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Waterbird and Wetland Monitoring at The Emiquon Preserve

Annual Report 2016

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INTRODUCTION

The Nature Conservancy (TNC) identified key ecological attributes (hereafter, KEAs) of specific biological characteristics or ecological processes that could indicate restoration success and trajectory at the Emiquon Preserve (hereafter Emiquon; The Nature Conservancy 2006). Because of the historic importance of the Illinois River valley 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). Therefore, we monitored the response of wetland vegetation and waterbirds to restoration efforts at Emiquon during 2016 to evaluate restoration success relative to desired conditions under the relevant KEAs. Our primary efforts included evaluating: 1) abundance, diversity, and behavior of waterfowl and other waterbirds through autumn aerial counts and spring ground 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

To estimate abundance of avifauna at Emiquon during spring, we enumerated waterbirds by species (Table 1) with a spotting scope and binoculars from fixed vantage points and while traveling between vantage points. We assumed ground counts from elevated vantage points approximated total population size of selected species and guilds. Spring surveys were conducted weekly from approximately mid-February through mid-April, during waterfowl migration. Although our ground inventories were designed to monitor waterfowl, we also recorded abundances of raptors and other waterbirds encountered incidentally.

We also estimated waterbird abundances aerially at Emiquon as part of the Illinois Natural History Survey's (INHS) fall waterfowl inventories (Havera 1999). Aerial inventories were conducted approximately weekly (weather permitting) during fall 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).

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 used INHS aerial inventory data to calculate fall waterfowl UDs in order to make these estimates comparable to other aerially surveyed locations in the IRV. Conversely, we used ground inventory data to derive spring waterfowl UDs, as aerial waterbird inventories were not conducted during spring 2016. Lastly, we expressed duck use estimates as UDs per ha of wetland (UDs/ha) to standardize for wetland size for comparison with past years.

Waterfowl Behavior

We conducted behavioral observations using scan sampling to evaluate the functional response of ducks to wetland restoration and habitat change at Emiquon (Altmann 1974). This method allowed for a rapid assessment of waterfowl behavior (Paulus 1988) that could be conducted simultaneously with ground counts. One behavioral sample consisted of at least 250 observations of the same species, in the same flock or within close proximity, and recording the behavior and gender of each individual. Behavioral categories included feeding, resting, social (e.g., courtship and aggression), locomotion (e.g., swimming, walking, and flying), and other (e.g., comfort and preening). We attempted to prevent underestimation of diving duck foraging behavior by modifying our scan sampling methodology (Hine et al. 2010). We observed each diving duck for ≤10 seconds during the scan to capture feeding behavior, essentially creating a series of short focal samples. We contend that this method should better represent the foraging behavior of diving ducks than unmodified scan sampling. We narrated all observations into a hand-held voice recorder for subsequent transcription. We attempted to achieve 500 observations during each ground count on species that were present at the wetland throughout the migration period to maximize sample sizes and inference. However, lack of visibility (e.g., dense vegetation), distances between observation points and waterbird concentrations, and difficulty in approaching flocks undetected, occasionally prevented us from achieving the desired number of observations during some ground counts.

Waterbird Productivity

We monitored waterbird production at Emiquon in 2016 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 marshbirds 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 2015 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.

Soil Properties

We randomly selected 15 points along east-west transects at lake-bed elevations $\pm$ 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 ($\pm$ 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^{o} 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^{o} 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 Preserve 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 (10–20 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 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 sub-sampled 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 2016. 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 70 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 10 ground inventories from 17 February to 21 April 2016. Peak waterfowl abundance reached 72,174 on 18 March (Table 3). We observed 25 species of waterfowl during spring (19 duck species, 3 goose species, and 3 swan species). Gadwall were the most abundant species during ground inventories, accounting for 20.7% of total waterfowl abundance, followed by lesser snow geese (19.5%) and ruddy ducks (15.0%). Dabbling duck and diving duck abundances were nearly equal, accounting for 38.5% and 38.2% of the total waterfowl abundance, respectively. Spring waterfowl UDs were 2,037,864 in 2016. Dabbling ducks

(789,553 UDs) contributed 38.7% of the spring waterfowl use at Emiquon, while diving ducks (805,763 UDs) accounted for 39.5% of the use (Fig. 2).

We conducted 16 aerial inventories at Emiquon from 31 August 2016 to 5 January 2017 (Table 4). We observed 19 species of waterfowl (16 duck species, 3 goose species, and unidentified swan species) with a peak abundance of 63,620 on 14 November. Gadwall (20.5%) were the most abundant species, followed by northern pintail (17.0%), mallards (16.9%), American green-winged teal (12.5%), and northern shoveler (11.1%). Estimated waterfowl UDs at Emiquon totaled 3,698,392 during fall. Dabbling ducks (3,297,455 UDs) accounted for 89.1% of UDs, whereas 8.3% of waterfowl UDs was attributable to diving ducks (306,953 UDs; Fig. 4).

Non-Waterfowl Abundance

We documented 13 waterbird and raptor species during ground counts in spring 2016 (Table 5). Peak abundance of non-waterfowl species observed during ground inventories was 63,694 individuals on 11 March. American coots were the most common species observed and accounted for 97.8% of non-waterfowl abundance from ground counts. American coot abundance peaked at 63,063, while their use of Emiquon totaled 1,929,112 UDs (Fig. 2).

American coots were the most abundant species during 16 aerial inventories in fall 2016. The peak estimate of American coots was 156,975 on 18 October (Table 6). American coots (5,547,603 UDs; Fig. 4) accounted for 98.1% of non-waterfowl use, followed by American white pelicans (1.0%) and double-crested cormorants (0.9%). American coots contributed 59.3% of all waterbird use (including waterfowl) during fall at Emiquon.

Duck Behavior

We conducted behavior observations (*n* = 5,162) between 17 February and 15 April 2016. Species observed included mallard, gadwall, northern shoveler, ruddy duck, common goldeneye, and common merganser. These species spent most of their time feeding (57.0%), followed by locomotion (22.3%) and resting (12.2%; Fig. 6). Dabbling ducks spent 66.9% of their time feeding, while diving ducks spent 38.9% of their time feeding.

Waterbird Productivity

We conducted fixed-point brood surveys (n = 8) from 17 May to 31 August 2016 and observed 153 waterbird broods comprised of 5 species (Table 7). The most abundant broods were wood ducks (n = 85), mute swans (n = 33) and Canada geese (n = 22). Brood observations peaked (n = 40) on 30 June. Brood densities ranged from 0 – 122.6 broods/km^2 and averaged 32.1 broods/km^2 at Emiquon during 2016. Mean brood densities were greatest for wood ducks (19.4 broods/km^2), followed by Canada geese (5.1 broods/km^2), mute swans (4.8 broods/km^2), mallards (2.5 broods/km^2), and American coots (0.2 broods/km^2). Moreover, age classes of broods increased throughout the observation period indicating recruitment at Emiquon.

We conducted 74 waterbird nest surveys in persistent emergent vegetation communities (hemi-marsh and dense emergent) during 3 June – 26 July, 2016 at Emiquon. We found 91 waterbird nests (includes incidental nests) comprised mostly of black-necked stilts (n = 39), common gallinule (n = 14), least bitterns (n = 13), and American coots (n = 13; Table 8). Annual nest survival ranged from 23.0% – 82.5% ($\bar{x}$ = 54.4%). Waterbird nest densities averaged 1.6 nests/ha (range, 1.0 – 7.1 nests/ha), and when extrapolated to the entire nesting area, we estimated 514 waterbird nests in the hemi-marsh community at Emiquon in 2016.

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 during 6–7 September. Water depths at sampling locations ranged from 3 cm – 225 cm with secchi readings ranging from 3 cm – 145 cm (Table 9). Soil bulk density averaged 1.0 g/cm^3 (range, 0.7 g/cm^3 – 1.3 g/cm^3). Percent organic material ranged from 4.1% – 7.3% and averaged 5.7%. Soil compaction estimates at core sites averaged 8.3 cm (range, 1 cm – 17 cm).

Plant and Seed Emigration

We sampled seeds and plant material emigrating from Emiquon on 4 dates during 13 July – 15 November. We identified 10 seed taxa and 6 plant taxa moving through the water control structure (Table 10). Mean seed emigration was 0.22 mg/m^3 (range, 0.00 mg/m^3 – 1.33 mg/m^3), comprised mostly of *Potamogeton* (0.05 mg/m^3), *Najas* (0.02 mg/m^3), and *Setaria* (0.02 mg/m^3) species. Aquatic plants emigrating from Emiquon averaged 10.8 mg/m^3 (range, 0.01 mg/m^3 – 55.8 mg/m^3). *Myriophyllum* (4.06 mg/m^3), *Potamogeton* (1.91 mg/m^3), and *Najas* (1.38 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 from 11–13 October to estimate seed abundance (kg/ha) and energetic carrying capacity of moist-soil plants for waterfowl. Average moist-soil plant seed density was 814.1 kg/ha (dry mass; Fig. 7). The estimated energetic carrying capacity from moist-soil plant seeds in 2016 was 6,039.6 EUDs/ha.

Wetland Covermapping

We mapped all wetland vegetation, open water and areas containing surface water in Thompson and Flag lake basins during 14–20 September 2016 (Fig. 8). Aquatic bed (1,034.9 ha) was most abundant, followed by open water (572.1 ha), hemi-marsh (215.4 ha), floating-leaved aquatic (i.e, American lotus, watershield; 85.6 ha), persistent emergent (73.4 ha), and non-persistent emergent (33.3 ha; Fig. 9). We covermapped 2,021.7 ha and documented 70 plant taxa at Emiquon in 2016 (Table 2).

Species composition data from randomly-selected 1-m^2 plots in 2016 indicated 49.2% of the aquatic bed community contained longleaf pondweed, followed by Eurasian watermilfoil (23.2%), coontail (17.7%), and sago pondweed (8.2%; Fig. 10). The hemi-marsh community contained mostly cattail (39.4%), coontail (30.8%), and Eurasian watermilfoil (17.2%), with lesser proportions of, naiads (8.1%) and lotus (2.5%). Non-persistent emergent vegetation (moist-soil) at Emiquon was mostly comprised of creeping water primrose (29.0%), nodding beggarticks (16.7%), rice cutgrass (16.7%), barnyardgrass (10.0%), and panicum (7.8%). Lastly, the persistent emergent vegetation community was dominated by cattail (98.5%) with longleaf pondweed (1.5%).

DISCUSSION

Waterbird use of Emiquon may serve as an indicator of wetland conditions or a measure of waterbird habitat quality (Austin et al. 2001, Gawlik 2006, Hagy et al. 2016). 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 increased more than 150% from spring 2015 and more than doubled the fall 2016 estimate. Furthermore, it was the highest diving duck density observed in either season at Emiquon since restoration began. Spring dabbling duck density in spring 2016 increased 50% from 2015 and was the highest dabbling duck density since spring 2012. Similar to diving ducks, density of other waterbirds (excluding waterfowl) in spring 2016 more than doubled that of 2015 and was the highest spring waterbird density observed at Emiquon. All spring waterbird densities in 2016 exceeded the desired KEA indicator ranges as well as the long-term averages of these indicators.

Fall dabbling duck density (1,599 UDs/ha) at Emiquon in 2016 increased 66% over the 2015 estimate but fell below the 2007–2015 average (1,911 UDs/ha). Similarly, the density of other dabbling ducks (1,331 UDs/ha; excluding mallards) increased 65% from 2015 but was slightly below the long-term average (1,509 UDs/ha). More specifically, gadwall density was the 3^{rd} highest observed at Emiquon and slightly above the 2007–2015 average (321 UDs/ha). Conversely, diving duck density in fall 2016 was less than half of the fall 2015 density and the lowest since 2008, but it remained above the desired indicator range. Fall density of other waterbirds in 2016 was the highest observed in any year. Other waterbird density is driven by American coots, which exhibited the highest density in fall 2016. American coot density at Emiquon also represented the highest in the IRV in 2016. Emiquon ranked 2^{nd} for non-mallard dabbling duck densities in the IRV, while contributing the 3^{rd} highest densities for dabbling ducks and total ducks in fall 2016. Lastly, Emiquon ranked 5^{th} in diving duck density in the IRV, which was Emiquon's lowest diving duck rank since 2007. Nonetheless, Emiquon exceeded the desired ranges of KEA indicators pertaining to all fall waterbird densities in 2016.

Our behavioral observations indicated that ducks spent 57% of their time foraging during spring 2016, exceeding the KEA target. This was the 2^{nd} highest proportion of time allocated to feeding (58% in 2010) since monitoring began in 2008 and 27% greater than the long-term average (45%). Excepting 2008, foraging has been the dominant activity of total ducks throughout restoration at Emiquon. On-going research suggests that submersed aquatic vegetation, invertebrates, and natural plant seeds are being consumed by ducks at Emiquon Preserve (Osborn et al. 2016, Yetter et al. 2017). Furthermore, we've documented that Emiquon has consistently produced an abundance of food, which is likely more than is required by ducks foraging there during fall and spring (Hine et al. 2016a).

Brood surveys during 2016 produced the highest peak waterbird brood density (74 broods/km^2) since surveys began in 2008. Peak waterbird brood density in 2016 was more than 150% higher than the next highest brood density (29 broods/km^2) observed at Emiquon and more than 2.5 times greater than the 2008–2015 average. The dramatic increase in 2016 may have been attributable to the decline in persistent emergent vegetation, which allowed broods to be more visible. While the peak waterbird brood density far exceeded the KEA indicator range, species richness of non-waterfowl broods remains low (2016, n = 1) 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 more difficult (Bolenbaugh et al. 2011). Observations of American coots in 2016 supported this notion as we were able to detect only 1 brood, and the brood density averaged only 0.2 broods/km^2. For comparison, 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 that our brood observations should be considered only as 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, we suggest these counts are most useful for assessing trends as the vegetation structure changes at Emiquon.

Marshbird nest surveys allowed us to further assess overall waterbird productivity at Emiquon. More species (n = 6) were documented in 2016 than in previous years, including first time nest records of pied-billed grebes. Furthermore, we found more least bittern (Illinois threatened, n = 17) and common gallinule (Illinois endangered, n = 15) nests in 2016 than in any other year. The number of found nests increased 65% from 2015 (n = 55) and was more than twice the 2013–2015 average ($\bar{x}$ = 43), which contributed to the highest nest density in 2016 (1.7 nests/ha). Consequently, the nest abundance estimate in 2016 was 2.5 times greater than the next highest nest abundance estimate in 2014 (n = 207 nests). While nest abundance increased substantially, overall nest survival in 2016 was below the 2013–2015 average ($\bar{x}$ = 64.6%) and has declined 26% since 2014. The decline in persistent emergent vegetation likely contributed to lower nest survival as few nests (n = 7) were located in this vegetation community with <1% nest survival, whereas nests located in hem-marsh experienced 58% survival. 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 2016 (0.3 nests/ha), but coot nest survival at Emiquon (65%) was similar to that reported in southeast Idaho (72%; Austin and Buhl 2011). Nest density of least bitterns at Emiquon in 2016 (0.7 nest/ha) was greater than nest densities in western New York (0.1 nests/ha), but nest survival was greater (46% – 80%) than what we observed at Emiquon (43%; Lor and Malecki 2006). Nest survival of pied-billed grebes at Emiquon (80%) was greater than those reported from New York (72%) in 1998 (Lor and Malecki 2006).

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 2016 (814 kg/ha) exceeded the desired indicator range as well as the long-term average ($\bar{x}$ = 739 kg/ha) at Emiquon. 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 501.5 to 1,030.0 kg/ha and averaged 691.3 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 2016 exceeded the averages of these published estimates.

We revised EUD estimates for CNWR based on mean daily energy requirements of dabbling ducks (337 kcal/d) published by Stafford et al. (2011). Consequently, CNWR averaged 5,860 EUD/ha during 1999−2001 (Bowyer et al. 2005), whereas energetic carrying capacity of moist-soil communities at IDNR waterfowl management areas averaged 5,128 EUD/ha during 2005−2007 (Stafford et al. 2011). Thus, energetic carrying capacity of the moist-soil community at Emiquon in 2016 (6,039 EUDs/ha) exceeded these published estimates for this region.

In an effort to measure Emiquon's contribution to the resources of the Illinois River following restoration, we attempted to monitor plant and seed emigration through the water control structure for the first time in 2016. There were few periods when the Illinois River was low enough to gravity flow water out of Emiquon Preserve during summer and fall 2016. Consequently, opportunities to monitor the discharge were limited. The limited data we collected indicated that the plant and seed emigration from Emiquon in 2016 appeared to be low (<11 mg/m^3 of water). An anticipated drawdown during summer 2017 should provide for more sampling opportunity and adjustments to our sampling strategy, permitting further evaluations of Emiquon's contribution of plant material to the Illinois River mainstem.

The spatial coverage of wetland vegetation (2,022 ha) at Emiquon remained nearly the same as 2015 (2,017 ha) and represented the largest area mapped since restoration began. Likewise, the area of aquatic bed in 2016 was slightly greater than 2015, and it was 23% above the 2007–2015 average (841 ha). Open water increased 13% from 2015 and 97% above the long-term average (290 ha). The spatial extent of persistent emergent vegetation in 2016 declined 15% from 2015 (86 ha) and was 56% below the 2007–2015 average (165 ha). The persistent emergent community has declined 75% since 2013. Hemi-marsh declined 25% in 2016 following a 63% increase between 2014 and 2015. We continued to observe areas of persistent emergent vegetation transition to hemi-marsh, then to dead hemi-marsh as sustained high water levels and muskrat (*Ondatra zibethicus*) herbivory and other factors have apparently contributed to declines in these vegetation communities at Emiquon. Conversely, we've observed rather substantial increases in the spatial coverage of open water since 2014, while there's been a subtle decline in aquatic bed since 2013. Changes in vegetation community structure at Emiquon mirror the phases of marsh vegetation cycles (van der Valk and Davis 1978, Hine et al. 2016b).

The criteria for KEAs related to community composition stipulate <10% invasive species coverage and 100% exclusion of purple loosestrife. Encounters with common reed declined 50% between 2016 (n = 9) and 2015 (n = 18; Fig 11). We did not encounter purple loosestrife at Emiquon during cover-mapping operations in 2016. Common reed and purple loosestrife have been targeted by wetland managers for eradication at Emiquon, and their efforts apparently have been effective. Encounters with reed canarygrass in 2016 declined 64% from 2015, and have declined 80% since 2013. Sustained high water has apparently set back the spread of reed canarygrass; however, future drawdowns could encourage expansion of this and other invasive plant species, so increased vigilance is encouraged. Overall, the proportion of vegetation polygons from the 2016 cover map containing invasive species declined 39% from 2015 and 43% from the high in 2013, the year following a drought. Eurasian watermilfoil comprised 23% of the aquatic bed community in 2016, which was a 26% decline from 2015. Conversely, Eurasian watermilfoil increased in the hemi-marsh community in 2016 (17%) from that in 2015 (7%), but Eurasian watermilfoil averaged 26% of the hemi-marsh community during 2013–2015. Although we've observed some apparent reduction in milfoil, it continued to be a prominent component of the aquatic bed and hemi-marsh communities at Emiquon.

Community composition goals for moist-soil vegetation specified forbs comprise $\geq$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 2016 indicated that the moist-soil plant community at Emiquon was within these KEA goals with the possible exception of barnyardgrasses, which comprised 10% 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 the soil characteristics of the wetland substrate at Emiquon in 2016. Future management plans include a substantial drawdown to reset the vegetation cycle and consolidate sediments. Our initial data indicated that the mean organic matter of the wetland sediments at Emiquon were very low ($\overline{x}$ = 5.7%) compared to those reported in Wisconsin (>40%) prior to drawdown (James et al. 2001). Furthermore, soil bulk density was much greater ($\overline{x}$ = 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). Brown and Wherrett (2014) reported that soil bulk densities >1.6 g/cm^3 restrict root growth. Our preliminary results suggest that accumulation of organic matter in the wetland substrates of Emiquon has been minimal during the first 10 years of restoration.

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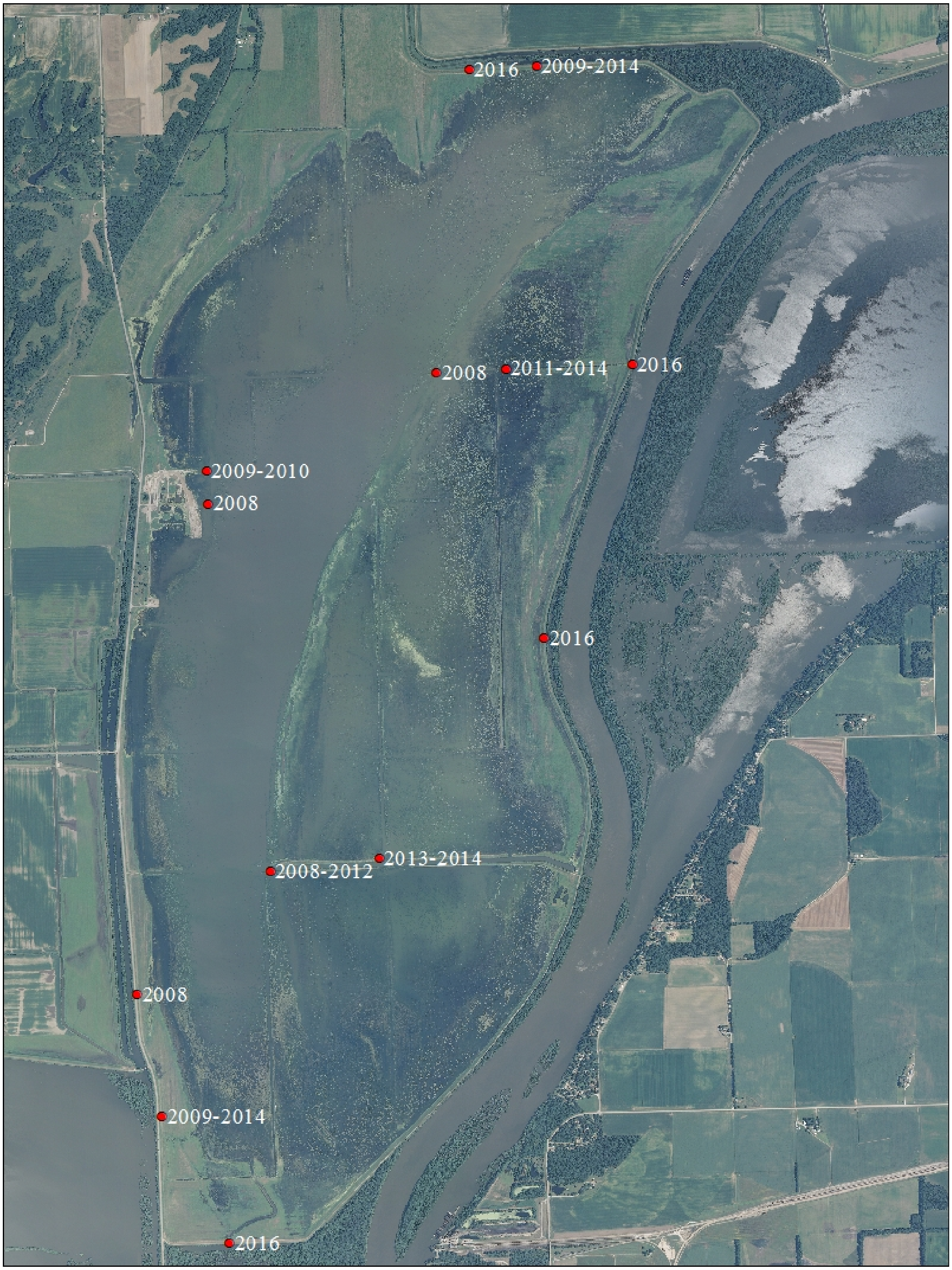


Figure 1. Brood observation locations by year at The Emiquon Preserve, summers 2008–2016. Observation points varied by year due to expanding water levels on the Preserve.

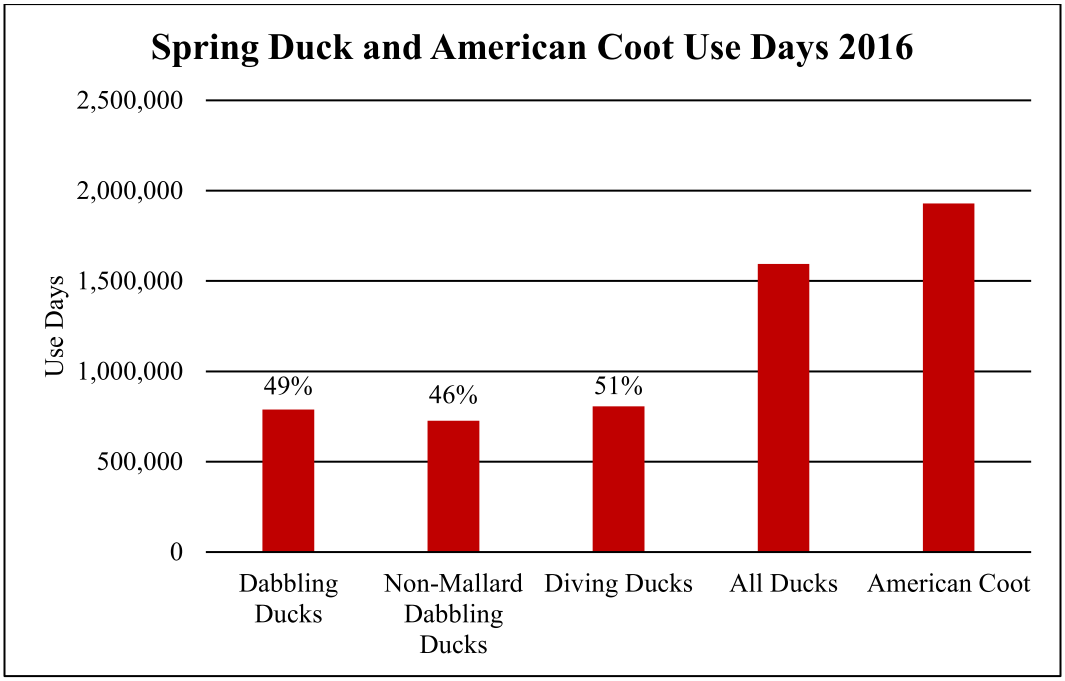


Figure 2. Use days of ducks and American coots at the Emiquon Preserve from ground inventories during spring 2016. Percentages represent proportions of total duck use days.

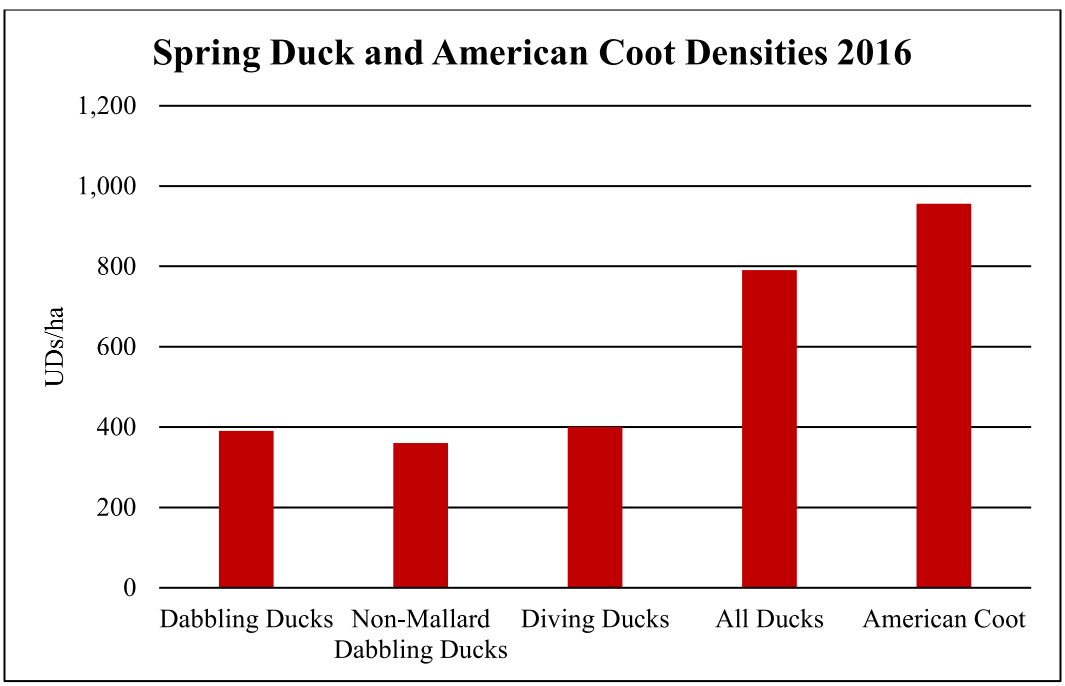


Figure 3. Use day densities of ducks and American coot at the Emiquon Preserve from ground counts during spring 2016.

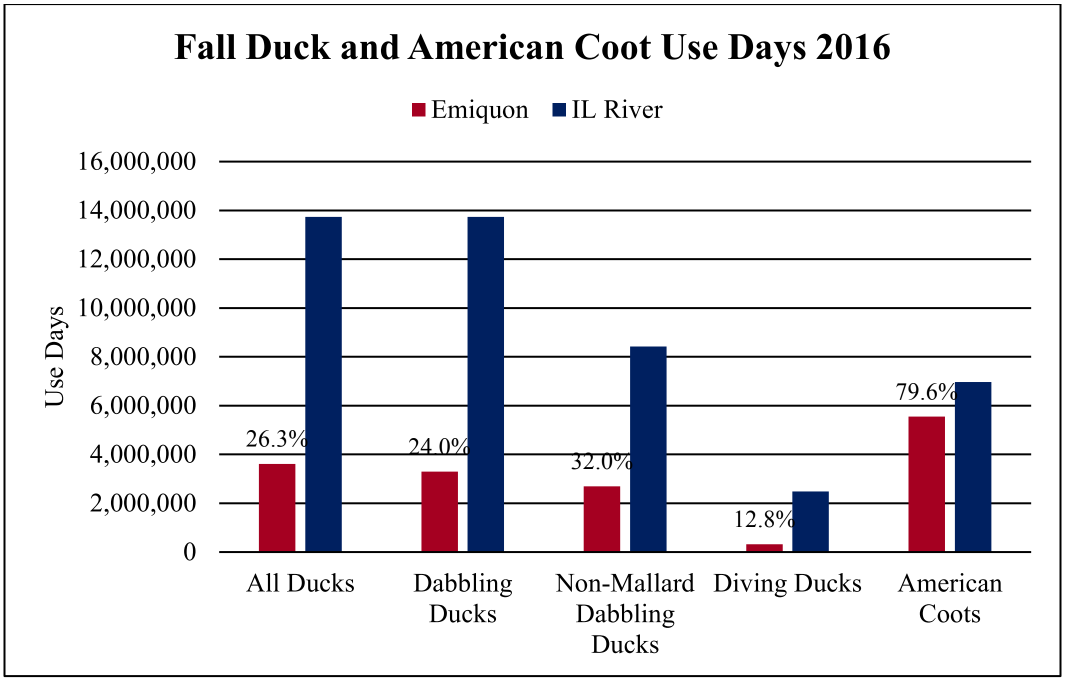


Figure 4. Use days of ducks and American coots at the Emiquon Preserve and other Illinois River sites from aerial inventories during fall 2016. Percentages represent proportions of Illinois River use days.

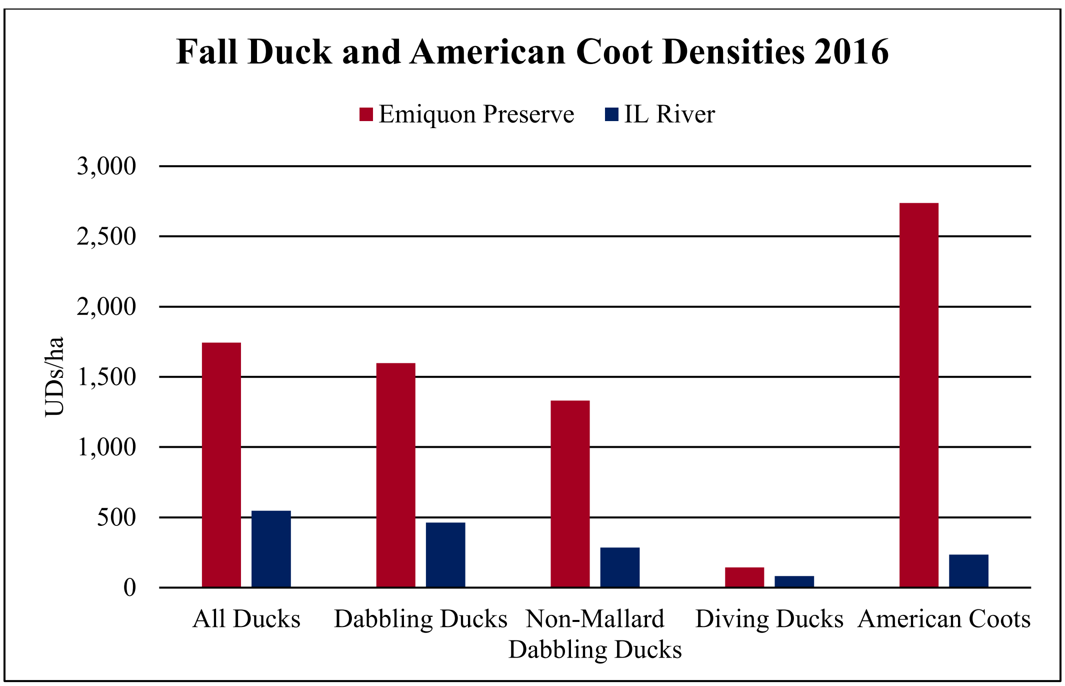


Figure 5. Duck and American coot densities at the Emiquon Preserve and other Illinois River sites from aerial inventories during fall 2016.

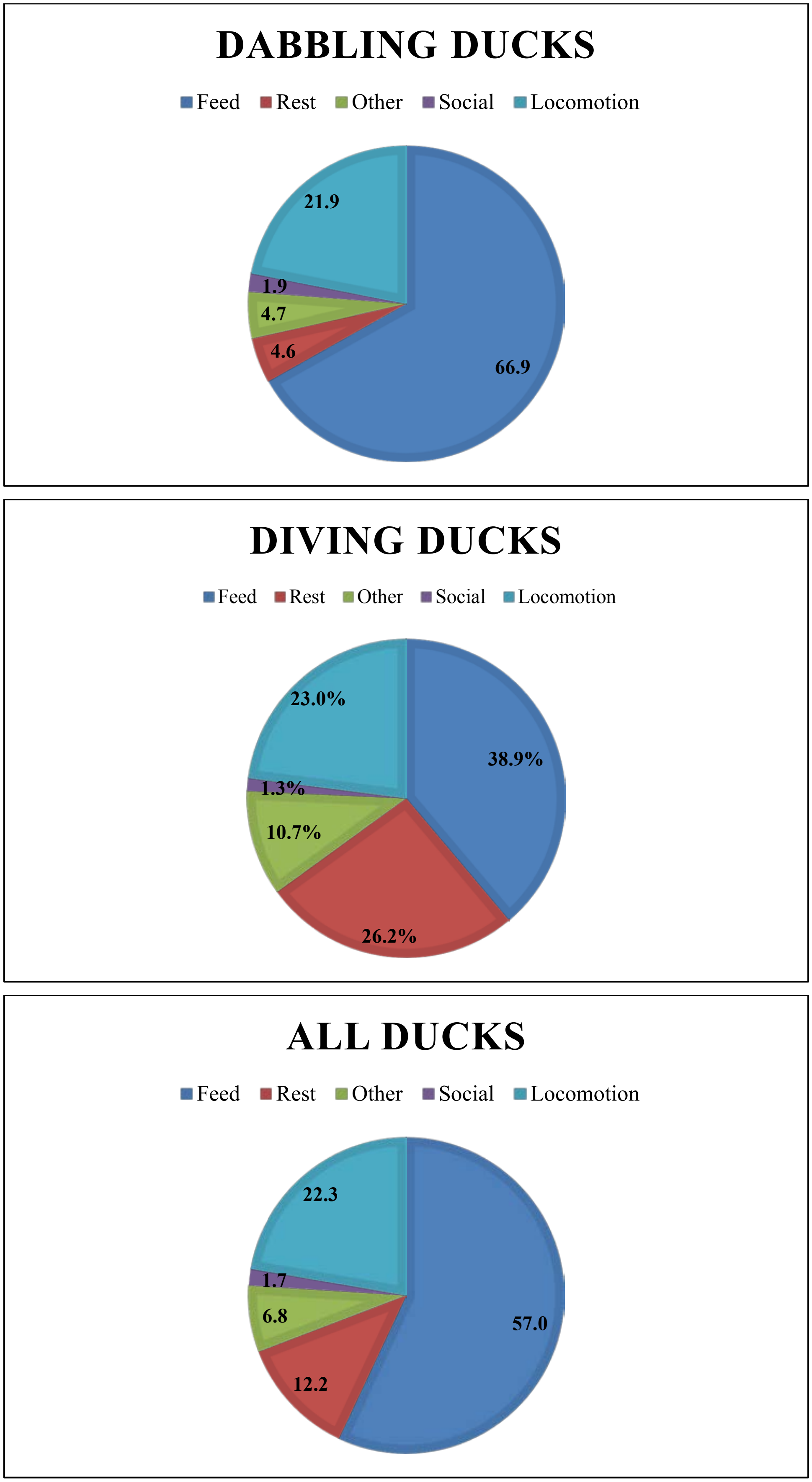
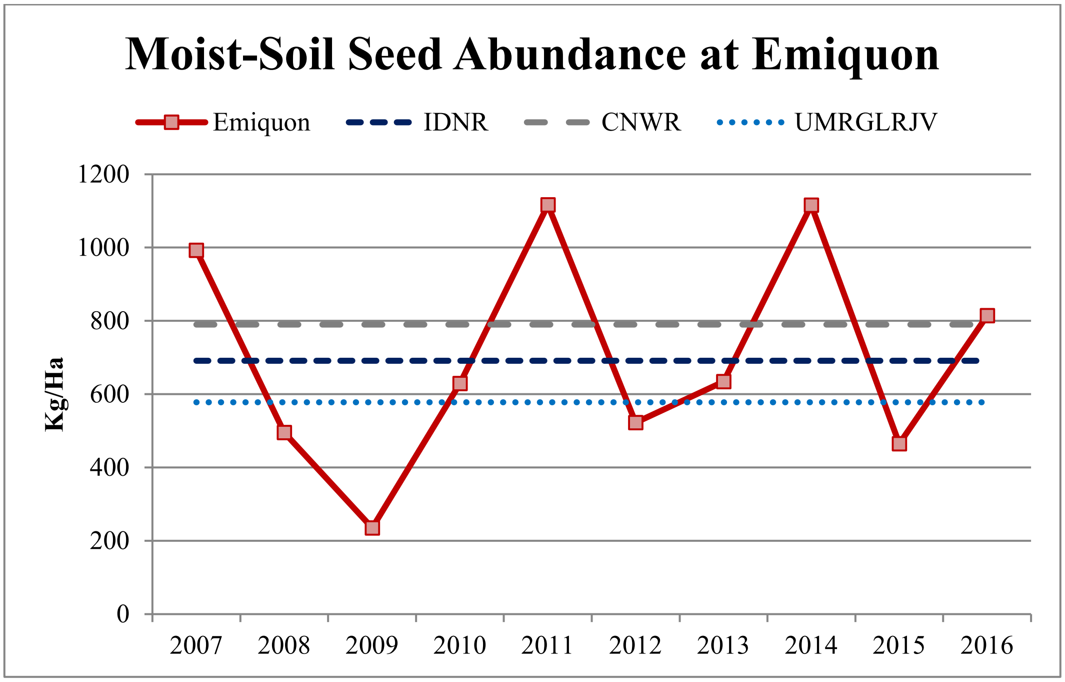


Figure 6. Time activity budgets of ducks at Emiquon Preserve during spring 2016.



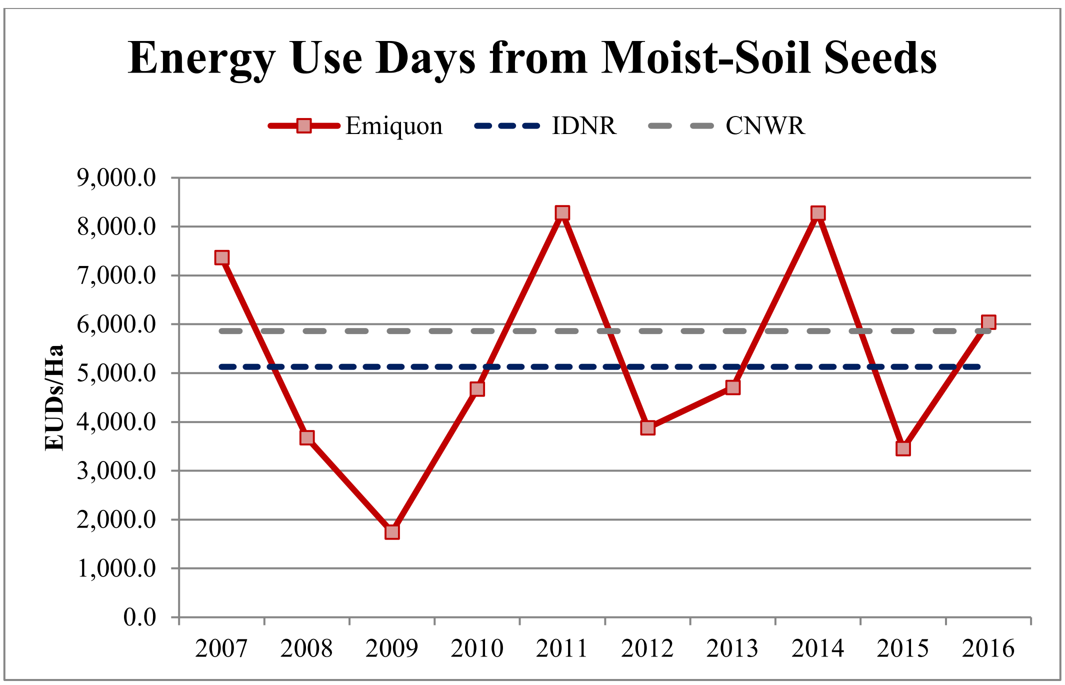


Figure 7. Moist-soil plant seed density and energy use days (EUDs) from moist-soil plants at the Emiquon Preserve compared to estimates (constants) from wetlands at Illinois Department of Natural Resources (IDNR) sites, Chautauqua National Wildlife Refuge (CNWR), and carrying capacity goals of the Upper Mississippi River/Great Lakes Region Joint Venture (UMRGLRJV) of the North American Waterfowl Management Plan.

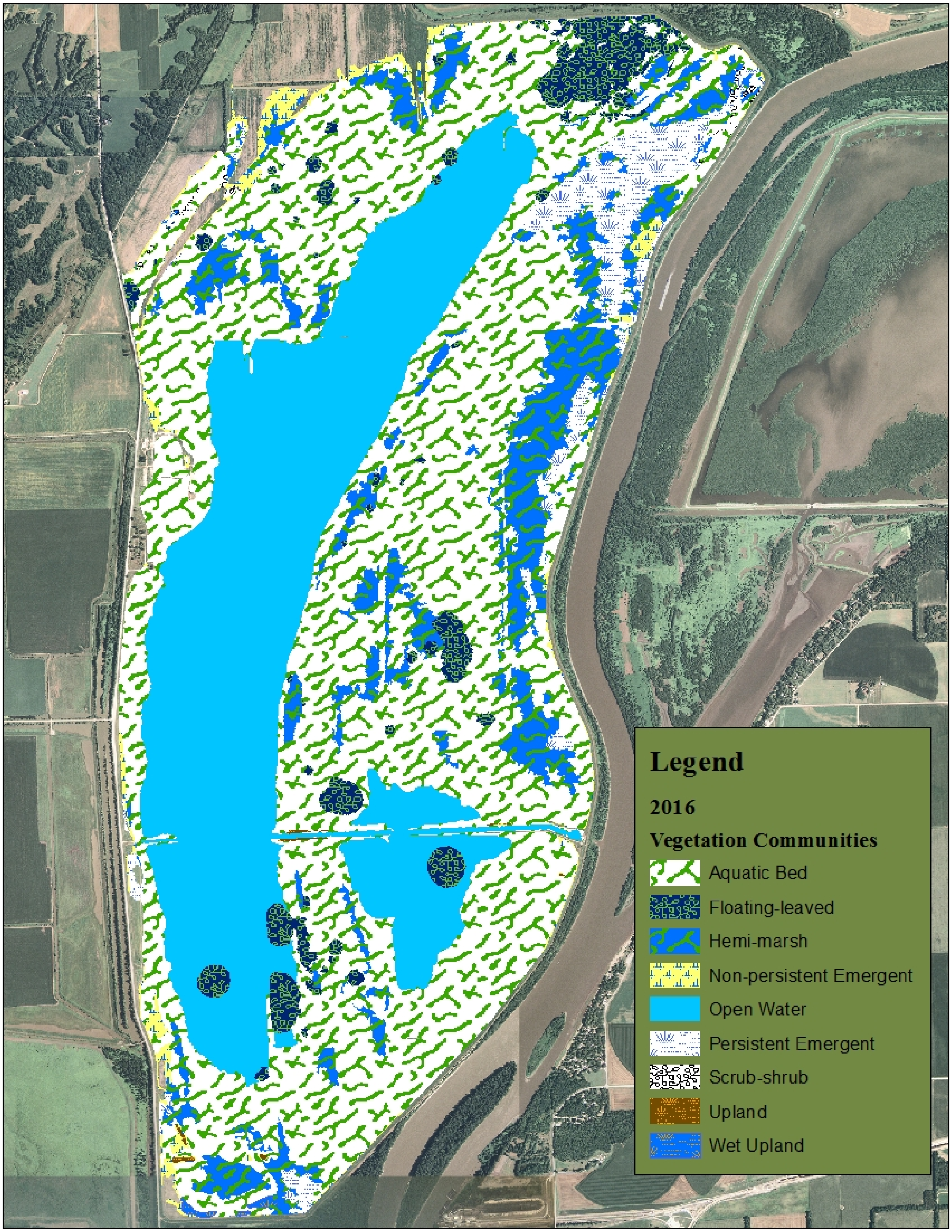


Figure 8. Wetland vegetation map of The Emiquon Preserve (2,021.7 ha), 14–20 September, 2016.

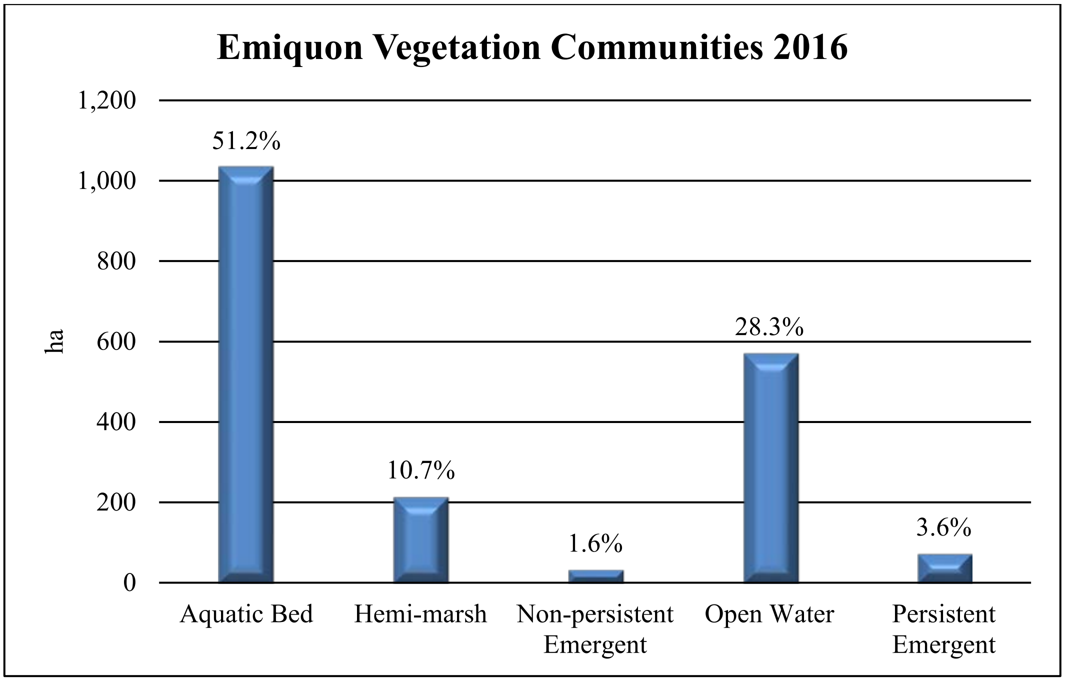


Figure 9. Proportional coverage of wetland vegetation communities at the Emiquon Preserve during September 2016.

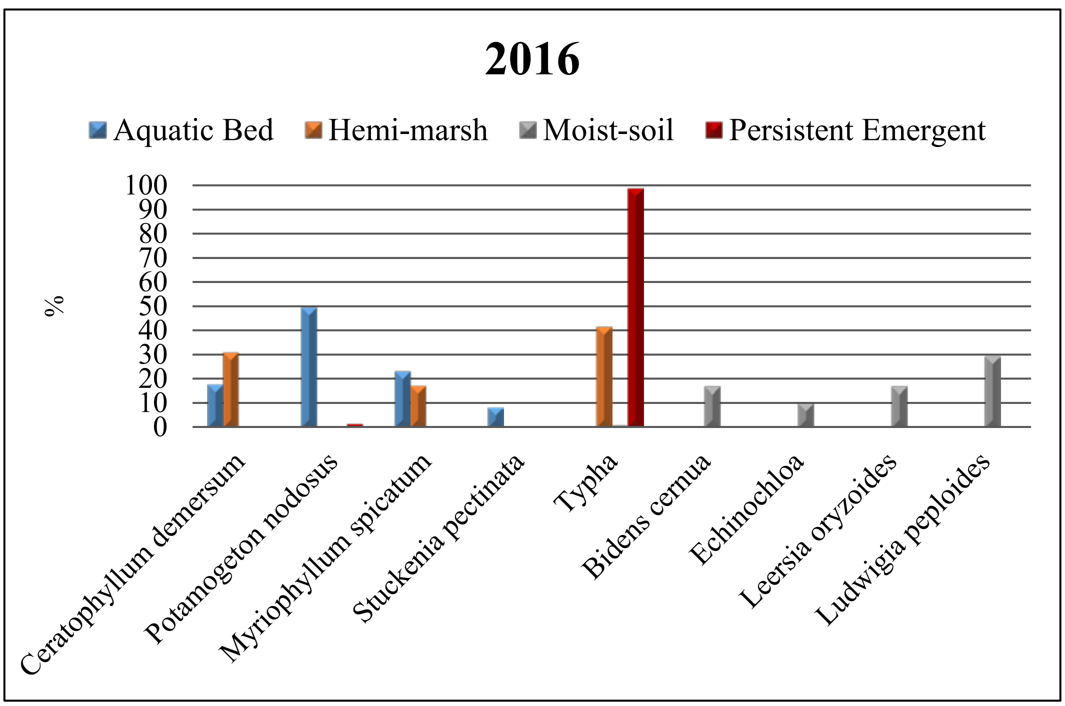


Figure 10. Composition of the major vegetation communities at the Emiquon Preserve during September 2016

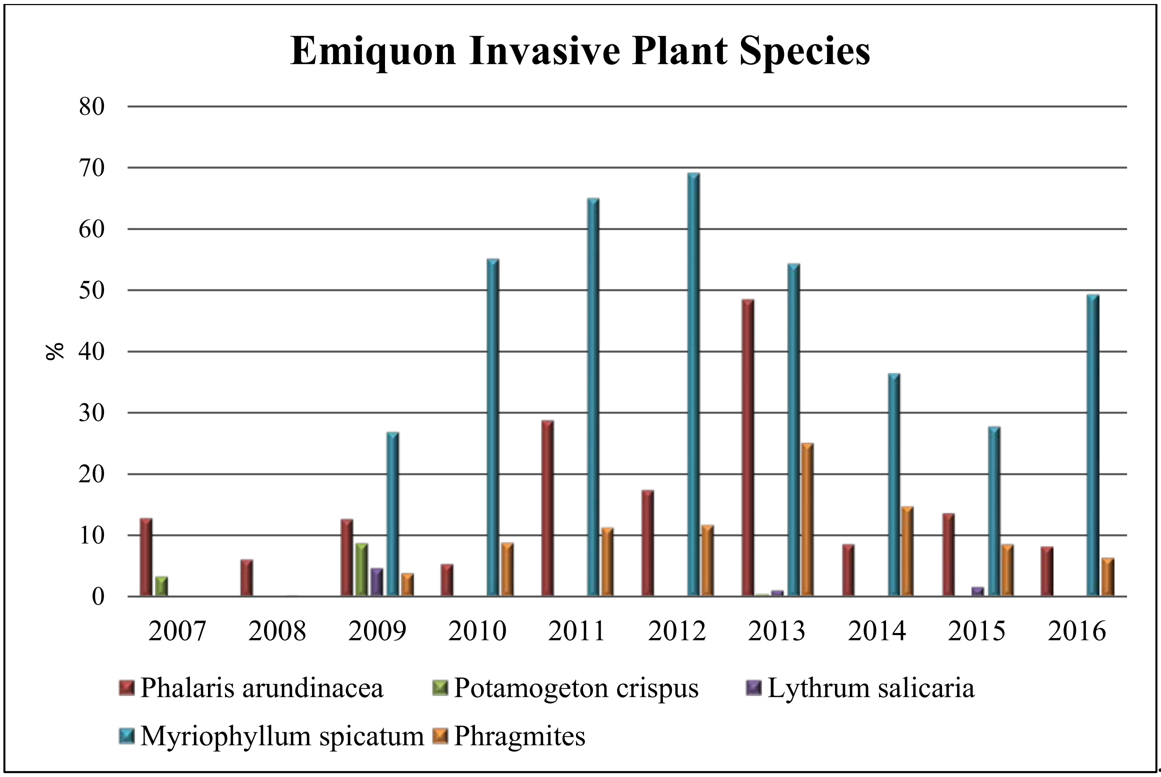


Figure 11. Invasive species encountered during wetland mapping at the Emiquon Preserve, 2007–2016. Percent represents proportion of covermap polygons containing invasive species.

Table 1. Avian species observed during monitoring activities at The Emiquon Preserve, 2007–2016.

Species	Common Name	Scientific Name
ABDU	American Black Duck	*Anas rubripes*
AGWT	American 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*
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*
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*
RTHA	Red-tailed Hawk	*Buteo jamaicensis*
RUDU	Ruddy Duck	*Oxyura jamaicensis*
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, 2007−2016.

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 Milfoil	*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*
Sowthistle	*Sonchus* spp.
Spikerush	*Eleocharis* spp.
Sprangletop	*Leptochloa fascicularis*

Table 2. Continued.

Common Name	Scientific Name
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 ground inventories at The Emiquon Preserve during spring 2016.

	Inventory Dates											
Species[a]	17 Feb	26 Feb	2 Mar	11 Mar	18 Mar	23 Mar	1 Apr	7 Apr	15 Apr	21 Apr	Total	%
ABDU	0	2	0	0	1	0	0	0	0	0	3	<0.1
AGWT	0	112	948	122	215	405	724	133	3	0	2,662	0.9
AMWI	0	0	4	30	567	2	0	1	0	0	604	0.2
BUFF	0	31	423	901	2,726	1,472	175	268	160	30	6,186	2.0
BWTE	0	0	0	6	14	120	415	532	671	1,299	3,057	1.0
CAGO	82	172	228	212	126	154	107	84	106	133	1,404	0.5
CANV	0	0	6	70	120	7	1	2	0	3	209	0.1
COGO	511	185	208	10	0	0	0	0	0	0	914	0.3
COME	1,390	2,290	1,520	10	0	0	0	0	0	0	5,210	1.7
GADW	101	1,127	4,571	15,625	24,639	9,640	3,224	1,022	1,039	2,714	63,702	20.7
GWFG	4,800	1,000	3,925	150	1	0	0	0	0	1	9,877	3.2
HOME	54	194	314	0	0	0	0	0	0	0	562	0.2
LESC	339	288	2,282	1,377	15,091	7,918	2,222	1,700	403	73	31,693	10.3
LSGO	35,000	6,004	18,525	207	160	131	30	3	4	3	60,067	19.5
MALL	1,172	1,046	2,827	462	3,482	329	88	40	252	100	9,798	3.2
MUSW	40	54	61	61	26	0	20	23	34	38	357	0.1
NOPI	60	3	491	50	0	0	0	0	0	0	604	0.2
NSHO	0	508	2,598	7,393	11,506	4,330	3,469	3,774	2,458	1,800	37,836	12.3
RBME	0	4	0	0	0	0	0	0	0	0	4	<0.1
REDH	8	0	2	60	0	0	0	22	3	0	95	<0.1
RNDU	0	1,206	6,601	10,933	5,311	1,814	147	437	14	9	26,472	8.6
RUDU	29	2,020	8,307	14,350	8,186	2,774	1,216	3,933	2,592	2,766	46,173	15.0
SWAN	86	0	0	0	0	0	0	0	0	0	86	<0.1
TRUS	2	0	0	0	0	0	0	0	0	0	2	<0.1
TUSW	0	9	0	30	1	0	1	0	0	0	41	<0.1
WODU	0	0	0	3	2	0	2	0	4	13	24	<0.1
Total	43,674	16,255	53,841	52,062	72,174	29,096	11,841	11,974	7,743	8,982	307,642	

[a] See Table 1.

Table 4. Estimates of waterfowl abundance from aerial inventories at The Emiquon Preserve during fall 2016.

	Inventory Dates																		
Species[a]	31-Aug	6-Sep	14-Sep	20-Sep	10-Oct	18-Oct	24-Oct	1-Nov	7-Nov	14-Nov	21-Nov	29-Nov	7-Dec	12-Dec	21-Dec	27-Dec	5-Jan	Total	%
MALL	255	395	2,950	2,920	1,535	1,950	1,010	5,575	10,020	17,145	5,140	9,375	7,630	12,450	1,130	1,170	300	80,950	16.9
ABDU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
NOPI	300	235	2,950	5,840	4,610	9,750	10,100	5,575	11,440	11,430	9,280	9,300	970	0	0	0	0	81,780	17.0
BWTE	5,765	9,285	11,850	11,685	3,070	1,950	505	0	0	0	0	0	0	0	0	0	0	44,110	9.2
AGWT	860	570	2,950	2,920	7,680	5,850	10,100	6,690	4,290	5,715	2,570	6,200	2,970	500	0	0	0	59,865	12.5
AMWI	0	0	295	200	770	1,950	505	560	2,000	570	260	0	0	0	0	0	0	7,110	1.5
GADW	0	0	295	200	1,535	9,750	15,150	16,725	17,160	17,145	5,140	9,300	4,850	1,100	55	0	0	98,405	20.5
NSHO	910	0	2,950	2,920	4,610	3,900	3,030	4,460	7,150	5,715	10,280	6,200	970	100	0	0	0	53,195	11.1
LESC	0	0	0	0	0	0	0	0	0	1,145	0	0	390	100	0	0	0	1,635	0.3
RNDU	0	0	0	0	770	975	505	2,230	1,430	2,285	2,540	1,000	195	0	0	0	0	11,930	2.5
CANV	0	0	0	0	0	500	800	400	3,000	570	0	200	580	55	5	0	0	6,110	1.3
REDH	0	0	0	0	0	0	50	5	300	250	0	5	0	75	0	0	0	685	0.1
RUDU	0	0	0	0	250	1,450	2,025	2,230	4,295	1,145	1,550	3,100	970	400	0	0	0	17,415	3.6
COGO	0	0	0	0	0	0	0	0	0	0	515	0	495	400	15	1,020	0	2,445	0.5
BUFF	0	0	0	0	0	0	0	0	0	250	1,030	205	195	0	0	0	0	1,680	0.4
COME	0	0	0	0	0	0	0	0	0	0	0	0	20	50	105	635	150	960	0.2
HOME	0	0	0	0	0	0	0	0	0	0	10	100	120	100	0	5	0	335	0.1
CAGO	70	230	210	30	70	270	275	540	100	170	120	250	210	400	890	1,920	1,140	6,895	1.4
GWFG	0	0	0	0	0	475	0	0	0	50	155	500	25	250	100	225	900	2,680	0.6
LSGO	0	0	0	0	0	0	0	0	0	30	0	1,500	0	0	0	0	0	1,530	0.3
Total	8,160	10,715	24,450	26,715	24,900	38,770	44,055	44,990	61,185	63,615	38,590	47,235	20,590	15,980	2,300	4,975	2,490	479,715	

[a] See Table 1.

Table 5. Estimates of waterbird and raptor abundance from ground inventories at The Emiquon Preserve during spring 2016.

	Inventory Dates											
Species[a]	17-Feb	26-Feb	2-Mar	11-Mar	18-Mar	23-Mar	1-Apr	7-Apr	15-Apr	21-Apr	Total	%
AMCO	0	2,337	8,328	63,063	58,928	46,386	41,984	20,560	20,586	22,927	285,099	97.8
AWPE	0	200	682	502	200	202	758	62	296	173	3,075	1.1
BAEA	31	70	69	52	36	43	40	20	4	3	368	0.1
BCNH	0	0	0	0	0	0	0	0	0	3	3	<0.1
BNST	0	0	0	0	0	0	0	0	0	3	3	<0.1
DCCO	0	2	0	70	450	483	286	0	739	680	2,710	0.9
GBHE	0	0	0	5	3	2	1	1	0	2	14	<0.1
GREG	0	0	0	0	0	0	1	0	0	11	12	<0.1
HOGR	1	0	0	0	0	0	2	1	0	0	4	<0.1
NOHA	2	1	2	1	0	0	1	0	0	0	7	<0.1
PBGR	0	1	1	0	5	2	9	34	58	9	119	<0.1
RTHA	0	1	0	1	0	0	0	0	2	0	4	<0.1
SORA	0	0	0	0	0	0	0	1	0	1	2	<0.1
Total	34	2,612	9,082	63,694	59,622	47,118	43,082	20,679	21,685	23,812	291,420	

[a] See Table 1.

Table 6. Estimates of waterbird and raptor abundance from aerial inventories at The Emiquon Preserve during fall 2016.

	Inventory Dates																		
Species[a]	31-Aug	6-Sep	14-Sep	20-Sep	10-Oct	18-Oct	24-Oct	1-Nov	7-Nov	14-Nov	21-Nov	29-Nov	7-Dec	12-Dec	21-Dec	27-Dec	5-Jan	Total	%
AMCO	5,470	2,020	28,910	29,210	129,025	156,975	58,075	67,460	81,930	50,865	11,280	17,195	1,940	3,700	5	0	10	644,070	97.6
AWPE	3,125	1,475	705	890	315	1,275	245	190	405	70	110	95	60	50	0	0	0	9,010	1.4
BAEA	0	0	1	0	2	2	2	0	6	3	10	3	7	13	6	18	18	91	0.0
DCCO	370	255	680	375	355	950	1,150	1,420	320	240	300	250	20	0	0	0	0	6,685	1.0
Total	8,965	3,750	30,296	30,475	129,697	159,202	59,472	69,070	82,661	51,178	11,700	17,543	2,027	3,763	11	18	28	659,856	

[a] See Table 1.

Table 7. Waterbird brood observations by species at The Emiquon Preserve, 2016.

	Observation Dates										
Species[a]	17 May	2 Jun	16 Jun	30 Jun	12 Jul	27 Jul	10 Aug	31 Aug	Total	%	Broods/km^2
AMCO	0	0	0	1	0	1	0	0	1	0.6	0.2
CAGO	4	3	8	5	1	1	0	0	22	14.4	5.1
MALL	1	1	0	3	2	3	2	0	12	7.8	2.5
MUSW	3	7	7	4	3	3	4	2	33	21.6	4.8
WODU	1	4	20	27	16	13	4	0	85	55.5	19.4
Total	9	15	35	40	22	20	10	2	153		32.1
Mean Age[b]	1C	1C	2A	2A	2B	2C	3	3			

[a] See Table 1.

[b] Gollop and Marshall 1954

Table 8. Waterbird nest abundance and survival at The Emiquon Preserve, 2016.

Species[a]	Nests Found	Density[b]	Abundance[c]	Survival
AMCO	13	0.34	107.0	0.650
COGA	14	0.48	149.8	0.256
LEBI	13	0.69	214.0	0.230
BNST	39	0.07	21.4	0.486
MALL	6	0.07	21.4	0.818
PBGR	6	–	–	0.825
Total	91	1.65	513.7	0.54

[a]See Table 1.

[b]Nests/ha

[c]Based on 2015 estimates of hemi-marsh and non-persistent emergent communities (311 ha).

Table 9. Soil and water characteristics at random locations within Thompson and Flag lakes to assess the effects of water-level manipulations at The Emiquon Preserve, 6–7 Sep 2016.

Location	Community	Water Depth[a]	Water Transparency[a]	Soil Compaction[a]	POM[b]	Bulk Density[c]
Flag	Moist-soil	N/A	N/A	1.0	5.6	1.1
Flag	Hemi-marsh	52.0	43.0	6.0	5.0	0.9
Flag	Aquatic Bed	137.0	113.0	7.0	5.9	1.4
Thompson	Aquatic Bed	225.0	115.0	15.0	5.2	1.1
Thompson	Aquatic Bed	86.0	86.0	5.5	4.3	1.2
Thompson	Aquatic Bed	113.0	86.0	17.0	4.2	1.3
Flag	Aquatic Bed	168.0	86.0	8.0	6.8	0.8
Flag	Hemi-marsh	188.0	81.0	8.0	5.2	1.3
Flag	Hemi-marsh	38.0	38.0	3.5	6.4	0.8
Flag	Aquatic Bed	106.0	106.0	8.5	6.8	1.1
Thompson	Aquatic Bed	3.0	3.0	10.0	5.1	0.8
Thompson	Aquatic Bed	111.0	111.0	16.0	7.0	0.7
Flag	Floating-leaved	135.0	40.0	2.5	4.6	1.0
Flag	Floating-leaved	145.0	145.0	1.5	6.8	0.9
Flag	Open Water	216.0	65.0	14.5	7.3	0.9
	$\bar{x}$	123.1	79.9	8.3	5.7	1.0

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

Table 10. Abundance (mg/m^3, dry mass) and percent occurrence of plants and seeds emigrating from Emiquon Preserve through the water-control structure, Jul–Nov, 2016.

Taxa	Biomass (mg/m^3)[a]	Percent Occurrence
Seeds		
Echinochloa walteri	<0.01	5.9
Ludwigia spp.	<0.01	11.8
Najas flexilis	<0.01	5.9
Najas minor	0.03	11.8
Polygonum lapathafolium	<0.01	5.9
Polygonum spp.	<0.01	11.8
Potamogeton nodosus	0.02	11.8
Potamogeton pusillus	0.06	5.9
Potamogeton spp.	0.05	41.2
Portulaca oleracea	<0.01	5.9
Rumex crispus	<0.01	5.9
Setaria	0.02	41.2
Total Seeds	0.22	
Plants		
Ceratophyllum demersum	0.45	47.1
Myriophyllum spicatum	4.07	76.5
Najas flexilis	0.76	41.2
Najas guadalupensis	0.01	29.4
Najas minor	3.37	70.6
Potamogeton pusillus	1.91	29.4
Total Plants	10.79	

Appendix A. Conservation targets and Key Ecological Attributes (KEAs) of The Nature Conservancy at The Emiquon Preserve during 2007−2016 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
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
	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
	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
	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
	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
	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
	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
	Spring Dabbling Duck Use Days	>486 UD/ha	486–376 UD/ha	<376 UD/ha	–	513	487	213	261	426	325	228	260	391
	Spring Other waterbird Use Days	>469 UD/ha	469–346 UD/ha	<346 UD/ha	–	358	713	334	192	470	107	411	456	975
	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
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	74
	Waterbird (Non-waterfowl) Brood Species Richness	>5 species	3–5 species	<3 species	–	3	2	1	3	3	3	3	4	1
	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
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
	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]
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]
	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]
	Forb and grass coverage	Forbs ≥10% coverage	–	Forbs <10% coverage	–	–	–	–	–	–	19	19	38	53

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

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