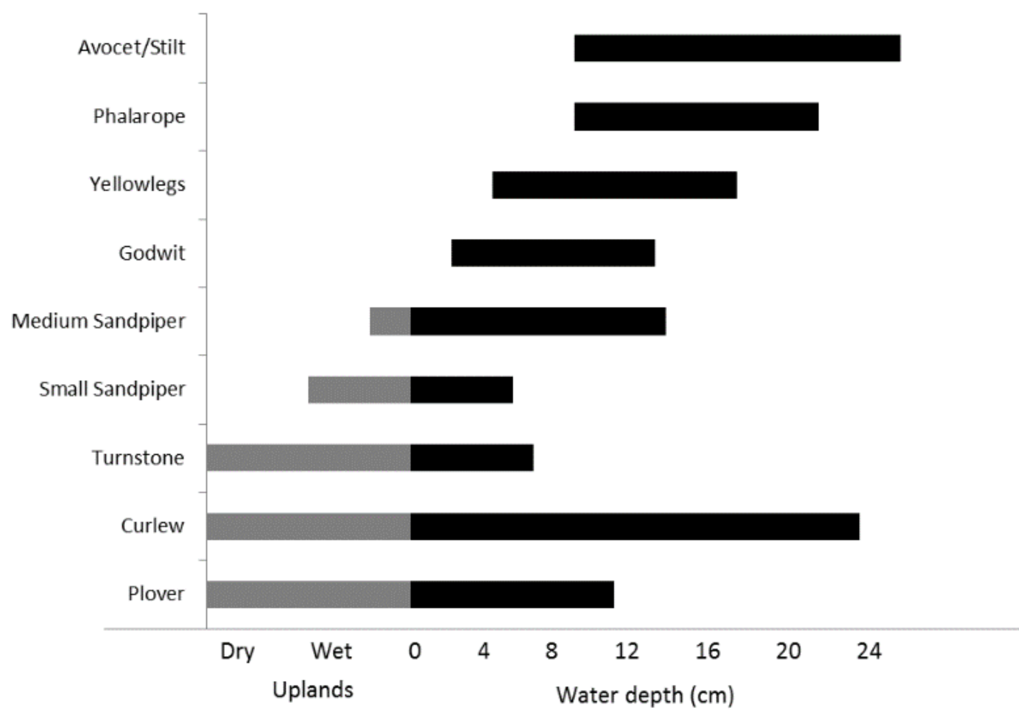

Figure 3. Approximate water depth (cm) and substrate preferences of shorebird guilds. Adapted from Helmers (1992; Figure 2.4).

Habitat is classified into two major categories: **Wetlands** and **Uplands**.

Wetlands are defined as lands transitional between terrestrial and deep water aquatic systems where the water table is at or near the soil surface or where the land is covered by shallow water. Helmers (1992) distinguishes between natural and altered wetlands, and the distinction is important from a management perspective, although shorebirds may not necessarily distinguish among these habitat types, all else equal. Natural wetlands have long-term, annual, and/or daily hydrologic cycles of water levels, driven by precipitation and/or tides. These cycles control vegetation and invertebrate animal populations. In altered or managed wetlands, managers must create these cycles to manage vegetation and invertebrates.

Uplands can be managed for short, sparse vegetation, preferred for nesting and foraging of some shorebirds. Uplands are typically mesic to xeric habitats and may be associated with adjacent wetlands.

Table 1. Shorebird foraging guilds and habitat types. Adapted from Helmers (1992; Table 1.2).

Shorebird group	Foraging Guild	Habitat Type		
			Vegetation Structure	
		Substrate	Height	Density
Plover	Terrestrial/Aquatic Gleaners	Dry-Saturated	None - short	Sparse
Curlew	Terrestrial/Aquatic Gleaners , Probers	Dry-Saturated	Short-medium	Moderate-dense
Sandpiper	Terrestrial/Aquatic Gleaners, Probers	Flooded-Saturated	None - short	Sparse
Godwit	Aquatic Probers	Flooded	Short-medium	Sparse-moderate
Yellowlegs	Aquatic Gleaners	Flooded	Short-medium	Sparse-moderate
Turnstone	Terrestrial/Aquatic Gleaner, Probers	Rock intertidal	None - short	Sparse
Avocet/Stilt	Aquatic Gleaner, Sweepers	Flooded	None - short	Sparse
Phalarope	Aquatic/Pelagic Gleaners	Flooded	None - short	Sparse-moderate

Lower Mississippi Valley Joint Venture Planning Habitats

The specific habitat types included in our planning are:

Wetlands

1) **Emergent palustrine marsh** – Generally 6" to 3' deep and containing vegetation rooted in soil that emerges above the water surface. Emergent plants include cattail, bulrush, spikerush and sedges (Nelms et al. 2007). These freshwater wetlands are considered perennial in nature and are typically unaltered which means they can be shorebird habitat available during periods of drought or prolonged low river levels.

2) **Moist-soil wetland** – Man-made impoundments are often managed as moist-soil wetlands. Moist-soil areas are characterized by seed producing annuals such as smartweeds, wild millets, panicums and sprangletop (Nelms et al. 2007). These wetlands are annual in nature and require periodic vegetation or soil manipulation.


Photo: JR Rigby

3) **Aquaculture** (active & fallow) - Commercial aquaculture ponds are distributed throughout the region, particularly in the Mississippi Alluvial Valley; crawfish farms are prevalent in Louisiana, catfish farms in Mississippi, and baitfish ponds in Arkansas.

4) **Rice field** – Flooded rice agriculture

5) **Other agricultural field** – Shallowly flooded agricultural crops other than rice, including soybean, corn, and sorghum

6) **Lake shoreline** – Margins of lacustrine wetlands

7) **River bars** – Elevated region of sediment in a river

8) **Open aquatic** – Deep, open water habitats that do not contain significant emergent vegetation

9) **Wooded swamp** – Forested wetlands

Uplands

1) **Pasture** – Hayed, mowed, or other grazed areas including turf/sod farms or airport fields

Shorebird Bioenergetic Model

Underlying Assumptions

1) Fall habitat (July to October) is the most limiting to shorebirds in this region (Loesch et al. 2000; Elliott and McKnight 2000)
2) Approximately 450,000-500,000 individual shorebirds migrate through the LMVJV geography each year during southward migration (Andres et al., unpublished data)
3) The average range of stopover duration is 16-20 days, with 8-10 days in the northern portion of the geography and 8-10 days in the south (Lehnen and Krementz 2007).
4) The weighted average of shorebird mass for fall migration is 54g (see Table 4)
5) The daily food requirement (for maintenance plus needed fat gain) is 8.75g (Loesch et al. 2000)
6) Macroinvertebrates are the primary food source for these birds, and 2-4g is available in each square meter of habitat (Augustin et al. 1999; Loesch et al. 2000; Foth 2016)

Conceptual Model

Our base biological model follows a simple Daily Ration Model with energy supply and energy demand sides of the equation (Figure 4). If all habitat objectives are being met, energy supply and energy demand should be balanced. Energy demand involves factors that pertain to shorebirds such as number of shorebirds and energy requirements. Turnover rate and species composition affect abundance. Species composition and what stage of the annual cycle (migration, breeding, or wintering) that a species is in affect daily energy requirements. Energy supply is influenced by habitat factors such as acres of flooded habitat and forage density. Forage density is related to explicitly to macroinvertebrate abundance.

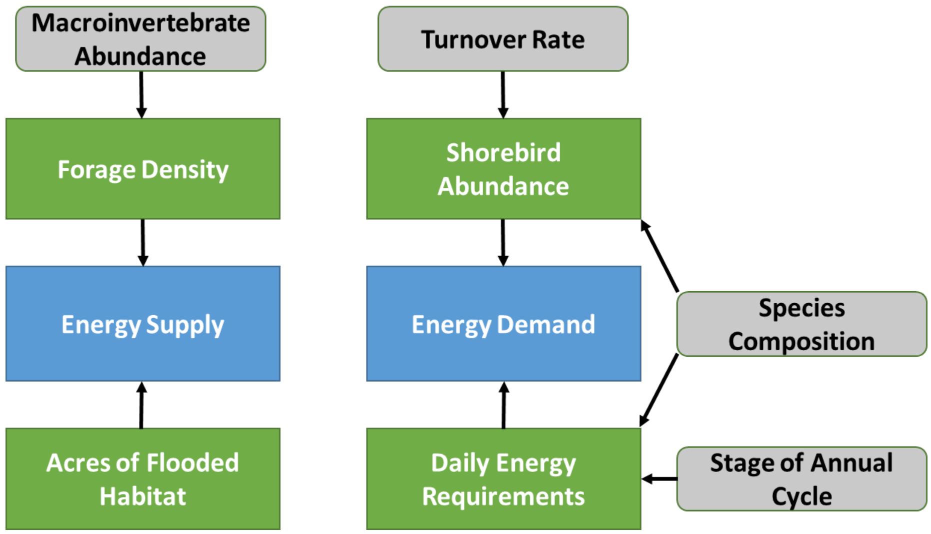

Figure 4. Conceptual model of factors affecting the amount of needed foraging habitat in the Mississippi Alluvial Valley and West Gulf Coastal Plain/Ouachitas. Blue boxes are the primary model results; green boxes are the primary model components; grey boxes are various factors driving the model components.

Population Sizes

LMVJV Regional Population Size

Central American Flyway population estimates were obtained from the U.S. Shorebird Conservation Partnership (B. Andres, unpublished data), which includes both the Central and Mississippi Flyways (https://flyways.us/; Figure 5). To partition Central American Flyway shorebird data to estimates that represent the Lower Mississippi Valley Joint Venture region, we created four bins of the percent of the Central American Flyway that migrate through the LMVJV geography (1%, 5%, 10%, and 25%; Table 2). We compared the estimates in each bin to 2010 estimates of peak migration through the LMVJV (Hunter, unpublished data; Appendix 1), and also compared these estimates to peak migration estimates recorded at Catahoula Lake in Louisiana (J. Olszak, unpublished data). We then used expert opinion to determine whether the percent of the Central American Flyway that the 2010 estimates are representative and relatively accurate.

Figure 5. Approximation of Central American Flyway represents the Central and Mississippi Flyways (blue stars)

Year-round residents, such as Killdeer, and wintering birds, such as Wilson's snipe, are considered separately for habitat needs. The most limiting time period for shorebirds is assumed to be fall migration when less water is available on the landscape (Loesch et al. 2000), and is the focus of this plan.

Bird Conservation Region Population Estimates

To facilitate planning by Bird Conservation Region, we used 'complete' checklist data from eBird (2017) to further partition the LMVJV-wide estimates (Table 2). For each species, we looked at the maximum percent frequency of reporting on a checklist either during fall (July - October), spring (Mar-May), winter (Dec-Feb), or breeding (Jun-Jul) depending on the designation in Table 2. "Frequency" is the percentage of checklists that report a species within a specified date range and region. Based on the ratio of maximum checklist frequencies between BCRs, we proportionally adjusted each population estimate. For example, based on eBird checklists, Black-necked Stilts were 17 times more likely to be reported in the MAV BCR (26) than the WGCPO BCR (25). Therefore, the BCR 26 population estimate was 17 times that of the BCR 25 estimate.

Table 2. Estimated shorebird populations migrating through the Mississippi Alluvial Valley and West Gulf Coastal Plain/Ouachitas based on season and percent of Central American Flyway represented. Central American Flyway population estimates were obtained from the U.S. Shorebird Conservation Partnership (B. Andres, unpublished data).

Common name	Primary Season[1]	1% of CenAm Flyway	5% of CenAm Flyway	10% of CenAm Flyway	25% of CenAm Flyway	LMVJV Estimate	BCR 25 WGCPO	BCR 26 MAV	BCR Ratio
Black-necked Stilt	B/R	350	1,750	3,500	8,750	12,500	690	11,810	17.0
American Avocet	M	140	700	1,400	3,500	3,500	1,258	2,242	1.8
Black-bellied Plover	M	1,000	5,000	10,000	25,000	1,000	119	881	7.4
American Golden-Plover	M-S	4,500	22,500	45,000	112,500	4,500	1,620	2,880	1.8
Semipalmated Plover	M	800	4,000	8,000	20,000	2,400	223	2,177	9.8
Piping Plover	M	41	205	410	1,025	205	36	169	4.6
Killdeer	R	10,000	50,000	100,000	250,000	250,000	96,630	153,370	1.6
Upland Sandpiper	M	730	3,650	7,300	18,250	730	490	240	0.5
Hudsonian Godwit	M-S	770	3,850	7,700	19,250	770	308	462	1.5
Marbled Godwit	M	300	1,500	3,000	7,500	85	3	82	26.0
Ruddy Turnstone	M	300	1,500	3,000	7,500	300	27	273	10.3
Red Knot	M	30	150	300	750	60	9	51	5.4
Stilt Sandpiper	M-S	12,287	61,435	122,870	307,175	41,000	5,555	35,445	6.4
Sanderling	M	700	3,500	7,000	17,500	700	110	590	5.4
Dunlin	M	2,500	12,500	25,000	62,500	2,500	319	2,181	6.8
Baird's Sandpiper	M	2,600	13,000	26,000	65,000	300	40	260	6.4
Least Sandpiper	M	4,500	22,500	45,000	112,500	112,500	23,318	89,182	3.8
White-rumped Sandpiper	M-S	16,840	84,200	168,400	421,000	16,840	4,264	12,576	2.9

Common name	Primary Season[1]	1% of CenAm Flyway	5% of CenAm Flyway	10% of CenAm Flyway	25% of CenAm Flyway	LMVJV Estimate	BCR 25 WGCPO	BCR 26 MAV	BCR Ratio
Buff-breasted Sandpiper	M	510	2,550	5,100	12,750	2,550	731	1,819	2.5
Pectoral Sandpiper	M	13,800	69,000	138,000	345,000	69,000	12,314	56,686	4.6
Semipalmated Sandpiper	M	16,500	82,500	165,000	412,500	82,500	11,806	70,694	5.9
Western Sandpiper	M	3,820	19,100	38,200	95,500	38,200	8,986	29,214	3.4
Short-billed Dowitcher	M	280	1,400	2,800	7,000	1,400	160	1,240	7.8
Long-billed Dowitcher	M	4,700	23,500	47,000	117,500	47,000	13,271	33,729	2.5
Wilson's Snipe	W	12,500	62,500	125,000	312,500	200,000	74,061	125,939	1.7
Spotted Sandpiper	M	3,160	15,800	31,600	79,000	15,800	5,204	10,596	2.0
Solitary Sandpiper	M	790	3,950	7,900	19,750	3,950	988	2,962	2.9
Greater Yellowlegs	M	1,000	5,000	10,000	25,000	10,000	3,114	6,886	2.2
Willet	M	200	1,000	2,000	5,000	200	42	158	3.8
Lesser Yellowlegs	M	5,500	27,500	55,000	137,500	55,000	9,529	45,471	4.8
Wilson's Phalarope	M	7,000	35,000	70,000	175,000	750	123	627	5.1
Total		**128,148**	**640,740**	**1,281,480**	**3,203,700**	**976,240**			

[1] B = breeding; M = fall & spring migration; M-S = spring migration only; R = Resident; W = winter

[2] BCR 25 = West Gulf Coastal Plain/Ouachitas; BCR 26 = Mississippi Alluvial Valley

Body Mass

Body mass averages for shorebirds were acquired from Loesch et al. (2000), Dybala et al. (2017), or individual Birds of North America species accounts (Table 3). A weighted average of body mass, based on estimates of regional population size, was used to determine the average mass of a shorebirds migrating through the Lower Mississippi Valley Joint Venture geography (Table 4). The weighted averages were divided into three categories – fall migration, breeding, and winter. We used the weighted average for fall migration body mass. Compared to Elliott and McKnight (2000), average body mass increased from 45g to 54g (Table 4).

Table 3. Average body mass (g) of shorebird species that migrate through or breed in the Mississippi Alluvial Valley and West Gulf Coastal Plain/Ouachitas.

Common name	Body Mass (g)	Body Mass Source
Black-necked Stilt	170	Dybala et al. 2017
American Avocet	305	Dybala et al. 2017
Black-bellied Plover	250	Dybala et al. 2017
American Golden-Plover	154	Johnson et al. 2018
Semipalmated Plover	47	Dybala et al. 2017
Piping Plover	54	Elliott-Smith & Haig 2004
Killdeer	97	Dybala et al. 2017
Upland Sandpiper	125	Loesch et al. 2000
Hudsonian Godwit	200	Loesch et al. 2000
Marbled Godwit	359	Dybala et al. 2017
Ruddy Turnstone	110	Nettleship 2000
Red Knot	157	Baker et al. 2013
Stilt Sandpiper	69	Klima and Jehl, Jr. 2012
Sanderling	55	Macwhirter et al. 2002
Dunlin	47	Dybala et al. 2017
Baird's Sandpiper	40	Moskoff and Montgomerie 2002
Least Sandpiper	23	Dybala et al. 2017
White-rumped Sandpiper	40	Loesch et al. 2000
Buff-breasted Sandpiper	64	McCarty et al. 2017
Pectoral Sandpiper	68	Farmer et al. 2013
Semipalmated Sandpiper	27	Hicklin & Gratto-Trevor 2010
Western Sandpiper	28	Dybala et al. 2017
Short-billed Dowitcher	105	Dybala et al. 2017
Long-billed Dowitcher	105	Dybala et al. 2017
Wilson's Snipe	122	Dybala et al. 2017
Spotted Sandpiper	40	Loesch et al. 2000
Solitary Sandpiper	60	Loesch et al. 2000
Greater Yellowlegs	153	Dybala et al. 2017
Willet	271	Dybala et al. 2017
Lesser Yellowlegs	78	Dybala et al. 2017
Wilson's Phalarope	60	Dybala et al. 2017

Table 4. Total population estimated and average weighted mass of shorebirds during fall migration, winter and breeding season.

	BCR 25	BCR 26	Total Population Estimate	Weighted Mass
Migration (Fall)	**96,537**	**377,056**	**473,593**	**54**
Breeding	690	11,810	12,500	170
Winter	146,533	240,967	387,500	108

Estimating Forage Needs of Shorebirds during Migration

We estimated forage needs based on estimates of metabolic rate, assimilation efficiency, energy content of macroinverterates, and invertebrate mass for maintenance. Additionally, we incorporated invertebrate mass needed to deposit fat during fall migration (Post and Browne 1976, Smith et al. 2012).

We first calculated daily estimated resting metabolic rate (RMR) and field metabolic rate (FMR) based on Dybala et al. (2017). FMR accounts for additional energy spent in daily activities (e.g., flying, foraging) and thermoregulation (Kersten and Piersma 1987). We used:

$$RMR = 437 * m^{0.729} = 437 * 0.054^{0.729}$$
$$FMR = 3 * RMR = 154\ kJ\ day^{-1}$$

Therefore, a 54g shorebird requires 154kJ day^{-1} on average.

One g (dry weight) of macroinvertebrates has a gross energy content of 23.8kJ (Cummins and Wuycheck 1971). Because the assimilation efficiency of birds feeding on invertebrates is approximately 73%, the net energy content (NEC) of macroinvertebrates is about 17.6kJ per g:

$$NEC = Gross\ energy\ content * Assimilation\ efficiency$$
$$NEC = 23.8\ kJ * 0.73 = 17.6\ kJ$$

The mass of invertebrates that a 54g shorebird requires to maintain its field metabolic rate is expressed as:

$$Maintenance\ invertebrate\ mass\ (IM_{m}) = FMR * NEC^{-1}$$
$$IM_{m} = 154\ kJ\ d^{-1} * (17.6\ kJ\ g^{-1}\ d^{-1})^{-1} = 8.75g$$

To accumulate fat reserves to complete migration, however, shorebirds must increase their biomass by about 1g per day. Assuming about 2g of invertebrate forage must be consumed each day to increase biomass by 1g, the mass of invertebrates required for fat deposition becomes 2g per day (Kersten and Piersma 1987).

$$Migration\ invertebrate\ mass = IM_{m} + 2g = 8.75g + 2g = 10.75g$$

Determining Habitat Requirements for Migrating Shorebirds

Because of the paucity of shallow, sparsely-vegetated surface water typically present in this region during late summer and early fall, we assume that habitat will be provided primarily in the form of shallow water intentionally managed to create optimal foraging habitat for shorebirds (e.g., ≥2g/m^2 of invertebrates).

However, there is a range of conditions that shorebirds could experience during migration. Population sizes may vary, the duration of stopover may vary, and the forage density also may vary. To account for some of the inherent variation in the system, we applied an updated model in Program R (Appendix 2) with the following components.

$$Foraging\ Habitat = IM_m * Duration * Forage\ Density^{-1} * Fall\ Population\ Size$$

1) **Population Size:** We used 1,000 iterations of simulated population sizes, sampling with replacement. Fall population sizes ranged from 450,000 to 500,000 shorebirds.
2) **Duration:** Stopover duration was set to vary between 16-20 days, representing a potential 8 to 10-day stop in the northern and southern portions of the Lower Mississippi Valley Joint Venture geography. The initial values were based on random selection of 1,000 values from a uniform

distribution between 16-20 days. Then that data frame was sampled with replacement for each habitat iteration.

3) **Forage Density:** Density of invertebrates was set to vary between 2-4g/m^2 based on biomasses found in pertinent research studies (Augustin et al. 1999; Foth 2016). The initial values were based on random selection of 1,000 values from a uniform distribution between 2-4g/m^2. Then that data frame was sampled with replacement for each habitat iteration.
4) IM_m**:** Factors contributing to IM_m (Weighted Average Body Mass, Daily Energy Expenditure, Gross Energy Content, Assimilation Efficiency, Net Energy Content, Invertebrate Mass for Maintenance, and Invertebrate Mass for Migration) were held constant.

Results of the bioenergetic modeling demonstrate that habitat objectives can vary based on the various factors affecting food demand and supply (Figure 6). However, an average of **3,190ha** ± 84ha (7,883ac ± 208ac) of shorebird habitat is assumed necessary in the fall to support shorebird populations that migrate through the region.

Habitat Objective Distribution – BCR level

Based on an assumed distribution of shorebirds across Bird Conservation Regions using eBird checklist frequencies, the majority of fall shorebird habitat should be provided in the Mississippi Alluvial Valley. This equates to **2,537ha** (6,269ac) **in the MAV** and **652ha** (1,611ac) **in the WGCPO**.

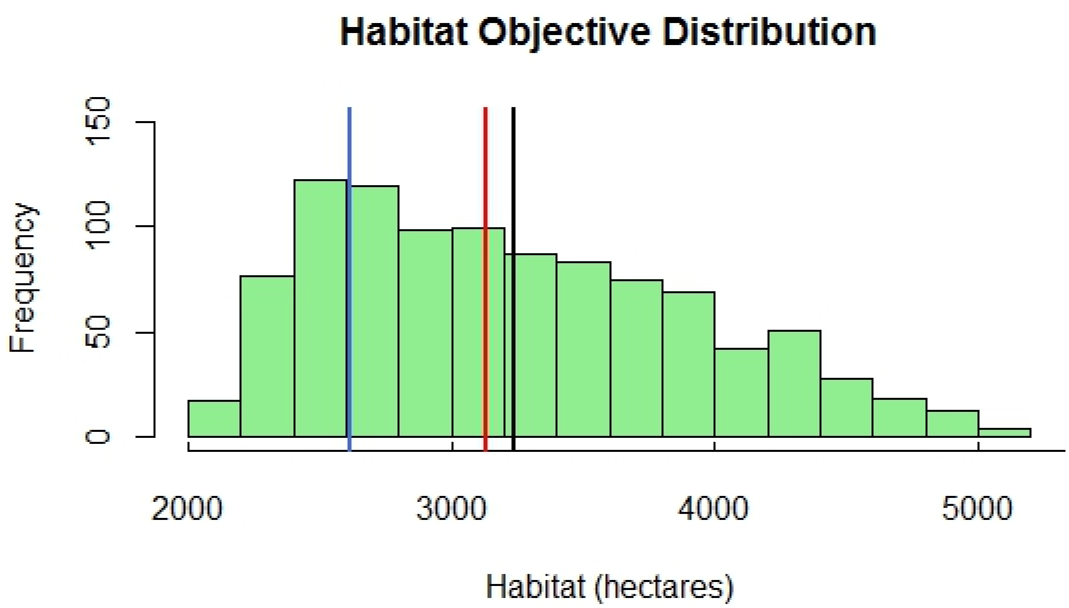

Figure 6. Shorebird habitat objective distribution in the Lower Mississippi Valley Joint Venture based on population size, stopover duration, density of invertebrates, weighted average body mass, daily energy expenditure, net energy content of invertebrates, and invertebrate mass needed for migration. Based on 1,000 iterations, the black line represents the mean value, the red line the median, and the blue line the mode.

Habitat Objective Distribution – State level

In the past, state-level objectives were set based on assumed capacity to provide shorebird habitat and this was focused on public land (Loesch et al. 2000). However, partners explored alternatives way to divide objectives among states. Potential reasonable methods to parse habitat objectives were based on splitting the objectives by the proportion of each state in each BCR, the proportion of public land in each state within a BCR, and the proportion of the sum of public land, emergent wetland, rice, and aquaculture in each state within a BCR. Data for distributions were derived from the USGS National Land Cover Database and the USDA National Agricultural Statistics Service Crop Data Layer. Because shorebirds require specific management for water depth, basing habitat objectives on known present capacity to provide shorebird habitat is the best approach.

The following objectives assume that public agencies, non-profit organizations, and interested private landowners will work to provide sufficient shorebird habitat in proportion to existing habitats and/or land uses that offer the greatest potential for provision of habitat (e.g., aquaculture, rice agriculture).

Table 5. State-level habitat objectives within each state in the Bird Conservation Region – Mississippi Alluvial Valley (MAV) or West Gulf Coastal Plain/Ouachitas (WGCPO). Cells with dashes represent states that do not have area in a particular BCR.

	MAV	WGCPO
Arkansas	868 ha	259 ha
Kentucky	32 ha	-
Louisiana	900 ha	112 ha
Mississippi	489 ha	-
Missouri	66 ha	-
Oklahoma	-	176 ha
Tennessee	182 ha	-
Texas	-	105 ha
Total	2,537 ha	652 ha

Based on a survey of partners, we calculated the amount of shorebird habitat likely provided on public land and potential shorebird habitat if that could be increased (Appendix 3). Current shorebird habitat includes shallow water managed specifically for shorebirds and waterfowl impoundments managed for fall-migrating blue-winged teal (as this practice is compatible with shorebird management). Potential shorebird habitat was estimated based on the expert opinion of managers regarding the amount of additional area that could be managed for shorebirds if they so decided.

Survey responses indicate that the entirety of the LMVJV habitat objective could be met on public managed lands if all units reported are managed properly for shorebirds (Table 6). In the WGCPO, provision of habitat seems to well exceed the 652ha goal. In the MAV, public lands potentially provide 98-100% of the 2,537ha goal. However, these goals are not equally achieved across states (Figure 7).

Table 6. Estimated current habitat (hectares) provided, and potential habitat that could be provided on public managed lands for fall migrating shorebirds.

	MAV		WGCPO	
	Current	**Potential**	**Current**	**Potential**
Arkansas	**251**	**312**	**1,299**	**1,376**
AGFC	85	146	85	162
USFWS	166	166	1,214	1,214
Kentucky	**418**	**418**	-	-
KDWF	418	418		
Louisiana	**1,140**	**4,167**	**105**	**200**
LDWF*	722	3,722	24	119
USFWS	418	445	81	81
Mississippi	**210**	**400**	-	-
MDWFP	89	117	-	-
USFWS	121	283	-	-
Missouri	**469**	**542**	-	-
MDC	267	328	-	-
USFWS	202	212	-	-
Oklahoma	-	**-**	**728**	**988**
ODWC	-	-	121	260
USFWS	-	-	607	728
Tennessee	**0**	**0**	-	-
TWRA	0	0	-	-
USFWS	0	0	-	-
Texas	-	-	**287**	**287**
TPWD	-	-	287	287
USFWS	-	-	0	0
TOTAL	**2,488**	**5,840**	**2,420**	**2,855**

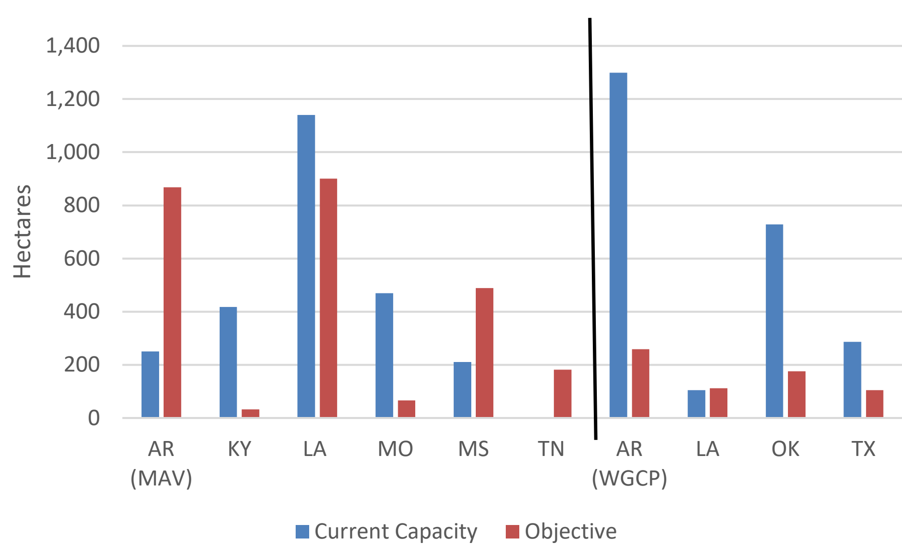

Figure 7. Comparison of current habitat capacity and habitat objectives by state in each Bird Conservation Region – the Mississippi Alluvial Valley (MAV) and West Gulf Coastal Plain/Ouachitas (WGCPO).

Management for Shorebird Habitat

Multi-guild management

Management for shorebirds can be compatible and beneficial for a wide range of bird taxa, including waterfowl and waterbirds. Water depth (Figure 7), vegetation structure, and wetland size are the primary factors influencing shorebird habitat, and a diversity of these factors can benefit all groups.

"Rotation of management options for rails, shorebirds, and waterfowl within a group of impoundments could potentially provide the greatest per dollar benefit to an array of species and publics" (Rundle and Fredrickson 1981).

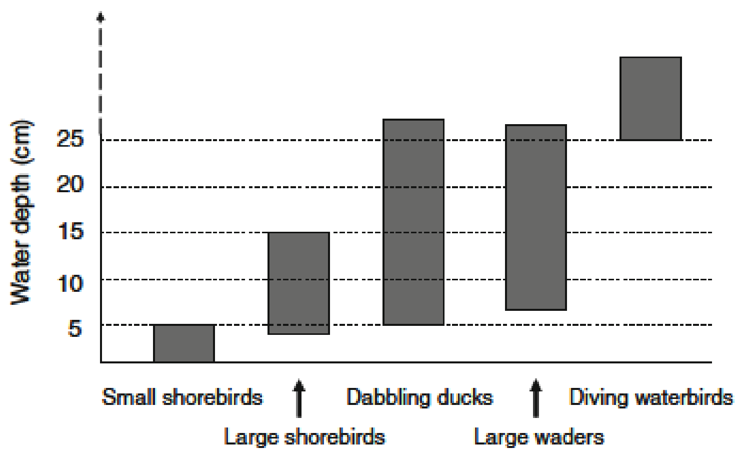

Figure 8. From Ma et al. (2010; Fig 1.) Variation of water depths at foraging sites among waterbird groups. Small shorebirds (such as sandpipers) forage in water less than 5cm deep; large shorebirds (such as godwits) forage in water up to 15cm deep; dabbling ducks (such as teals and mallards) and large waders (such as herons, egrets and ibis) forage in water up to 30cm deep. Diving waterbirds (such as cormorants and grebes) require a minimum water depth of >25cm and can forage in water up to several meters deep.

Shorebird and Waterfowl

"With slight modification of management practices, typically with little effect on traditional waterfowl objectives, there is a huge potential for practicing shorebird management on refuge lands" (Harrington 2003).

Managed impoundments in the region historically have been managed predominantly for migrating and wintering dabbling ducks. Management for migrating and wintering dabbling ducks and shorebirds are not mutually exclusive (Gray et al. 1999, Short 1999). However, shorebird tolerances for vegetative density and water level generally are narrower than those of most dabbling ducks. Furthermore, timing of southward migration in shorebirds is somewhat earlier than for most dabbling duck species, except for perhaps management for blue-winged teal. Hence, to optimize shorebird habitat on managed impoundments, it is necessary to give special consideration to the timing and extent of drawdown, and to vegetation manipulation (Short 1999). Water depth is the primary determinant in shorebird versus waterfowl management (Isola et al. 2000).

Shorebird and Marshbirds

Marshbird habitat typically is discussed in terms of compatibility with waterfowl management, and can be compatible with shorebird management as well. Impoundments normally flooded in fall or winter for waterfowl can be flooded in late summer to provide habitat for post-breeding rails (Pickens and Meanley 2018). Alternatively, wherever feasible, some wetland units can be allowed to naturally dry or be slowly de-watered during the summer months to provide brood habitat for rails (Pickens and Meanley 2018). This could be compatible with management for migrant shorebirds and annual plant production for waterfowl stopover habitat.

General Habitat Management

Wetlands

Shorebirds tend to avoid wetlands with heavy vegetation structure that impairs their visibility of the landscape due to predation pressure (Helmers 1992; Cresswell 1994). This results in the need to reduce stands of vegetation so that two-thirds or more of managed units are open, muddy or shallow water habitat (Helmers 1992).

Moist-soil wetland –

Because shorebirds generally use only the shallowest portions of a wetland (0-18cm), substantial control over water level in impoundments is desirable. Fine-tuned control of water levels can be facilitated by at least two factors: small basin size and shallow boards in the water control structures. Because less water must be moved in or out, management units of 5-10ha allow timely maintenance of appropriate depths. Also, 5-cm and 7.5-cm vs. standard 10-cm flashboards allow for more precise adjustment of water depth. Managers should be mindful of temporal limitations of usability by shorebirds due to rapid germination and colonization of emergent hydrophytic and mesophytic plants.

Emergent palustrine marsh –

Semi-permanent or permanent wetlands (Cowardin et al. 1979) without water control capabilities provide foraging sites for shorebirds if appropriate habitats are available. Short, sparse vegetation, shallowly flooded during early spring, can provide foraging habitats within wet meadow zones (Colwell and Oring 1988, Eldridge 1990). Summer/fall drawdowns from natural evaporation also can provide habitats for south-bound migrants (Hands et.al. 1991). During periods of natural drawdown, dense emergent vegetation can be reduced by burning or mowing the edges. When basins are reflooded, shallowly flooded habitats will be available at wetland edges the following spring. Removing dense vegetation from wetlands by burning or mowing after basins have dried in late summer or fall will provide additional foraging areas for migrant shorebirds the following spring.

Semi-permanent and permanent wetlands with water control can be drawn down in a similar fashion to those described for moist-soil units. However, complete drawdowns are not always necessary if wetlands are sufficiently large (>20ha) and have low relief (< 1m).

Specific Management Practices

The summer/fall shorebird migration period is much more extended than the spring migration, generally occurring between mid-July and late October. Management for summer/fall shorebird habitats includes two different strategies:

1) Draw down: Moist soil-units that remained flooded through spring and early summer can be drawn down. If units were flooded through spring and early summer to provide habitats for breeding herons and rails, then natural evaporation or slow drawdowns make invertebrates available to shorebirds and concentrate prey for other waterbirds (Reid 1989).
2) Flood up: If dry units are to be flooded for shorebirds, units should be shallowly flooded 10-15cm for 2-3 weeks before summer/fall migration begins. This allows invertebrates to re-populate the newly created habitats (Rundle and Fredrickson 1981, Hands et al. 1991, Helmers 1992). Usually the vegetation must be manipulated by disking before re-flooding to assure shorebird response, but can also be mowed or burned if herbicide has killed the vegetation first. The type of disking is critical since the rationale behind it is not only to eliminate standing vegetative structure, but also to convert plant biomass to a detrital base attractive to invertebrates. Deep disking that completely buries plant material is less desirable than shallow disking that only partially buries plant biomass. Thus, shallow disking acts as man-induced senescence and provides excellent substrates for invertebrates, whereas deep disking buries the plant biomass too deeply, reducing the availability of plant material for invertebrate processing (Fredrickson and Reid 1986).

Moist-soil units may need reconditioning every several years to remove undesirable vegetation. Reconditioning units through shallow disking and re-flooding can provide excellent opportunities for shorebird management during the summer. As with spring management, staggering the manipulations among several units extends the availability of habitats.

Drawdown management of units through retention of water retained from spring is, perhaps, the most desirable approach to providing shorebird habitat in managed units for several reasons (Twedt et al. 1998). First, floodwater typically is scarce in late summer/fall, and pumping can be expensive. Second, weedy vegetation can rapidly invade areas that have been disked and flooded. Finally, bird densities on areas that have been drawn down tend to be higher than densities in areas that are "flooded up" (Twedt et al. 1998), probably due to greater invertebrate densities in areas that have been inundated for a longer duration.

Aquaculture ponds

Commercial aquaculture ponds are distributed throughout the region. Crawfish farms are prevalent in Louisiana, catfish farms in Mississippi, and baitfish ponds in Arkansas. These areas likely provide a significant amount of shorebird habitat because they contain numerous small basins that are periodically drawn down. Data collected by U.S. Fish and Wildlife Service biologists in 1995 and 1996 suggests that as many as 531,000 shorebirds may use these habitats in the MAV during southward migration (USFWS, unpubl. data). Lehnen and Krementz (2013) demonstrated that potentially 1,100ha of drained aquaculture ponds could provide high densities of shorebirds (33.5 birds/ha).

Whereas all three types of aquaculture practice hold potential for providing shorebird habitat, crawfish and catfish production have been studied more in this regard (e.g., Lehnen and Krementz 2013, Feaga et al. 2015, Foth 2016). Further assessment of shorebird use of aquaculture ponds and realistic opportunities for management will be essential to refining habitat goals and objectives.

Crawfish Impoundments -

Impoundments managed for commercial crawfish production represent a substantial potential for providing shallow water and mudflat habitat for shorebirds. Land area in crawfish production Louisiana exceeded 189,000 ac in 2011 (LSU Agricultural Center 2011).

Crawfish production follows one of two general cycles of (a) crawfish--dryland crop (e.g., soybeans) or fallow--rice, or (b) crawfish--rice. Timing of de-watering in the regular production cycle often coincides with periods of high shorebird abundance. For example, if the crawfish harvest (typically no later than May) is to be followed by a fallow period, then water may be left on the field to draw down naturally through late summer/early fall when shorebirds are migrating south. The earliest draw down suggested is late July.

Daily shorebird densities on crawfish basins experimentally allowed to remain flooded until July/August have been shown to be very high (42 birds/ha; J. Huner, unpubl. data). Rettig (1994) reported a single-day shorebird density of 133 birds/ha on an 18.8-ha crawfish complex in southwest Louisiana in August 1992. Although this habitat occupies a relatively small proportion of the overall landscape, crawfish ponds often represent a large proportion of the available shallow water habitat in the region during early southward migration (July/August; Rosenberg and Sillett 1991, Rettig 1994).

Even though crawfish ponds can provide substantial shorebird habitat in late summer/fall, availability of habitat within these basins is both variable and unpredictable. Availability of shorebird habitat depends on the timing of water level management and vegetative density. The precise sequence of events within crawfish operations varies among operations and years, depending on rainfall, commodity prices, geographic location, etc. Hence, there may be a variety of opportunities for accommodating shorebirds in particular crawfish farm management schemes.

Catfish Impoundments -
The Migratory Bird Habitat Initiative (MBHI), which was initiated in 2010, was successful in creating additional fall shorebird habitat on idled or fallow catfish ponds (Kaminski and Davis 2014; Foth 2016). Flooded, idled catfish ponds enrolled in MBHI had seven times more shorebirds than production ponds (Kaminski and Davis 2014) in August to September. This habitat has great potential to provide shorebird habitat if specifically managed for that purpose.

Specific Management Practices
Availability of shorebird habitat within aquaculture ponds depends entirely on timing of drawdown. Timing of drawdowns to coincide with shorebird migration should be similar to that recommended below for agricultural fields. Hence, further attention should be placed on understanding and working with the management of these operations, particularly rotations of crawfish/rice/fallow in crawfish ponds. Emphasis should be placed on supporting research efforts aimed at elucidating management schemes that are compatible with crawfish production while simultaneously providing habitat for shorebirds, particularly in late summer/early fall. Opportunities for education and extension relative to the value of crawfish farms to shorebirds and other wildlife (i.e., wading birds) should be explored. Clearly, slight modification of water and vegetation management on a small proportion of the aquaculture ponds in this region could result in a potentially large increase in available shorebird habitat.

Rice fields
In Arkansas, Louisiana, and Mississippi over 650,000 ha (1,613,000 ac) were in rice production [2017; https://www.ers.usda.gov/data-products/rice-yearbook/], and these areas potentially could be managed for shorebirds. Most rice fields in the LMVJV are harvested in late summer (August to September), which precedes the arrival of wintering waterfowl (Petrie et al. 2014). This habitat is useable by shorebirds during and immediately after seeding and post-harvest, but stubble management is usually required.

In the MAV, rice and soybean crops are often rotated (Kaminski and Davis 2014). The MBHI program promoted flooding of rice fields for migrating and wintering birds. Flooded, idled rice fields were frequently used by shorebirds (Kaminski and Davis 2014).

Specific Management Practices
Rice fields have contour levees used to regulate water depths during the growing season. After harvest, rice fields can be rolled with a water-filled drum or shallowly disked to remove stubble. This creates open areas preferred by shorebirds. Flooding contoured fields to different water depths creates feeding opportunities for different shorebirds. Several level fields without contours should be flooded to different depths to provide foraging opportunities for different waterbird guilds (e.g. 5cm, 10cm, 15cm).

Agricultural fields
Natural flooding and mudflat conditions on "dryland" agricultural fields during spring likely provides a significant amount of shorebird habitat during most years. However, the amount of habitat and its frequency of availability is unknown.

Louisiana NRCS offers a Shorebirds of Louisiana Wetlands project through Working Lands for Wildlife. The goal is to create shallow wetlands on agricultural lands, as a continuation of the successful MBHI program in Louisiana. Three main practices are promoted in Louisiana: (1) shallow water habitat development and management with risers closed November 1-February 15; (2) shallow water habitat development and management with risers closed September 1 – March 1; and (3) early successional habitat management with wetland disking or mowing. The program has so far been successful in creating shallow water habitat.

Specific Management Practices: Winter

Between November and February, when the majority of wintering waterfowl occurs in southern regions, agricultural fields managed for dabbling ducks are typically flooded 20 cm (Ringelman 1990), which is too deep for most shorebirds. Wintering shorebirds in the extreme southern portion of the region, such as Long-billed Dowitchers (*Limondromus scolopaceus*), require areas with water depth of $\leq$10cm, whereas Dunlin (*Calidris alpina*) and Western Sandpipers (*C. mauri*) require mudflats and water depths <5cm. Staggered water depths within and between fields during this period will provide foraging opportunities for a variety of species. Fields not flooded by irrigation can have levees pulled up or gates put in, for gradual flooding by winter rains. This management action should benefit a diversity of waterbirds, including shorebirds.

As is generally the case, fields with sparse or no vegetation are more attractive to the most common shorebird species in this region. In agricultural fields in Arkansas and Mississippi, winter shorebird densities were higher in flooded soybean fields than in rice fields or moist soil habitats (Twedt et al. 1998), presumably because soybean fields had less vegetative cover. Augustin et al. (1999), however, found substantially lower benthic invertebrate biomass in a flooded soybean field (0.02g/m^2) than in a flooded moist soil impoundment (1.9g/m^2) during fall in west Tennessee. Furthermore, soybean fields typically are not associated with water control structures, and therefore, may offer limited opportunity for managed flooding. Reasons for high densities of shorebirds in soybean fields in Twedt et al. (1998), given the low biomass of invertebrates found in the west Tennessee soybean field (Augustin et al. 1999) require further investigation.

Specific Management Practices: Spring Migration

In most years there are many areas that are naturally flooded during spring, typically into May. Some agricultural fields flooded for dabbling ducks over winter are drawn down quickly in early spring to prepare fields for planting. These fields, planted in long-season crops, such as corn or rice, can be drawn down slowly beginning in late February through March so that early migrant shorebirds are provided with invertebrates. Fields planned for crops with a shorter growing season, such as soybeans and milo, can be drawn down slowly in late March or early April to provide habitats for later migrating shorebirds. During the spring, fields flooded for winter waterfowl that are to be left fallow (unplanted), should not be drawn down completely until late May to ensure that habitat remains for late migrating shorebirds. Water also should be held as long as possible before preparing fields for later crops such as cover crops or millet.

Specific Management Practices: Summer/Fall Migration

Agricultural fields are harvested from July to November, depending on the number of crops, planting date, and type of crop. Between late July and October, shallowly flooded fields (1-15cm) can provide foraging opportunities for southbound shorebirds such as Semipalmated (*Calidris pusilla*) and Pectoral (*C. melanotos*) Sandpipers, as well as early migrating Blue-winged Teal (*Spatula discors*).

In the southern portion of the planning region, shallow flooding of fallow or harvested fields for shorebirds in late summer typically results in abundant vegetation growth. For these areas to be of maximum value to shorebirds, vegetation must be mechanically reduced by rolling or shallow disking – sometimes as many as two to three times during southward migration (July-October).

Other wetland habitats

Lake shoreline, river bars, open aquatic, and wooded swamp represent important habitat types, however, there are no available management practices for these natural habitats that would benefit shorebirds.

Uplands

According to Eldridge (1992), flooding the uplands surrounding the emergent vegetation zone of semi-permanent wetlands in the early spring will kill the wet meadow plants, and midges will rapidly colonize the detritus. Wet upland habitat typically is used by species such as buff-breasted sandpiper.

Next Steps

The LMVJV partnership needs to provide the tools and evaluation necessary to ensure that high quality shorebird habitat is provided on the landscape.

1) **Continue promoting habitat management for shorebirds on public and private land:** In the fall of 2015, the LMVJV partnership held a successful Shorebird Habitat Management Workshop for public land managers (2-day workshop) and private land managers (1-day workshop), hosted by Manomet, Delta Wind Birds, and U.S. Fish and Wildlife Service. These workshops received good turnout and were well-received within our geography. Such workshops align with the LMVJV mission and should continue to be organized and promoted throughout the region. A modest amount of funding and in-kind support is needed from partner agencies to continue these workshops.
2) **Continue evaluation of shorebird numbers:** Periodic assessment of shorebird populations migrating through the LMVJV from the U.S. Shorebird Conservation Plan partnership is needed and encouraged to help improve biological planning and conservation design.
3) **Continue evaluation of shorebird habitat provided on public and private lands:** A habitat tracking system, such as what the LMVJV partnership has for waterfowl, would be beneficial for shorebird management on public lands. The partnership also needs to assess methods to geospatially identify shorebird habitat on private land.
4) **Continue evaluation of habitat management practices and response of invertebrates and shorebirds:** Because our modeling is based on bioenergetics, we need to ensure that habitat management is actually providing expected volume of food for shorebirds, and that shorebirds are responding as predicted to the availability of food.
5) **Better understand movements of shorebirds through the region and linkages to other geographies:** The LMVJV geography is a migratory corridor for most of the shorebird species listed in this plan. Therefore, we are a linkage between breeding and wintering grounds. A better understanding of movements through our region would allow better communication and coordination with neighboring geographies.

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Appendix 1. Estimates of shorebird populations for Bird Conservation Region 25 and 26 in 2010 (Hunter, unpublished data)

June 5, 2010. Shorebird estimated populations for planning regions in the Southeast U.S. All BCR percentages and population estimates are for the maximum number of birds that occur during non-breeding (nb: transient and wintering) periods unless otherwise indicated as breeding (b: which includes numbers of pairs + on average one surviving young per pair). Habitat breakdown percentages are estimates made for species occurring in the Southeastern Coastal Plain regional plan and may vary somewhat in other planning regions (e.g., 100% of all birds for all species occurring in the Lower Mississippi Valley planning region would use managed and all inland wetlands, agricultural lands, and grasslands). Updated March 10, 2007, based on estimates from Morrison et al. 2006.

Species	Habitat breakdown %: beach-inlet/intertidal/ managed and all inland wetlands, ag, and grasslands	NA pop estimate (US and Canada)	LMV (BCR 25 & 26) % max	LMV (BCR 25& 26) Pop Est.
Black-bellied Plover	50/40/10	200,000	1.00	2,000
American Golden-Plover	0/0/100	200,000 (formerly 150,000)	0.50	1,000
Snowy Plover	90/10/0	18,200 (formerly 16,000)	--	--
Wilson's Plover	80/20/0	12,250*	--	--
Semipalmated Plover	60/30/10	150,000	6.00	9,000
Piping Plover	100/0/0	5,945 (formerly 6,500*) nb	4.00	240 nb
Killdeer	0/0/100	>5,000,000 (formerly 2,000,000*)	10.00	200,000 nb
Black-necked Stilt	0/25/75	175,000 (formerly 150,000)	3.00	5,250 b
American Avocet	15/0/85	450,000	0.10	450
Greater Yellowlegs	0/40/60	100,000	5.00	5,000
Lesser Yellowlegs	0/25/75	400,000 (formerly 500,000)	5.00	20,000
Solitary Sandpiper	0/0/100	150,000	3.00	4,500
Willet	60/35/5	250,000 (eastern breeding 90,000; western non-breeding160,000)	0.10	250 nb
Spotted Sandpiper	0/40/60	500,000*	3.00	15,000
Upland Sandpiper	0/0/100	350,000	0.25	875
Whimbrel	10/70/20	66,000 (formerly 57,000, but SE estimates rise to 40,000 from 18,000)	--	--
Long-billed Curlew	10/30/60	100,000*	--	--
Hudsonian Godwit	0/0/100	70,000 (formerly 50,000)	0.20	140

Species	Habitat breakdown %: beach-inlet/intertidal/ managed and all inland wetlands, ag, and grasslands	NA pop estimate (US and Canada)	LMV (BCR 25 & 26) % max	LMV (BCR 25& 26) Pop Est.
Marbled Godwit	70/20/10	173,500 (170,000 Great Plains, 1,500 Hudson Bay, 2,000 Alaska)	0.05	85
Ruddy Turnstone	75/20/5	245,000 (formerly 235,000)	0.20	490
Red Knot	75/20/5	120,000 (formerly 400,000**) (20,000 rufa and 20,000 roselaari)	0.05	60
Sanderling	80/15/5	300,000	0.67	2,000
Semipalmated Sandpiper	10/55/35	2,000,000 (formerly 3,500,000)	1.00	20,000
Western Sandpiper	10/55/35	3,500,000	2.50	87,500
Least Sandpiper	5/35/60	700,000 (formerly 600,000)	25.00	175,000
White-rumped Sandpiper	0/0/100	1,120,000 (formerly 400,000)	0.05	5,600
Baird’s Sandpiper	0/0/100	300,000	0.10	300
Pectoral Sandpiper	0/0/100	500,000 (formerly 400,000)	10.00	50,000
Dunlin	5/60/35	1,525,000	0.10	1,525
Stilt Sandpiper	0/20/80	820,000 (formerly 200,000)	5.00	41,000
Buff-breasted Sandpiper	0/0/100	56,000(2009, formerly 15,000)	10.00	5,600
Short-billed Dowitcher	10/70/20	153,000 (formerly 320,000) (two eastern subspecies now 78,000, formerly 170,000)	0.50	765
Long-billed Dowitcher	0/0/100	400,000 (formerly 500,000)	5.00	20,000
Wilson’s Snipe	0/0/100	2,000,000	10.00	200,000
American Woodcock***		3,500,000		
Wilson’s Phalarope	0/0/100	1,500,000	0.05	750
Red-necked Phalarope****		2,500,000		
Red Phalarope****		1,250,000 (formerly 1,000,000)		
Total				874,380

* Some population estimates for U.S. and Canadian populations differ from those published in Brown et al. (2001). Most of these are based on more recent thorough direct counts (Wilson’s and Piping plovers, American Oystercatchers, and Long-billed Curlew), a few are needed corrections from Brown et al.

(2001) using BBS-based population estimates where existing published population estimates clearly were very low (Killdeer and Spotted Sandpiper).

** Very recent surveys of Atlantic Coast migrating Red Knots (those going to and from Tierra de Fuego, most presumably moving through Delaware Bay) indicate a very steep decline from estimated population levels in 2001 to the present (from 170,000 to ~17,000 total individuals). Declines have not been documented for Red Knots migrating through or wintering in the Southeast U.S. as of yet, however. Some small declines may have occurred so far undetected, but the figures used here of 3,000 birds for BCR 37 and 15,000 for BCR's 27 and 31 are retained for now.

***American Woodcock is taxonomically a shorebird, but is based on its habitat use a landbird and is not considered further here.

****Red-necked and Red phalaropes are occasionally found inland, but in the Southeast U.S. are mostly pelagic in their habitat use (an most on the Atlantic, very few if any in the Gulf). Although these species should be considered at least by the Atlantic Coast Joint Venture (probably not the Gulf Coast Joint venture) they should be included with pelagic waterbirds and are no considered further here.

Appendix 2. Program R code used for shorebird bioenergetic model in the Mississippi Alluvial Valley and West Gulf Coastal Plain/Ouachitas

```
#1,000 Iterations of Habitat Model with Central Valley JV#
n=1000 #number of iterations
#set up blanks
Habitat = NULL
Upper95 = NULL
Lower95 = NULL
Lower95max = NULL
Lower95min = NULL
Upper95max = NULL
Upper95min = NULL
#iterations
for(i in 1:n)
{
 Abun = sample(450000:500000, 1000, replace=T) #population size range
 Abundance = data.frame(Abun) #dataframe for abundance
 Abun_gen = sample(Abundance$Abun, 1, replace=T) #sample with replacement

 #select stopover duration and density from uniform distribution
 Dur = runif(1000, 16,20)#stopover duration range
 Duration = data.frame(Dur)#dataframe for duration
 Dur_gen = sample(Duration$Dur,1,replace=T)#sample with replacement

 Den = runif(1000,2,4)#stopover duration range
 Density=data.frame(Den)#dataframe for density
 Den_gen=sample(Density$Den,1,replace=T)#sample with replacement

 Mass = 53 #weighted average
 DEE = ((437*((Mass/1000)^0.729))*3) #daily energy needs (based on FMR)
 GEC = 23.8 #gross energy content
 AE = 0.73 #assimilation efficiency
 NEC = GEC*AE #net energy content

 IMm=(DEE*NEC^-1) #invertebrate mass needed for FMR
 IMd=2 #increase daily energy needs apporx 33% for fat deposition
 IMmig=IMm +IMd #invertebrate mass needed for migration

 #run iterations
 Habitat[i]=(IMmig*Dur_gen*(Den_gen^-1)*Abun_gen)/10000
 Lower95[i] = mean(Habitat)-qt(0.975,99)*sqrt(var(Habitat)/n)
 Upper95[i] = mean(Habitat)+qt(0.975,99)*sqrt(var(Habitat)/n)
 Lower95max[i] = max(Habitat)-qt(0.975,99)*sqrt(var(Habitat)/n)
 Upper95max[i] = max(Habitat)+qt(0.975,99)*sqrt(var(Habitat)/n)
 Lower95min[i] = min(Habitat)-qt(0.975,99)*sqrt(var(Habitat)/n)
 Upper95min[i] = min(Habitat)+qt(0.975,99)*sqrt(var(Habitat)/n)
}
```

```
#mean statistics
mean(Habitat)
mean(Upper95,na.rm=TRUE)
mean(Lower95,na.rm=TRUE)

#estimate mode of data
estimate_mode <- function(x) {
  d <- density(x)
  d$x[which.max(d$y)]
}
modes = estimate_mode(Habitat)

#historgram habitat objectives with lines for mean, median and mode
hist(Habitat, main="Habitat Objective Distribution",xlab="Habitat (hectares)",col="lightgreen",
breaks=20,ylim=c(0,150),xaxt='n',plot=TRUE)
axis(side=1,at=seq(2000,7500,1000),tck=.02)
abline(v = mean(Habitat),col = "black",lwd = 2)
abline(v = median(Habitat),col = "red",lwd = 2)
abline(v = modes,col = "royalblue",lwd = 2)
```

Appendix 3. Survey responses of land managers regarding current area (acres) managed for fall shorebird habitat and potential area (acres) that could be managed for shorebird habitat

State	Organization	Site	BCR	Acres Current	Acres Potential	Hectares Current	Hectares Potential
AR	AGFC	R3	MAV	120	200	52	81
AR	AGFC	R2	MAV	60	100	24	40
AR	AGFC	R1	MAV	20	60	8	24
AR	AGFC	R5	WGCPO	20	100	8	40
AR	AGFC	R6	WGCPO	150	200	61	81
AR	AGFC	R8	WGCPO	40	100	16	40
AR	USFWS	White River NWR	MAV	50	50	20	20
AR	USFWS	Cache NWR	MAV	50	50	20	20
AR	USFWS	Bald Knob NWR	MAV	150	150	61	61
AR	USFWS	Big Lake NWR	MAV	10	10	4	4
AR	USFWS	Wapanocca NWR	MAV	150	150	61	61
AR	USFWS	Felsenthal NWR	WGCPO	3,000	3,000	1,214	1,214
KY	KDFWR	Ballard, Boat Wright, Doug Travis WMA	MAV	1,035	1,035	418	418
LA	LDWF	Bayou Macon WMA	MAV	17.8	89	7	36
LA	LDWF	Boeuf WMA	MAV	149.4	747	60	302
LA	LDWF	Red River WMA	MAV	15.4	77	6	31
LA	LDWF	Russell Sage WMA	MAV	1400	7198	567	2,913
LA	LDWF	Sherburne WMA	MAV	202	1087	82	440
LA	LDWF	Bayou Pierre WMA	WGCPO	32	160	13	65
LA	LDWF	Elbow Slough WMA	WGCPO	7	35	3	14
LA	LDWF	Loggy Bayou WMA	WGCPO	7	35	3	14
LA	LDWF	Soda Lake WMA	WGCPO	13	65	5	26
LA	USFWS	Tensas NWR	MAV	32	100	13	40
LA	USFWS	D'Arbonne NWR	MAV	500	500	202	202
LA	USFWS	Upper Ouachita NWR	MAV	500	500	202	202
LA	USFWS	Red River NWR	WGCPO	200	200	81	81
MO	MDC	Duck Creek WMA, Otter Slough WMA, Ten Mile WMA	MAV	659	811	267	328
MO	USFWS	Mingo NWR	MAV	500	530	202	214
MS	MDWFP	Mahannah WMA	MAV	70	140	28	57
MS	MDWFP	Twin Oaks WMA	MAV	10	10	4	4
MS	MDWFP	Muscadine Farms WMA	MAV	50	50	20	20
MS	MDWFP	Charlie Capps WMA	MAV	15	15	6	6
MS	MDWFP	Howard Miller WMA	MAV	75	75	30	30
MS	USFWS	Coldwater River NWR	MAV	100	300	40	121
MS	USFWS	St. Catherine Creek NWR	MAV	200	400	81	162
OK	ODWC	Red Slough WMA	WGCPO	200	200	61	61

OK	ODWC	Hugo WMA	WGCPO	200	500	61	202
OK	USFWS	Sequoyah NWR	WGCPO	1,500	1,800	607	728
TX	TPWD	Alazan Bayou WMA	WGCPO	100	100	40	40
TX	TPWD	Old Sabine Bottom WMA	WGCPO	145	145	59	59
TX	TPWD	White Oak Creek WMA	WGCPO	465	465	188	188
TX	TPWM	Cooper WMA*	WGCPO/OPJV	180	180	73	73

* Within NE TX CDN geography but outside LMVJV boundary, so not included in totals