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Bee Communities on Managed Emergent Wetlands in the lower Mississippi Alluvial Valley of Arkansas

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Bee Communities on Managed Emergent Wetlands in the lower Mississippi Alluvial Valley of Arkansas

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ABSTRACT

Native bee communities that use emergent wetlands are among the least studied systems in bee research. Most native bee species are thought to be in decline based on the loss of usable habitat across the United States. I surveyed emergent wetlands in the lower Mississippi Alluvial Valley of Arkansas during the summers of 2015 and 2016 using pan traps, blue-vane traps, and sweep nets to determine the current status of bee communities in this system. I surveyed 11 sites in 2015 and 17 sites in 2016 and found that bee communities were similar in actively versus passively managed emergent wetlands. I estimated that the probability of detecting a bee species in my study area to be high (67-86%). I also estimated that species richness in emergent wetlands ranged from 69.5-83.5 species throughout the growing season. Actively managed emergent wetlands had a lower percent cover of flowering plants throughout the growing season in comparison to passively managed wetlands. Through better understanding of bee communities in emergent wetlands, I provide a foundation to inform conservation and management decisions on emergent wetlands while also justifying continued support of Farm Bill programs like the Wetlands Reserve Program.

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INTRODUCTION

The lower Mississippi Alluvial Valley (LMAV) of Arkansas was once dominated by bottomland hardwood stands, emergent wetlands, and prairies. These lands were extensively cleared and converted between the 1950's and the 1970's for agricultural purposes after commodity prices reached an all-time high (King et al. 2006). Land conversions as well as agricultural intensification have rendered native bee communities in critical need of conservation, with native bee communities along the Mississippi River valley at the most risk of extirpation (Koh et al. 2015). Along with changes in the land use, conservation programs have been established to counteract habitat loss. The Agricultural Conservation Easement Program (ACEP), previously known and hereafter referred to as the Wetland Reserve Program (WRP), is administered through the U.S. Department of Agriculture Natural Resource Conservation Service, was established in 1990 under the Farm Bill to offer landowners the opportunity to voluntarily protect, restore, and enhance wetlands or previous wetlands on their property. Since the Wetland Reserve Program was established, the LMAV has restored/reestablished over 279,235 ha of wetlands and 91,886 ha of wetlands were in Arkansas (NRCS 2017; Twedt and Uihlein 2005). Though the intent of the WRP is to provide flood protection, reduce soil erosion, improve water quality, and provide wildlife habitat, their role in providing nesting and food resources for bees and other pollinators has not been documented (NRCS 2017; Brown and Paxton 2009; Costanza et al. 1997).

Ecological services provide required processes to sustain a biologically diverse community of flora and fauna. Insects are one of the most diverse and effective providers of ecological services through pollination, biological control, decomposition, and population control (Losey and Vaughan 2006). Although some moths, flies, and beetles are also pollinators, bees are the major pollinators of native plants and crops in terrestrial ecosystems (Buchmann and Nabhan 1996; Klein et al. 2007). Though native bees provide the bulk of pollination to native plants, we currently do not have sufficient benchmark data to determine the conservation status of our native bees (Colla et al. 2012). Native bee population declines have been thought to reflect the decline of suitable habitat through degradation and clearing for agricultural purposes (Brown and Paxton 2009).

Bees require nesting sites (bare-ground, pithy stems, cavities), nest materials, and food resources (pollen and nectar) to survive and reproduce. (Gathmann and Tscharntke 2002; Steffan-Dewenter 2003). These habitat requirements must also be within an appropriate foraging range of species-specific nesting habitat. Body length of bees has been correlated with flight distance, with small (6-13 mm) bees traveling up to 300 meters and large (21-25 mm) bees traveling up to 1,200 meters from their nest to forage (Gathmann and Tscharntke 2002; Zurbuchen et al. 2009). These foraging distances reiterate the need for proper juxtaposition of suitable habitat to sustain a variety of bee species.

My thesis focuses on bee communities in emergent wetlands because knowledge of these communities in this system is poorly documented. Here I will focus on emergent wetlands under two management strategies commonly applied to yield seed producing plants for migratory birds. I will estimate abundance, richness, and species composition of bee communities at restored emergent wetlands and also estimate the overlap of bee communities in emergent wetlands and adjacent soybean fields.

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CHAPTER 1: IMPACTS OF EMERGENT WETLAND MANAGEMENT PRACTICES ON BEE SPECIES DIVERSITY

ABSTRACT

USDA Farm Bill programs like the Wetland Reserve Program provide ecological services including water and soil conservation as well as meeting wildlife and fisheries needs. The value of these wetlands to pollinators, in particular bees, has not been examined despite these wetlands producing large numbers of flowering plants and most likely breeding and overwintering habitat. Additionally, these wetlands are usually surrounded by croplands that might benefit from pollination services provided by wetland bees. In this study, I compared species richness and diversity of bee communities between actively and passively managed palustrine emergent wetlands in the lower Mississippi Alluvial Valley in Arkansas throughout the growing season. Active management practices include disking, mowing, water level manipulation while passive management practices include only natural drying. Solitary bees (Hymenoptera: Apoidea) were surveyed using pan traps, blue-vane traps, and sweep nets. I collected 17,454 individual bees that included five families, 31 genera, and 84 species. Of these species, five (*Anthophorula asteris*, *Ceratina cockerelli*, *Diadasia enavata*, *Dieunomia triangulifera*, *Svastra cressonii*) were new Arkansas state records. I found that the probability of detecting a species in actively (0.64, 95% CI = 0.515-0.868) and passively (0.73, 95% CI = 0.592-0.933) managed emergent wetlands were both high in 2015. Estimated species richness values in actively managed emergent wetlands (76.1, 95% CI = 55.52-94.19) overlapped with estimated species richness in passively managed emergent wetland (69.5, 95% CI = 54.53-86.09) in 2015, though there were unique species specific to each management type. . Shannon-Wiener diversity estimates were not significantly different between actively (2.38, 95% CI = 2.133-2.633) and passively (2.079, 95% CI = 1.466-2.693) managed emergent wetlands in 2015. I found that the probability of detecting a species in actively (0.86, 95% CI = 0.722-0.986) and passively (0.78, 95% CI = 0.637-0.946) managed emergent wetlands were both high in 2016. My

estimated species richness in actively managed emergent wetlands (70.7, 95% CI = 61.49-84.33) overlapped with my estimated species richness in passively managed emergent wetland (83.5, 95% CI = 68.00 – 101.66) in 2016, though there were unique species specific to each management type. Shannon-Wiener diversity estimates were not significantly different between actively (2.315, 95% CI = 2.065-2.564) and passively (1.948, 95% CI = 1.583-2.313) managed emergent wetlands in 2016. Actively and passively managed emergent wetlands support a similar suite of bee species throughout the growing season. The USDA Farm Bill Wetland Reserve Program can create suitable resources for bees and so further justifies this important management program.

INTRODUCTION

Ecological services provide required processes to sustain a biologically diverse community of flora and fauna. Insects are one of the most diverse and effective providers of ecological services through pollination, biological control, decomposition, and population control (Losey and Vaughan 2006). Although some moths, flies, and beetles are also pollinators, bees are the major pollinators of native plants and crops in terrestrial ecosystems (Buchmann and Nabhan 1996; Klein et al. 2007). Though native bees provide the bulk of pollination to native plants, we currently do not have sufficient benchmark data to determine the conservation status of our native bees (Colla et al. 2012). Native bee population declines are thought to reflect the decline of suitable habitat through degradation and clearing for agricultural purposes (Brown and Paxton 2009). Of those areas cleared for agricultural practices, wetlands have suffered the most. The lower 48 states lost over 50% of their original wetlands between 1780-mid-1980's with a wetland loss of 72% in Arkansas alone (Mitsch and Gosselink 2000). The Agricultural Conservation Easement Program (ACEP), previously known and hereafter referred to as the Wetland Reserve Program (WRP), is administered through the U.S. Department of Agriculture Natural Resource Conservation Service. The Wetland Reserve Program was established in 1990 under the Farm Bill to offer landowners technical and financial assistance to protect, restore, and enhance wetlands or previous wetlands on their property. Wetland reserve easements are designed to improve water quality, recharge groundwater, reduce flooding, and protect biological diversity. According to Costanza et al. (1997), wetlands provide $14,785/ha per year in ecological services through gas regulation, water treatment, recreation, and habitat/refuge. Since 1990, over 279,235 ha of wetlands in the lower Mississippi Alluvial Valley (LMAV) have been restored/reestablished and over 91,886 ha of wetlands in the state of Arkansas have been restored/reestablished through the WRP (NRCS(a) 2017; Twedt and Uihlein 2005). Through programs like the WRP, the contiguous United States gained one percent of emergent wetlands back onto the landscape between 2004 and 2009 (Dahl 2011). Though the intent of WRP is to provide flood protection, reduce soil erosion, improve water quality, and provide wildlife habitat, WRP wetlands role in providing nesting and food resources for bees and other pollinators have not been fully appreciated (NRCS(b) 2017; Brown and Paxton 2009; Costanza et al. 1997). Emergent wetlands have been heavily studied for waterfowl use and seed producing plants, but I was only able to locate a single reference on bee communities in wetlands (Park et al. 2017) demonstrating a surprising lack of information on these bee communities. The lack of information on bee communities in emergent wetlands is even more surprising given that emergent wetlands contain an abundance of flowering plants (Heaven et al. 2003).

Emergent wetlands are not all managed the same. Some are managed intensively to promote annual seed producing plants and others are not managed annually to allow natural succession to take place. I categorize these management types into active and passive treatments. Actively managed emergent wetlands are generally disturbed every 1-3 years by disking, herbicide applications, or mowing to reset succession. These wetlands are often referred as moist-soil units and are usually impounded and managed to produce annual seed producing plants targeted at providing stopover and wintering sites for migratory birds. These units are typically moist in the spring, dry in the summer, and moist or inundated again in the fall. Passively managed emergent wetlands are generally disturbed every 3-7 years, but it is not uncommon to have an emergent wetland convert to the next successional stage (scrub-shrub) due to the lack of disturbance. These wetlands can be impounded or naturally occurring and are managed to produce perennial plants. These wetlands are typically moist or inundated from the fall to the late spring and fluctuate with natural evaporation and rain events throughout the summer. In this study, I compared bee community species richness and diversity between actively and passively managed emergent wetlands.

STUDY AREA

I conducted this study in the LMAV of Arkansas (Fig. 1). The LMAV is bounded on the southwest by the West Gulf Coastal Plain and Ouachita Mountains, on the northwest by the Ozark Plateaus, and on the east by the Mississippi River. The LMAV of Arkansas is a result of large rivers forming the character of the land. The Arkansas River, White River, St. Francis River, Black River, Cache River, L'Anguille River, and Mississippi River have been flowing through this region, cutting away older deposits and building up deposits of sand, gravel, and clay (Crow 1974). The soils in the LMAV of Arkansas include clay, sand, and loess, and change with distance from rivers. Historically the LMAV of Arkansas included vast wetlands in the floodplains and prairies between the floodplains (Fig. 2, Branner 1908; Foti 2001). I argue that these prairies were probably wet prairies based on hydric soil characteristics found there (Fig. 3, Branner 1908). The elevation of the LMAV varies by ~46 m throughout the entire 402 km length of the LMAV in Arkansas (Crow 1974). The region is now dominated by agriculture (soybean, rice, corn, sorghum, and cotton; ~61%) with fragments of remnant emergent wetland (1%) and bottomland hardwood forest (17%) (King et al. 2006; USDA-NASS 2016). The LMAV averages 118-134 cm of rainfall annually with an average of 35 cm of rainfall between June and September (Scott et al. 1998).

I surveyed palustrine emergent wetlands across the LMAV. All of the sites I surveyed were used for agricultural or aquacultural production in the past 20 years before being restored back to emergent wetlands (see supplemental data). All of the sites I surveyed had been impounded and were either being managed as moist-soil units, reestablished to functioning emergent wetlands through the WRP, or were naturally succeeding back to emergent wetlands. Palustrine emergent wetlands are classified as areas <8 ha in size, lacking active wave-formed or bedrock shoreline features, water depth in the deepest part of the basin <2.5 m at low water, and salinity due to ocean-derived salts less than 0.5 ppt (Cowardin et al. 1979). I selected two groups of wetland sites that were distinguished based on their previous management histories (see supplemental data). Actively managed emergent wetland sites were defined if >10% of the management unit had been disked, sprayed, or mowed that year and/or if >75% of the unit was disked or sprayed in the previous 2 years. Passively managed emergent wetland sites were defined if <10% of the unit had been disked, sprayed, or mowed that year and/or if <75% of the unit was disked or sprayed in the previous 2 years. Actively managed emergent wetlands were usually drained by late May and disked in early July to reset succession and produce seeding grasses for migratory birds, whereas passively managed emergent wetlands were allowed to naturally evaporate throughout the growing season, retaining soil moisture, and providing a longer bloom period for hydrophytic plants such as *Hydrolea uniflora* and *Ludwigia peploides ssp. glabrescens*. Reduced disturbance on passively managed emergent wetlands provided floral resources continuously throughout the growing season. Sites included Wildlife Management Areas (WMA) managed by the Arkansas Game and Fish Commission (AGFC), National Wildlife Refuges (NWR) managed by the U.S. Fish and Wildlife Service (USFWS), one Natural Area (NA) managed by the Arkansas Natural Heritage Commission (ANHC), and five private lands (Table 2). Wetlands ranged in size from 0.33 hectares - 12.24 hectares and periodically had standing water based on natural hydrology or water control structures. All study sites were >2 km apart except Shirey Bay North and Shirey Bay South (0.55 km apart) to decrease the chance of bees moving among sites (Araujo et al. 2004).

METHODS

Bee Surveys

In 2015, I sampled 11 wetland sites for 64 visits and in 2016 I sampled 17 wetland sites for 136 visits. I sampled bees (Hymenoptera: Apoidea) during 19 May – 18 September 2015 and from 22 May – 9 September 2016. Sampling took place during 4 collection periods: late spring (19 May- 20 June), early summer (21 June -13 July), mid-summer (18 July- 12 August), and late summer (15 August – 18 September). I collected bees using pan traps (Droege et al. 2009; Kirk 1984; Leong and Thorp 1999), blue-vane traps (Kimoto et al. 2012; Stephen and Rao 2005), and sweep nets (Roulston et al. 2007; Stephen and Rao 2007). Pan trapping was used because it is known to attract smaller bodied bees and avoids the need for skilled collectors (Cane et al. 2000; Westphal et al. 2008). Blue-vane traps were incorporated to collect medium to large bodied bees (Geroff et al. 2014) and sweep nets were used to collect bees that might not be represented in either pan or blue-vane traps (Cane et al. 2000; Stephen and Rao 2007). Honey bees (*Apis mellifera*) are known to be poorly collected using pan traps and vane traps, but were successfully accounted for through sweep net samples (Stephen and Rao 2007; Westphal et al. 2008; Kimoto et al. 2012). I captured bees by placing 10 pan trap stations throughout wetlands along a permanent transect following an opportunistic path avoiding open water (Fig. 4). Pan trap stations had a set interval of 20 m between stations. Pan trap station platforms (Fig. 5) held 3, 266 mL cups (Solo, Lake Forest, IL) that were painted either fluorescent blue, fluorescent yellow, or white (Guerra Paint and Pigment Corp., New York, NY; Krylon CoverMaxx, Cleveland, OH). These cups were filled ¾ full with a soapy water (Dawn Ultra – Original Scent, Cincinnati, OH) mixed daily to capture visiting bees. Pan trap platforms were adjusted to the average vegetation height surrounding the platform at every collection point. The pan traps were set out between 0700-0900 hrs and were collected the same day between 1800-2000 hrs. Samples were combined at each pan trap station and strained using an 180µm sieve to isolate the insects from the soapy water mix. The sample was then transferred to a Whirl-Pak (Nasco, Fort Atkinson, WI) in 70% ethanol for storage. Thus there were 10 Whirl-Pak bags from the 10 pan trap stations at a site. I used one blue-vane trap (1.89 L jar) per field site suspended from a shepherds hook pole, with the bottom of the trap ~1 m above the ground (Kimoto et al. 2012; Stephen and Rao 2005). The blue-vane trap was filled with ~475 ml of the same soapy mix as the pan traps. These blue-vane traps were placed and collected on the same schedule as the pan traps. Samples were also strained using an 180µm sieve and were placed in a Whirl-Pak in 70% ethanol for storage. I used sweep netting to sample for bees that were not attracted to either pan or blue-vane traps. I placed 5 transects at random start points within each wetland. I sampled along each transect by taking 50 sweeps to capture bees. Sweeps were conducted between 1100-1345 hrs (Stephen and Rao 2007) in 2015 and between 0900-1000 hrs (Roulston et al. 2007) hours in 2016. Sweep net collection periods were altered between years for logistical reasons and because bees were observed to be more active between 0730-1000 hrs the previous year. All sweep net samples were placed in gallon Ziploc bags (S.C. Johnson, Racine, WI) and were placed in the freezer until processed. All bees were washed, dried, pinned, and labeled. Bees were identified to species when possible or to genus by me using discoverlife.org (Ascher and Pickering 2017). I confirmed identifications with M. Arduser – Missouri Department of Conservation (retired); H. Ikerd – USDA-Agricultural Research Service Pollinating Insect-biology, Management, Systematics Research Unit; T. Griswold – USDA-Agricultural Research Service, Pollinating Insect-biology, Management, Systematics Research Unit; J. S. Ascher –

American Museum of Natural History; and K. Parys – USDA-Agricultural Research Service, Southern Insect Management Research Unit.

Plant Surveys

To assess the relative abundance of flowers available to bees at each site, I assigned a floral score (1-3) to each site during each sampling period. A floral score of 1 (Low) was assigned if <30% of the site was covered in desirable flowering plants, a floral score of 2 (Medium) was considered if 30-60% of the unit was covered in desirable flowering plants, and a floral score of 3 (High) was considered if 60-100% of the unit was covered in desirable flowering plants. Desirable plants were any flowering plant that I observed being visited by a bee. Representative specimens of all desirable flowering plants were pressed, dried, mounted, identified to species (Gentry et al. 2013), and catalogued in the University of Arkansas Herbarium. I confirmed plant identifications with Karen Willard – University of Arkansas Herbarium.

DATA ANALYSIS

To estimate probability of detection, species richness, extinction (ϕ), turnover (Γ), and colonization between actively and passively managed emergent wetland sites, I used the programs SPECRICH (Burnham and Overton 1979; Hines 1996) and COMDYN4 (Nichols et al. 1998). Following this procedure, I found that in all cases, the data fit the model (M(h) GOF test, $p>0.05$ for all tests). Detection probabilities <~80% suggest that raw species counts do not represent the true number of species that occur at those sites (MacKenzie et al. 2002). Hence, if it met the assumptions I relied on estimated species richness values to describe bee communities on both the actively and passively managed sites. To assess community structure I calculated

Shannon – Wiener diversity indices for bee communities in both treatment types using $H = \sum -(P_i * \ln P_i)$ for each site over the entire growing season. Evenness was calculated using $E = H/\ln(S)$ for each site over the entire growing season where S is the species richness (Elliott 1990). The indices data were then analyzed using a one-way ANOVA with 2 treatment types. To determine how the number of individuals collected by different methods was affected by management type I generated rarefaction curves using an interpolation and extrapolation of species diversity model with the "iNEXT" package (Hseih et al. 2016) in R (R Core Team 2016. R Version 3.3.2). Rarefaction curves were produced to quantity the number of species per individual captured between management types. I compared floral resource scores over time and between actively and passively managed emergent wetland sites by examining the overlap of the 95% confidence intervals by treatment type.

RESULTS

2015 Sampling

I captured 2,937 individual bees made up of 23 genera and 64 species across 9 sites (Table 1); 20 (31%) were singletons. I found that the probability of detecting a species in actively managed emergent wetlands was 0.67 (95% CI = 0.534-0.902) while detecting a species in passively managed emergent wetlands was 0.74 (95% CI = 0.591-0.913). I collected 49 species in actively managed emergent wetlands. Because the GOF test indicated the data did not fit the heterogeneity model ($\chi^2 = 9.864$, $P = 0.02$), my species richness (R) estimate (R = 76.1, 95% CI = 55.52-94.19) was not reliable. For the passively managed emergent wetland sites, I collected 51 species with the GOF test indicating the data fit the heterogeneity model ($\chi^2 = 1.082$, $P = 0.78$) so I estimated species richness was 69.5 (95% CI = 54.53-86.09). The 95% confidence intervals for species richness by management type overlapped indicating that actively and passively managed emergent wetlands supported a similar number of species. The estimated species richness value for the actively managed emergent wetland was used because of the overlap in confident intervals between the treatment types and the lack of strength in the raw species counts. The extinction probability (ϕ) is the proportion of species in actively managed emergent wetlands still present in passively managed emergent wetlands. The species turnover (Γ) is the proportion of species in passively managed emergent wetlands still present in actively managed emergent wetlands. I found that the extinction probability (ϕ = 0.78, 95% CI = 0.60-0.975) and the species turnover (Γ = 0.82, 95% CI = 0.601-1.00) was high. Colonization is the number of species not present in actively managed emergent wetlands, but present in passively managed emergent wetlands. I found that local colonization was 10.4 (95% CI = 0.0-29.68). Of the 49 species collected in actively managed emergent wetlands, 13 (Appendix I) were not captured at passively managed sites, whereas 15 (Appendix I) of 51 species found in passively managed emergent wetlands were not captured at actively managed sites.

The major genera and species in both managed wetland types overlapped: Actively managed wetlands - *Augochlorella aurata* (26%), *Lasioglossum spp.* (22%), *Melissodes spp.* (17%), and *Ptilothrix bombiformis* (10%); passively managed wetlands - *Augochlorella aurata* (33%), *Lasioglossum spp.* (29%), *Melissodes spp.* (10%), and *Ptilothrix bombiformis* (7%). These most commonly collected genera and species made up the majority of the species distributions (Fig 6, Fig. 7). The average Shannon-Wiener index was 2.38 (95% CI = 2.133 - 2.633) for actively managed emergent wetlands whereas the average Shannon-Wiener index was 2.079 (95% CI = 1.466-2.693) for passively managed emergent wetlands. There was no difference in diversity between treatment types ($F_{1,10}$ = 0.926, p = 0.31). Species evenness of actively managed emergent wetlands on average was 0.786 (95% CI = 0.71 – 0.863) and passively managed emergent wetlands was 0.648(95% CI = 0.521 - 0.775). There was no difference in evenness between treatment types ($F_{1,10}$ = 3.614, p= 0.09). One of the passively managed emergent sites (Gumbo) had the lowest Shannon-Wiener diversity index (H=0.839) and the lowest evenness (J=0.403) of all the sites.

2016 Sampling

I captured 14,517 individual bees made up of 29 genera and 74 species across 17 sites (Table 1); 14 (18%) were singletons. I found that the probability of detecting a species in actively managed emergent wetlands was 0.86 (95% CI = 0.722-0.986) while detecting a species in passively managed emergent wetlands was 0.78 (95% CI = 0.637-0.946). I collected 61 species in actively managed emergent wetlands with the GOF test indicating the data fit the heterogeneity model (χ^2 = 5.57, P = 0.13). I estimated species richness was 70.7 (95% CI = 61.49-84.33). For the passively managed emergent wetland sites, I collected 65 species with the GOF test indicating the data fit the heterogeneity model (χ^2 = 6.02, P = 0.11) so I estimated species richness was 83.5 (95% CI = 68.00-101.66). The 95% confidence intervals for species richness by management type overlapped indicating that actively and passively managed emergent wetlands supported a similar number of species. I found that the extinction probability (ϕ = 0.98, 95% CI = 0.812-1.00) and the species turnover (Γ = 0.88, 95% CI = 0.74-1.00) was high. I found that local colonization was 13.7 (95% CI = 0.0-35.63). Of the 61 species collected in actively managed emergent wetlands, 9 (Appendix II) were unique; whereas 12 (Appendix II) of 65 species found in passively managed emergent wetlands were unique.

The major genera and species in both managed wetland types were overlapped: actively managed wetlands - *Augochlorella aurata* (35%), *Lasioglossum spp.* (20%), *Melissodes spp.* (19%), and *Ptilothrix bombiformis* (11%); passively managed wetlands - *Augochlorella aurata* (55%), *Lasioglossum spp.* (18%), *Ptilothrix bombiformis* (8%), and *Melissodes spp.* (7%). These most commonly collected genera and species made up the majority of the species distributions (Fig 6, Fig. 7). The average Shannon-Wiener index was 2.315 (95% CI = 2.065-2.564) for actively managed emergent wetlands whereas the average Shannon-Wiener index was 1.948 (95% CI = 1.583-2.313) for passively managed emergent wetlands. There was no difference in diversity between treatment types ($F_{1,16} = 2.186$, $p = 0.16$). Species evenness of actively managed emergent wetlands on average was 0.684 (95% CI = 0.601-0.768) and passively managed emergent wetlands was 0.566 (95% CI = 0.462-0.67). There was no difference in evenness between treatment types ($F_{1,16} = 2.644$; $p = 0.12$). One of the passively managed emergent sites (Gumbo) had the lowest Shannon-Wiener diversity index (H=0.888) and the lowest evenness (J=0.276) of all the sites.

Overall Sampling

I captured 17,454 individual bees during 2015 and 2016, representing five families, 84 species, and 31genera; 18 (21%) were singletons. Five species captured (*Anthophorula asteris*, *Ceratina cockerelli*, *Diadasia enavata, Dieunomia triangulifera*, *Svastra cressonii*) were new Arkansas state records. I also captured two species of cleptoparasitic bees, *Triepeolus quadrifasciatus* which is known to prey on *Melissodes*, *Svastra*, *Xenoglossa*, and *Eucera* and *Sphecodes mandibularis* which is known to prey on the subgenus *Dialictus* (Michener 2007; Engel and Prado 2014). I collected 84 species in both managed emergent wetland types between 2015 and 2016 with the GOF test indicating the data fit the heterogeneity model ($\chi^2 = 5.75$, P =

0.12). I estimated species richness was 108 (95% CI = 91.14-124.86). Actively (Fig. 6) and passively (Fig. 7) managed emergent wetlands had a strongly negative binomial distribution of number of individuals by species. A majority of the species collected had <20 individuals captured across all sites (Fig 6 and Fig. 7), indicating a high amount of species on the brink of extirpation in these emergent wetlands. Species accumulation curves (Fig. 8) suggest that my sampling techniques effectively captured most species present in both treatment types. Nevertheless, it seems that passively managed emergent wetlands could harbor more species than were collected based on the curve not reaching an asymptote and also the estimates produced in program COMDYN4. Probability of detection, species richness, extinction (ϕ), turnover (Γ), colonization, and Shannon-Wiener diversity indices were not significantly different between the treatments types in 2015 or 2016.

Augochlorella aurata accounted for 46% (8,038 individuals) of the total abundance collected during both years. *Augochlorella aurata*, *Ptilothrix bombiformis*, *Melissodes comptoides*, *Melissodes communis*, and *Lasioglossum creberrimum* were the most commonly collected bees in actively managed emergent wetlands. *Augochlorella aurata*, *Ptilothrix bombiformis*, *Lasioglossum creberrimum*, *Lasioglossum nelumbonis*, and *Lasioglossum hartii* were the most commonly collected bees in passively managed emergent wetlands. Honey bees (*Apis mellifera*) were detected at all sites throughout the study, but were poorly represented in my collections due to their lack of attraction to pan traps and blue-vane traps (Stephen and Rao 2007). Honey bees were observed visiting wetland plants in large numbers (~10-30 per m^2) during peak bloom.

Actively and passively managed emergent wetlands harbored the same number of bee species though the total number of individuals collected in both treatment types differed.

Average floral score remained constant ~1.5 (~35% cover) in actively managed emergent wetlands throughout the sampling period in 2015 and 2016 (Fig. 9). Average floral score steadily increased from ~1.5 to 2.5 (~35-50% cover) in passively managed emergent wetlands over the sampling period in both 2015 and 2016.

Hibiscus lasiocarpos, Ludwigia peploides ssp. glabrescens, *Persicaria spp.*, and *Sesbania herbacea* were found in both treatment types. *Coreopsis tinctoria*, *Croton capitatus*, annual *Persicaria spp.*, and grasses (e.g. *Leptochloa spp., Echinochloa spp.*) were more frequently found in actively managed emergent wetlands, whereas *Asclepias perennis*, *Cephalanthus occidentalis*, *Echinodorus cordifolius*, *Heliotropium indicum*, *Hydrolea uniflora*, *Nelumbo lutea*, *Sagittaria brevirostra*, perennial *Persicaria spp.*, and *Salix nigra* were "more frequently" found in passively managed emergent wetlands. Actively managed emergent wetlands did not have many flowering plants between mid-June - early July until *Persicaria spp*. began to bloom. Reduced soil disturbance sustained floral availability on passively managed emergent wetlands by retaining soil moisture and providing a longer bloom period for hydrophytic plants such as *Hydrolea uniflora* and *Ludwigia peploides ssp. glabrescens*. Moisture loss and disking were the two most contributing factors to floral score differences between actively and passively managed emergent wetlands throughout the sampling period. Though the floral scores varied by management type, the bee species richness did not change by overall number, but species composition did differ (Appendix I & II).

DISCUSSION

Bee communities that use emergent wetlands have been poorly documented as compared to those that use other habitat types. I found that restored emergent wetlands, whether actively or passively managed, support a species rich and diverse bee community. These results confirm and encompass the findings of previous wetland related studies, which found that emergent wetlands can harbor similar bee species richness (Table 3). These other studies had a similar number of genera collected as this study, but had a wide range of specimens collected (962-86,500+). Wetland bee communities have not been documented extensively, but three of these studies (Table 3) create the published knowledge of wetland bee communities in the contiguous United States. Compared to prairie bee communities, emergent wetland bee communities are not as diverse (Geroff et al. 2014; Williams et al. 2001), but harbor species specific to these systems. My study is the first to my knowledge to document bee communities in emergent wetlands in the LMAV. The LMAV coincides with what Koh et al. (2015) describes as a predominantly agricultural region with the greatest risk of loss to native bee populations in the United States. This loss of native bees should be of great concern considering that a majority of the species collected in this study were represented by <20 individuals.

Augochlorella aurata was the most abundant species collected across all sites in both years. *Augochlorella aurata* are a very common bee found from Texas to Nova Scotia and from the central plains to the east coast in North America. The genus *Augochlorella* are eusocial compared to other augochlorine bees and nest in the ground in aggregated groups or colonies (Ordway 1966).The annual life cycle of *A. aurata* includes emergence in spring, a first brood (worker phase) in early summer, a second brood (reproductive) in late summer, and an overwintering phase (Mueller 1996). Each colony can sustain up to 10 individuals apiece as the summer concludes (Ordway 1966). Males leave the nest after emergence and do not return to the nest (Ordway 1966). *Augochlorella aurata* continue to fly and feed on nectar until the first frost. Females dig a hibernation burrow under their nest below the frost line. They are also known to be generalist and will visit multiple genera of flowers before partitioning the pollen load (Ordway 1966). *Augochlorella aurata* accounted for 46% (8,038 individuals) of the total catch in this project compared to only 2% (1,744 individuals) in the Playa Lake region of Nebraska (Park et al. 2017). Playa lakes are classified as palustrine emergent wetlands. This difference begs the question of what other factors are causing these communities to be drastically different in two emergent wetland systems. Park et al. (2017) did not use pan traps in their study, which accounted for >70% of individuals caught in this study, accounting for some variation in collected specimens.

Though actively and passively managed emergent wetlands supported different percentages of desirable plants, bees seemed to use what was available. This argues the case that floral availability is not the only factor driving species richness, but nesting needs and flight distance limitations might determine a sustainable community (Cane 2001). This notion and the fact that these patches of wetlands were once a contiguous landscape of bottomland hardwood forests, emergent wetlands, and wet prairies could explain the overlap in species richness, detection, treatment overlap, and diversity between treatment types. The similarities between treatment types could also be explained through natural succession. Actively managed emergent wetlands are one of the earliest successional stages of the emergent wetland classification system. As these systems continue to develop, they transition into passively managed emergent wetlands that have annual plant species carrying over while also adding perennial plants not found in the other treatment type.

I believe the bee species that I collected in my study area were those species that have survived a variety of perturbations including land use changes, pesticide use, and honey bee competition. Current species richness could also be a product of specialist species going extinct in the past decades due to land conversion. Land conversion not only decreases the amount of usable habitat for bees, but also inhibits the recolonization of other isolated patches because of known flight distance limitations of bees. Pesticide is used in the surrounding agriculture fields to control pest insects harmful to the economic threshold of desirable crops. Aerial applications of pesticides are common in the lower Mississippi Alluvial Valley of Arkansas creating the chance for drift, accidental spray, or deliberate applications to sensitive invertebrate communities (Tome et al. 1991). Isolated wetlands do not have adequate buffers or protection to mitigate the use of insecticides near their edges against agricultural practices (Park et al. 2015). Honey bees (*Apis mellifera*), managed and feral, also compete with native bees for nectar and pollen in these emergent wetlands. Though honey bees are not considered a direct threat to the survival of native bees, they have been known to exploit patches of resources until moving to the next location (Aslan et al. 2016). Unfortunately for the native bees, those patches are needed for their daily survival. Though all these factors have been limiting to the bee community, species richness is adequate compared to other bee studies in these restored emergent wetlands. Sheffield et al. (2013) claimed cleptoparasitic bees to be an apex/indicator species of bee community strength. Based on site histories over the past 20 years, I would conclude that these wetlands restored though the Wetland Reserve Program, moist-soil management, and natural succession have created patches of high-quality habitat based on the presence of cleptoparasitic bee species.

Farm bill programs like WRP have the capacity to create source populations of bee diversity in a mosaic of agriculture/wetland interfaces. I believe these restored emergent wetlands serve as a refuge for sensitive invertebrate communities from anthropogenic disturbances, while promoting groundwater recharge, soil retention, and providing habitat to a range of flora and fauna. My data should strengthen our knowledge of bee species distribution in

Arkansas and also serve as a benchmark for future population assessments in palustrine emergent wetlands.

When attempting to manage for a diverse bee community in emergent wetland systems, consideration should be given to desirable plants mentioned in this study. Some of these plants (e.g. *Ludwigia peploides ssp. glabrescens*, *Coreopsis tinctoria*, *Hydrolea uniflora*) are not always seen as beneficial to wetland managers and private landowners, but should be preserved at a minimum of 5-10% cover area of the managed wetland. Mid- to late summer could be the most limited time of the year for flowering plants to be present in actively managed wetlands in part because of lack of available standing water and disturbance events (disking/planting). Additionally, wetland managers should realize that other characteristics of emergent wetlands are valuable to bee communities. For example, standing water and moist soil are important to the construction of nesting sites and serve a crucial role in the survival of specialized species (Michener 2007). Future work should look into the minimum habitat requirements to sustain a diverse bee community standard met in this study and similar wetland projects. Future studies could also study the difference between bee communities in intensively managed wetlands that undergo 100% disking vs 30-50% disking. A multiple year project could also assess the rate of colonization of bee species in a field before and after restoration.

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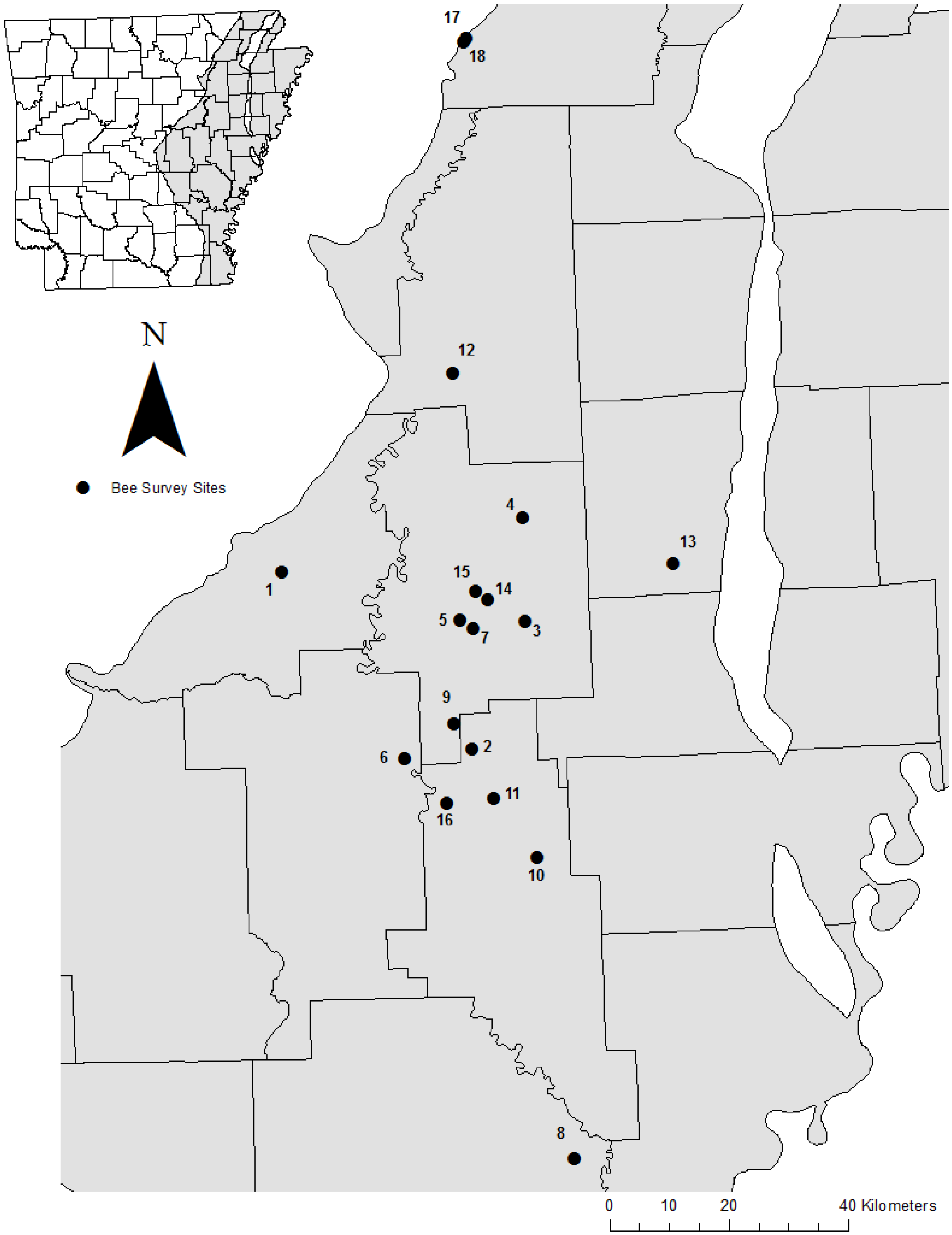
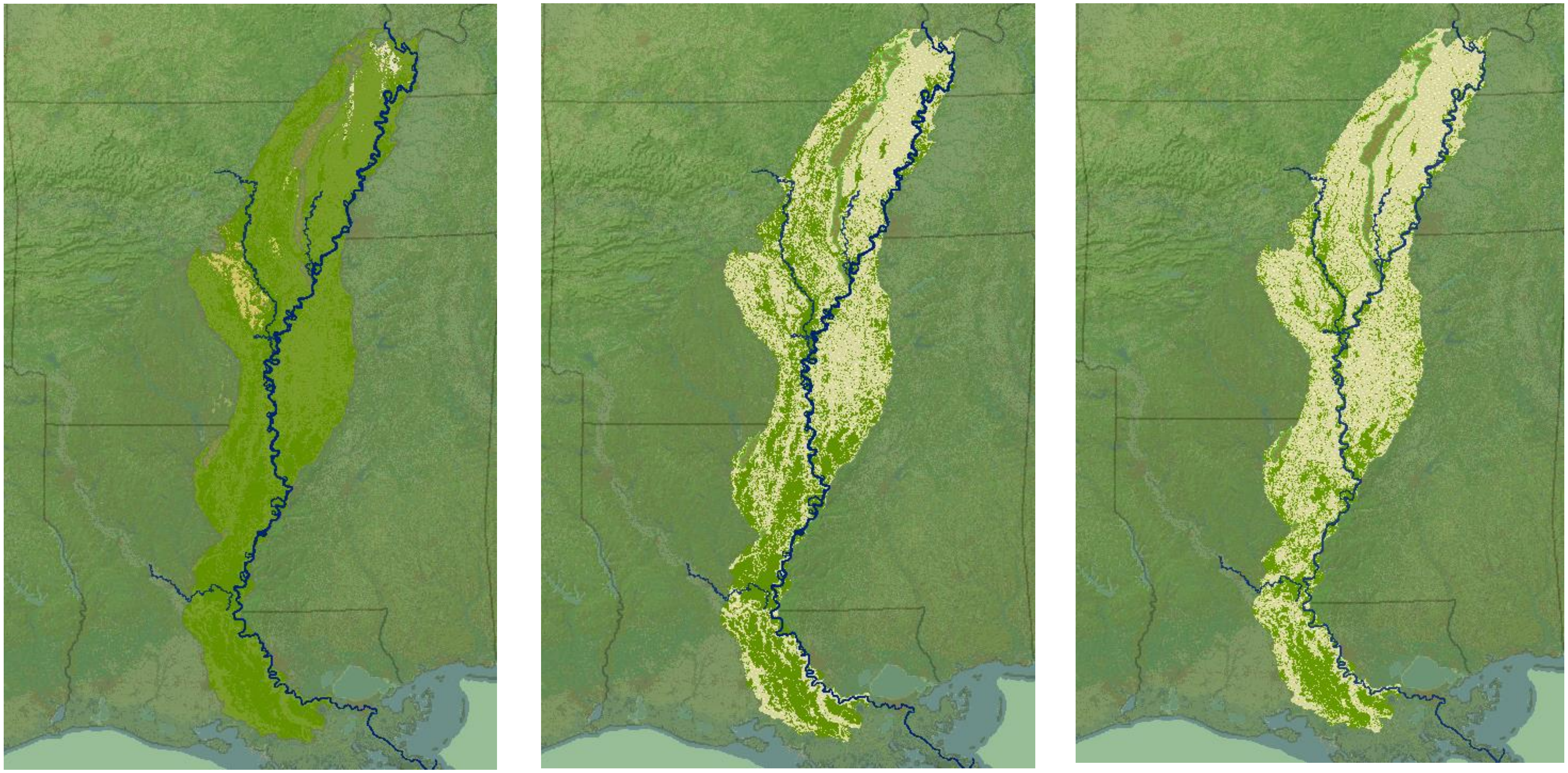


Figure 1. Distribution of managed palustrine emergent wetlands surveyed for bees in the Lower Mississippi Alluvial Valley of Eastern Arkansas, USA in 2015 and 2016. See Table 1 for site names and coordinates.



Pre-settlement 1950’s 2011

Figure 2. Estimated bottomland hardwood cover before European settlement (~9,712,455 hectares), in the 1950’s (~4,249,199 hectares; MacDonald et al. 1979), and in 2011(~2,994,674 hectares; Mitchell et al. 2016) in the Lower Mississippi Alluvial Valley, USA. Graphics created by Blaine Elliot – Lower Mississippi Valley Joint Venture. Light green – bottomland hardwoods, Light yellow – prairie, Off-white – agriculture

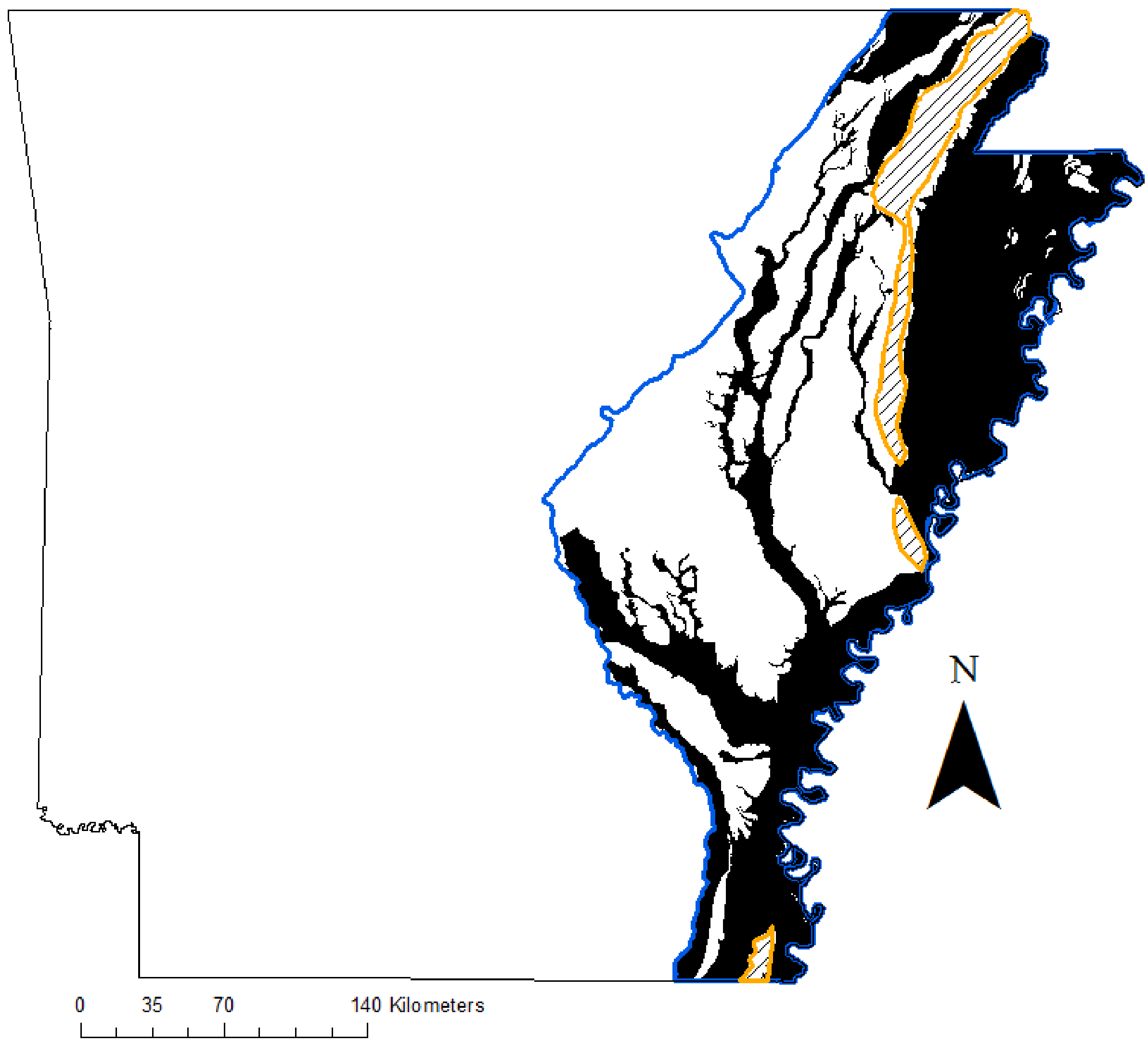


Figure 3. Historical flood plain of the lower Mississippi Alluvial Valley in Eastern Arkansas, USA in 1899 is represented in black (GCPO 2017). The blue outline represents the geographic area known as the “Delta” and as the lower Mississippi Alluvial Valley of Arkansas. The orange polygons represent Crowley’s Ridge in the North and Macon Ridge in the South.

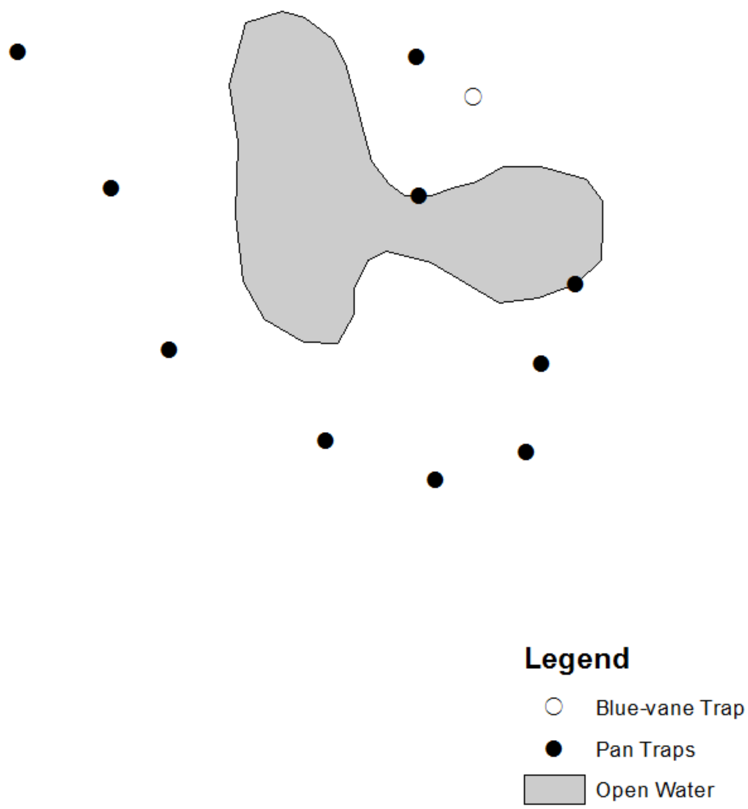


Figure 4. Example of pan trap placement along a permanent transect following an opportunistic path avoiding open water in emergent wetlands.

Figure 5. Pan trap station platform used for sampling of bees in managed emergent wetlands in the lower Mississippi Alluvial Valley of Eastern Arkansas, USA in 2015 and 2016.

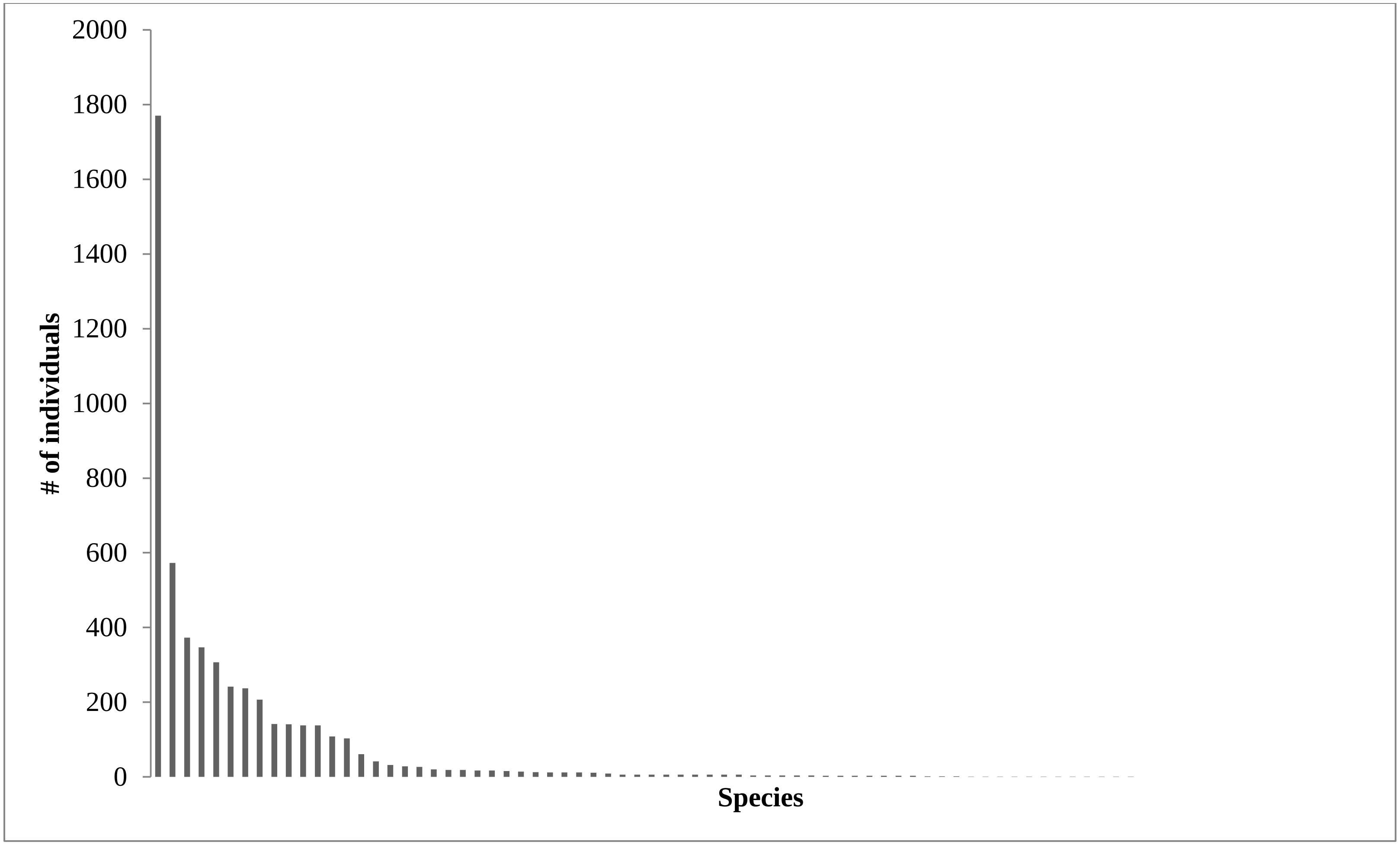


Figure 6. Frequency histogram of number of individuals captured by species in actively managed emergent wetlands in the lower Mississippi Alluvial Valley of Arkansas during the growing season of 2015 and 2016.

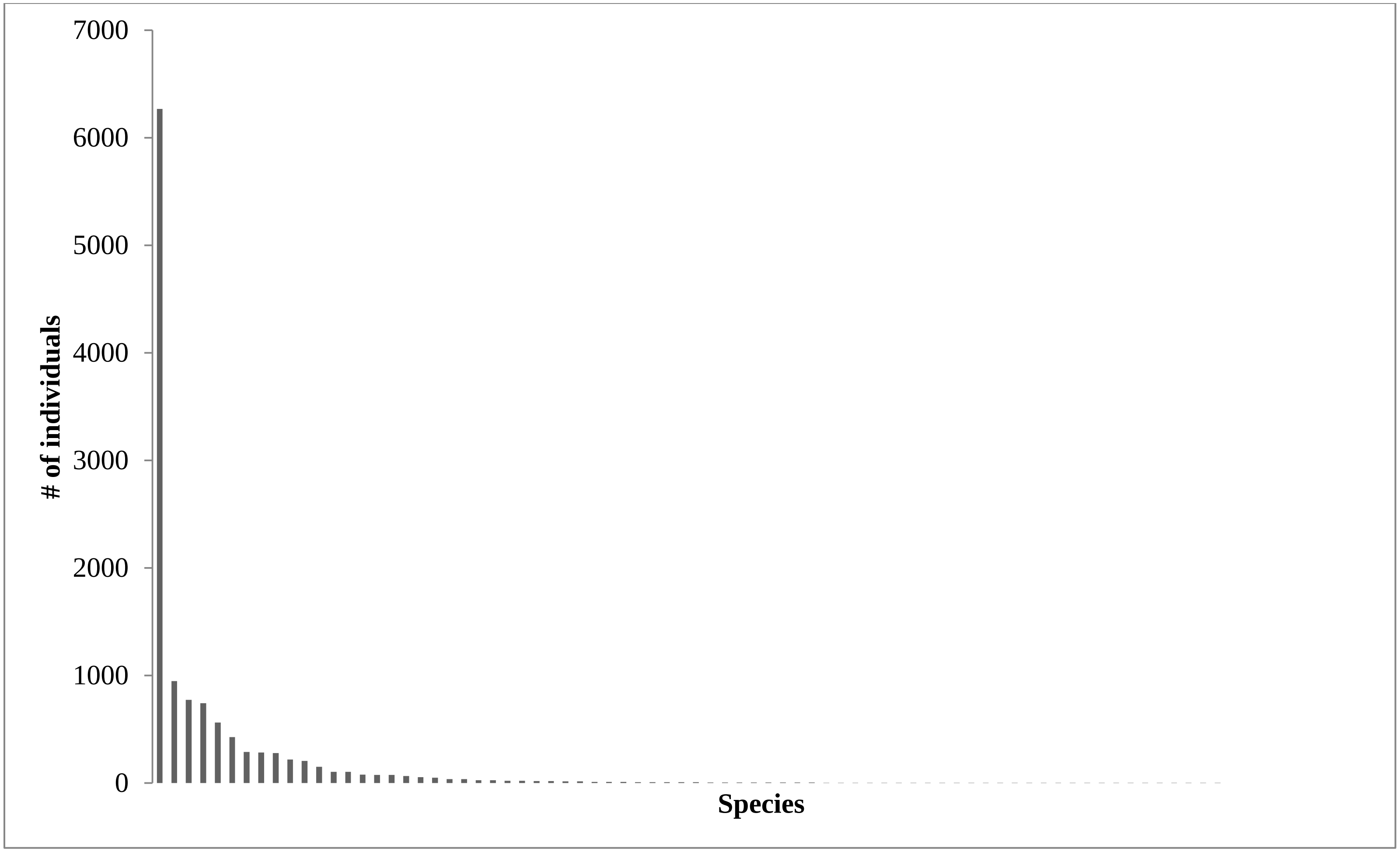


Figure 7. Frequency histogram of number of individuals captured by species in passively managed emergent wetlands in the lower Mississippi Alluvial Valley of Arkansas during the growing season of 2 015 and 2016.

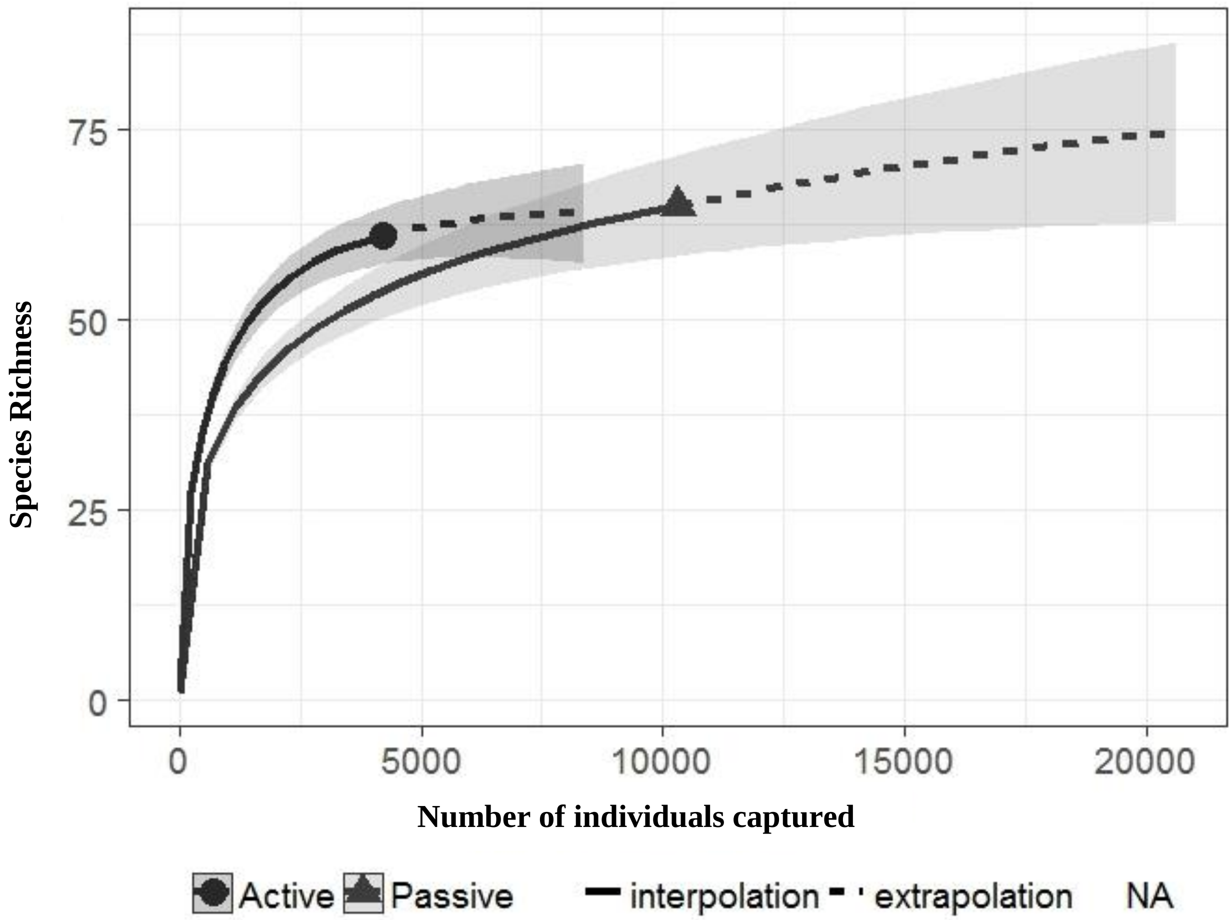


Figure 8. Interpolation and extrapolation of bee species based on number of bees collected in the lower Mississippi Alluvial Valley of Eastern Arkansas, USA in 2016.

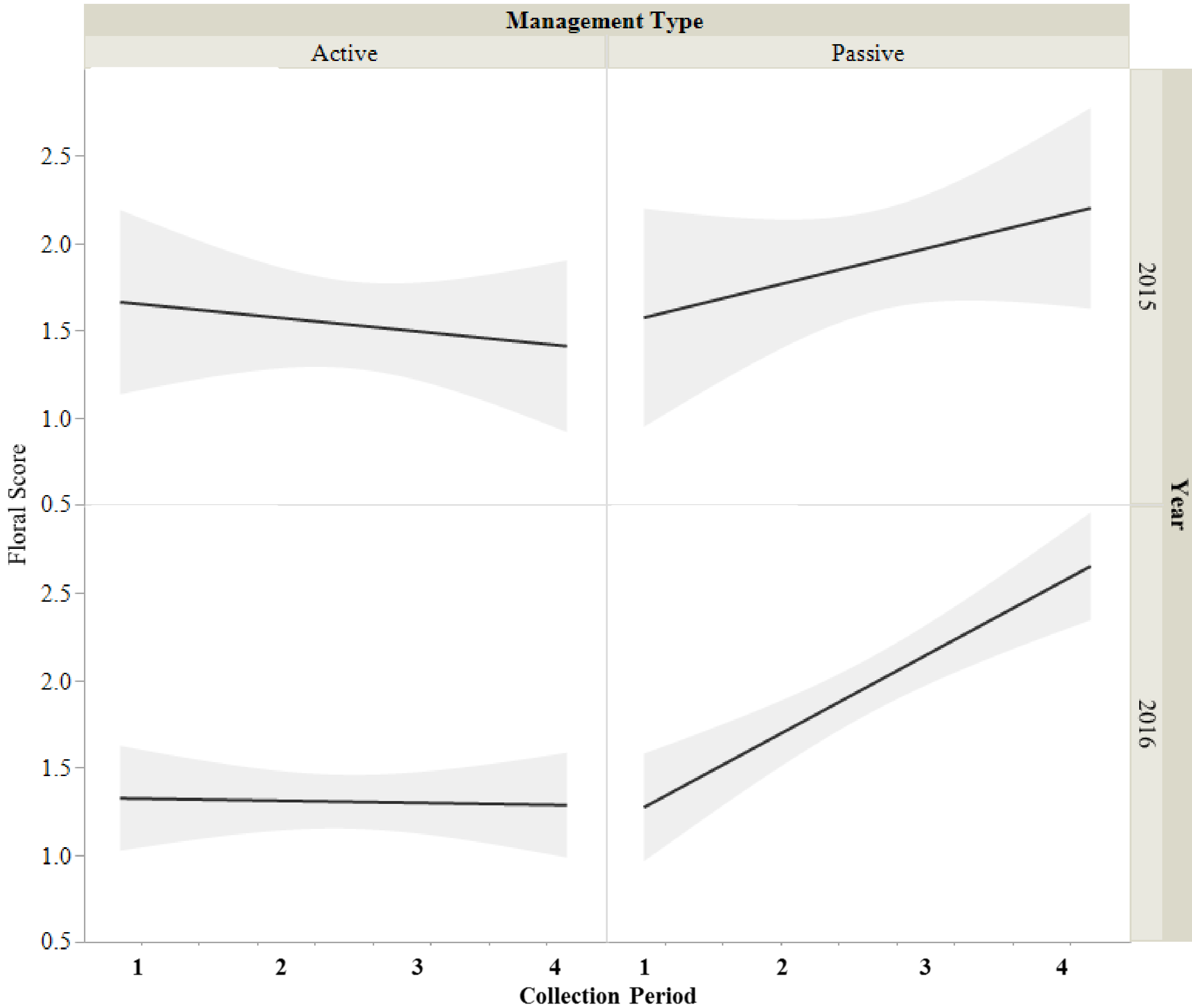


Figure 9. Average floral score throughout the sampling period at actively and passively managed emergent wetlands in the lower Mississippi Alluvial Valley of Eastern Arkansas, USA in 2015 and 2016. The error ellipses represent a 95% confidence interval around the mean.

Table. 1 Site number, site name, ownership, latitude, longitude, county, and year surveyed during 2015 and 2016 and number of surveys per site per year in the lower Mississippi Alluvial Valley of Eastern Arkansas, USA.

						Year Surveyed	
Site Number	Study Site[a]	Ownership[b]	Latitude	Longitude	County	2015	2016
1	Bald Knob NWR	USFWS	35.210614	-91.608737	White	X	X
2	Benson Creek Natural Area	ANHC	34.932789	-91.272666	Monroe	X	X
3	Cache River NWR Cabin	USFWS	35.118294	-91.160946	Woodruff	-	X
4	Cache River NWR Hwy 64	USFWS	35.273179	-91.156697	Woodruff	-	X
5	Cache River NWR Lower Howell Unit	USFWS	35.126017	-91.281515	Woodruff	X	X
6	Cache River NWR Plunkett Farm Unit	USFWS	34.92312	-91.395941	Prairie	X	-
7	Cache River NWR Upper Howell Unit	USFWS	35.112987	-91.259239	Woodruff	X	X
8	White River NWR Farm Pond #2	USFWS	34.311726	-91.121353	Arkansas	-	X
9	Gin Road	Private	34.971019	-91.302877	Woodruff	-	X
10	Gumbo	Private	34.764475	-91.161115	Monroe	X	X
11	Hallum Cemetery Road	Private	34.857014	-91.236786	Monroe	-	X
12	Jackson County Hwy 224	Private	35.495896	-91.273169	Jackson	-	X
13	Oldham Duck Club	Private	35.193993	-90.882663	Cross	-	X
14	Black Swamp WMA Wiville East	AGFC	35.153624	-91.228901	Woodruff	X	X
15	Black Swamp WMA Wiville West	AGFC	35.167774	-91.250383	Woodruff	X	X
16	Dagmar WMA Conway George C	AGFC	34.852126	-91.324203	Monroe	X	X
17	Shirey Bay Rainey Brake WMA North	AGFC	35.994752	-91.217169	Lawrence	X	X
18	Shirey Bay Rainey Brake WMA South	AGFC	35.988878	-91.221381	Lawrence	X	X

[a] NWR – National Wildlife Refuge, WMA – Wildlife Management Area [b] USFWS – U.S. Fish and Wildlife Service, ANHC – Arkansas Natural Heritage Commission, Private – Private land, AGFC – Arkansas Game and Fish Commission

Table 2. Desirable flowering plants observed, collected, and their accession number at actively and passively managed palustrine emergent wetlands sites in the lower Mississippi Alluvial Valley of Eastern Arkansas, USA in 2015 and 2016. Taxonomy is according to Gentry et al. (2013).

Genus species	Family	Common Name	Indicator Status	Accession number
Ammannia sp.	Lythraceae	Toothcup	OBL	
Apocynum cannabium	Apocynaceae	[illegible]hemp	FACU	20323
Asclepias perennis	Asclepiadaceae	Swamp milkweed	OBL	20314
Bidens sp.	Asteraceae	Beggarstick	FACW	
Cephalanthus occidentalis	Rubiaceae	Common buttonbush	OBL	
Coreopsis tinctoria	Asteraceae	Golden tickseed	FAC	20315
Croton capitatus	Euphorbiaceae	Wooly croton	FAC	20311
Echinodorus cordifolius	Alismataceae	Creeping burhead	OBL	20317
Heliotropium indicum	Boraginaceae	Indian heliotrope	FAC	20312
Hibiscus lasiocarpos	Malvaceae	Rosemallow	FACW	20326
Hydrolea uniflora	Hydrophyllaceae	Hydrolea	OBL	20319
Ludwigia peploides ssp. glabrescens	Onagraceae	Floating primrose	OBL	20310
Nelumbo lutea	Nelumbonaceae	American lotus	OBL	20320
Persicaria glabra	Polygonaceae	Denseflower knotweed	OBL	20313
Persicaria hydropiperoides	Polygonaceae	Swamp smartweed	OBL	20324
Persicaria pensylvanica	Polygonaceae	Pennsylvania smartweed	FACW	20322
Persicaria setacea	Polygonaceae	Bog smartweed	OBL	20325
Phyla sp.	Verbenaceae	Frog-fruit	OBL	
Pluchea camphorata	Asteraceae	Camphor pluchea	FACW	20327
Ranunculus sp.	Ranunculaceae	Buttercup	FAC	
Sagittaria brevirostra	Alismataceae	Shortbeak arrowhead	OBL	20318
Sesbania herbacea	Fabaceae	Bigpod sesbania	FACW	
Vicia villosa spp. villosa	Fabaceae	Winter vetch	FAC	20321

Table 3. Wetland bee community species richness, habitat description and locations collected.

No. specimens	No. Species	No. genera	Habitat type	Location	Reference
17,454	84	31	Emergent wetland	Eastern Arkansas, USA	This study
86,500+	77	47	Emergent wetland/Upland edge	South central Nebraska, USA	Park et al. 2017
962	81	-	Wet flatwood	Southeastern Louisiana, USA	Bartholomew & Prowell 2006
1,211	105	22	Wet meadow	Krakow, Poland	Moron et al. 2008

APPENDIX I – Numbers of bees captured by species in actively and passively managed emergent wetlands by sampling period in the lower Mississippi Alluvial Valley of Eastern Arkansas, USA in 2015.

	Actively Managed [a]				Passively Managed [a]			
Genus species	1	2	3	4	1	2	3	4
Agapostemon angelicus/texanus	0	0	9	0	0	5	5	2
Agapostemon sericeus	2	5	3	0	1	8	5	3
Agapostemon splendens	0	0	1	0	0	1	0	0
Agapostemon virescens	0	0	5	0	10	1	46	3
Andrena imitatrix [c,d]	0	0	0	0	2	0	0	0
Andrena macra	10	2	0	0	10	0	0	0
Andrena nasonii [b,d]	1	0	0	0	0	0	0	0
Apis mellifera	0	2	2	3	6	1	2	4
Augochlorella aurata	38	31	193	30	86	219	254	44
Augochloropsis metallica	0	0	2	0	2	0	1	0
Augochloropsis metallica fulgida [c]	0	0	0	0	1	0	0	1
Bombus bimaculatus [c]	0	0	0	0	0	0	1	0
Bombus fraternus [b]	0	0	1	0	0	0	0	0
Bombus impatiens [b]	0	0	0	0	0	0	0	1
Bombus pensylvanicus	1	2	2	4	2	3	1	4
Calliopsis coloradensis [b]	0	0	1	0	0	0	0	0
Ceratina cockerelli [b]	0	0	2	0	0	0	0	0
Ceratina dupla [c,d]	0	0	0	0	0	1	0	0
Ceratina sp. 1	0	2	0	0	0	4	1	0
Ceratina sp. 2 [c,d]	0	0	0	0	0	1	0	0
Eucera hamata	1	0	0	0	47	0	0	0
Eucera rosae [c]	0	0	0	0	1	0	0	0
Florilegus condignus	2	49	29	8	1	36	16	4
Halictus ligatus	4	6	27	1	11	4	0	1
Halictus parallelus	13	17	4	0	25	20	2	0
Hylaeus affinis [b]	1	0	0	1	0	0	0	0
Hylaeus mesillae [b,d]	0	0	1	0	0	0	0	0
Hylaeus nelumbonis	0	5	1	3	7	4	4	1

[a] Collection period 1 (19 May- 20 June), 2 (21 June -13 July), 3 (18 July- 12 August), and 4 (15 August – 18 September). [b] Species collected in active but not passive emergent wetlands in 2015. [c] Species collected in passive but not active emergent wetlands in 2015. [d] Species collected in 2015 but not in 2016.

APPENDIX I – Cont.

	Active [a]				Passive [a]			
Genus species	1	2	3	4	1	2	3	4
Hylaeus ornatus [b]	0	0	1	2	0	0	0	0
Hylaeus sp. 2 [b,d]	1	0	0	0	0	0	0	0
Lasioglossum bruneri [b]	0	0	1	0	0	0	0	0
Lasioglossum coreopsis	3	6	18	5	0	4	4	2
Lasioglossum creberrimum	17	16	11	13	15	32	33	0
Lasioglossum cressonii	0	1	8	1	8	5	2	1
Lasioglossum hartii	6	17	10	17	52	48	47	14
Lasioglossum lustrans	2	1	0	0	3	0	0	0
Lasioglossum nelumbonis	38	9	9	3	43	119	76	14
Lasioglossum pilosum	0	15	13	11	4	0	0	2
Lasioglossum sp. 1 [b]	0	0	1	0	0	0	0	0
Lasioglossum sp. 2 [c,d]	0	0	0	0	0	0	1	1
Lasioglossum sp. 3 [c]	0	0	0	0	0	1	0	0
Megachile albitarsis	0	0	0	3	1	1	1	1
Megachile brevis	1	1	0	2	0	0	1	1
Megachile gentilis	0	0	0	2	0	0	2	1
Megachile petulans	0	1	0	0	0	2	1	0
Melissodes agilis [c]	0	0	0	0	0	0	0	1
Melissodes bimaculata	0	3	24	0	0	8	51	5
Melissodes boltoniae	0	0	0	4	0	0	0	3
Melissodes communis	4	48	33	5	5	38	17	8
Melissodes comptoides	2	27	22	16	2	10	13	14
Melissodes druriella [c]	0	0	0	0	0	0	0	1
Melissodes nivea [c,d]	0	0	0	0	0	0	0	1
Melissodes tepaneca	0	2	0	0	0	1	1	0
Melitoma taurea	0	1	1	0	1	1	0	0
Nomia nortoni [c]	0	0	0	0	0	0	1	0
Panurginus polytrichus [c,d]	0	0	0	0	1	0	0	0

[a] Collection period 1 (19 May- 20 June), 2 (21 June -13 July), 3 (18 July- 12 August), and 4 (15 August – 18 September).[b] Species collected in active but not passive emergent wetlands in 2015. [c] Species collected in passive but not active emergent wetlands in 2015. [d] Species collected in 2015 but not in 2016.

APPENDIX I – Cont.

	Active [a]				Passive [a]			
Genus species	1	2	3	4	1	2	3	4
Perdita sp.1 [c]	0	0	0	0	0	0	0	1
Ptilothrix bombiformis	0	56	51	7	1	77	48	9
Svastra atripes	0	0	4	3	0	0	1	9
Svastra cressonii [b]	0	1	0	1	0	0	0	0
Svastra obliqua	0	2	15	1	0	2	8	1
Svastra petulca [b]	0	0	1	0	0	0	0	0
Xenoglossa strenua [d]	0	0	0	1	0	0	1	0
Xylocopa virginica [b]	0	2	0	0	0	0	0	0

[a] Collection period 1 (19 May- 20 June), 2 (21 June -13 July), 3 (18 July- 12 August), and 4 (15 August – 18 September).[b] Species collected in active but not passive emergent wetlands in 2015. [c] Species collected in passive but not active emergent wetlands in 2015. [d] Species collected in 2015 but not in 2016.

APPENDIX II - Counts of bees by species collected in actively and passively managed emergent wetlands by sampling period in the lower Mississippi Alluvial Valley of Eastern Arkansas, USA in 2016.

	Active				Passive			
Genus species	1	2	3	4	1	2	3	4
Agapostemon angelicus/texanus	0	2	19	2	0	4	23	7
Agapostemon sericeus	1	2	3	1	0	5	9	4
Agapostemon splendens [c]	0	0	0	0	0	1	1	0
Agapostemon virescens	2	2	5	0	39	16	54	28
Andrena macra	4	0	0	0	5	0	0	0
Andrena rudbeckiae [d]	0	3	0	0	0	1	0	0
Anthophorula asteris [b,d]	0	0	0	1	0	0	0	0
Apis mellifera	22	13	3	16	25	43	32	34
Augochlora pura [d]	1	0	0	2	0	1	0	0
Augochlorella aurata	98	172	960	248	591	1091	2751	1051
Augochloropsis metallica	0	3	1	0	2	4	9	0
Augochloropsis metallica fulgida	0	1	1	0	1	0	1	0
Bombus bimaculatus [b]	3	1	0	0	0	0	0	0
Bombus fraternus [c]	0	0	0	0	0	1	0	1
Bombus griseocollis [d]	1	2	2	1	0	1	1	0
Bombus impatiens	2	0	1	1	2	0	0	0
Bombus pensylvanicus	0	1	0	2	0	2	6	8
Calliopsis coloradensis [b]	0	2	1	2	0	0	0	0
Ceratina cockerelli [b]	0	0	1	0	0	0	0	0
Ceratina sp. 1	3	3	3	1	6	9	4	0
Colletes nudus [b,d]	1	0	0	0	0	0	0	0
Diadasia enavata [d]	20	6	1	0	1	2	1	3
Dianthidum subrufulum [b,d]	0	0	1	0	0	0	0	0
Dieunomia triangulifera [b,d]	0	1	0	0	0	0	0	0
Eucera hamata	16	0	0	0	30	0	0	0
Eucera rosae	11	0	1	0	2	0	0	0
Florilegus condignus	5	20	11	14	14	213	81	55
Halictus ligatus	21	13	27	9	38	35	10	4

[a] Collection period 1 (19 May- 20 June), 2 (21 June -13 July), 3 (18 July- 12 August), and 4 (15 August – 18 September).[b] Species collected in active but not passive emergent wetlands in 2016. [c] Species collected in passive but not active emergent wetlands in 2016. [d] Species collected in 2016 but not in 2015.

APPENDIX II – Cont.

Genus species	Active 1	Active 2	Active 3	Active 4	Passive 1	Passive 2	Passive 3	Passive 4
Halictus parallelus	44	54	6	0	31	101	32	3
Halictus rubicundus [d]	2	1	0	0	4	0	0	0
Hylaeus affinis	0	4	0	0	1	0	7	0
Hylaeus nelumbonis	3	3	4	0	13	13	9	3
Hylaeus ornatus	0	0	0	1	1	2	2	0
Hylaeus sp. 1 [c,d]	0	0	0	0	0	0	1	0
Lasioglossum bruneri	1	1	4	2	2	13	1	0
Lasioglossum callidum [c,d]	0	0	0	0	1	0	0	0
Lasioglossum coreopsis	24	63	18	5	21	23	20	2
Lasioglossum creberrimum	84	82	62	22	325	212	105	26
Lasioglossum cressonii	2	3	4	9	13	6	19	10
Lasioglossum hartii	47	34	52	54	101	135	84	73
Lasioglossum hitchensi [c,d]	0	0	0	0	0	0	0	1
Lasioglossum lustrans	3	0	0	0	12	0	0	2
Lasioglossum nelumbonis	69	35	33	14	203	88	79	105
Lasioglossum pilosum	16	29	30	27	41	37	13	4
Lasioglossum sp. 1	0	2	0	0	0	1	2	0
Lasioglossum sp. 3 [c]	0	0	0	0	1	0	0	0
Megachile albitarsis	1	2	9	5	0	1	1	2
Megachile brevis	1	1	2	11	1	1	4	13
Megachile campanulae [c,d]	0	0	0	0	0	0	1	0
Megachile gentilis	0	0	1	3	0	0	4	0
Megachile mendica [d]	0	0	0	1	0	0	0	1
Megachile petulans [b]	0	1	1	0	0	0	0	0
Megachile texana [d]	0	0	2	0	0	0	1	0
Melissodes agilis [c]	0	0	0	0	0	3	1	0
Melissodes bimaculata	0	26	186	3	1	31	145	18
Melissodes boltoniae	0	0	3	4	0	0	0	8

[a] Collection period 1 (19 May- 20 June), 2 (21 June -13 July), 3 (18 July- 12 August), and 4 (15 August – 18 September).[b] Species collected in active but not passive emergent wetlands in 2016. [c] Species collected in passive but not active emergent wetlands in 2016. [d] Species collected in 2016 but not in 2015.

APPENDIX II – Cont.

	Active				Passive			
Genus species	1	2	3	4	1	2	3	4
Melissodes communis	21	85	103	48	10	83	72	41
Melissodes comptoides	12	109	106	29	2	76	69	94
Melissodes denticulata [b,d]	0	0	2	1	0	0	0	0
Melissodes druriella	0	0	3	3	0	0	3	5
Melissodes tepaneca	2	0	0	0	0	1	0	2
Melissodes trinodis [d]	0	1	1	0	0	0	0	2
Melitoma taurea	1	1	2	0	6	6	2	0
Nomia nortoni [c]	0	0	0	0	0	1	2	0
Perdita foveata [c,d]	0	0	0	0	1	0	0	0
Perdita sp.1	2	2	0	2	0	1	0	1
Ptilothrix bombiformis	10	250	170	29	8	401	279	45
Sphecodes mandibularis [c,d]	0	0	0	0	0	1	0	0
Svastra atripes	0	1	30	4	0	0	41	24
Svastra cressonii	0	1	1	0	0	4	3	0
Svastra obliqua	0	7	76	2	0	2	16	7
Svastra petulca [c]	0	0	0	0	0	1	0	0
Triepeolus quadrifasciatus [c,d]	0	0	0	0	0	0	1	0
Xylocopa virginica	2	5	4	0	7	1	1	1

[a] Collection period 1 (19 May- 20 June), 2 (21 June -13 July), 3 (18 July- 12 August), and 4 (15 August – 18 September).[b] Species collected in active but not passive emergent wetlands in 2016. [c] Species collected in passive but not active emergent wetlands in 2016. [d] Species collected in 2016 but not in 2015.

CHAPTER 2: MOVEMENT OF BEES FROM EMERGENT WETLANDS INTO ADJACENT SOYBEAN FIELDS

ABSTRACT

USDA Farm Bill emergent wetlands create valuable floral resources for pollinators throughout the growing season and occur adjacent to croplands throughout the Southeastern United States. Bee communities that use renovated emergent wetlands have been poorly documented and their benefits to surrounding croplands are not fully understood. In this study, I compared bee community dynamics in both soybean fields and adjacent Farm Bill emergent wetlands while also documenting flight distance into soybean fields in Monroe and Woodruff Counties in the lower Mississippi Alluvial Valley of Arkansas. Solitary bees (Hymenoptera: Apoidea) were surveyed using pan traps, blue-vane trap, and sweep nets. I found that the probability of detecting a species in soybean fields (0.92, 95% CI = 0.822-1.00) and adjacent emergent wetlands (0.87, 95% CI = 0.753-1.00) was high. My estimated species richness in soybean fields (40.5, 95% CI = 37.00-45.00) overlapped with my estimated species richness in adjacent emergent wetlands (39.1, 95% CI = 34.00 – 45.14). Shannon-Wiener diversity estimates were not significantly different between soybean fields (1.69, 95% CI = 0.731- 2.646) and adjacent emergent wetlands (1.74, 95% CI =1.042 - 2.437). There were unique species specific to each habitat type. By trap type, in soybean fields, I captured more bees in pan traps (1,785 individuals, 31 species) then blue vane traps (294 individuals, 26 species), and finally in sweep nets (65 individuals, 11 species). The most abundant species collected in soybean fields and emergent wetlands included *Augochlorella aurata*, *Lasioglossum creberrimum*, *Ptilothrix bombiformis*, *Melissodes communis*, *Melissodes comptoides*, and *Melissodes bimaculata*. I documented bee flight distance up to 150 meters into soybean fields from the adjacent wetland edge. Soybean fields provide supplemental nectar and pollen sources during bloom for bee communities while also benefiting from cross-pollination from source bee populations in adjacent natural areas. Farm Bill programs like the Wetland Reserve Program can create suitable

habitat to support and maintain bee communities that in turn can enhance pollination in adjacent croplands and so further justifies this important conservation program.

INTRODUCTION

Insect pollinators supply ecological services to crops and flowering plants by pollinating many wild and domesticated plants and increasing the size and quality of harvest in agriculture production systems (Allen-Wardell et al. 1998; Delaplane and Mayer 2000; Fontaine et al. 2006). Despite the European honeybee's (*Apis mellifera*) effectiveness as a pollinator for many crops, the risks associated with reliance on a single managed pollinator species by the agricultural community have become evident over the past decades as North American honeybee populations have declined by 25% due to the parasitic mite *Varroa destructor*, Colony Collapse Disorder, farming intensification, habitat fragmentation, habitat loss, and agrochemicals (Steffan-Dewenter et al. 2002; Tylianakis et al. 2005; Biesmeijer et al. 2006; National Research Council 2006; VanEngelsdorp et al. 2009). Though cotton (*Gossypium spp.*), rice (*Oryza sativa*), and soybeans (*Glycine max*) are considered autogamous (self-pollinating), cross-breeding (via pollinators) helps increase yield, produce more viable seed, and enhance genetic diversity of the crop (Kremen et al. 2002; Pu et al. 2014).

Emergent wetlands occur adjacent to croplands throughout the Southeastern United States and create valuable floral resources for pollinators throughout the growing season. Bee communities that use emergent wetlands have been poorly documented and their benefits to plant communities on surrounding lands are not fully understood. Also, solitary bee communities that travel between emergent wetlands and adjacent croplands have not been documented. In this study, I compared pollinator communities between emergent wetlands and adjacent soybean fields, while documenting flight distance into crop fields.

STUDY AREA

I conducted this study in the lower Mississippi Alluvial Valley (LMAV) of Arkansas (Fig. 1). The LMAV is bounded on the southwest by the West Gulf Coastal Plain and Ouachita Mountains, on the northwest by the Ozark Mountains, and on the east by the Mississippi River. The LMAV of Arkansas is a result of large rivers forming the character of the land. The Arkansas River, White River, St. Francis River, Black River, Cache River, L'Anguille River, and Mississippi River have flown through this region, cutting away older deposits and building up deposits of sand, gravel, and clay (Crow 1974). The soils in the LMAV of Arkansas are mainly comprised of clay, sand, and loess, but change with increasing distance from rivers. Historically the LMAV of Arkansas was comprised of vast wetlands in the floodplains and prairies between the floodplains (Branner 1908; Foti 2001). I argue that these prairies were wet prairies based on hydric soil characteristics found there (Branner 1908). The elevation of the LMAV varies by ~46 m throughout the entire 402 km length of the LMAV in Arkansas (Crow 1974). The region is now dominated by ~61% agriculture (soybean, rice, corn, sorghum, and cotton) with fragments of remnant emergent (1%) and bottomland hardwood (17%) forest (King et al. 2006; USDA-NASS 2016). The LMAV averages 118-134 cm of rainfall annually with an average of 35 cm of rainfall between June-September (Scott et al. 1998).

I surveyed palustrine emergent wetlands and their adjacent soybean fields in Monroe and Woodruff counties of Arkansas (Fig. 1). All of the emergent wetland sites I surveyed were in row crops before being converted back into emergent wetlands. Most of the sites I surveyed were impounded and were either being reestablished to functioning emergent wetlands through the agricultural conservation easement program (ACEP), previously known and hereafter referred to as the Wetland Reserve Program (WRP), or were reverting back to emergent wetlands through natural succession. Palustrine emergent wetlands are classified as areas <8 ha in size, lacking active wave-formed or bedrock shoreline features, water depth in the deepest part of the basin <2.5 m at low water, and salinity due to ocean-derived salts less than 0.5 ppt (Cowardin et al. 1979). All wetland sites surveyed had not been manipulated during the last 5 years. These emergent wetlands were allowed to naturally evaporate through the growing season which retained soil moisture, and provided a longer flowering period for hydrophytic plants such as *Hydrolea uniflora* and *Ludwigia peploides ssp. glabrescens*. Reduced disturbance (e.g. disking, mowing, burning) also sustained floral availability on these emergent wetlands through the growing season for bees. Wetland sites used included one Natural Area (NA) managed by the Arkansas Natural Heritage Commission (ANHC), and three private lands (Table 1), and ranged in size from 3.6 - 11 ha. Soybean fields included four private lands adjacent to emergent wetlands previously mentioned (Table 1), and ranged in size from 4.8 - 25 ha. All study site pairs were >2 km apart to reduce the chance of bees moving among sites (Araujo et al. 2004).

METHODS

Bee Surveys

In 2016, I sampled 4 paired emergent wetland and soybean sites. Sampling took place during 2 soybean reproductive stages: reproductive stage 1 (R1) and reproductive stage 2 (R2). R1 is a soybean plant having at least one flower appearing on any node on the main stem, whereas R 2 is a soybean plant having multiple flowers on the main steam with at least one flower open at one of the two uppermost main-stem nodes (McWilliams et al. 2009). Emergent wetland sites and their adjacent soybean field were sampled on the same day, except for the Hallum field site during the first collection period. Hallum's emergent wetland was sampled on 2

August and the adjacent R1 soybean field was sampled on 5 August. I sampled bees on 20 June and 28 June (Benson Creek NA), 13 July and 20 July (Gin), 1 August and 8 August (Gumbo), and 2/5 August and 9 August (Hallum).

I collected bees using pan traps (Fig. 2; Droege et al. 2009; Kirk 1984; Leong and Thorp 1999), blue-vane traps (Kimoto et al. 2012; Stephen and Rao 2005), and sweep nets (Roulston et al. 2007; Stephen and Rao 2007). Pan trapping was used because it is known to attract smaller bodied bees and avoids the need for skilled collectors (Cane et al. 2000; Westphal et al. 2008). Blue-vane traps were used to collect medium to large bodied bees (Geroff et al. 2014) and sweep nets were used to collect bees that might not be represented in either pan or blue-vane traps (Cane et al. 2000;Stephen and Rao 2007). I captured bees by placing 10 pan trap stations throughout passively managed emergent wetlands along a permanent transect with a random starting location, a set interval of ~20m between stations, while following an opportunistic path avoiding open water. Ten pan trap stations were used in the adjacent soybean fields. Pan trap stations in soybean fields were arranged in a rectangular block, perpendicular to the adjacent wetland with a 50 m buffer between the wetland/soybean interface. Pan trap stations were placed along two parallel transects that were 30 meters apart. Individual pan trap stations were placed 25 meters apart, extending 100 meters into soybean fields (Fig. 3), thus the furthest pan trap was 150 m from the wetland edge. Pan trap station platforms held 3, 266 mL cups (Solo, Lake Forest, IL) that were painted either fluorescent blue, fluorescent yellow, or white (Guerra Paint and Pigment Corp., New York, NY; Krylon CoverMaxx, Cleveland, OH). These cups were filled ¾ full with a soapy water (Dawn Ultra – Original Scent, Cincinnati, OH) mixed daily to capture visiting bees. Pan trap platforms were adjusted to the average vegetation height surrounding the platform at every collection point in passively managed emergent wetlands and were placed at flowering height in soybean fields. The pan traps were set out between 0700-900 hrs and were picked up the same day between 1800-2000 hrs. Samples were combined at each pan trap station and strained using an 180μm sieve to isolate the insects from the soapy water mix. The sample was then transferred to a Whirl-Pak (Nasco, Fort Atkinson, WI) in 70% ethanol for storage. Thus there were 10 Whirl-Pak bags from the 10 pan trap stations at a given site. I used one blue-vane trap (1.89 L. jar) per passively managed emergent wetland suspended from a shepherds hook pole, with the bottom of the trap ~ 1 m above the ground (Kimoto et al. 2012; Stephen and Rao 2005). I used three blue vane traps (1.89 L. jar) per soybean field placed at 0 m, 50 m, and 100 m directly between the two parallel transects. The blue-vane traps were filled with ~475 ml of the same soapy mix as the pan traps. These blue-vane traps were placed and collected on the same schedule as the pan traps. Samples were also strained using a 180 μm sieve and were placed in a Whirl-Pak in 70% ethanol for storage. The blue vane traps were positioned in a location that was visible across the entire field site. These blue-vane traps were placed and collected on the same schedule as the pan traps. Samples were also strained using a sieve and were placed in a Whirl-Pak in 70% ethanol for storage. I used sweep netting to sample for bees that were not attracted to the pan trap or the blue-vane trap. In passively managed emergent wetlands, I conducted 5 random transects of 50 sweeps apiece totaling 250 sweeps. These sweeps were conducted in different vegetation types at each site to capture bees that may prefer particular vegetation. In soybean fields, I conducted four random transects of 62-63 sweeps apiece totaling 250 sweeps. These sweeps were conducted perpendicular to the rectangular block to not disturb the pan and blue-vane trapping area. These sweeps were collected perpendicular to the 0-25m, 25-50m, 50-75m, and 75-100m pan trap stations. Sweep netting was conducted between 0900-1000 hours in passively managed emergent wetlands. Sweep netting was conducted at 0900 and 1200 hrs in soybean fields. All sweep net samples were placed in one gallon Ziploc bags (S.C. Johnson, Racine, WI) and were placed in the freezer until processed. All bees were washed, dried, pinned, and labeled. I identified all bees to species, when possible, or to genus using discoverlife.org (Schuh et al. 2010). I confirmed identifications with M. Arduser – Missouri Department of Conservation (retired); H. Ikerd – USDA-Agricultural Research Service Pollinating Insect-biology, Management, Systematics Research Unit; T. Griswold – USDA-Agricultural Research Service, Pollinating Insect-biology, Management, Systematics Research Unit; J. S. Ascher – American Museum of Natural History; and K. Parys – USDA-Agricultural Research Service, Southern Insect Management Research Unit.

DATA ANALYSIS

To estimate probability of detection, species richness, extinction (ϕ), turnover (Γ), and colonization between soybean fields and emergent wetland sites, I used the programs SPECRICH (Burnham and Overton 1979; Hines 1996) and COMDYN4 (Nichols et al. 1998). I found that in all cases, the data fit the model (M(h) GOF test, $p>0.05$ for all tests). Detection probabilities <~80% suggest that raw species counts do not represent the true number of species that occur at those sites (MacKenzie et al. 2002). Hence, if it met the assumptions I relied on estimated species richness values to describe bee communities on both the actively and passively managed sites. To assess community structure I calculated Shannon – Wiener diversity indices for bee communities in both treatment types using $H = \sum - (Pi * \ln Pi)$ for each site over the entire growing season. Evenness was calculated using $E = H/\ln(S)$ for each site over the entire growing season where S is the species richness (Elliott 1990). The indices data were then analyzed using a one-way ANOVA with 2 treatment types.

RESULTS

I captured 2,144 individual bees made up of 37 species and 15 genera in soybean fields; 6 (16%) were singletons. I captured 931 individual bees made up of 34 species and 16 genera in adjacent emergent wetlands; 12 (35%) were singletons. The most abundant species collected in soybean fields and emergent wetlands include *Augochlorella aurata*, *Lasioglossum creberrimum*, *Ptilothrix bombiformis*, *Melissodes communis*, *Melissodes comptoides*, and *Melissodes bimaculata*. I found that the probability of detecting a species in soybean fields was 0.92 (95% CI = 0.822-1.00) while detecting a species in adjacent emergent wetlands was 0.87 (95% CI = 0.753-1.00). Because the GOF test indicated the soybean data fit the heterogeneity model (χ^2 = 3.6, P = 0.06), I used the estimated species richness of 40.5 (95% CI = 37.00-45.00). For the adjacent emergent wetland sites, the GOF test indicated the data fit the heterogeneity model (χ^2 = 0.077, P = 0.78) so I used the estimated species richness of 39.1 (95% CI = 34.00-45.14). The 95% confidence intervals for species richness estimates overlapped indicating that both soybean fields and emergent wetlands supported similar species richness. The extinction probability (ϕ) is the proportion of species in actively managed emergent wetlands still present in passively managed emergent wetlands. The species turnover (Γ) is the proportion of species in passively managed emergent wetlands still present in actively managed emergent wetlands. I also found that the probability of a species being present in soybean fields also occurring in emergent wetlands extinction probability (ϕ = 0.7681, 95% CI = 0.539658-0.945)1.00) and species turnover (Γ = 0.8197, 95% CI = 0.658807-1.00) was high. Colonization is the number of species not present in actively managed emergent wetlands, but present in passively managed emergent wetlands. I found that local colonization was 8.5 (95% CI = 0.0-17.0). Of the 37 species collected in soybean fields, 11 (30%) were unique to soybeans; whereas 8 (24%) of 34 species found in the adjacent emergent wetlands were unique to wetlands (Table 2). Three species; *Lasioglossum disparile*, *Lasioglossum versatum*, and *Triepeolus lunatus*, were only captured in soybeans fields throughout the entire study (Chapter 1).

One of the passively managed emergent sites (Gumbo) had the lowest Shannon-Wiener diversity index (H = 0.347 in soybeans and H = 0.976 in emergent wetlands) and the lowest evenness (J = 0.12 in soybeans and J = 0.345 in emergent wetlands) of all the sites. The average Shannon-Wiener index was 1.688 (95% CI = 0.731- 2.646) for soybeans whereas the average Shannon-Wiener index was 1.74 (95% CI =1.042 - 2.437) for emergent wetlands. There was no difference in diversity between treatment types ($F_{1,7} = 0.007$, $p = 0.94$). Species evenness of soybeans on average was 0.54 (95% CI = 0.225 - 0.855) and emergent wetlands on average was 0.59 (95% CI = 0.385 – 0.797). There was no difference in evenness between treatment types ($F_{1,7} = 0.071$; $p = 0.8$). I documented higher abundances of bees in soybean fields (2,144) during bloom than their adjacent emergent wetlands (931).

Mean abundance of bees captured by pan traps, blue vane traps, and sweep net transects were not statistically different (Fig. 4, 5, 6) at varying distances into soybean fields at R1 and R2 reproductive stages. The variation around the means was high due to the differing individuals captured at each site and should be considered. I detected bees moving up to 150 m into the soybean fields beyond the wetland edge. Per trap type, the most bees were captured in pan traps (1,785 individuals, 31 species), blue vane traps (294 individuals, 26 species), and sweep nets (65 individuals, 11 species) in soybean fields (Table 2).

DISCUSSION

Farm bill programs like the Wetland Reserve Program have the capacity to create source populations of bee diversity in a mosaic of agriculture wetland interfaces. These emergent wetlands are rare across the landscape, but have survived in large part due to easement programs through the Farm Bill. Palustrine emergent wetlands provide sufficient habitat to support a sustainable native bee community in the present of anthropogenic disturbance while providing ecological services to the surrounding plant communities including agricultural fields. Solitary bees were documented in emergent wetlands at lower quantities than in adjacent soybean fields during the same collection timeframe indicating a movement from the emergent wetlands into the soybean fields. Although bee abundances collected were not significantly different, I would argue that bees were taking advantage of the supplemental resource soybeans flowers provide during bloom. The lack of usable habitat in agricultural areas has prompted the creation of other easement programs (e.g. CP-42) and university extension example plots demonstrating the benefit of providing pollinator habitat adjacent and within agricultural production. These ecological services are important to the farming community and are slowly being incorporated into agricultural practices.

Pollinators have been documented across a range of habitat types traveling between natural areas and managed agricultural fields (Garibaldi et al. 2011). Erickson et al. (1978) found that soybean yields were significantly higher at distances up to 100 m from the *A. mellifera* apiaries than at greater distances into fields. I documented solitary bees 150 m into soybean fields with higher abundances that non-native honey bees. Honey bees are known for their abilities to travel great distances (17 km) to forage and also as local pollinators, but their native bee counterparts are often over looked and understudied. Garibaldi et al. (2013) found that visitation by wild insects and honey bees promoted fruit set independently, thus honey bees are supplementing pollination instead of substituting for native bees. This reiterates the importance of maintaining our native bee populations through management and restoration of natural areas.

Honey bees are also known to exploit floral resources that native bees need for survival. Though more honey bees in the environment would seem to increase pollination events, Garibaldi et al. (2013) found that an increase in wild insect visitation enhanced fruit set by twice as much as an equivalent increase in honey bee visitation. Also, honey bees do not tend to forage for long periods of time per foraging event. Mattu et al. (2012) recorded honey bees foraging on apple blossoms for 12.15-16.13 minutes per foraging event. Whereas Ordway (1966) observed *Augochlorella aurata*, a common eusocial bee found at all of my study sites, foraged for a minimum of 20 minutes and on average foraged for an hour before returning to their nest. This highlights the impact solitary bees have on cross-pollinating agricultural crops and in particular soybeans. Gill (2015) collected bees from soybean fields in Iowa during bloom and captured 50 species predominately in pan traps, as in this study. Gill (2015) also reported of the bees with pollen present, 38% contained soybean pollen alone or intermixed with other pollen grains.

I believe these restored emergent wetlands serve as a refuge for sensitive invertebrate communities from anthropogenic disturbances, while promoting groundwater recharge, soil retention, and providing habitat to a range of flora and fauna. These conservation easements also provide a “free source” of pollinators to surrounding croplands by promoting native bee habitat and biodiversity. These semi-natural habitats can also provide a source of non-bee pollinators that apiaries cannot. Radar et al. (2016) found that non-bees increased fruit set independently of bee visitations and performed 25-50% of the total crop flower visits. Native bees harbored in emergent wetlands and other semi-natural habitats can serve as insurance against the loss of non-native honey bees (Winfree et al. 2007). These data should also serve as a pilot study for future projects examining how native pollinators from wetlands impact adjacent soybean and other agriculture production. Future studies should also examine maximum flight distances of solitary bees into croplands from adjacent semi-natural patches.

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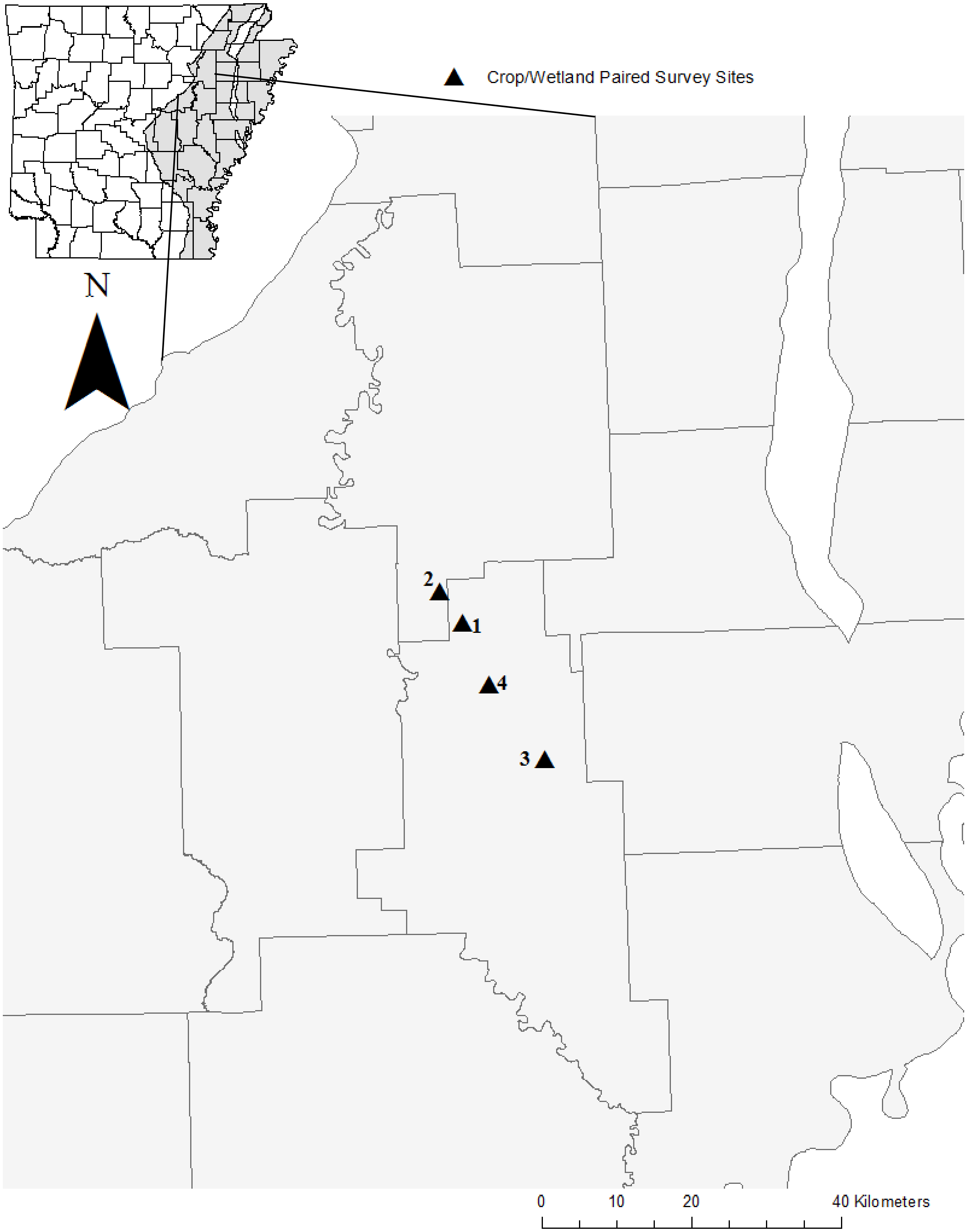

Figure 1. Distribution of soybean/wetland paired surveyed for bees in the Lower Mississippi Alluvial Valley of eastern Arkansas, USA in 2016. See Table 1 for site names and coordinates.

Figure 2. Pan trap station platform used for bi-weekly sampling of bees in managed emergent wetlands and soybean fields in the lower Mississippi Alluvial Valley of Eastern Arkansas, USA in 2015 and 2016.

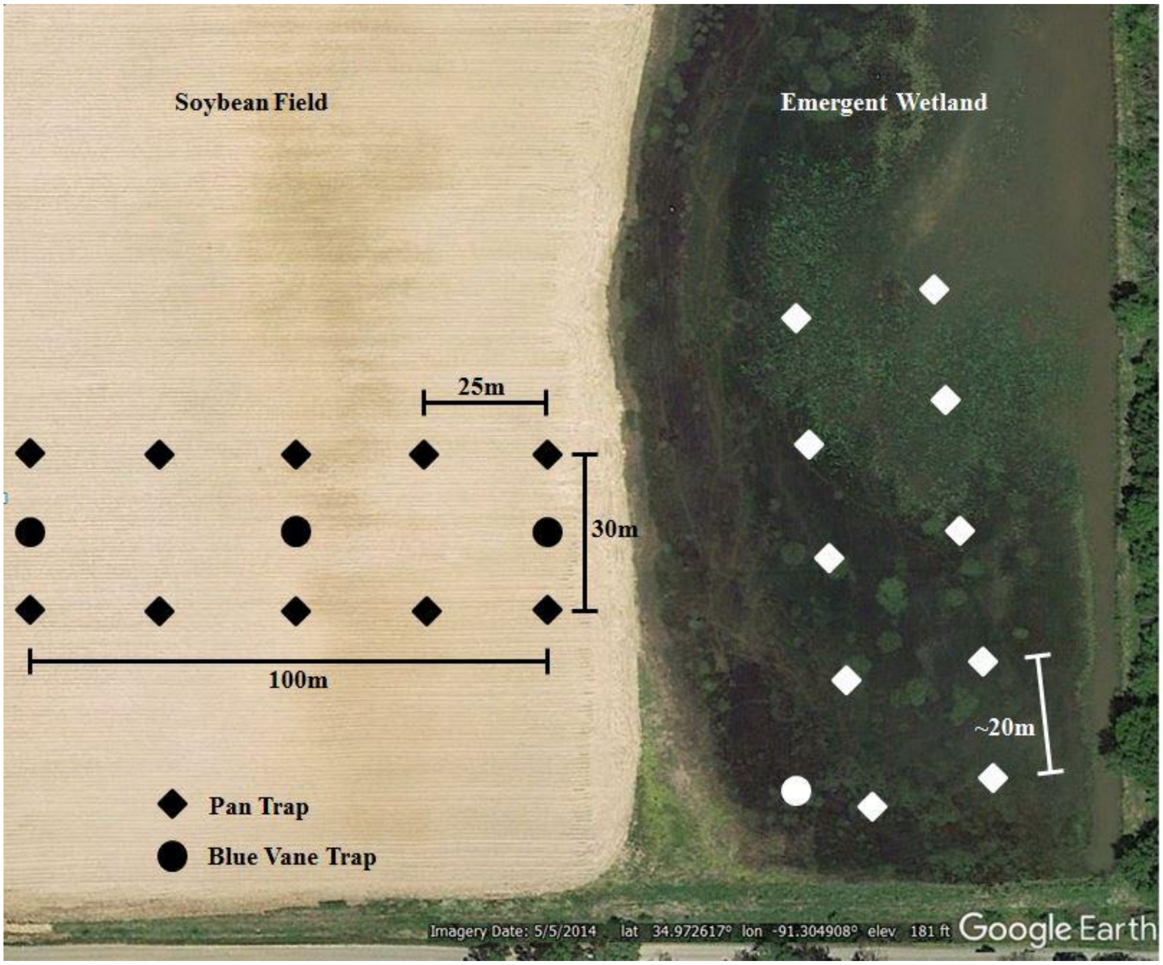

Figure 3. Pan and vane trap placement example in soybeans (black) and the adjacent emergent wetland (white) at the Gin Road site (Private; Cotton Plant, AR) in the lower Mississippi Alluvial Valley of eastern Arkansas, USA in 2016.

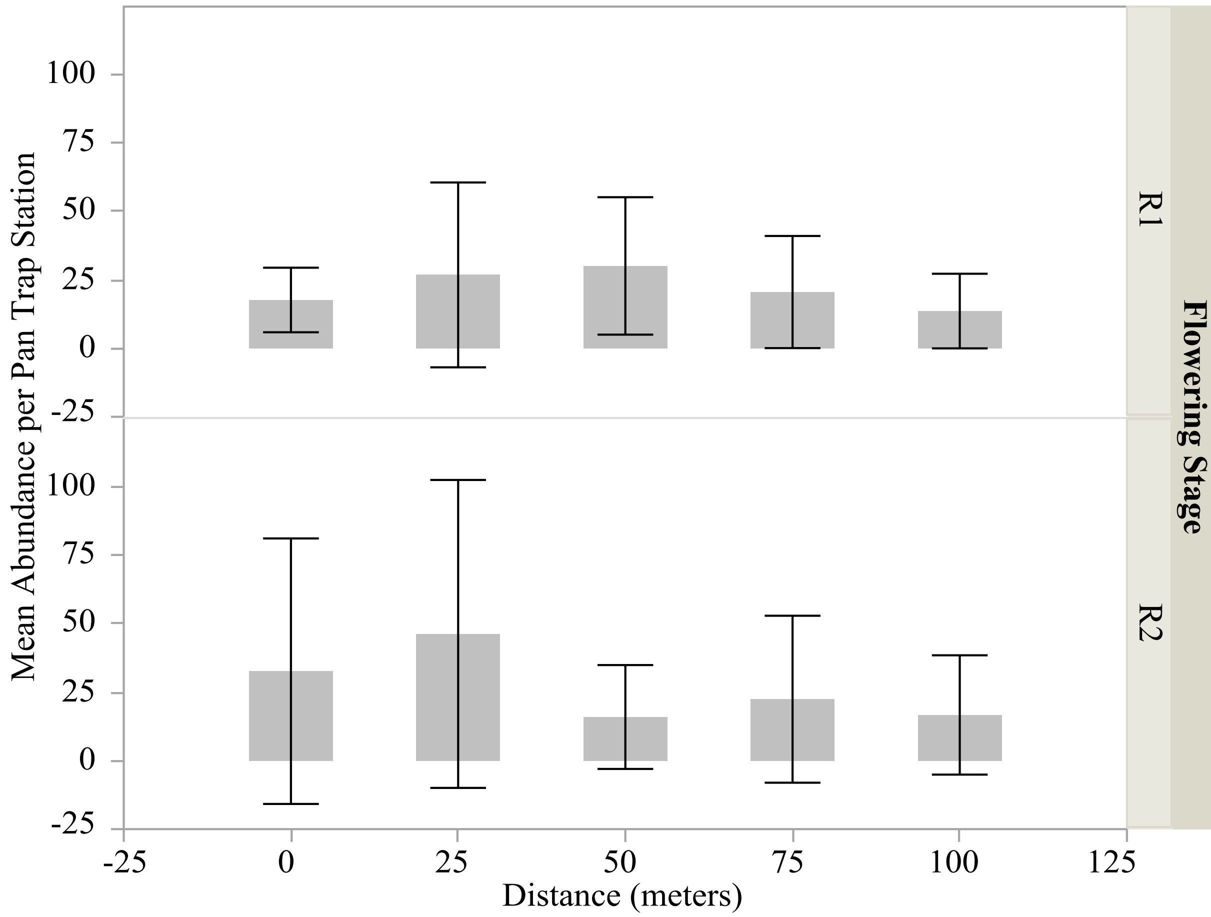

Figure 4. Mean abundance of bees captured per pan trap station in soybean fields at differing flowering stages with increasing distance from the wetland buffer in the Lower Mississippi Alluvial Valley of Eastern Arkansas, USA in 2016. Error bars are constructing using 95% confidence intervals of the mean.

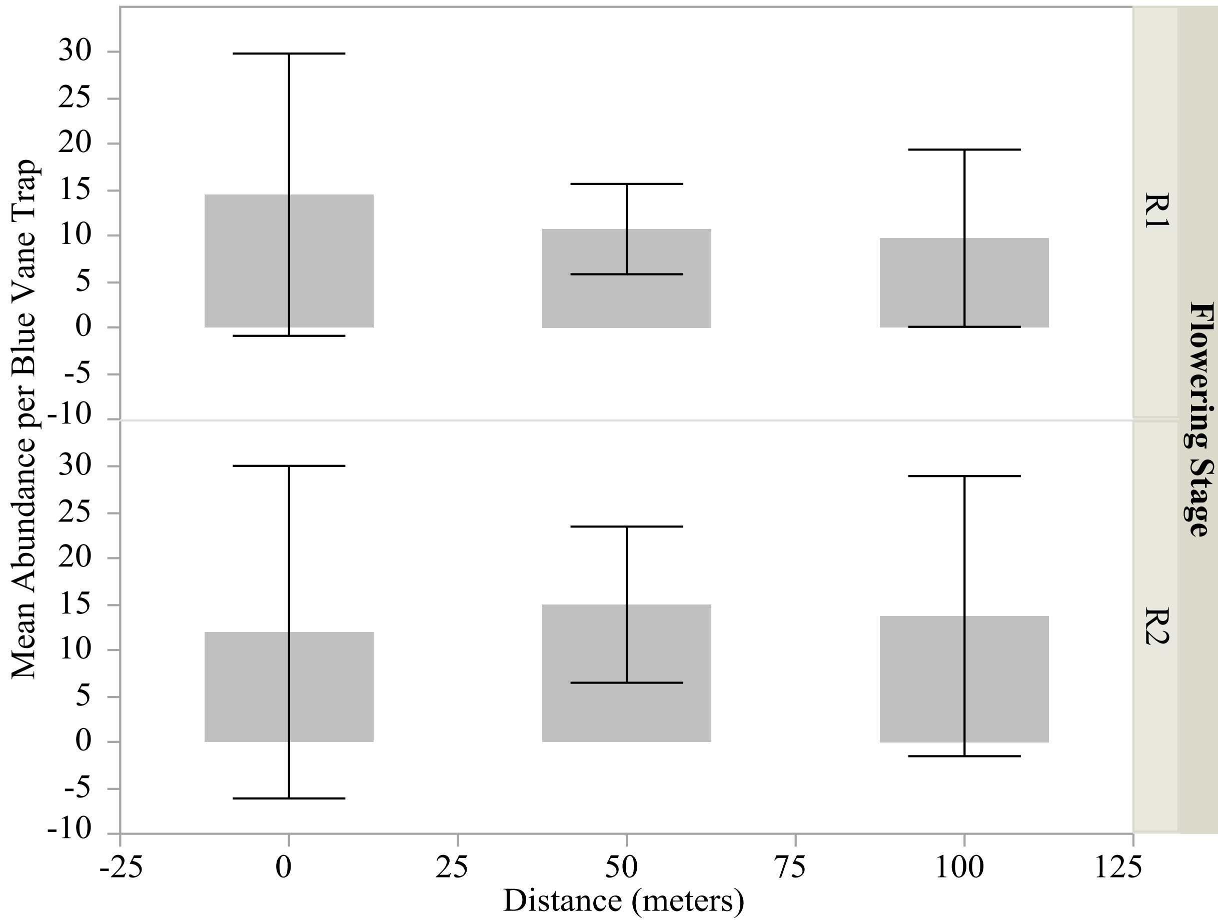

Figure 5. Mean abundance of bees captured per blue vane trap in soybean fields at differing flowering stages with increasing distance from the wetland buffer in the Lower Mississippi Alluvial Valley of Eastern Arkansas, USA in 2016. Error bars are constructing using 95% confidence intervals of the mean.

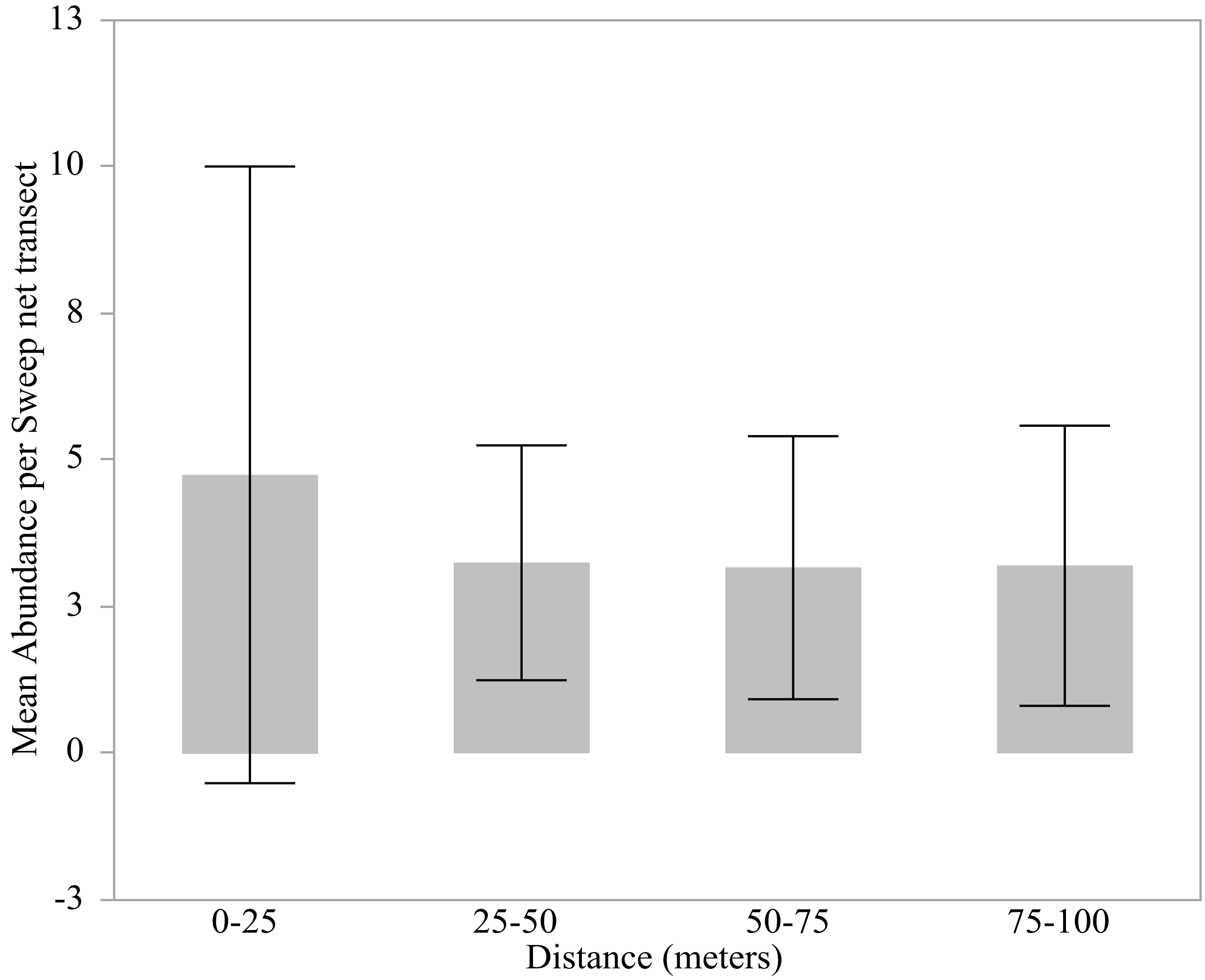

Figure 6. Mean abundance of bees captured per sweep net transect in soybean fields at increasing distance from the wetland buffer in the Lower Mississippi Alluvial Valley of Eastern Arkansas, USA in 2016. Error bars are constructing using 95% confidence intervals of the mean.

Table 1. Site number, site name, ownership, latitude, longitude, and county of paired survey sites in the Lower Mississippi Alluvial Valley of Eastern Arkansas, USA in 2016.

Site Number	Site Name	Ownership[1]	Latitude	Longitude	County
1	Benson Creek Natural Area	ANHC	34.932789	-91.272666	Monroe
2	Gin Road	Private	34.971019	-91.302877	Woodruff
3	Gumbo	Private	34.764475	-91.161115	Monroe
4	Hallum Cemetery Road	Private	34.857014	-91.236786	Monroe

[1]ANHC – Arkansas Natural Heritage Commission, Private – Private land

Table 2 - Number of bee specimens collected by pan traps, blue vane traps, and sweep nets at soybean fields adjacent to managed emergent wetlands in the Lower Mississippi Alluvial Valley of Eastern Arkansas, USA in 2016.

Genus species	Author	Pan Trap	Blue Vane	Sweep Net
Agapostemon angelicus/texanus		2	3	0
Agapostemon sericeus	Forster	2	2	1
Agapostemon virescens	Fabricius	5	8	0
Apis mellifera	Linnaeus	9	14	3
Augochlorella aurata	Smith	1,322	47	41
Augochloropsis metallica	Fabricius	3	2	0
Bombus fraternus	Smith	0	1	0
Bombus griseocollis	DeGeer	0	1	1
Bombus pensylvanicus	DeGeer	0	6	1
Diadasia enavata	Cresson	1	1	0
Florilegus condignus	Cresson	10	5	0
Halictus ligatus	Say	3	6	0
Halictus parallelus	Say	1	7	0
Lasioglossum bruneri	Crawford	3	0	0
Lasioglossum callidum	Sandhouse	2	0	0
Lasioglossum coreopsis	Robertson	2	0	0
Lasioglossum creberrimum	Smith	307	3	11
Lasioglossum cressonii	Robertson	1	0	0
*Lasioglossum disparile**	Cresson	1	0	0
Lasioglossum hartii	Robertson	4	1	0
Lasioglossum nelumbonis	Robertson	5	1	0
Lasioglossum pilosum	Smith	10	2	0
*Lasioglossum versatum**	Robertson	1	0	0
Megachile albitarsis	Cresson	1	0	3
Megachile brevis	Say	4	0	2
Megachile gentilis	Cresson	0	0	2
Melissodes agilis	Cresson	3	3	0
Melissodes bimaculata	Lepeletier	15	28	0
Melissodes communis	Cresson	25	36	0
Melissodes comptoides	Robertson	26	25	0
Melissodes tepaneca	Cresson	0	2	0
Ptilothrix bombiformis	Cresson	17	90	0

*Indicates species only collected in soybean fields

Table 2-Cont.

Genus species	Author	Pan Trap	Blue Vane	Sweep Net
Svastra atripes	Cresson	2	4	0
Svastra cressonii	Dalla Torre	1	0	0
Svastra obliqua	Say	1	4	1
*Triepeolus lunatus**	Say	0	0	1
Xylocopa virginica	Linnaeus	3	1	0
Total		1,785	294	65

*Indicates species only collected in soybean fields

CONCLUSION

To manage emergent wetland bee communities in an effective way, benchmarks for bee communities that use these unique systems need to be documented. The constant challenges of studying native bee communities, coupled with limited ability to access remote areas, has left our native bee communities largely undocumented in the Unites States of America. I have presented a foundation for understanding bee communities that occupy emergent wetlands and conservation and management of them and their habitats in the lower Mississippi Alluvial Valley of Arkansas.

Bee specimens are easy to collect because of their know attraction to specific florescence, but difficulty in proper identification of specimens and lack of consideration of imperfect detection has made documenting bee communities difficult. Although methods have been developed to optimize detection during peak flight months, variation in trap efficiency creates the need for various trapping methods to optimally document bee communities in their entirety. I collected bee specimens during the summer to document bee communities in emergent wetlands in the lower Mississippi Alluvial Valley of Arkansas. These collections produced bee specimens that can be used to create a benchmark for bee communities in emergent wetlands, while also addressing conservation and management strategies.

As public and private land managers evaluate future wetland management options, preference should be given to providing adequate flowering plants in the wetland unit to provide sustainable nectar and pollen resources for bee communities. In addition, wetland managers should also avoid resetting succession throughout entire wetland units, but leave patches of differing successional stages to promote annual and perennial flowing plants. These management recommendations in emergent wetlands can provide diverse bee communities that have the capability to provide ecological services to adjacent croplands.

In conclusion, probability of detection, species richness, probability of a species overlapping both treatment types, and Shannon-Wiener diversity indices were not significantly different between the treatments types in 2015 or 2016. Average floral score remained constant in actively managed emergent wetlands compared to steadily increasing in passively managed emergent wetlands. Moisture loss and disking were the two most contributing factors to floral score differences between actively and passively managed emergent wetlands throughout the sampling period. Though the floral scores varied by management type, the bee species richness did not change by overall number, but species composition did differ. These emergent wetlands also serve as a source population of bees that have the capacity to cross-pollinate soybeans in adjacent fields.