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Waterbird and Wetland Monitoring at The Emiquon Preserve

Annual Report 2017

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INTRODUCTION

The Nature Conservancy (TNC) identified key ecological attributes (hereafter, KEAs) of specific biological characteristics or ecological processes that evaluate restoration success and trajectory at The Emiquon Preserve (hereafter Emiquon; The Nature Conservancy 2006). Because of the historic importance of the Illinois River valley (IRV) to waterfowl and other waterbirds, several conservation targets and associated KEAs at Emiquon were related to waterbird communities and their habitats (Appendix A). Indeed, use of wetlands by waterbirds may serve as an indicator of landscape condition or a measure of restoration success (Austin et al. 2001, Gawlik 2006, Hagy et al. 2017). Therefore, we monitored the response of wetland vegetation and waterbirds to restoration efforts at Emiquon during 2017 to evaluate restoration success relative to desired conditions under the relevant KEAs. Our primary efforts included evaluating: 1) abundance and diversity of waterfowl and other waterbirds through spring and autumn aerial counts; 2) productivity by waterfowl and other waterbirds through brood counts and nest searches; 3) plant seed biomass to estimate energetic carrying capacity for waterfowl during autumn migration; 4) biomass of wetland plants and seeds emigrating from Emiquon through the water control structure; and 5) composition and arrangement of wetland vegetation communities and associated cover types through geospatial covermapping and soil properties in response to water management. Herein, we report results of our monitoring efforts and interpret them as a means of evaluating restoration activities at Emiquon with respect to desired conditions under the KEAs.

METHODS

Avian Abundance

We estimated waterbird abundances at Emiquon as part of the Illinois Natural History Survey's (INHS) aerial waterfowl inventories (Havera 1999). Aerial inventories were conducted approximately weekly (weather permitting) during spring (mid-Feb to mid-Apr) and fall (late-Aug to early-Jan) migration periods from a fixed-wing, single-engine aircraft at altitudes of 60–140 m and speeds of 160–240 km/hr (Havera 1999, Stafford et al. 2007). A single observer estimated abundances of American coots, American white pelicans, bald eagles, double-crested cormorants, and waterfowl by species (except wood ducks; Table 1).

We converted abundance estimates to use days (UDs) to evaluate overall waterbird use of Emiquon (Stafford et al. 2007). Use days are estimates of abundances extrapolated over a period of interest (i.e., fall or spring). For example, 100 birds using a wetland for 10 days equates to 1,000 UDs. This method is useful for comparing waterbird use among sites, years, and seasons and can be used to calculate energetic carrying capacity needs. We expressed duck use estimates as UDs per ha of wetland (UDs/ha) to standardize for wetland size for comparison with past years.

Waterbird Productivity

We monitored waterbird production at Emiquon in 2017 through passive brood observations (Rumble and Flake 1982). We conducted bi-weekly brood surveys between mid-May and late-August using 4 observers at fixed points (Fig. 1). This approach was used to maximize coverage and minimize double counting and disturbance associated with a single observer moving between points. Surveys began at sunrise and lasted for one hour to coincide with a period of increased brood activity (Ringelman and Flake 1980, Rumble and Flake 1982). During each survey, we continually scanned wetland habitat using spotting scopes and binoculars and documented species, number of young and adults, distance from observer, and brood age class of all waterbirds (Gollop and Marshall 1954).

For marsh birds and waterbirds that typically nest in persistent emergent vegetation, we randomly selected locations within distinct vegetation communities (e.g., persistent emergent and hemi-marsh) likely to be used for nesting. We used our 2016 vegetation covermap as our sampling frame and ArcGIS to randomly locate up to 10 points within each habitat class. A 25-m buffer around each point was systematically searched for nests on foot or by boat in a manner that did not destroy nests or vegetation (Austin and Buhl 2011). All nests located within search areas and others located incidentally were marked with a GPS waypoint and flagged at least 1-m away from the nest. Species were identified by presence of adults or characteristics of the eggs or feathers in the nest. We monitored nest status every 5-10 days (depending on sample size) until terminated (i.e., hatched, destroyed, abandoned) and recorded vegetation characteristics, water depths and turbidity, and nest demographics (i.e., clutch size, incubation stage) following Austin and Buhl (2011). Nest demographics were documented by using a flotation method to determine incubation stage (Westerkov 1950) and counting eggs or membranes to determine nest fate. Lastly, we calculated nest success using the Mayfield estimate of daily nest survival (Mayfield 1975), and nest densities (nests/ha) for each vegetation community sampled.

During mid-April to mid-July, we searched for and monitored duck nests in upland grasslands at Emiquon. We used chain-drag methodology to locate nests (Higgins et al. 1969) in 6 grassland tracts (Fig. 2). Tracts were divided up into 3 groups (Group 1: South Levee, West Prairie, and Prairie 1; Group 2: Prairie 2; Group 3: Prairie 3 and Butt Tract), and each group was searched once every third week (i.e., Week 1 – Group 1, Week 2 – Group 2, Week 3 – Group 3, Week 4 – Group 1, etc.). Nests that were discovered during searches were monitored weekly until terminated (i.e., hatched, destroyed, or abandoned). We documented nest demographics (e.g., clutch size, incubation stage) and vegetation characteristics (e.g., species composition, vegetation height) in a 1-m^2 area around each nest (Klett et al. 1986, Weller 1956). We calculated nest survival following Mayfield (1975) and nest densities (nests/ha) for each grassland tract.

Soil Properties

We randomly selected 15 points along east-west transects at lake-bed elevations ± 1.5 m of 130.5 m (potential drawdown elevation) to assess, water depth, water transparency, and soil characteristics to determine organic matter accumulation before and loss following a drawdown, and relate these factors to water management and wetland condition. We measured soil compaction (i.e., a surrogate for consolidation following a drawdown) using a penetrometer (± 0.5 cm) modified for use in deep water areas with attachable extension rods. We measured organic matter accumulation by calculating soil bulk density (g/cm^3) and carbon content (%) measured using the loss-on-ignition method from cores (5-cm diameter x 10-cm depth) collected at the random locations along transects. Following collection, core samples were weighed to the nearest 0.1 mg to obtain a wet weight, then dried for 24 hours at 105° C to dry mass (Black 1965). We calculated soil bulk density following Brown and Wherrett (2014):

$$Bulk\ Density = \frac{Dry\ soil\ mass\ (g)}{Soil\ volume\ (cm^3)}$$

We placed a 10-g subsample from each dried core in a muffle furnace at 440° C for 12 hours to burn organic matter (James et al. 2001). Subsamples were allowed to cool in a desiccator and then weighed to the nearest 0.1 mg. Percent organic matter was calculated as the proportional difference between pre- and post-burn subsample masses.

Plant and Seed Emigration

During periods when the water control structure was operational, we estimated the number and species of seeds and plants moving from Emiquon to the Illinois River (emigration). Plant and seed movement was assessed by inserting a 500-µm screen into the outflow for a predetermined period of time (30 min). A flow meter was used to determine the volume of water (m^3) passing through the screen. When water was flowing through both bays of the structure, we alternated the screen between bays, so each bay was sampled equally. In the laboratory, plant material and seeds were rinsed through a 500-µm sieve, sorted, and identified. We dried plants and seeds separately for 24–48 hours at 60° C and weighed them by taxa to the nearest 0.1 mg. We present results as biomass per volume of water sampled (mg/m^3).

Moist-soil Plant Seeds

During early-fall prior to peak waterbird migration, we estimated above- and below-ground biomass of moist-soil plant seeds by extracting a 10-cm diameter x 5-cm depth soil core in standing vegetation at 30 randomly-allocated points along the shores of Thompson and Flag lakes (Stafford et al. 2006, Kross et al. 2008, Stafford et al. 2011). We froze samples in individually labeled bags until processing. Prior to sorting, we thawed core samples at room temperature and soaked them in a 3% solution of hydrogen peroxide (H_2O_2) to dissolve clays (Bohm 1979:117, Kross et al. 2008). We washed samples with water through 2.0-mm and 250-µm sieves and allowed them to air dry at room temperature. We classified seeds as large if they were retained by the 2.0-mm sieve and small if they remained in the 250-µm sieve. We separated all large seeds from debris by hand and weighed to the nearest 0.1 mg. Due to the extensive processing time, we subsampled a portion (25% by mass) of small seed samples and multiplied the subsample mass by the reciprocal of the proportion subsampled to estimate biomass. We separated all seeds by taxa and dried them to constant mass at approximately 80° C for 24 hours prior to weighing (Manley et al. 2004, Greer et al. 2007, Stafford et al. 2011). We corrected seed abundances for recovery biases (Hagy et al. 2011) and only included seeds that were known duck foods (Havera 1999, Smith 2007, Hitchcock 2008). We combined small and large seed masses and extrapolated totals to estimate overall moist-soil plant seed density (kg/ha; dry mass; Stafford et al. 2011) and energetic use days (EUD). A EUD is defined as the number of days that a given area could support a mallard-sized duck (Reinecke et al. 1989, Stafford et al. 2011). We used an average true metabolizable energy of 2.5 kcal/g for moist-soil plant seeds (Kaminski et al. 2003) and an average daily energy expenditure of dabbling ducks (337 kcal/day) for EUD calculations (Stafford et al. 2011).

Wetland Covermapping

We mapped all wetland vegetation, mudflat, and areas containing surface water in Thompson and Flag lake basins at Emiquon (Havera et al. 2003) to document changes in wetland area, plant species composition, vegetation communities, and other cover types during fall 2017. We traversed east-west transects spaced at 500-m intervals on foot, ATV, or by boat and delineated changes in vegetation communities (e.g., moist-soil, hemi-marsh) using a handheld field computer (Archer Field PC, Juniper Systems, Inc.) with global positioning system (GPS; Bowyer et al. 2005, Stafford et al. 2010). We recorded plant species encountered (Table 2) along transect lines and delineated vegetation communities and other cover types (e.g., open water, mudflat) between transects. We digitized wetland vegetation in ArcGIS 10.3 using field notes and GPS waypoints overlaid on high-resolution aerial imagery from the U.S. Geological Survey (Upper Midwest Environmental Sciences Center, La Crosse, WI; Bowyer et al. 2005, Stafford et al. 2010).

Our classifications of wetland vegetation communities and other cover types at Emiquon generally followed conventions of Cowardin et al. (1979) and Suloway and Hubbell (1994). Woody vegetation was classified as bottomland forest if trees were >6 m in height or scrub-shrub if trees were ≤6 m tall (Cowardin et al. 1979). Other wetland classifications included non-persistent emergent vegetation (e.g., moist-soil plants; Fredrickson and Taylor 1982), persistent emergent vegetation (i.e., cattails and bulrushes with >70% horizontal coverage), mudflats, floating-leaved aquatic vegetation (e.g., American lotus and watershield), aquatic bed (e.g., coontail), hemi-marsh (i.e., open water or aquatic bed interspersed with 30%–70% coverage of persistent emergent vegetation; Weller and Spatcher 1965), and open water (flooded habitat without vegetation; Cowardin et al. 1979, Suloway and Hubbell 1994, Stafford et al. 2010). We also included a category to account for areas of non-wetland associated vegetation (e.g., goldenrod and foxtail) growing within the wetland basin that had been inundated with surface water (i.e., upland-wet).

Additionally, we documented vegetation characteristics (i.e., species composition, quality for waterfowl forage, occurrence of invasive species, etc.) in 1-m^2 plots at 80 random locations within the major vegetation communities (aquatic bed, hemi-marsh, persistent emergent, and moist-soil). We averaged the percent composition estimates of each dominant species (>5% coverage) among locations within plant communities.

RESULTS

Waterfowl Abundance

We conducted 7 aerial inventories from 14 February–16 April, 2017. Peak waterfowl abundance reached 111,170 on 21 February (Table 3). We observed 20 species of waterfowl during spring (16 duck species, 3 goose species, and unidentified swan species). Lesser snow geese were the most abundant species during spring inventories, accounting for 30.5% of total waterfowl abundance, followed by gadwall (15.6%), ruddy ducks (10.0%), and green-winged teal (9.9%). Dabbling ducks and diving ducks accounted for 39.6% and 25.3% of the spring waterfowl abundance, respectively. Spring waterfowl UDs were 1,712,400 at Emiquon in 2017. Dabbling ducks (698,883 UDs) contributed 10.5% of the spring waterfowl use days in the IRV, while non-mallard dabbling ducks (590,213 UDs) accounted for 14.2% of the use in the river valley. Diving duck use of Emiquon (403,258 UDs) provided 8.7% of the spring diving duck use days in the IRV (Fig. 3). Spring duck densities at Emiquon exceeded mean duck densities of other IRV locations combined in 2017 (Fig. 4).

We conducted 16 aerial inventories at Emiquon from 6 September 2017 to 3 January 2018 (Table 4). We observed 21 species of waterfowl (17 duck, 3 goose, and unidentified swan) with a peak abundance of 42,215 on 13 November. Mallards (20.4%) were the most abundant species, followed by gadwall (18.3%), green-winged teal (15.2%), and northern pintail (11.5%). Estimated waterfowl UDs at Emiquon totaled 2,543,365 during fall. Dabbling ducks (2,043,255 UDs) accounted for 80.3% of UDs, whereas 12.2% of waterfowl UDs was attributable to diving ducks (309,422 UDs; Fig. 5). Fall duck densities at Emiquon exceeded mean duck densities of other IRV locations combined in 2017 (Fig. 6).

Non-Waterfowl Abundance

We estimated abundances of 3 waterbird and 1 raptor species during aerial surveys in spring 2017 (Table 5). Peak abundance of non-waterfowl species was 54,614 on 16 March. American coots were the most common species observed and accounted for 98.9% of the spring non-waterfowl abundance. American coot abundance peaked at 54,400 on 16 March, and their use of Emiquon totaled 1,975,450 UDs (Fig. 3). The density of American coots at Emiquon during spring 2017 was greater than the mean coot density at other IRV locations combined (Fig. 4).

American coots were the most abundant species during 16 aerial surveys in fall 2017. The peak estimate of American coots was 84,000 on 26 October (Table 6), down 47% from the 2016 peak estimate (156,975). American coots (2,756,400 UDs; Fig. 5) accounted for 95% of non-waterfowl use, followed by American white pelicans (3.8%) and double-crested cormorants (1.1%). Fall UD estimates of American coots at Emiquon declined 50% from fall 2016 (5,547,603 UDS). Nevertheless, American coots still accounted for 50.6% of all waterbird use (including waterfowl) during fall at Emiquon. Furthermore, American coot density at Emiquon surpassed that of other IRV locations during fall 2017 (Fig. 6).

Waterbird Productivity

We conducted fixed-point brood surveys (n = 8) from 16 May–23 August, 2017 and observed 198 waterbird broods comprised of 6 species (Table 7). The most abundant broods were wood ducks (n = 99), Canada geese (n = 38), and mute swans (n = 30). Brood observations peaked (n = 38) on 25 July. Brood densities ranged from 0 – 185.4 broods/km^2 and averaged 45.8 broods/km^2 at Emiquon during 2017. The brood density estimate in 2017 was 43% higher than 2016 and the highest density observed at Emiquon. Mean brood densities were greatest for wood ducks (23.7 broods/km^2), followed by Canada geese (11.1 broods/km^2), mallards (5.2 broods/km^2), and mute swans (3.9 broods/km^2). Moreover, age classes of broods increased throughout the observation period indicating recruitment at Emiquon.

We conducted 62 waterbird nest surveys in hemi-marsh and dense persistent emergent vegetation communities during 2 June–31 July, 2017 at Emiquon. We found 83 waterbird nests (includes incidental nests) comprised mostly of common gallinule (n = 27), American coots (n =

15), least bitterns (n = 13), black-crowned night herons (n = 13), and mallards (n = 13; Fig. 7). Annual nest survival estimates across all species and vegetation communities averaged 50.9% (Table 8). Nest survival was highest for pied-billed grebes ($\bar{x}$ = 100.0%; n = 1), least bitterns ($\bar{x}$ = 92.6%), and common gallinules ($\bar{x}$ = 50.8%). The dense persistent emergent community exhibited the highest nest survival ($\bar{x}$ = 55.0%), while the hemi-marsh community had higher nest densities ($\bar{x}$ = 1.7 nests/ha). Waterbird nest densities averaged 1.5 nests/ha (range, 0 – 15.3 nests/ha) overall, and when extrapolated to the hemi-marsh and dense persistent emergent communities combined, we estimated 435 waterbird nests at Emiquon in 2017.

Finally, we conducted 15 chain-drag nest searches over 6 grassland tracts covering 87 ha during 20 April–25 July, 2017. We found 70 nests of 2 duck species (mallard [n = 68], blue-winged teal [n = 2]). We estimated the first nest was initiated (i.e., first egg laid) on 8 April, and the last nest terminated on 10 July. Overall nest density averaged 0.8 nest/ha with peak nest density occurring in the west prairie tract (0.9 nest/ha) on 15 June (Fig. 8). Nest survival ranged from 0.9% – 26.8% ($\bar{x}$ = 13.5%) with the highest nest survival occurring in the west prairie tract ($\bar{x}$ = 22.2%; Table 9). Nest survival for mallards averaged 11.6%, while both blue-winged teal nests hatched.

Soil Characteristics

We collected soil cores (n = 15) at random locations within the moist-soil, hemi-marsh, aquatic bed, and floating-leaved vegetation communities and in open water on 26 September. Water depths at sampling locations ranged from 0 – 220 cm with secchi readings ranging from 11 – 85 cm (Table 10). Soil bulk density averaged 0.9 g/cm^3 (range, 0.6 – 1.3 g/cm^3). Percent organic matter ranged from 3.4 – 11.4% and averaged 5.6%. Soil compaction estimates at core sites averaged 5.8 cm (range, 1 – 13.5 cm).

Plant and Seed Emigration

We sampled seeds and plant material emigrating from Emiquon on 6 dates during 14 August – 2 October. We identified 19 seed taxa and 9 plant taxa moving through the water control structure (Table 11). Mean seed emigration was 0.25 mg/m^3 (range, 0.00 – 0.20 mg/m^3), comprised mostly of *Potamogeton* (0.20 mg/m^3), *Setaria* (0.03 mg/m^3), *Ceratophyllum* (0.01 mg/m^3), and *Ludwigia* (0.01 mg/m^3) species. Aquatic plants emigrating from Emiquon averaged 7.28 mg/m^3 (range, 0.01 – 6.83 mg/m^3). *Ceratophyllum* (6.83 mg/m^3), *Potamogeton* (0.46 mg/m^3), and *Najas* (0.09 mg/m^3) were the most abundant plant species moving through the water control structure.

Moist-soil Plant Seeds

We collected soil cores (n = 30) at the terminus of transect lines along the east shore of Flag Lake and the west shore of Thompson Lake on 3 October to estimate seed abundance (kg/ha) and energetic carrying capacity of moist-soil plants for waterfowl. Average moist-soil plant seed density was 1,544.0 kg/ha (dry mass; Fig. 9). The estimated energetic carrying capacity from moist-soil plant seeds in 2017 was 11,453.9 EUDs/ha.

Wetland Covermapping

We mapped all wetland vegetation, open water and areas containing surface water in Thompson and Flag lake basins during 12–21 September 2017 (Fig. 10). Aquatic bed (898.8 ha) was most abundant, followed by open water (464.5 ha), persistent emergent (217.5 ha), mudflat (172.7 ha), floating-leaved (i.e, American lotus, watershield; 120.2 ha), hemi-marsh (93.4 ha) and non-persistent emergent (37.1 ha; Fig. 11). We covermapped 2,010.7 ha and documented 50 plant taxa at Emiquon in 2017 (Table 2).

Species composition data from randomly-selected 1-m^2 plots in 2017 indicated 30.5% of the aquatic bed community contained longleaf pondweed, followed by Eurasian watermilfoil (25.8%), sago pondweed (23.2%), and coontail (17.8%; Fig. 12). The hemi-marsh community contained mostly cattail (29.5%), coontail (17.5%), and sago pondweed (13.0%), slender naiad (11.5%), and brittle naiad (9.5%). Non-persistent emergent vegetation (moist soil) was mostly comprised of fragrant (ferruginous) flatsedge (23.7%), creeping water primrose (17.0%), barnyardgrass (16.2%), nodding smartweed (14.0%), and rice cutgrass (11.5%). Lastly, the persistent emergent vegetation community was dominated by cattail (80.5%) and coontail (10.0%).

DISCUSSION

Waterbird use of Emiquon can serve as an indicator of wetland conditions or a measure of waterbird habitat quality (Austin et al. 2001, Gawlik 2006, Hagy et al. 2017). Although not explicitly outlined in current KEAs, we've provided some modified KEA indicator ranges relative to waterbird abundances during spring and fall based upon past observations at Emiquon or the IRV to assist in guiding restoration (Appendix A). Spring diving duck density declined 46% from the high observed in spring 2016 (399 UDs/ha) but remained well above the KEA desired range. Spring dabbling duck density in 2017 also declined (-13%) from 2016 and has remained below the desired range since spring 2009. Density of other waterbirds (excluding waterfowl) in spring 2017 was slightly below the high observed in 2016 and has nearly doubled the KEA goal the last two years.

Fall dabbling duck density (996 UDs/ha; Fig. 6) at Emiquon in 2017 declined 38% from the 2016 estimate and was 47% below the 2007–2016 average (1,880 UDs/ha). This was the second lowest fall dabbling duck density at Emiquon, and it ranked 6th in the IRV. Similarly, the density of other dabbling ducks (780 UDs/ha; excluding mallards) declined 41% from 2016 and was only about half of the long-term average (1,491 UDs/ha). The fall density of non-mallard dabbling ducks at Emiquon ranked 6^{th} in the IRV. Contributing to this reduction in densities of other dabbling ducks, gadwall density declined 26% in fall 2017, and ranked 4^{th} in the IRV. Conversely, diving duck density in fall 2017 increased slightly (+5%; 6^{th} in IRV) from that in 2016 but remained about 18% below the 2007–2016 average. Fall density of other waterbirds in 2017 declined by nearly half of the high recorded in 2016 and was the lowest density for this group of birds at Emiquon. Other waterbird density is driven by American coots, which also exhibited the lowest density in 2017 than during any other fall. American coot density at Emiquon also represented the highest in the IRV in 2016. Despite the numerous declines in waterbird densities observed in 2017, most guilds are still near or above the desired ranges of the KEA indicators.

Brood surveys during 2017 produced the highest peak waterbird brood density (66 broods/km^2) since surveys began in 2008. Peak waterbird brood density in 2017 was 18% greater than the peak brood density observed in 2016 (56 broods/km^2) and 175% greater than the 2008–2016 average (24 broods/km^2). The dramatic increase in 2016 and 2017 may have been attributable to the decline in persistent emergent vegetation, which may have increased their visibility. While peak waterbird brood density far exceeded the KEA indicator range, species richness of non-waterfowl broods remains low (2017, $n = 2$) and has yet to reach 5 or more species by means of passive brood counts. Waterbird broods, especially species such as American coots and common gallinules, tend to be very secretive and seek dense cover for safety, which makes detection through passive observations difficult (Bolenbaugh et al. 2011). Our 2017 brood surveys supported this notion as we were unable to detect any American coot broods. For comparison to brood density estimates at Emiquon, Yetter (1992) reported a waterfowl brood density of 0.7 brood/km^2 in northeastern Illinois, and Wheeler and March (1979) reported 1.0 brood/km^2 in southern Wisconsin. Conversely, Evans and Black (1956) reported a brood density of 9.1 broods/km^2 in South Dakota, and Hudson (1983) documented substantially higher waterfowl brood densities ranging from 4.7−10.7 broods/ha in stock ponds in Montana. We acknowledge our brood observations only provide an index of waterbird production. We clearly did not document all broods that used the site, and we may have observed individual broods more than once during multiple surveys. Thus, our counts are most useful for assessing trends as the vegetation structure changes at Emiquon.

Marsh bird nest surveys allowed us to further assess overall waterbird productivity at Emiquon. More species (n = 7) were documented in 2017 than in previous years. Furthermore, we found more common gallinule (Illinois endangered, n = 27) nests in 2017 than in any other year, and we found the second highest number of American coot nests (n = 15) in 2017 since 2013 (n = 16). Marsh bird nests (n = 87) declined slightly from 2017 (n = 91) but remained 58% above the 2013–2016 average ($\bar{x}$ = 55), which contributed to the second highest nest density in 2017 (1.5 nests/ha). Consequently, nest abundance remained above the 2013–2016 average ($\bar{x}$ = 420) despite the area of hemi-marsh and dense persistent emergent vegetation communities in 2017 being 27% below the 2013–2016 average ($\bar{x}$ = 394 ha). While nest abundance was above average and nest survival increased 23% over 2016, overall nest survival in 2017 remained below the 2013–2016 average ($\bar{x}$ = 54.9). Vaa et al. (1974) reported substantially greater nest density for American coots in South Dakota (4.2 nests/ha) than what we observed at Emiquon in 2017 (0.4 nests/ha), and coot nest survival at Emiquon (15%) was much lower than that reported in southeast Idaho (72%; Austin and Buhl 2011). Nest density of least bitterns at Emiquon in

2017 (0.7 nest/ha) was greater than nest densities in western New York (0.1 nest/ha), and nest survival of least bitterns at Emiquon (92%) exceeded what was observed in New York (46 – 80%; Lor and Malecki 2006).

Chain drags for upland nesting ducks were conducted for the first time during spring and summer 2017. The nesting period for ducks at Emiquon (8 Apr–10 Jul) was very similar to that reported by Yetter et al. (2009; 12 Apr–9 Jul) for mallards nesting in reclaimed strip-mined lands in Fulton and Peoria counties, Illinois during 1998–2003. Duck nest densities at Emiquon in 2017 ranged from 0.2–2.9 nests/ha ($\bar{x}$ = 0.8 nest/ha) for individual tracts. Several studies in the prairie pothole region of north-central South Dakota during 1968–1973 reported similar mean nest densities ranging from 0.7–1.2 nests/ha (Duebbert and Kantrud 1974, Duebbert and Lokemoen 1976, Duebbert and Lokemoen 1980). Furthermore, Livezey (1981) reported nest densities at Horicon National Wildlife Refuge averaged 1.2 nests/ha in retired agricultural fields during 1977–1978. Mallard nest survival at Emiquon ($\bar{x}$ = 12%) was on the lower end of the range recorded for other Great Lakes states. Davis (2008) reported that mallard nest survival ranged from 10–25% ($\bar{x}$ = 16%) for states in the Great Lakes region. Moreover, mean nest survival for mallards in west-central Illinois (19.6%) during 1998–2003 was substantially higher than that observed at Emiquon in 2017 (Yetter et al. 2009). Cowardin et al. (1985) reported a nest survival rate of 15% was required to maintain mallard populations in North Dakota prairies, whereas Gatti (1987) reported nest survival of 20% was needed for a stable mallard population in Wisconsin.

One of the waterbird habitat quality KEA indicators focused on achieving at least 578 kg/ha of moist-soil plant seed, with ≥800 kg/ha considered to be very good production. Moist-soil plant seed abundance in 2017 (1,544 kg/ha) exceeded the desired indicator range as well as the long-term average ($\overline{x}$ = 746 kg/ha) at Emiquon, and it was the largest seed abundance estimate for Emiquon to date. The Upper Mississippi River and Great Lakes Region Joint Venture (UMRGLRJV) of The North American Waterfowl Management Plan uses a moist-soil seed abundance estimate of 578 kg/ha for waterfowl conservation planning in this region. Moist-soil seed abundance at Illinois Department of Natural Resources (IDNR) waterfowl management areas ranged from 502–1,030 kg/ha and averaged 691 kg/ha during 2005–2007 (Stafford et al. 2011). Furthermore, Bowyer et al. (2005) reported average seed abundance of 790 kg/ha for moist-soil plants at Chautauqua National Wildlife Refuge (CNWR) during 1999−2001. Thus, moist-soil plant seed abundance at Emiquon in 2017 greatly exceeded the averages of these published estimates. Likewise, the 2017 seed abundance estimate converted to EUDs ($\overline{x}$ = 11, 454 EUDs/ha) overshadowed the carrying capacity estimates of IDNR moist-soil wetlands ($\overline{x}$ = 5,128 EUDs/ha; Stafford et al. 2011) during 2005–2007 and CNWR ($\overline{x}$ = 5,860 EUD/ha; Bowyer et al. 2005) during 1999–2001. The exposure of mudflats during drawdowns in 2016 and 2017 likely contributed to the increase in moist-soil plant seed abundance.

In an effort to measure Emiquon's contribution to the resources of the Illinois River, we monitored plant and seed emigration through the water control structure for the second consecutive year in 2017. We sampled the outflow at Emiquon for nearly 6 consecutive weeks in 2017 as opposed to periods of 1–2 months in between sampling days in 2016 due to high river levels. Despite additional sampling and a similar sampling period (14 Aug–2 Oct) as 2016 (13 Jul–15 Nov), seed and plant biomass in the outflow to the Illinois River was 32% less than that of 2016. Extrapolating the 2016–2017 outputs (7.5–11 mg/m^3) over a 30-day period, Emiquon would contribute approximately 53–112 kg of seed and plant biomass to the Illinois River. This contribution is surprisingly low considering the amount of aquatic vegetation that Emiquon produces annually.

The spatial coverage of wetland vegetation (2,011 ha) at Emiquon remained similar to 2016 (2,022 ha) despite water levels dropping approximately 1 m during a mid-August–early October drawdown. Nonetheless, the area of aquatic bed in 2017 declined 13% from 2016 and occupied the lowest proportion of Emiquon (45%) since 2008 (22%). Likewise, open water declined 19% from 2016 but remained 46% above the long-term average ($\bar{x}$ = 318 ha, 20%). Following 2 years of sharp decline, the spatial extent of persistent emergent vegetation in 2017 exhibited signs of recovery with a 20% increase from 2016 and a 24% increase over the 2007–20145 average. Conversely, hemi-marsh declined to its lowest level (93 ha) since fall 2007 (30 ha), occupying <5% of the wetland basin. This decline was likely due to the final senescence of dead hemi-marsh observed since 2014, which was believed to be caused by factors associated with sustained high water and muskrat (*Ondatra zibethicus*) herbivory. Finally, we mapped 173 ha of mudflat that occupied nearly 9% of Emiquon, which was the largest area of mudflat observed to date. The extent and timing of drawdown (Aug–Oct) at Emiquon was likely beneficial to fall-migrating shorebirds in 2017. Recent changes in vegetation community structure at Emiquon mirror the phases of marsh vegetation cycles (van der Valk and Davis 1978, Hine et al. 2017).

The criteria for KEAs related to community composition stipulate <10% invasive species coverage and 100% exclusion of purple loosestrife. Encounters with common reed increased 88% between 2017 (n = 17) and 2016 (n = 9; Fig 13). We did not encounter purple loosestrife at Emiquon during cover-mapping operations in 2017. Common reed and purple loosestrife have been targeted by wetland managers for eradication at Emiquon and efforts to control loosestrife apparently have been effective. Common reed can be easily dispersed by wind, wildlife, and researcher/manager activities and difficult to control. Encounters with reed canarygrass in 2017 declined 33% from 2016, and have declined 87% since 2013. Sustained high water has apparently deterred the spread of reed canarygrass; however, future drawdowns could encourage expansion of this and other invasive plant species, so continued vigilance is encouraged. Overall, the proportion of vegetation polygons from the 2017 cover map containing invasive species was the same as 2016 (24%) and remained 22% below the high in 2013, a year following a drought. Eurasian watermilfoil comprised 26% of the aquatic bed community in 2017, which was similar to 2016 (23%). Conversely, Eurasian watermilfoil decreased in the hemi-marsh community in 2017 (6%) from that in 2016 (17%). Although we observed an apparent reduction of milfoil in the hemi-marsh community, it continued to be a prominent component of the aquatic bed community at Emiquon.

Community composition goals for moist-soil vegetation specified forbs comprise ≥10% of the coverage, <10% composition of exotic species, <50% composition of non-woody invasives (e.g., goldenrod, cocklebur), and <25% coverage of woody invasives (Appendix. A). Species composition data from 2017 indicated that the moist-soil plant community at Emiquon was within these KEA goals with the possible exception of barnyardgrasses, which comprised 16% of the moist-soil plant composition. Common barnyardgrass (*Echinochloa crus-galli*) is exotic and rough barnyardgrass (*E. muricata*) is native, but both look very similar in the field, and we did not distinguish between the two species in our surveys. Nonetheless, both species of barnyardgrass provide important forage for waterfowl. We did not document reed canarygrass in our moist-soil sample plots in 2016.

We began collecting some baseline data to monitor soil characteristics of the wetland substrate in 2016, and this work continued in 2017. A drawdown to reset the vegetation cycle and consolidate sediments at Emiquon was conducted intermittently during July–November, 2016 and again from August–October, 2017, reducing the water level approximately 1 m. Our initial data indicated that the mean organic matter of the wetland sediments at Emiquon was very low in 2016 ($\bar{x}$ = 5.7%) and 2017 ($\bar{x}$ = 5.6%) compared to those reported in Wisconsin (>40%) prior to drawdown (James et al. 2001). Furthermore, soil bulk density in 2016 was much greater ($\bar{x}$ = 1.0 g/cm^3; range, 0.8–1.2 g/cm^3) at Emiquon than soil density estimates prior to and following drawdown at Big Muskego Lake in Wisconsin (<0.1–0.2 g/cm^3; James et al. 2001). Likewise, we found no change in soil bulk density in 2017 ($\bar{x}$ = 0.9 g/cm^3; range, 0.5–1.2 g/cm^3). Brown and Wherrett (2014) reported that soil bulk densities >1.6 g/cm^3 restrict root growth. We also observed little change in soil moisture content between 2016 and 2017 (2016, $\bar{x}$ = 39%; 2017 $\bar{x}$ = 43%), and our values were less than half of that reported by James et al. (2001). We did detect a mean difference of -2.4 cm in penetrometer readings at core sites, suggesting that some soil consolidation had occurred. These preliminary data suggest that accumulation of organic matter in the wetland substrates of Emiquon has been minimal during the first 10 years of restoration. Soil characteristics are expected to change substantially following the completion of the 2018 drawdown when the substrate will be exposed for a substantial portion of the growing season.

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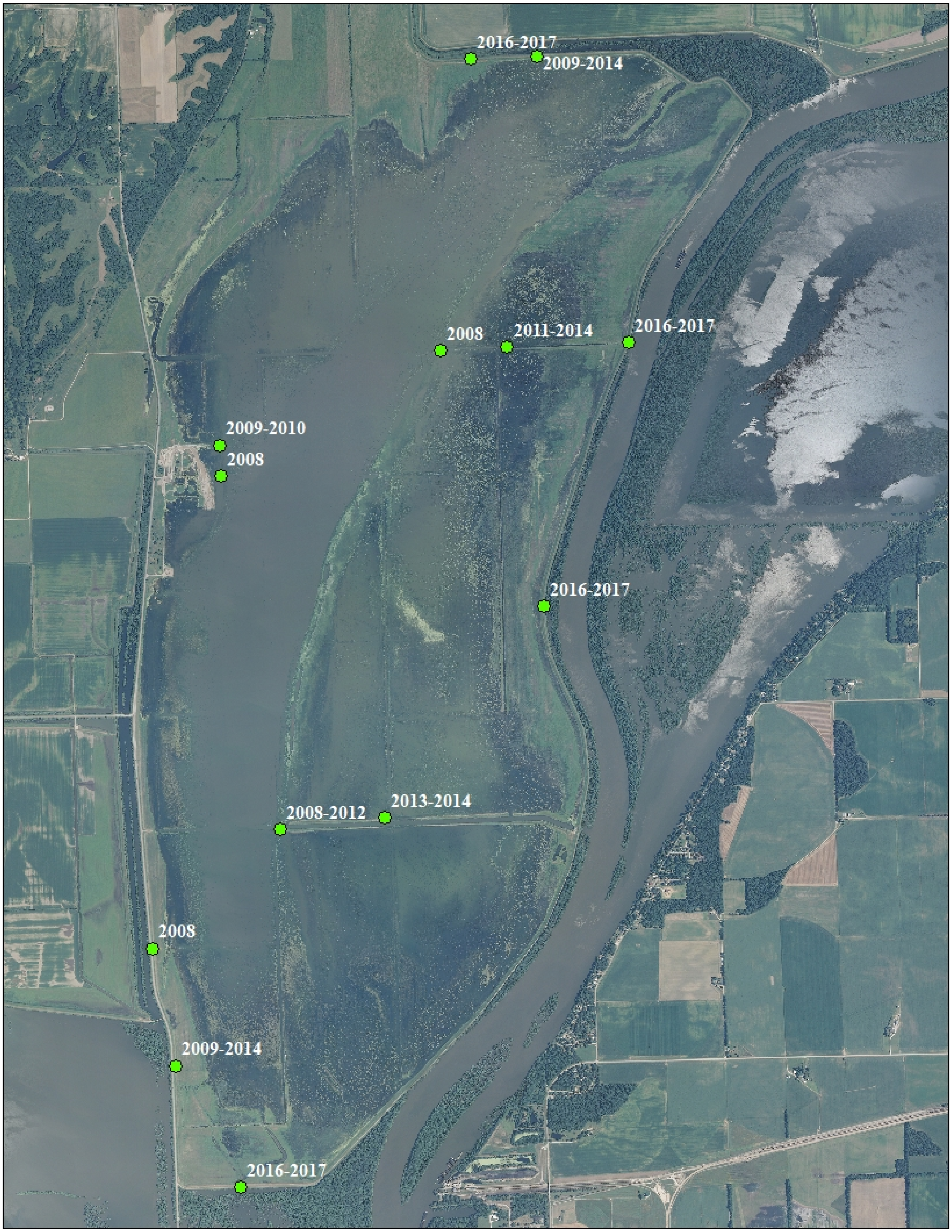


Figure 1. Brood observation locations by year at The Emiquon Preserve, summers 2008–2017. Observation points varied by year due to expanding water levels on the Preserve.

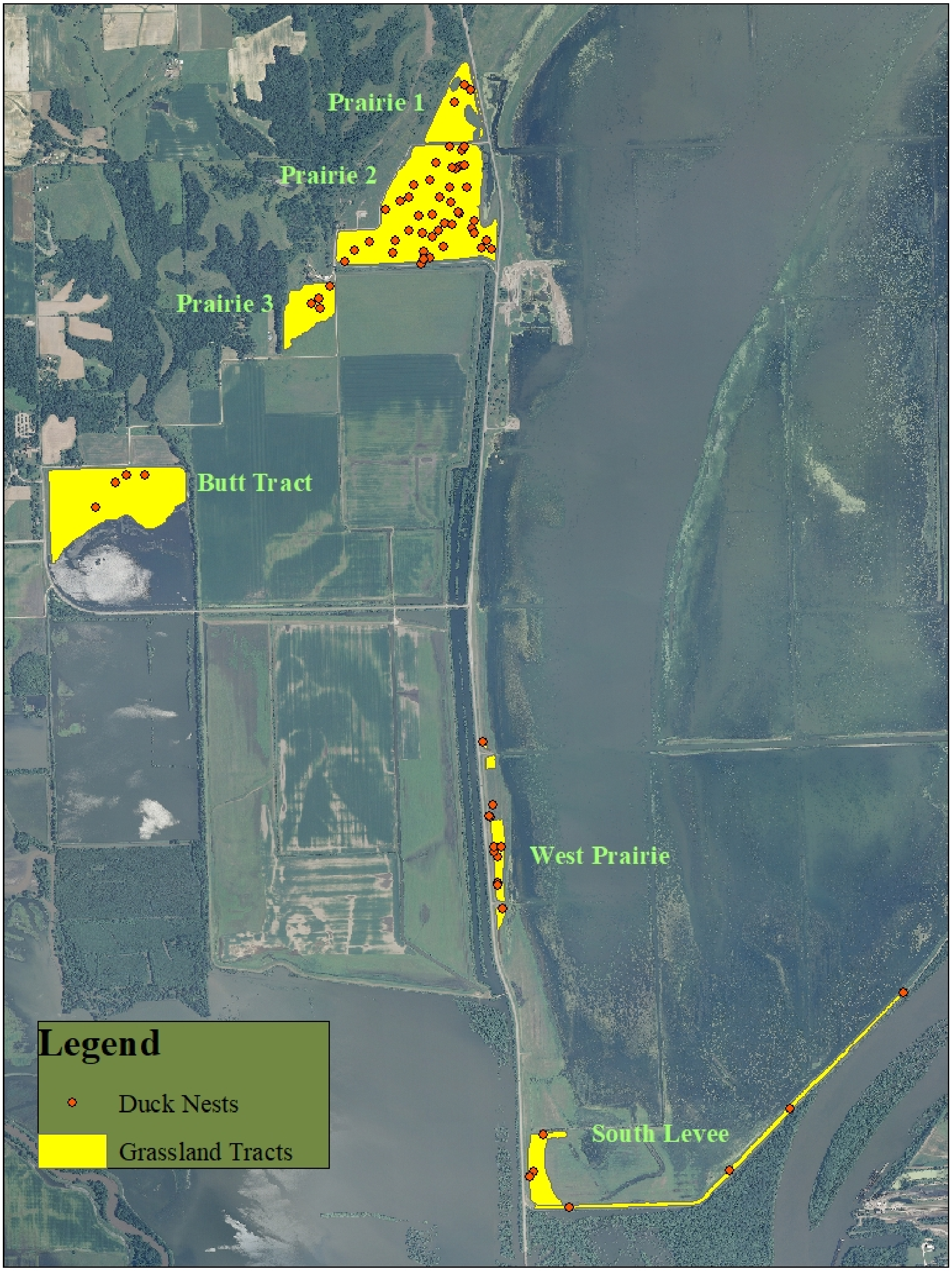


Figure 2. Grassland tracts searched and locations of duck nests found during weekly chain drags at The Emiquon Preserve, 20 April–25 July, 2017.

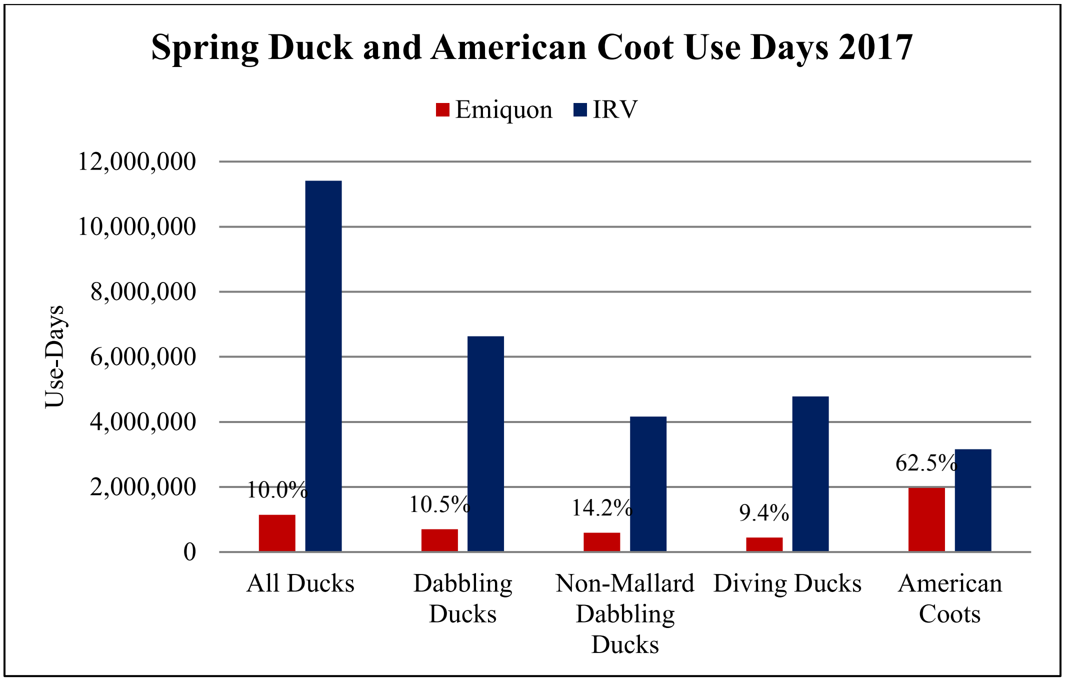


Figure 3. Use days of ducks and American coots at The Emiquon Preserve and other Illinois River sites from aerial inventories during spring 2017. Percentages represent proportions of Illinois River use days.

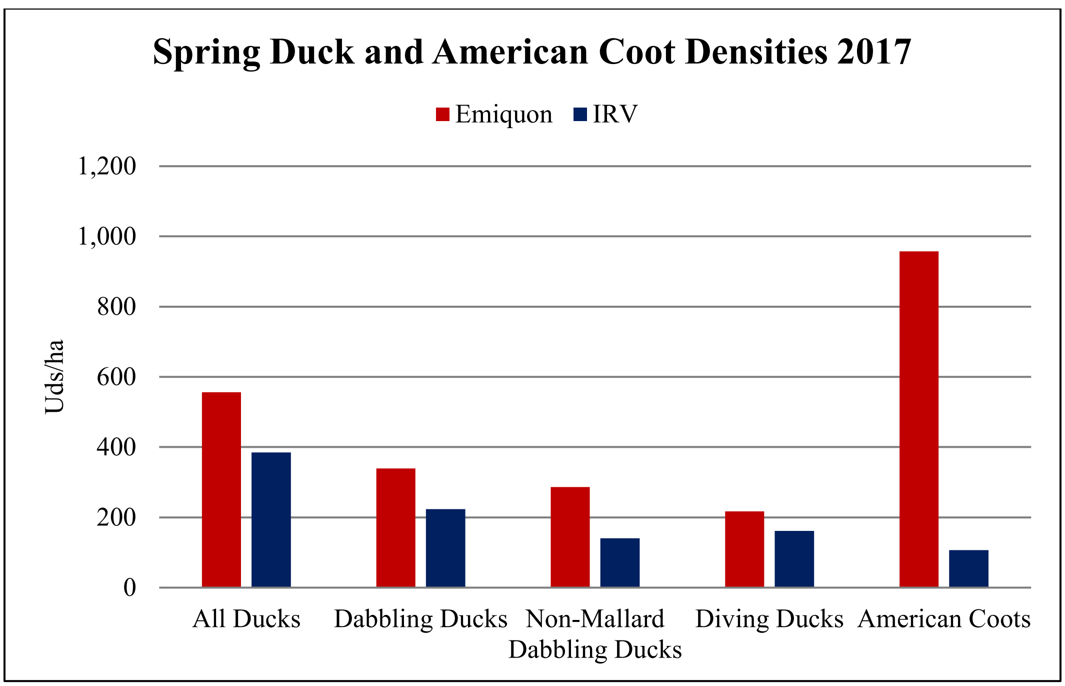


Figure 4. Duck and American coot densities at The Emiquon Preserve and other Illinois River sites from aerial inventories during spring 2017.

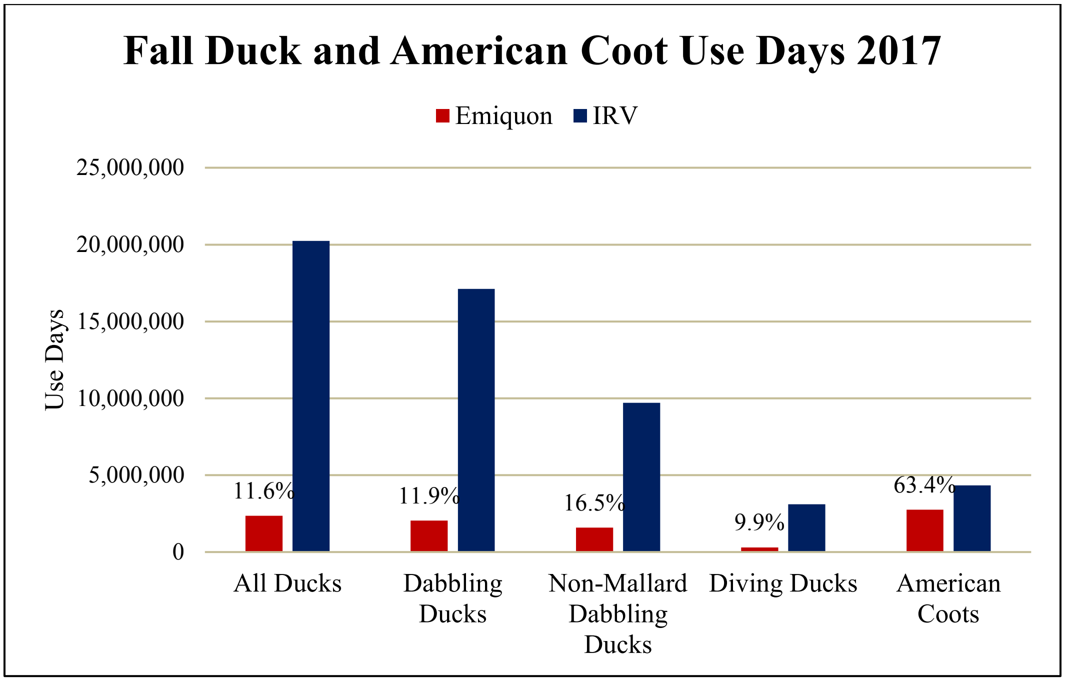


Figure 5. Use days of ducks and American coots at The Emiquon Preserve and other Illinois River sites from aerial inventories during fall 2017. Percentages represent proportions of Illinois River use days.

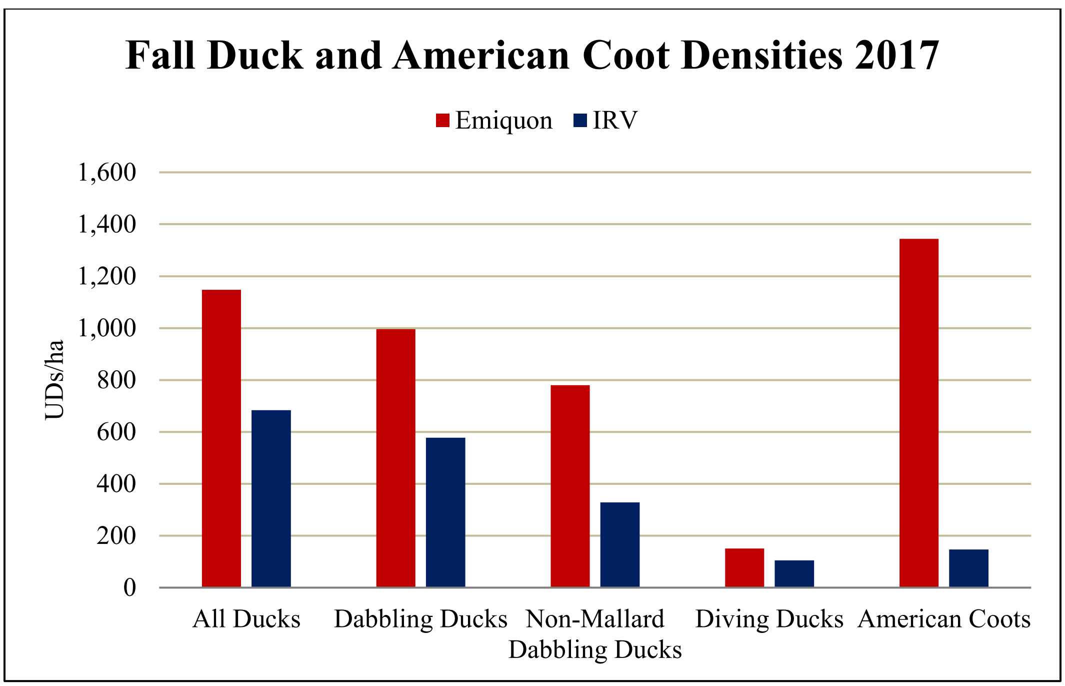


Figure 6. Duck and American coot densities at The Emiquon Preserve and other Illinois River sites from aerial inventories during fall 2017.

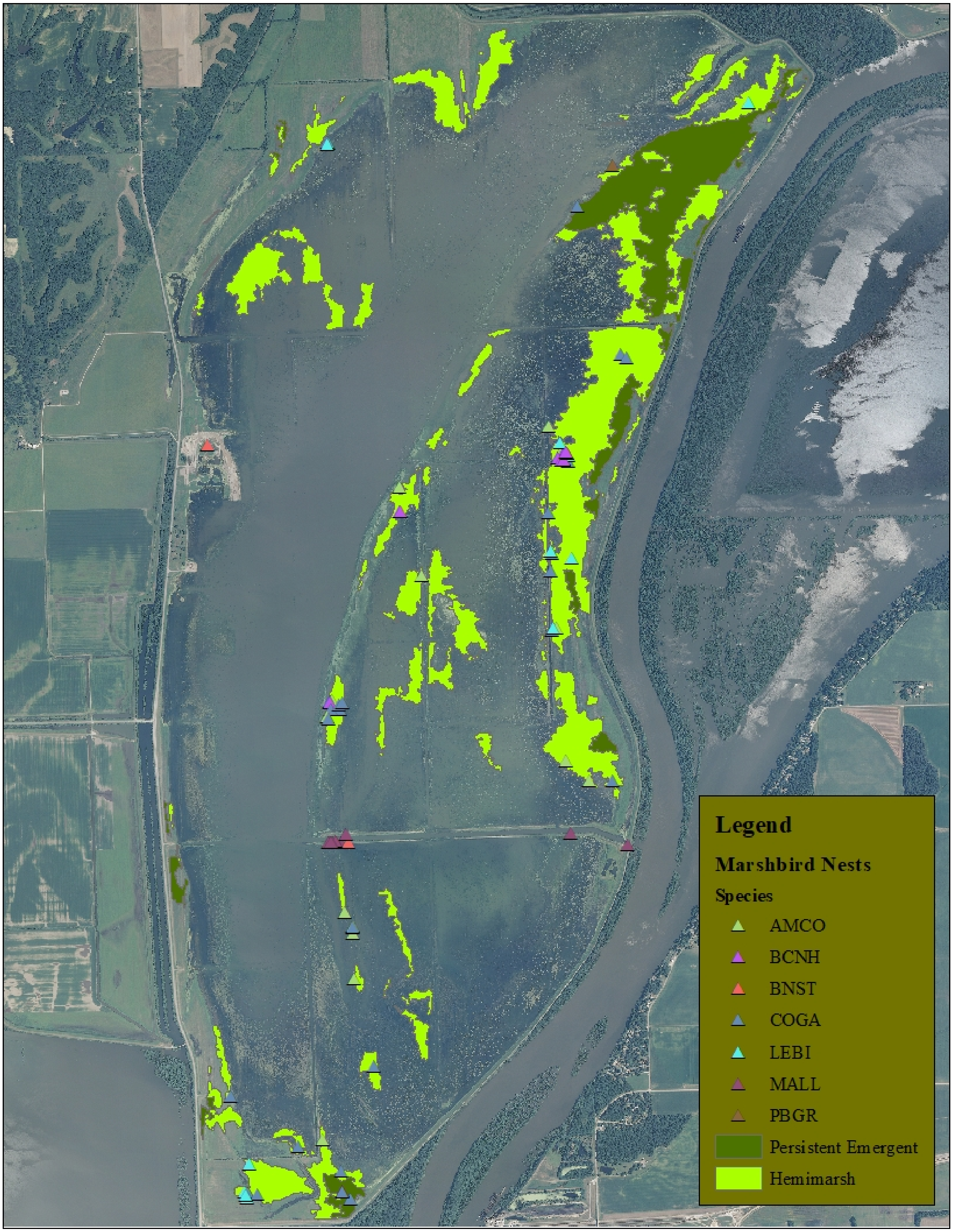


Figure 7. Locations of waterbird nests found during searches of hemi-marsh and dense persistent emergent vegetation communities at The Emiquon Preserve, 2 June–31 July, 2017.

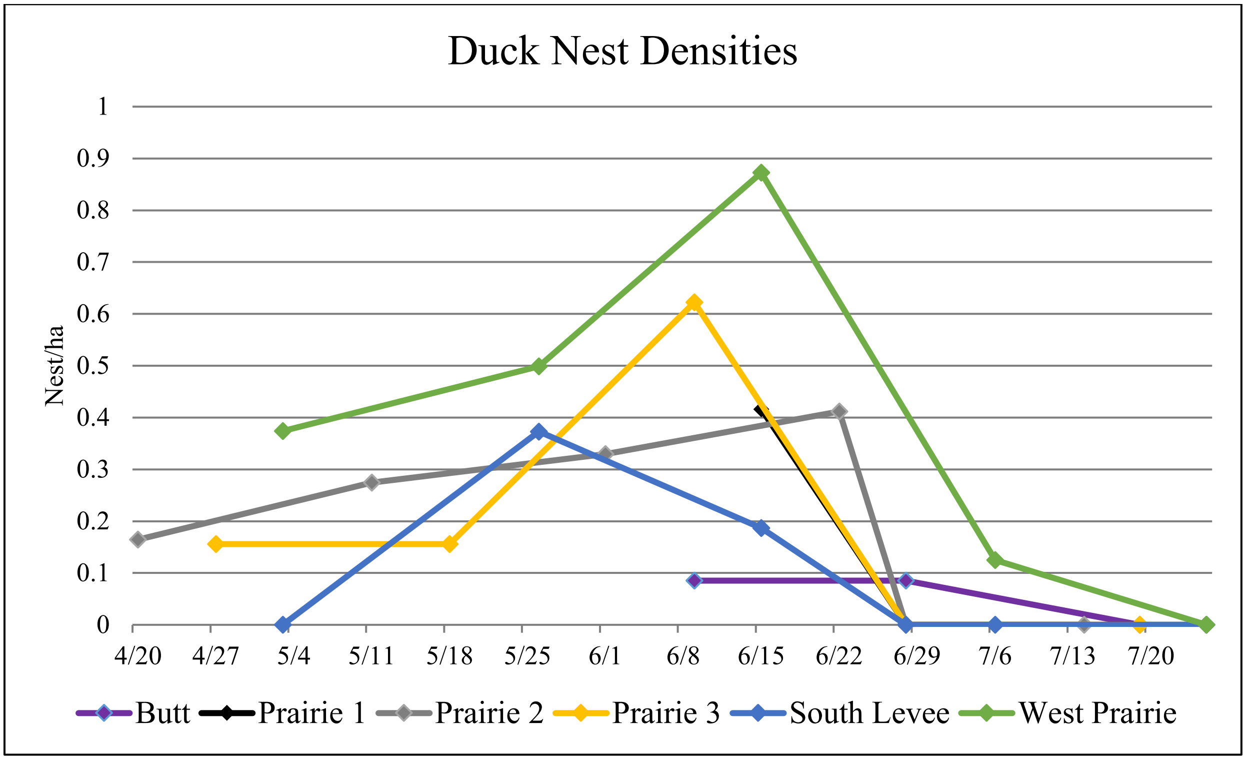
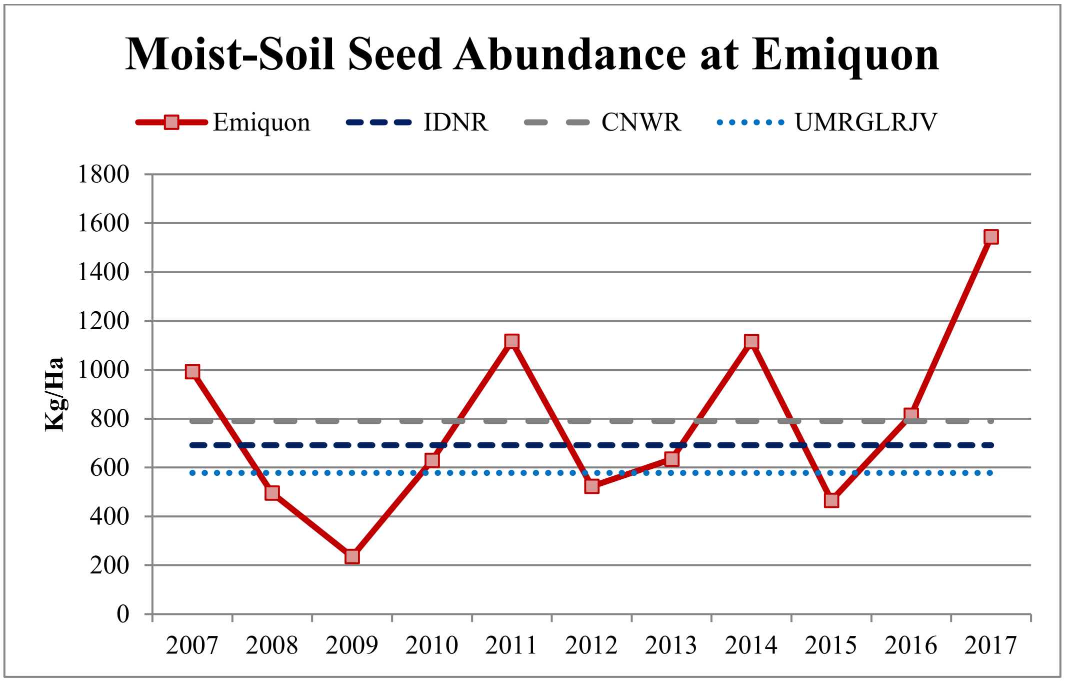


Figure 8. Weekly duck nest densities derived from chain drags of six grassland tracts at The Emiquon Preserve during 20 April–25 July, 2017.



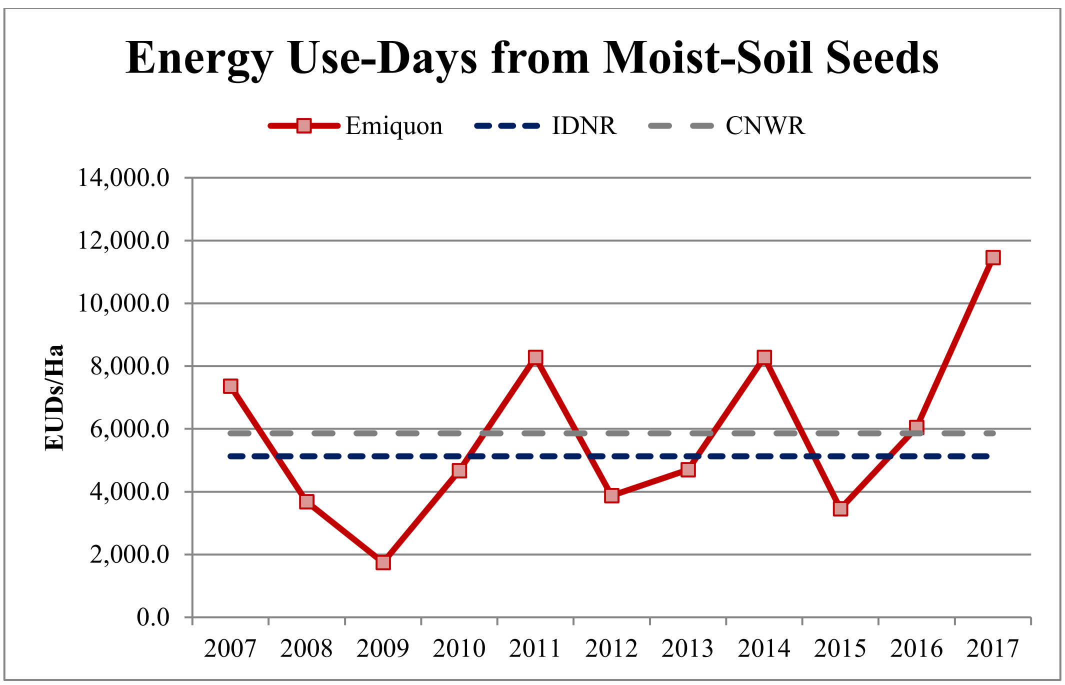


Figure 9. Moist-soil plant seed density and energetic use days (EUDs) from moist-soil plants at The Emiquon Preserve compared to estimates (constants) from wetlands at Illinois Department of Natural Resources (IDNR) sites, Chautauqua National Wildlife Refuge (CNWR), and carrying capacity goals of the Upper Mississippi River/Great Lakes Region Joint Venture (UMRGLRJV) of the North American Waterfowl Management Plan.

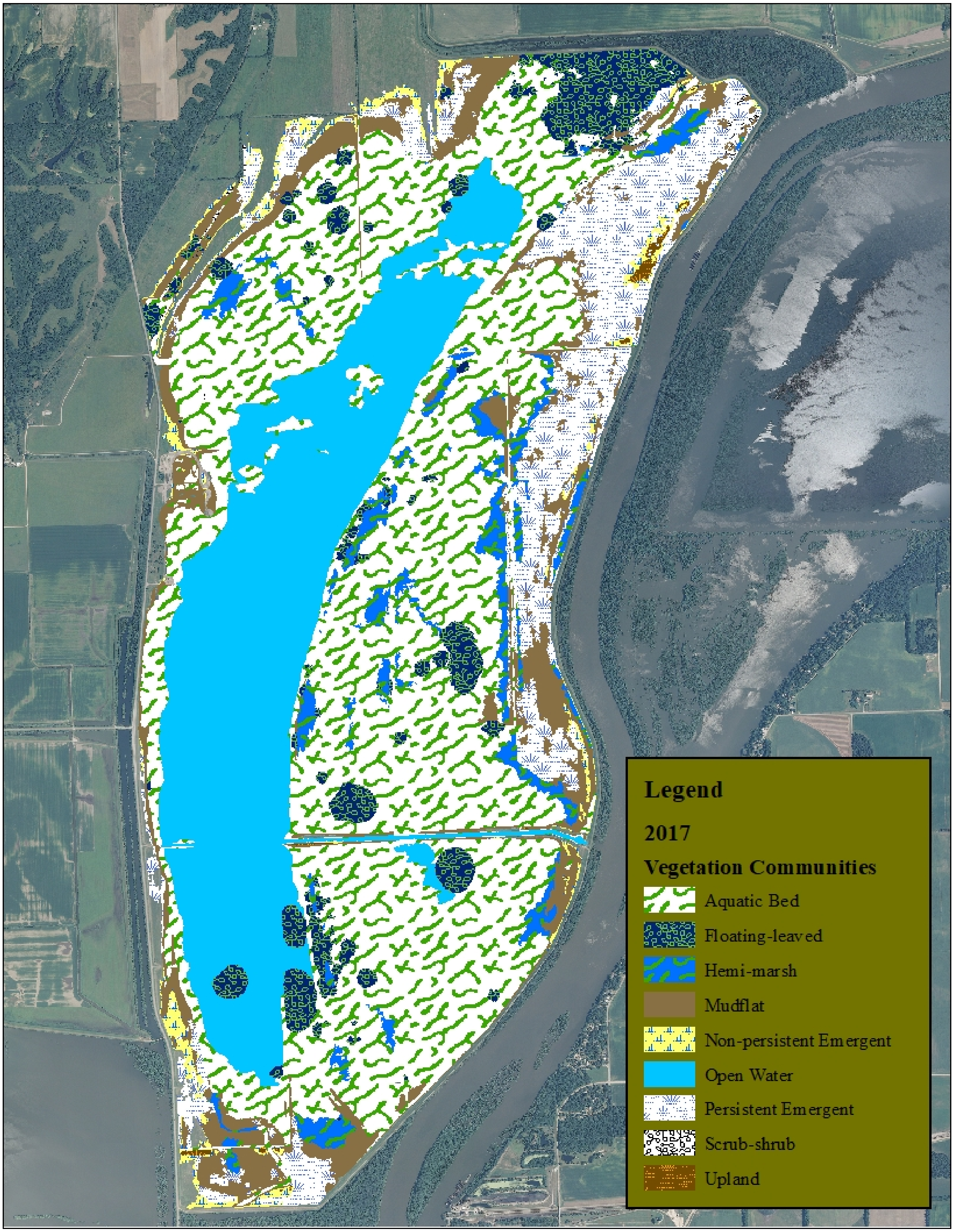


Figure 10. Wetland vegetation map of The Emiquon Preserve (2,010.7 ha), 12–21 September, 2017.

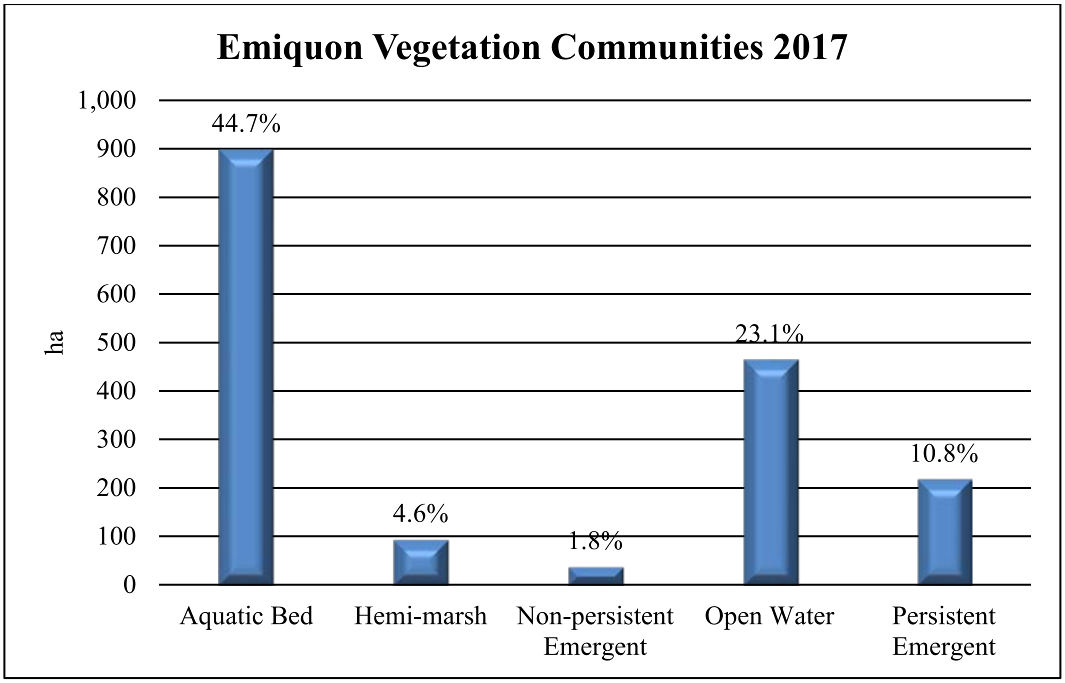


Figure 11. Proportional coverage of wetland vegetation communities at The Emiquon Preserve during September 2017.

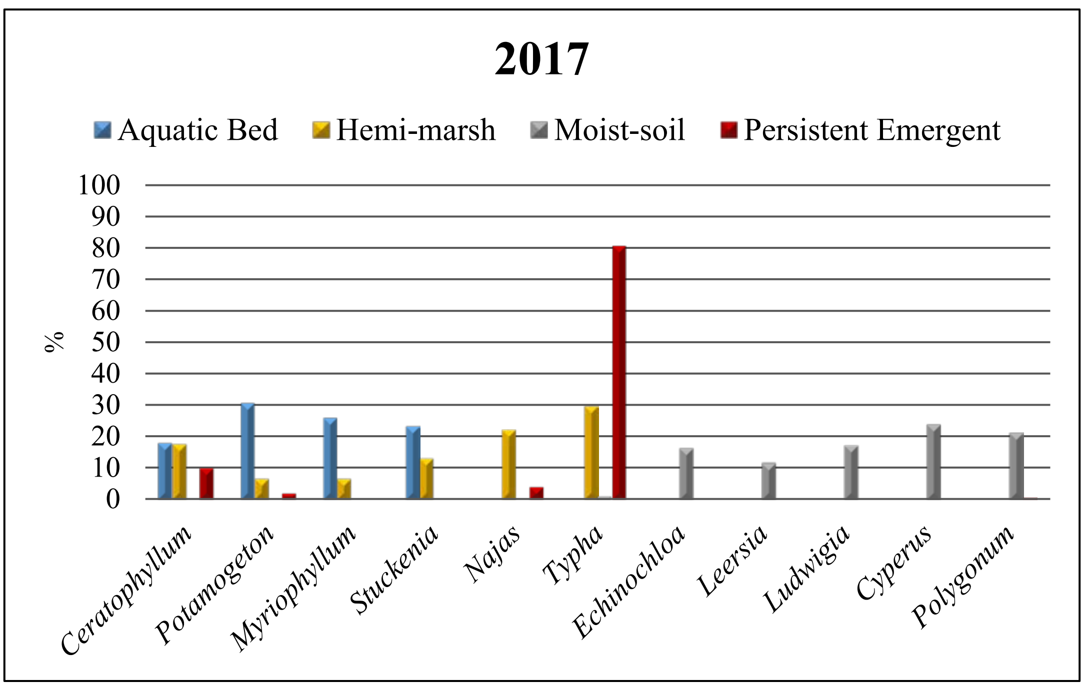


Figure 12. Composition of the major vegetation communities at The Emiquon Preserve during September 2017

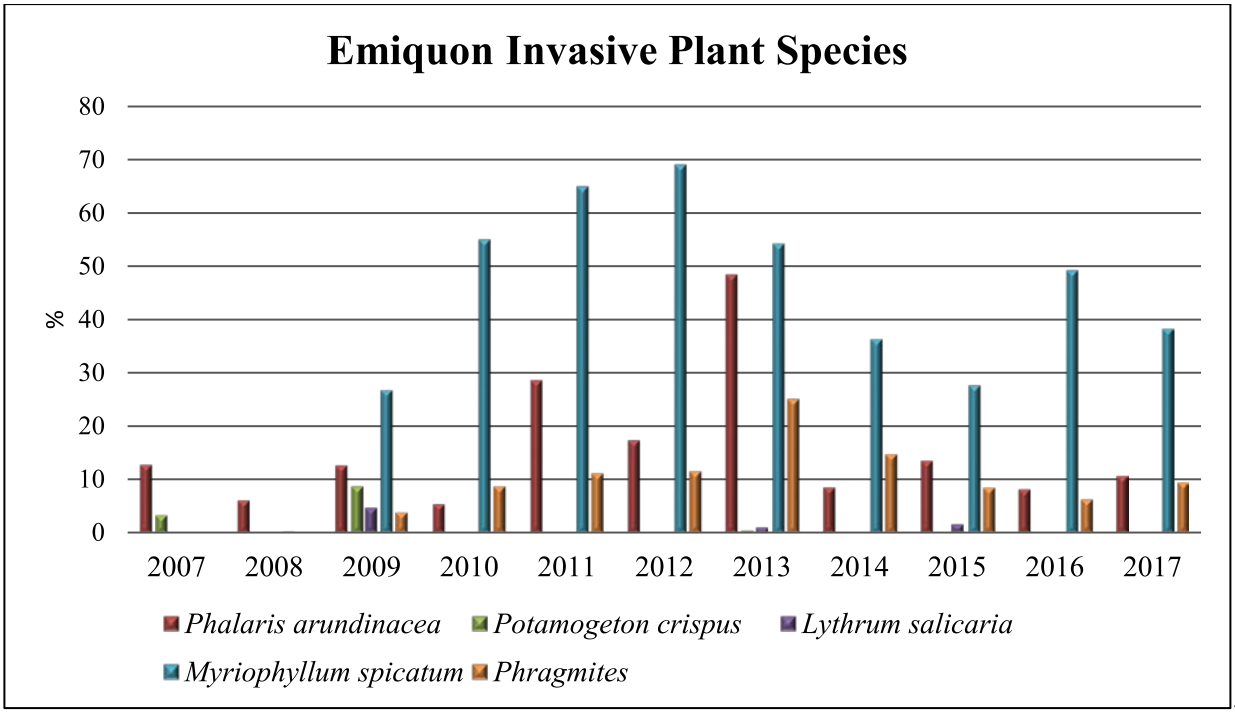


Figure 13. Invasive species encountered during wetland mapping at The Emiquon Preserve, 2007–2017. Values represents the proportion of covermap polygons containing invasive species.

Table 1. Avian species observed during monitoring activities at The Emiquon Preserve, 2007–2017.

Species	Common Name	Scientific Name
ABDU	American Black Duck	*Anas rubripes*
GWTE	Green-winged Teal	*Anas crecca*
AMBI	American Bittern	*Botaurus lentiginosus*
AMCO	American Coot	*Fulica americana*
AMWI	American Wigeon	*Anas americana*
AWPE	American White Pelican	*Pelecanus erythrorhynchos*
BAEA	Bald Eagle	*Haliaeetus leucocephalus*
BCNH	Black-crowned Night Heron	*Nycticorax nycticorax*
BEKI	Belted Kingfisher	*Megaceryle alcyon*
BLGO	Lesser Snow Goose (blue phase)	*Chen caerulescens*
BLTE	Black Tern	*Chlidonias niger*
BNST	Black-necked Stilt	*Himantopus mexicanus*
BOGU	Bonaparte's Gull	*Chroicocephalus philadelphia*
BUFF	Bufflehead	*Bucephala albeola*
BWTE	Blue-winged Teal	*Anas discors*
CAEG	Cattle Egret	*Bubulcus ibis*
CAGO	Canada Goose	*Branta canadensis*
CANV	Canvasback	*Aythya valisineria*
COGA	Common Gallinule	*Gallinula galeata*
COGO	Common Goldeneye	*Bucephala clangula*
COHA	Cooper’s Hawk	*Accipiter cooperii*
COLO	Common Loon	*Gavia immer*
COME	Common Merganser	*Mergus merganser*
COSN	Common Snipe	*Gallinago gallinago*
COTE	Common Tern	*Sterna hirundo*
DCCO	Double-crested Cormorant	*Phalacrocorax auritus*
EAGR	Eared Grebe	*Podiceps nigricollis*
FRGU	Franklin’s Gull	*Leucophaeus pipixcan*
GADW	Gadwall	*Anas strepera*
GLIB	Glossy Ibis	*Plegadis falcinellus*
GBHE	Great Blue Heron	*Ardea herodias*
GHOW	Great Horned Owl	*Bubo virginianus*
GREG	Great Egret	*Ardea alba*
GRHE	Green Heron	*Butorides virescens*
GWFG	Greater White-fronted Goose	*Anser albifrons*
HOGR	Horned Grebe	*Podiceps auritus*
HOME	Hooded Merganser	*Lophodytes cucullatus*
KILL	Killdeer	*Charadrius vociferus*
LBHE	Little Blue Heron	*Egretta caerulea*

Table 1. Continued.

Species	Common Name	Scientific Name
LEBI	Least Bittern	*Ixobrychus exilis*
LESC	Lesser Scaup	*Aythya affinis*
LSGO	Lesser Snow Goose	*Chen caerulescens*
MAGO	Marbled Godwit	*Limosa fedoa*
MALL	Mallard	*Anas platyrhynchos*
MUSW	Mute Swan	*Cygnus olor*
NOHA	Northern Harrier	*Circus cyaneus*
NOPI	Northern Pintail	*Anas acuta*
NSHO	Northern Shoveler	*Anas clypeata*
NSHR	Northern Shrike	*Lanius excubitor*
OSPR	Osprey	*Pandion haliaetus*
PALO	Pacific Loon	*Gavia pacifica*
PBGR	Pied-billed Grebe	*Podilymbus podiceps*
PEFA	Peregrine Falcon	*Falco peregrinus*
RBGU	Ring-billed Gull	*Larus delawarensis*
RBME	Red-breasted Merganser	*Mergus serrator*
REDH	Redhead	*Aythya americana*
RLHA	Rough-legged Hawk	*Buteo lagopus*
RNDU	Ring-necked Duck	*Aythya collaris*
RNGR	Red-necked Grebe	*Podiceps grisegena*
RTHA	Red-tailed Hawk	*Buteo jamaicensis*
RTLO	Red-throated Loon	*Gavia stellata*
RUDU	Ruddy Duck	*Oxyura jamaicensis*
SAGU	Sabine's Gull	*Xema sabini*
SACR	Sandhill Crane	*Grus canadensis*
SORA	Sora	*Porzana carolina*
TRUS	Trumpeter Swan	*Cygnus buccinator*
TUSW	Tundra Swan	*Cygnus columbianus*
WIPH	Wilson's Phalarope	*Phalaropus tricolor*
WODU	Wood Duck	*Aix sponsa*
WWSC	White-winged Scoter	*Melanitta fusca*
YHBL	Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*

Table 2. Plant species encountered during wetland covermapping at The Emiquon Preserve, 2007−2017.

Common Name	Scientific Name
American Lotus	*Nelumbo lutea*
American Sycamore	*Plantanus occidentalis*
American Water Plantain	*Alisma subcordatum*
Annual Marsh Elder	*Iva annua*
Arrowhead	*Sagittaria* spp.
Ash	*Fraxinus* spp.
Aster	*Aster spp.*
Barnyardgrass	*Echinochloa crus-galli*
Bidens	*Bidens* spp.
Big Bluestem	*Andropogon gerardi*
Black Willow	*Salix nigra*
Blackeyed Susan	*Rudbeckia hirta*
Bog Bulrush	*Schoenoplectus mucronatus*
Boneset	*Eupatorium* spp.
Brasenia (Watershield)	*Brasenia schreberi*
Brittle Naiad	*Najas minor*
Broadleaf Cattail	*Typha latifolia*
Bur Reed	*Sparganium spp.*
Buttonweed	*Diodia virginiana*
Canada Wild Rye	*Elymus canadensis*
Cardinal Flower	*Lobelia cardinalis*
Carex	*Carex* spp.
Cattail	*Typha* spp.
Chara	*Chara* spp.
Chufa	*Cyperus esculentus*
Clover	*Trifolium* spp.
Cocklebur	*Xanthium* spp.
Common Buttonbush	*Cephalanthus occidentalis*
Common Reed	*Phragmites* spp.
Coontail	*Ceratophyllum demersum*
Crabgrass	*Digitaria* spp.
Creeping Water Primrose	*Ludwigia peploides*
Curly Dock	*Rumex crispus*
Curly Pondweed	*Potamogeton crispus*
Dandelion	*Taraxacum officinale*
Decurrent False Aster	*Boltonia decurrens*
Devil's Beggartick	*Bidens frondosa*

Table 2. Continued.

Common Name	Scientific Name
Dogbane	*Apocynum* spp.
Dogwood	*Cornus* spp.
Eastern Cottonwood	*Populus deltoides*
Elm	*Ulmus* spp.
Elodea	*Elodea canadensis*
Elodea (Waterweed)	*Elodea* spp.
Eurasian Watermilfoil	*Myriophyllum spicatum*
Fall Panicum	*Panicum dichotomiflorum*
Ferruginous Flatsedge	*Cyperus ferruginescens*
Fescue	*Festuca* spp.
Flatsedge	*Cyperus* spp.
Fog Fruit	*Phyla* spp.
Foxtail	*Setaria* spp.
Giant Ragweed	*Ambrosia trifida*
Goldenrod	*Solidago* spp.
Hoary Vervain	*Verbena stricta*
Hooded Arrowhead	*Sagittaria calycina*
Hop Sedge	*Carex lupulina*
Horned Pondweed	*Zannichellia palustris*
Horseweed	*Conyza* spp.
Japanese Millet	*Echinochloa esculenta*
Lambsquarters	*Chenopodium album*
Largeseed Smartweed	*Polygonum pensylvanicum*
Lemna (Duckweed)	*Lemna minor*
Lesser Ragweed	*Ambrosia artemisiifolia*
Lobelia	*Lobelia* spp.
Locust	*Robinia* spp.
Longleaf Pondweed	*Potamogeton nodosus*
Long-leaved Ammania	*Ammania coccinea*
Maple	*Acer* spp.
Mare's Tail	*Hippuris vulgaris*
Marsh Smartweed	*Polygonum hydropiperoides*
Marshpepper Smartweed	*Polygonum hydropiper*
Milfoil	*Myriophyllum* spp.
Milkweed	*Asclepias* spp.
Mint	*Mentha* spp.
Morning Glory	*Ipomoea* spp.
Mulberry	*Morus* spp.

Table 2. Continued.

Common Name	Scientific Name
Mullein	*Verbascum* spp.
Multiflora Rose	*Rosa multiflora*
Naiad	*Najas* spp.
Narrowleaf Cattail	*Typha angustifolium*
Nodding Beggartick	*Bidens cernua*
Nodding Smartweed	*Polygonum lapathifolium*
Oak	*Quercus* spp.
Orange Jewelweed	*Impatiens capensis*
Peach-leaved Willow	*Salix amygdaloides*
Pecan	*Carya ilinoinensis*
Pickerelweed	*Pontederia cordata*
Pigweed	*Amaranthus* spp.
Plantain	*Plantago* spp.
Pokeweed	*Phytolacca* spp.
Prairie Cordgrass	*Spartina pectinata*
Prickly Sida	*Sida spinosa*
Purple Loosestrife	*Lythrum salicaria*
Ragweed	*Ambrosia* spp.
Rattlesnake Master	*Eryngium yuccifolium*
Red-rooted Nutgrass	*Cyperus erythrorhizos*
Reed Canarygrass	*Phalaris arundinacea*
Ribbonleaf Pondweed	*Potamogeton epihydrus*
Rice Cutgrass	*Leersia oryzoides*
River Birch	*Betula nigra*
River Bulrush	*Scirpus fluviatilis*
Rush	*Juncus* spp.
Sagittaria (Arrowhead)	*Sagitarria* spp.
Sago Pondweed	*Stuckenia pectinata*
Sallow Sedge	*Carex lurida*
Scouring Rush	*Equisetum hyemal affinis*
Shattercane	*Sorghum bicolor*
Silver Maple	*Acer saccharinum*
Small Pondweed	*Potamogeton Pusillis*
Smooth Brome	*Bromus inermis*
Softstem Bulrush	*Schoenoplectus Tabernaemontani*
Southern Naiad	*Najas guadalupensis*
Sowthistle	*Sonchus* spp.
Spikerush	*Eleocharis* spp.

Table 2. Continued.

Common Name	Scientific Name
Sprangletop	*Leptochloa fascicularis*
Spurge	*Euphorbia* spp.
Straw-colored Flatsedge	*Cyperus strigosus*
Sumac	*Rhus* spp.
Switchgrass	*Panicum virgatum*
Tealgrass	*Eragrostis hypnoides*
Thistle	*Cirsium* spp.
Torrey's Rush	*Juncus torreyi*
Velvetleaf	*Abutilon* spp.
Walter's Millet	*Echinochloa walteri*
Water Plantain	*Alisma* spp.
Water Smartweed	*Polygonum amphibium*
WhiteTturtlehead	*Chelone glabra linifolia*
Wild Carrot	*Daucus pusillus*
Wild Oat	*Avena fatua*
Wild rye	*Elymus* spp.
Willow	*Salix* spp.
Wolffia (Watermeal)	*Wolffia* spp.
Woolgrass	*Scirpus cyperinus*

Table 3. Estimates of waterfowl abundance from aerial inventories at The Emiquon Preserve during spring 2017.

	Inventory Dates								
Species[a]	14-Feb	21-Feb	3-Mar	9-Mar	16-Mar	28-Mar	16-Apr	Total	%
MALL	750	9505	1000	1050	500	450	40	13,295	6.6
ABDU	0	0	0	0	0	0	0	0	0.0
NOPI	500	700	300	120	0	0	0	1,620	0.8
BWTE	0	0	0	10	0	100	200	310	0.2
AGWT	200	4600	1910	7500	3105	2300	160	19,775	9.9
AMWI	0	200	50	0	0	205	0	455	0.2
GADW	850	18900	1410	2000	4500	3300	275	31,235	15.6
NSHO	200	3400	800	3000	1300	3500	370	12,570	6.3
LESC	400	1700	550	2360	3300	1350	170	9,830	4.9
RNDU	600	2800	100	500	500	100	0	4,600	2.3
CANV	900	2400	550	300	200	200	0	4,550	2.3
REDH	120	150	20	15	110	10	0	425	0.2
RUDU	200	6600	850	3200	3500	4200	1450	20,000	10.0
COGO	1700	1400	0	0	300	0	0	3,400	1.7
BUFF	50	110	380	570	715	110	10	1,945	1.0
COME	5000	600	5	5	185	0	0	5,795	2.9
HOME	40	10	0	0	10	10	0	70	0.0
CAGO	335	310	110	50	35	70	55	965	0.5
GWFG	100	5700	100	300	1250	310	0	7,760	3.9
LSGO	5000	52010	4000	10	0	60	0	61,080	30.5
SWN	220	75	75	60	120	40	30	620	0.3
Total	17,165	111,170	12,210	21,050	19,630	16,315	2,760	200,300	

[a] See Table 1.

Table 4. Estimates of waterfowl abundance from aerial inventories at The Emiquon Preserve during fall 2017.

	Inventory Dates																	
Species[a]	6-Sep	14-Sep	21-Sep	27-Sep	20-Oct	26-Oct	31-Oct	10-Nov	13-Nov	22-Nov	29-Nov	7-Dec	14-Dec	19-Dec	26-Dec	3-Jan	Total	%
MALL	425	360	255	1,065	2,425	4,200	3,050	5,680	9,570	2,710	1,705	6,850	16,050	10,005	350	0	64,700	20.4
ABDU	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	20	<0.1
NOPI	1,670	600	650	2,665	7,235	14,000	2,285	2,100	4,780	250	100	300	0	0	0	0	36,635	11.5
BWTE	3,050	1,700	650	1,600	600	1,400	100	0	0	0	0	0	0	0	0	0	9,100	2.9
AGWT	2,100	3,400	2,140	2,665	12,500	9,800	2,385	2,950	8,560	950	720	100	0	10	0	0	48,280	15.2
AMWI	0	0	215	530	2,410	2,800	760	0	955	0	0	0	0	0	0	0	7,670	2.4
GADW	0	0	0	530	18,075	14,000	11,415	2,650	6,170	1,310	1,070	650	1,000	1,100	0	0	57,970	18.3
NSHO	1,150	400	430	1,600	3,615	4,200	3,805	300	2,390	100	250	150	600	400	0	0	19,390	6.1
LESC	0	0	0	0	300	0	760	300	240	510	100	0	100	100	0	0	2,410	0.8
RNDU	0	0	0	0	0	2,800	1,620	1,000	1,435	0	500	0	0	0	0	0	7,355	2.3
CANV	0	0	0	0	300	700	760	600	955	0	200	0	200	10	10	0	3,735	1.2
REDH	0	0	0	0	0	0	380	0	0	0	0	0	0	0	0	0	380	0.1
RUDU	0	0	0	0	1,205	4,015	1,260	700	2,390	1,500	900	700	1,005	600	0	0	14,275	4.5
COGO	0	0	0	0	0	0	0	100	0	100	100	0	3,600	1,000	1,000	0	5,900	1.9
BUFF	0	0	0	0	0	0	100	440	2,390	660	455	460	1,000	550	0	0	6,055	1.9
COME	0	0	0	0	0	0	0	0	0	10	20	0	800	1,055	1,220	0	3,105	1.0
HOME	0	0	0	0	0	0	0	0	600	0	400	400	800	200	0	0	2,400	0.8
CAGO	405	745	175	325	215	350	300	560	1,655	720	650	540	1,255	1,170	1,400	0	10,465	3.3
GWFG	0	0	0	0	200	700	10	230	25	2,010	110	550	5,550	5,200	0	0	14,585	4.6
LSGO	0	0	10	5	0	0	10	30	0	300	10	0	0	0	0	0	365	0.1
SWN	70	115	85	90	20	10	5	60	100	310	205	225	265	580	287	0	2,427	0.8
Total	8,870	7,320	4,610	11,075	49,100	58,975	29,005	17,700	42,215	11,440	7,495	10,925	32,245	21,980	4,267	0	317,222	

[a] See Table 1.

Table 5. Estimates of waterbird and raptor abundance from aerial inventories at The Emiquon Preserve during spring 2017.

	Inventory Dates								
Species[a]	14-Feb	21-Feb	3-Mar	9-Mar	16-Mar	28-Mar	16-Apr	Total	%
AWPE	100	450	0	135	200	290	410	1,585	0.8
AMCO	500	11,700	34,400	42,600	54,400	48,900	8,300	200,800	98.9
BAEA	39	2	8	2	4	2	1	58	0.0
DCCO	0	0	0	5	10	300	260	575	0.3
Total	639	12,152	34,408	42,742	54,614	49,492	8,971	203,018	

[a] See Table 1

Table 6. Estimates of waterbird and raptor abundance from aerial inventories at The Emiquon Preserve during fall 2017.

	Inventory Dates																
Species[a]	6-Sep	14-Sep	21-Sep	27-Sep	20-Oct	26-Oct	31-Oct	10-Nov	13-Nov	22-Nov	29-Nov	7-Dec	14-Dec	19-Dec	26-Dec	3-Jan	Total	%
AWPE	755	1,490	2,160	2,760	2,000	1,150	90	50	165	40	80	50	50	175	5	0	11,020	3.6
AMCO	3,900	6,100	14,980	39,975	72,300	84,000	47,945	11,000	8,000	300	200	150	0	30	0	0	288,880	95.3
BAEA	0	0	4	0	0	3	6	20	15	21	1	7	22	36	42	1	178	0.1
DCCO	750	600	310	320	650	400	100	15	40	10	0	0	0	0	0	0	3,195	1.1
Total	5,405	8,190	17,454	43,055	74,950	85,553	48,141	11,085	8,220	371	281	207	72	241	47	1	303,273	

[a] See Table 1.

Table 7. Waterbird brood observations by species at The Emiquon Preserve, 2017.

	Observation Dates										
Species[a]	16 May	31 May	13 Jun	27 Jun	12 Jul	25 Jul	11 Aug	23 Aug	Total	%	Broods/km^2
CAGO	16	9	10	1	1	0	1	0	38	19.2	11.1
COGA	0	0	0	0	0	0	1	4	5	2.5	1.7
MALL	0	3	3	6	3	6	3	1	25	12.6	5.2
MUSW	2	11	5	2	2	1	3	4	30	15.2	3.9
PBGR	0	0	0	0	0	0	0	1	1	0.5	0.2
WODU	1	2	9	17	29	31	9	1	99	50.0	23.7
Total	9	15	35	40	22	20	10	2	198		45.8
Mean Age[b]	1C	1C	2A	2A	2A	2C	2C	2C			

[a] See Table 1.
[b] Gollop and Marshall 1954

Table 8. Waterbird nest abundance and survival in hemi-marsh, dense emergent, and other vegetation communities at The Emiquon Preserve, 2017.

	Nests Found			Density[a]		Abundance[b]		Survival		
Species[c]	Hemi	Dense	Other	Hemi	Dense	Hemi	Dense	Hemi	Dense	Other
AMCO	9	6	0	0.41	N/A	87.8	N/A	0.04	0.42	N/A
BCNH	0	13	0	N/A	N/A	N/A	N/A	N/A	0.44	N/A
BNST	0	0	1	N/A	N/A	N/A	N/A	N/A	N/A	0.00
COGA	16	11	0	0.81	0.42	175.6	31.2	0.44	0.54	1.00
LEBI	7	5	1	0.31	0.42	65.8	31.2	0.86	1.00	1.00
MALL	1	1	11	0.20	N/A	43.9	N/A	0.00	0.00	0.36
PBGR	0	0	1	N/A	N/A	N/A	N/A	N/A	N/A	1.00
Total	33	36	14	1.73	0.85	373.1	62.3	0.47	0.55	0.46

[a]Nests/ha. Includes nests found in random plots only.
[c]Based on 2016 estimates of hemi-marsh (215 ha) and dense emergent communities (73 ha). Includes only nests found in random plots.
[a]See Table 1.

Table 9. Duck nest survival estimates (95% CI) derived from chain-dragged grassland tracts at The Emiquon Preserve during 20 April–25 July, 2017.

	Nest Survival			
Tract	*n*	$\hat{s}$	LCL	UCL
Butt	4	0.0749	0.0012	0.3832
Prairie 1	3	0.0096	0.0000	0.2346
Prairie 2	41	0.1189	0.0518	0.2173
Prairie 3	5	0.2681	0.0182	0.6565
South Levee	3	0.0371	0.0001	0.3541
West Prairie	13	0.2221	0.0619	0.4463
Total	69	0.1351	0.0749	0.2138

Table 10. Soil and water characteristics at random locations within Thompson and Flag lakes to assess the effects of water-level manipulations at The Emiquon Preserve, 26 September 2017.

Location	Community	Water Depth[a]	Water Transparency[a]	Soil Compaction[a]	POM[b]	Bulk Density[c]
Thompson	Moist-soil	0	N/A	2.0	11.4	0.6
Flag	Aquatic Bed	113.0	70.0	9.0	6.0	0.7
Flag	Floating-leaved	53.0	28.0	2.0	4.0	0.9
Thompson	Open Water	220.0	38.0	6.0	5.7	0.7
Thompson	Aquatic Bed	15.0	15.0	9.0	6.0	0.8
Flag	Mudflat	0.0	N/A	1.5	7.1	0.8
Flag	Aquatic Bed	81.0	70.0	7.0	5.5	1.0
Flag	Aquatic Bed	71.0	71.0	6.0	5.1	1.0
Thompson	Aquatic Bed	11.0	11.0	13.5	3.4	1.1
Flag	Hemi-marsh (Dead)	15.0	15.0	13.0	5.6	0.7
Flag	Moist-soil	0.0	N/A	0.5	4.4	1.2
Flag	Persistent Emergent	0.0	N/A	1.0	7.3	0.7
Flag	Aquatic Bed	42.0	42.0	2.0	4.3	1.2
Thompson	Aquatic Bed	119.0	85.0	10.0	4.9	1.3
Thompson	Floating-leaved	23.0	23.0	5.0	4.0	0.9
	$\bar{x}$	50.9	42.5	5.8	5.6	0.9

[a]centimeters
[b]Percent organic matter
[c]grams/cm^3

Table 11. Abundance (mg/m^3, dry mass) and percent occurrence of plants and seeds emigrating from The Emiquon Preserve through the water-control structure, August–October, 2017.

Taxa	Biomass (mg/m^3)	Percent Occurrence
Seeds		
Ambrosia spp.	<0.01	4.5
Carex lupulina	<0.01	4.5
Ceratophyllum demersum	0.01	4.5
Chenopodium spp.	<0.01	4.5
Echinochloa spp.	<0.01	4.5
Eupatorium spp.	<0.01	4.5
Ludwigia peploides	0.01	36.4
Medicago spp.	<0.01	4.5
Morus spp.	<0.01	9.1
Najas guadalupensis	<0.01	4.5
Najas minor	<0.01	4.5
Panicum spp.	<0.01	4.5
Poa spp.	<0.01	4.5
Potamogeton spp.	0.20	59.1
Portulaca spp.	<0.01	4.5
Rumex crispus	<0.01	13.6
Setaria spp.	0.03	63.6
Trifolium spp.	<0.01	9.1
Zanichellia palustris	<0.01	4.5
Total Seeds	0.25	
Plants		
Ceratophyllum demersum	6.83	95.5
Ludwigia peploides	0.03	4.5
Myriophyllum spicatum	0.06	50.0
Najas guadalupensis	0.05	63.6
Najas minor	0.04	50.0
Potamogeton nodosus	0.21	4.5
Potamogeton pusillus	0.25	18.2
Stuckenia pectinata	0.04	4.5
Zanichellia palustris	<0.01	9.1
Total Plants	7.28	

Appendix A. Conservation targets and Key Ecological Attributes (KEAs) of The Nature Conservancy at The Emiquon Preserve during 2007−2017 for waterbird and wetland monitoring objectives with observed values good (green), fair (yellow), or poor (red) relative to desired ranges.

Key Ecological Attribute	Indicator	Desired range			Results										
		Good	**Fair**	**Poor**	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Waterbird Habitat Quality	Fall Dabbling Duck Use Days	IRV ranking 1–5 (>1,132 UD/ha)	IRV ranking 5–10 (289–1,131 UD/ha)	IRV ranking <10 (<289 UD/ha)	4,813	2,035	1,418	1,773	2,131	1,722	1,611	739	960	1,599	996
	Fall Other Dabbling Duck Use Days	IRV ranking 1–5 (>493 UD/ha)	IRV ranking 5–10 (88–492 UD/ha)	IRV ranking <10 (<88 UD/ha)	3,821	1,261	1,082	1,507	1,680	1,438	1,391	598	805	1,331	780
	Fall Other Waterbird Use Days	IRV ranking 1–5 (>110 UD/ha)	IRV ranking 5–10 (37–110 UD/ha)	IRV ranking <10 (<37 UD/ha)	2,280	1,454	2,337	1,621	1,640	1,444	1,947	1,631	2,759	2,792	1,414
	Fall Diving Duck Use Days	IRV ranking 1–5 (>47 UD/ha)	IRV ranking 5–10 (8–47 UD/ha)	IRV ranking <10 (<8 UD/ha)	21	69	438	158	190	157	167	194	299	144	151
	Fall Gadwall Use Days	IRV ranking 1–5 (>104 UD/ha)	IRV ranking 5–10 (18–104 UD/ha)	IRV ranking <10 (<18 UD/ha)	627	297	289	310	272	272	392	166	262	345	255
	Fall American Coot Use Days	IRV ranking 1–5 (>88 UD/ha)	IRV ranking 5–10 (12–88 UD/ha)	IRV ranking <10 (<12 UD/ha)	2,280	1,454	2,306	1,578	1,606	1,394	1,928	1,610	2,727	2,738	1,344
	Spring Diving Duck Use Days	IRV ranking 1–12 (>120 UD/ha)	IRV ranking 13–28 (40–120 UD/ha)	IRV ranking <28 (<40 UD/ha)	–	336	383	236	237	214	156	216	158	399	217
	Spring Dabbling Duck Use Days	>486 UD/ha	486–376 UD/ha	<376 UD/ha	–	513	487	213	261	426	325	228	260	391	339
	Spring Other waterbird Use Days	>469 UD/ha	469–346 UD/ha	<346 UD/ha	–	358	713	334	192	470	107	411	456	975	969
	Duck Foraging Rates	>50%	30–50%	<30%	–	22	46	58	53	51	45	36	50	57	–
	Moist-soil Plant Seed Production	≥800 kg/ha	578–779 kg/ha	<578 kg/ha	1,132	547	256	733	1,246	591	565	1,115	465	814	1,544
Waterbird Production	Waterbird Brood Density	>10 broods/km2 peak	5–9 broods/km2 peak	<5 broods/km2 peak	–	22	24	28	25	29	19	6	10	56	66
	Waterbird (Non-waterfowl) Brood Species Richness	>5 species	3–5 species	<3 species	–	3	2	1	3	3	3	3	4	1	2
	American Coot Brood Density	>2.4 broods/km2 peak	0.8–2.4 broods/km2 peak	<0.8 broods/km2 peak	–	6.9	8.4	0	0.8	1.3	9.3	1	2	5	0
Community Composition (Emergent Floating-leaved Vegetation)	Cattail, river bulrush, bur reed dominance	Hemi-marsh >15% of wetland area	Hemi-marsh 10–15% of wetland area	Hemi-marsh <10% of wetland area	12	21	16	6	6	5	7	9	14	11	5
	Cattail, river bulrush, bur reed dominance	Single species <50% of emergent coverage	–	Single species >50% of emergent coverage	>50%[a]	>50%[a]	>50%[a]	>50%[a]	>50%[a]	>50%[a]	>50%[a]	>50%[a]	>50%[a]	>50%[a]	>50%[a]
Community Composition (Moist-soil Vegetation)	Non-woody invasives	<50% goldenrod, cocklebur, etc.	–	>50% goldenrod, cocklebur, etc.	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]
	Woody encroachment	<25% coverage of woody invasives	–	>25% coverage of woody invasives	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]
	Forb and grass coverage	Forbs ≥10% coverage	–	Forbs <10% coverage	–	–	–	–	–	–	19	19	38	53	43

[1]Based on anecdotal information. Not formally quantified during monitoring activities.

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