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Waterbird and Wetland Monitoring at The Emiquon Preserve

Final Report 2007–2018

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EXECUTIVE SUMMARY

Historically, the wetlands of the Illinois River valley (IRV) provided extensive and valuable habitat to migrating waterbirds and other wetland-dependent wildlife in the Upper Midwest (Havera 1999). The Nature Conservancy's Emiquon Preserve (2,700 ha) is a portion of a former floodplain of the Illinois River that was farmed for >80 years, isolated behind river levees, and has been undergoing restoration to a complex of wetlands and uplands since 2007. Since hydrology returned in 2007, we have monitored key ecological attributes (hereafter, KEAs) of specific biological characteristics or ecological processes related to waterbird communities and their habitats. Wetland vegetation communities and associated cover types have increased almost 700% since 2007, expanding from 255 ha to 2022 ha in fall 2016. Aquatic bed vegetation has comprised >50% of Emiquon Preserve since 2009, but important emergent plant communities have declined in recent years as the complex reached the lake marsh stage due to elevated and stabilized water levels (van der Valk and Davis 1978). Waterfowl and other waterbirds visit Emiquon Preserve in great numbers each fall and spring migration, with species such as American coot, northern pintail, green-winged teal, and gadwall selecting Emiquon compared to other wetlands and lakes in the IRV. The abundant aquatic bed and hemi-marsh plant communities collectively provide more food for waterbirds than do other nearby wetlands, such as the south pool of Chautauqua National Wildlife Refuge. Consistent with the >30 million energetic use days provided annually during 2013–2015 at Emiquon Preserve, dabbling and diving duck behaviors were dominated by feeding indicating the importance of the aquatic plant communities as foraging habitat. Emiquon also provides breeding habitat for species of conservation concern, such as common gallinule, black-crowned night herons, least bitterns, and American bitterns, as well as several species of ducks, geese, and swans. However,

we have noted recent declines in persistent emergent vegetation, moist-soil vegetation, brood counts which act as an index of waterbird productivity, duck use days during fall migration, and invertebrate abundance during brood-rearing periods, which we assume is related to the transition of Emiquon Preserve into the lake marsh stage. Consequently, Emiquon Preserve is currently undergoing an extensive drawdown to reverse declining trends in wetland health and corresponding waterbird use. Future monitoring will assess the effects of drawdown on emergent vegetation communities and the response of wildlife in the system.

INTRODUCTION

Historically, the wetlands of the Illinois River valley (IRV) provided extensive and valuable habitat to migrating waterbirds and other wetland-dependent wildlife in the Upper Midwest (Havera 1999). For example, 1.6 million mallards (scientific names presented in Tables 1–2) were counted during aerial inventories in the IRV in 1948, and peak numbers of lesser scaup exceeded 500,000 prior to the mid-1950s (Havera 1999:227–236). Unfortunately, extensive leveeing and drainage has eliminated 53% of the natural wetlands in the IRV and existing wetlands have been further degraded by sedimentation, exotic species, and eutrophication (Havera 1999).

Despite dramatic anthropogenic alterations, the IRV remains a critical ecoregion for migratory birds. The Upper Mississippi River and Great Lakes Region Joint Venture of the North American Waterfowl Management Plan considers the IRV a focal region to provide habitat for millions of waterfowl during spring and fall migrations (Soulliere et al. 2007). Fortunately, restoration and reclamation efforts are ongoing to return structure and function to backwater lakes and wetlands in the region. One of the most substantial efforts is The Nature

Conservancy's Emiquon Preserve (hereafter, Emiquon), directly restoring, enhancing, or protecting more than 2,700 ha of former wetlands and uplands in the central IRV.

The Nature Conservancy identified key ecological attributes (hereafter, KEAs) of specific biological characteristics or ecological processes that would guide and evaluate success of their restoration efforts at Emiquon (The Nature Conservancy 2006). Because of the region's historic importance to waterfowl and other waterbirds, several conservation targets and associated KEAs at Emiquon were related to waterbird communities and their habitats (Appendix A). Waterbird use of wetlands 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 2007–2018 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; 2) productivity by waterfowl and other waterbirds; 3) wetland plant seed and invertebrate biomass; and 4) composition and arrangement of wetland vegetation communities and wetland soils. 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 enumerated avifauna by species (Table 1) during fall (early September, mid-October–early January) and spring (mid-February– mid-April) migration periods (Havera 1999). Counts were conducted aerially (2007–2018) during fall migration in cooperation with the Illinois Natural History Survey's long-term aerial inventories and by ground counts (2007–2009; Hine et al. 2013). We conducted ground counts during springs 2008–2016, while aerial surveys were conducted during springs 2017–2019. During ground surveys, birds were counted from fixed, elevated vantage points and during travel between points. Aerial inventories were conducted from a fixed-wing, single-engine aircraft at altitudes of 60–140 m and speeds of 160–240 km/hr (Havera 1999). All counts were made weekly, excepting ground counts during fall 2009 and spring 2010, which were conducted biweekly.

We converted counts to use days to evaluate overall waterbird use of Emiquon (UDs; 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 concurrent fall aerial survey data from 23 backwater lakes and wetlands located along the Illinois River, which account for approximately 90% of IRV peak duck abundances, to compare to UDs and abundances at Emiquon with other available habitats (Havera 1999). We also expressed duck use estimates as UDs per ha of wetland (UDs/ha) to standardize for wetland size.

Waterfowl Behavior

We conducted behavioral observations using scan sampling to evaluate the functional response of ducks to wetland restoration and habitat change at Emiquon during spring migrations 2008–2016 (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 observing at least 50 individuals 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 narrated observations into a hand-held voice recorder for subsequent transcription. We attempted to conduct 10 scan samples during each ground count, regardless of season, 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), increasing distances between observation points and waterbird concentrations, and difficulty in approaching flocks undetected, occasionally prevented us from conducting all 10 scan samples during some ground counts.

Brood Observations

We monitored waterbird production at Emiquon through passive brood observations during 2008–2018 (Rumble and Flake 1982). We conducted biweekly brood surveys from mid-May to late-August using 4 observers at fixed points (Fig. 1). This approach intended to maximize coverage and minimize double counting and disturbance associated with a single observer moving between points. All fixed-point 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, and brood age class of all waterbirds (Gollop and Marshall 1954).

Waterbird Nesting

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 during 2013–2018. We used the previous year's 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, 2017–2019, 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.

Aquatic Invertebrates

We collected 20 sweep-net samples bi-monthly during waterbird breeding and brood-rearing periods (i.e., April–August) to estimate abundance of nektonic invertebrates during 2008–2012. During 2013–2015, we collected 40 sweep-net samples annually in mid-August, which is typically the peak of invertebrate and brood abundance. We used a 454-cm^2 (~0.05 m^2) D-frame sweep-net (500 µm; Voigts 1976, Kaminski and Murkin 1981) to sample invertebrates from randomly-allocated locations in shallow water (≤46 cm) along the margins of Thompson Lake (2008–2015) and Flag Lake (2013–2015), and preserved them in 10% buffered formalin solution containing rose bengal until processing. In the laboratory, we rinsed samples through a 500-µm sieve to remove substrate and vegetation. Invertebrates were removed from samples by hand, identified according to the lowest practical taxonomic level (e.g., Family; Pennak 1978, Merritt and Cummins 1996), dried at ~70^o C to constant mass, and weighed to the nearest 0.1 mg. Samples containing >200 individuals of a single invertebrate taxa were sub-sampled (up to ¼) using a Folsom plankton splitter. We converted invertebrate biomass estimates to per-unit-volume (mg/m^3) to account for different volumes of water sampled at various water depths.

Moist-soil Plant Seeds

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. Cores were collected in early fall at 20 randomly-allocated points along the shore of Thompson Lake during 2007–2012 and at 30 randomly-allocated points along the shores of Thompson and Flag lakes during 2013–2018 (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, if necessary, 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 a #10 (2,000 µm) and #60

(250 µm) sieves, and classified seeds as large if they were retained by the 10 sieve (e.g., barnyardgrass, smartweed) and small if they remained in the 60 sieve (e.g., nutgrass, pigweed). Samples were allowed to dry at room temperature ≥24 hours. We separated all large seeds from debris by hand, but due to the extensive processing time, we separated seeds from a sub-sampled portion (≥2.5% by mass) of the small seed samples. We then dried seeds at approximately 80°C for 24 hours and weighed them by taxa to the nearest 0.1 mg (Greer et al. 2007, Stafford et al. 2011). We multiplied the subsample mass by the reciprocal of the proportion subsampled to estimate biomass. We combined small and large seed masses to estimate total seed biomass per core (Stafford et al. 2011). We used biomass data from core samples to estimate overall moist-soil plant seed abundance (kg/ha; dry mass).

We used our overall estimates of seed abundance to estimate energetic carrying capacity for waterfowl, expressed as 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 of 337 kcal/day (Stafford et al. 2011) for EUD calculations.

Energetic Carrying Capacity

During falls, 2013–2015, we collected seeds, invertebrates, and plants at random locations (2013, *n* = 15; 2014–2015, *n* = 10) within each of the 4 dominant cover types at Emiquon (i.e., aquatic bed, hemi-marsh, persistent emergent, and open water) to estimate total energetic carrying capacity for waterfowl. At each location, we sampled seeds, tubers, and benthic invertebrates using a 6-cm x 10-cm core sampler (universal core sampler, Rickly Hydrological Company, Columbus, OH). Immediately following collection, core samples were washed through a #35 (500 μm) sieve bucket in the field and preserved in a 10% buffered formalin solution. In the laboratory, we removed and identified invertebrates to the lowest practical taxonomic level (i.e., Order or Family; Pennak 1978, Merritt and Cummins 1996) from a 25% subsample from each core. Aquatic macroinvertebrates (e.g., chironomids, dytiscids, gastropods, etc.) were dried at 60–70° C to constant mass and weighed by taxa to the nearest 0.1 mg (Smith et al. 2012), whereas aquatic microinvertebrates (e.g., cladocerans, ostracods, copepods, etc.) were counted and multiplied by a constant average mass for each taxon. Following removal of invertebrates, we allowed the remainder of the subsample to air dry at room temperature for ≥12 hours. We removed seeds and tubers by hand and identified each to Order or Family. Lastly, we dried seeds and tubers for ≥24 hours at 60° C and weighed them by taxa to the nearest 0.1 mg.

In addition to core samples, we collected aquatic plants (submersed and floating-leaved), seeds, and invertebrates within the top 45 cm of water (approximate depth available to dabbling ducks) using a modified Gerking box sampler at each sample point (Sychra and Adamek 2010). We froze samples in individually labeled bags until processing. In the laboratory, we thoroughly washed aquatic plants in a #35 sieve to remove seeds and invertebrates, identified aquatic plants by species, dried each for 24–48 hours at 60° C, and weighed them to the nearest 0.1 mg. We enumerated and identified aquatic invertebrates to the lowest practical taxonomic level from a 25% subsample of each box sample. Macroinvertebrates were dried at 60–70° C to constant mass and weighed by taxon to the nearest 0.1 mg (Smith et al. 2012). Microinvertebrates were counted to reduce processing time, and an average mass was calculated for each taxon using a subset of individuals and applied to the count to estimate biomass of microinvertebrate taxa. We combined density estimates (kg/ha) of seeds and tubers, aquatic invertebrates, and plants from benthic cores, box samples, and moist-soil cores to estimate total energetic carrying capacity for waterfowl, expressed as EUDs. We calculated diving duck energetic carry capacity by combining forage estimates from all sampling gear, assuming all forage was available to diving ducks; however, we only included forage estimates from gear (i.e., box sampler and moist-soil core sampler) which sampled within a 45-cm depth (the foraging range of most dabbling ducks) when calculating energetic carrying capacity for dabbling ducks.

Additionally, we recorded plant species composition within a 1-m^2 plot at each core and box sample location. We averaged the percent composition estimates of each dominant species (>5% coverage) among locations within plant communities and cover types.

Plant and Seed Emigration

During periods when the water control structure was operational by means of gravity flow (2016–2017), we estimated the number and species of seeds and plants moving from Emiquon to the Illinois River (emigration). Plant and seed movement was assessed weekly 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 to genus or species. 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).

Soil Characteristics

During 2016–2018, we randomly selected 15 points along east-west transects at lake-bed elevations ranging ± 1.5 m of 130.5 m (428 ft msl; 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° 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.

Wetland Cover Mapping

We mapped all contiguous areas of wetland vegetation (FAC, FACW, and OBL), 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, and vegetation communities during fall 2007–2018. 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 global positioning system (GPS; Bowyer et al. 2005, Stafford et al. 2010) and field computers (Juniper Systems, Inc.). We recorded plant species encountered (Table 2) along transect lines and delineated vegetation communities or other physical features (e.g., vegetation islands, ditches) outside transects. We digitized wetland vegetation in ArcGIS 9.3–10.6 using field notes and waypoints overlaid on color aerial photos obtained from U.S. Department of Agriculture's Geospatial Data Gateway in 2007, high-resolution color aerial photographs from Sanborn Map Company (Chesterfield, MO) during 2008–2011, color infrared aerial photographs from U.S. Fish and Wildlife Service (Region 3 Office, Twin Cities, MN) in 2012, and color infrared imagery from U.S. Geological Survey (Upper Midwest Environmental Sciences Center, La Crosse, WI) during 2013–2018 (Bowyer et al. 2005, Stafford et al. 2010).

Our classifications of wetland vegetation communities at Emiquon generally followed those defined by 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 (e.g., cattails and bulrushes), mudflats, floating-leaved aquatic vegetation (e.g., American lotus and watershield), aquatic bed (e.g., coontail), hemi-marsh (open water interspersed with persistent emergent; 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 upland vegetation (e.g., goldenrod and foxtail) growing within the wetland basin that had been inundated or insular.

We attempted to be as descriptive as possible when categorizing wetland vegetation and, as such, it was possible for some plant species to occur in multiple categories. For instance, cattail was present in 3 vegetation classes: hemi-marsh, persistent emergent, and cattail. We categorized cattail as hemi-marsh if there was approximately even interspersion of cattail and open water or aquatic bed (i.e., 30–70% cover of emergent vegetation by ocular estimate). We classified cattail as persistent emergent when accompanied by other persistent emergent species, such as bulrush and bur reed and occupied >70% of emergent cover by ocular estimate. Finally, cattail was a stand-alone category when it occurred as a dense monotypic stand. Likewise, willows occurred in multiple categories (i.e., bottomland forest and scrub-shrub).

Although we did not measure the spatial extent of individual invasive species, we compared the proportion of covermap polygons containing invasive species within each vegetation community among years. For example, we used the percent of all polygons within the aquatic bed, hemi-marsh, and persistent emergent communities containing Eurasian watermilfoil to monitor annual changes in coverage. Similarly, we used this method to monitor reed canarygrass, curly pondweed, purple loosestrife, and common reed.

RESULTS

Waterfowl Abundance

We identified and enumerated waterfowl and other waterbirds during 185 aerial surveys in falls 2007–2018 (Table 3). The most abundant species encountered were mallards (19%), gadwall (16%), northern pintail (15%) and green-winged teal (14%). We conducted 79 ground surveys during springs 2008–2016 (Table 4); the most abundant species were lesser snow geese (29.9%), ruddy ducks (10.7%), gadwall (10.2%), and northern shoveler (9.2%). Furthermore, we conducted 21 aerial surveys during springs 2017–2019 (Table 5) with lesser snow geese (62.9%), gadwall (6.4%), green-winged teal (5.6%), and greater white-fronted geese (4.5%) the most abundant species encountered.

Fall dabbling duck UDs at Emiquon ranged from 1,405,890 in 2007 to 3,965,248 in 2011 and averaged 2,598,925 during 2007–2018 (Fig. 3). During the same period, Emiquon supported 11–33% ($\bar{x}$ = 18%) of dabbling duck UDs in the IRV. Non-mallard dabbling duck UDs ranged from 1,116,053 to 3,124,865 and averaged 2,046,411 during fall (Fig. 3). Emiquon supported 16–51% ($\bar{x}$ = 26%) of the non-mallard dabbling duck use in the IRV. Fall diving duck UDs ranged from 6,125 in 2007 to 806,785 in 2009, which represented 42% of diving duck use in the IRV during fall 2009. Diving ducks averaged 323,513 UDs at Emiquon, or 18% of the diving duck UDs in the IRV (Fig. 3). Lastly, total ducks averaged 2,928,770 UDs with a peak of 4,322,685 UDs in 2011. Emiquon hosted 12–32% ($\bar{x}$ = 18%) of all ducks inventoried along the Illinois River (Fig. 3).

During 2007–2018, fall dabbling duck densities at Emiquon ranged from 739 UDs/ha in 2014 to 4,813 UDs/ha in 2007 and represented the highest mean density of dabbling ducks (1,729 UDs/ha) in the IRV. Emiquon hosted the highest dabbling duck densities in 2007, 2010, and 2011, but represented only the 8th highest densities in 2013 and 2014. Non-mallard dabbling duck densities averaged 1,369 UDs/ha (highest in the IRV) and ranged from 598 UDs/ha in 2014 to 3,821 UDs/ha in 2007. Non-mallard dabbling duck densities at Emiquon ranked highest in the IRV during 2007–2012 but dropped to 6th highest in 2014. Diving duck densities ranged from 21 UDs/ha in 2007 to 438 UDs/ha in 2009 and averaged 167 UDs/ha (4th in the IRV) during 2007–2018. Finally, total duck density at Emiquon averaged 1,898 UDs/ha (highest in IRV) and ranged from 933 UDs/ha in 2014 to 4,834 UDs/ha in 2007. Emiquon duck densities ranked highest in the IRV in 2007 and 2009–2011 but fell to 8th in the IRV in 2014.

Spring dabbling duck UDs derived from ground counts ranged from 453,127 in 2014 to 896,718 in 2009 and averaged 618,211 during 2008–2016 (Fig. 4). Dabbling ducks comprised

39–66% ($\bar{x}$ = 50%) of all duck use at Emiquon in spring. Non-mallard dabbling duck UDs ranged from 322,066 in 2011 to 726,101 in 2016 and averaged 488,980 UDs, representing 30–51% of all duck use in spring (Fig. 4). Diving duck use peaked in 2009 at 950,950 UDs, comprising 51% of all ducks using Emiquon that spring. During spring 2008–2016, diving ducks contributed 49% of the duck use at Emiquon and represented as much as 58% of all ducks in spring 2008 and 2010 (Fig 4). Finally, total ducks use peaked in spring 2009 at 1,847,752 UDs and declined to a low of 930,267 UDs in 2015. Total duck use in spring at Emiquon averaged 1,241,563 UDs during 2008–2016 (Fig. 4).

Spring dabbling duck UDs from aerial surveys ranged from 251,945 in 2018 to 765,203 in 2019 and averaged 572,010 during 2017–2019 (Fig. 5). During the same period, Emiquon supported 3–30% ($\bar{x}$ = 15%) of dabbling duck UDs in the IRV. Non-mallard dabbling duck UDs ranged from 230,168 to 590,213 and averaged 469,469 UDs during spring (Fig. 5). Emiquon supported 5–58% ($\bar{x}$ = 26%) of the non-mallard dabbling duck use in the IRV. Spring diving duck UDs ranged from 179,308 in 2018 to 403,258 in 2017, and averaged 288,653 UDs, which represented only 5% of spring diving duck use in the IRV during 2017–2019 (Fig. 5). Lastly, total ducks averaged 889,056 UDs with a peak of 1,146,893 UDs in spring 2017. Emiquon hosted 3–12% ($\bar{x}$ = 8%) of all ducks inventoried along the Illinois River during springs 2017–2019 (Fig. 5).

During 2017–2019, spring dabbling duck densities from aerial surveys at Emiquon ranged from 129 UDs/ha in 2018 to 387 UDs/ha in 2019 ($\bar{x}$ = 285 UDs/ha) and ranked 5th–19th in dabbling duck density in the IRV. Non-mallard dabbling duck densities averaged 232 UDs/ha (range, 112–297 UDs/ha) and ranked highest in the IRV during 2019, but ranked only 12th and 13th in 2017 and 2018, respectively. Diving duck densities ranged from 120 UDs/ha in 2017

(25th in the IRV) to 217 UDs/ha in 2017 (8th in the IRV) and averaged 165 UDs/ha during 2017–2019. Finally, total duck density at Emiquon averaged 450 UDs/ha and ranged from 249 UDs/ha in 2018 to 556 UDs/ha in 2017. Emiquon duck densities ranked 6th–20th in the IRV during springs 2017–2019.

Non-Waterfowl Abundance

American coots used Emiquon more than any other species during fall migration. Use by American coots ranged from 580,668–5,609,688 UDs and averaged 3,102,921 UDs annually. Incredibly, Emiquon hosted nearly all of the coots (93%) using the IRV in 2008 and averaged 67% of the coot use during fall 2007–2018 (Fig. 6). American white pelicans did not begin using Emiquon during fall until 2009. With the exception of 2011, pelican use rapidly increased during fall to more than 82,000 UDs in 2012 and peaked at over 112,000 UDs in 2017 but dropped off to only 17,458 UDs in 2018 (Fig. 7). Double-crested cormorants began using Emiquon in fall 2008, and like pelicans, their numbers grew steadily. Cormorant use increased from 615 UDs in 2008 to 50,338 UDs in 2016, but declined substantially during low water years of 2012 (8,860 UDs) and 2018 (3,030 UDs). Bald eagle use increased rapidly from fall 2007 (12 UDs) to 2010 (796 UDs), but similar to cormorants, experienced a substantial reduction (-62%) in fall UDs followed by a recovery to 1,391 UDs in 2018 (Fig. 7).

American coot UDs from spring ground counts declined sharply following 2009 (1,306,843 UDs) to a low of 202,128 UDs in spring 2013, representing an 85% decline (Fig. 6). Nonetheless, coots steadily increased each spring since 2013 to a high of 1,929,112 UDs in 2016. American coots averaged 808,542 UDs during spring 2008–2016. Spring UDs of American white pelicans increased from 1,835 in 2008 to 33,667 in 2010, and subsequently decline 90% to only 3,352 UDs by spring 2015 (Fig. 7). Pelican use of Emiquon recovered to 21,514 UDs in spring 2016, representing the second highest estimate observed during the 2008–2016 monitoring period. Likewise, double-crested cormorant UDs exhibited a similar pattern, growing from 174–32,327 UDs during spring 2008–2010 and then declining 85% to only 4,798 UDs in 2013. Cormorant use has increased each year following the low to 16,013 UDs in spring 2016. Lastly, bald eagle UDs remained relatively stable during spring 2008 (240 UDs) and 2009 (283 UDs), and then dropped 72% in 2010 (79 UDs). Excepting 2014, bald eagle use of Emiquon has exhibited remarkable growth since 2010 to more than 2,500 UDs in spring 2016 (Fig. 7).

Spring aerial surveys during 2017–2019 indicated American coot UDs at Emiquon represented 53–62% of the coot use in the IRV. American coot UDs ranged from a low of 101,325 in 2019 to 1,975,450 in spring 2017 and averaged 1,056,416 UDs during the 3-year period (Fig. 8). American white pelicans at Emiquon averaged 27,087 UDs (range, 15,295–36,363 UDs) and represented 4–34% of the pelican use in the IRV during 2017–2019. Emiquon supported 9–44% and averaged 22% of the double-crested cormorant spring UDs in the IRV. Cormorant use of Emiquon averaged 6,108 UDs and ranged 848–6,950 UDs. Lastly, bald eagle use increased dramatically during springs 2017–2019 from 363–4,256 UDs, representing the highest bald eagle use observed at Emiquon in any season. Emiquon hosted nearly half of the bald eagle use in the IRV in spring 2019 (Fig. 8).

Duck Behavior

During springs 2008–2016, we conducted more than 37,000 behavior observations of dabbling and diving ducks at Emiquon. Dabbling ducks spent most of their time feeding (57%), followed by locomotion (21%), resting (12%), and other behaviors (7%) across 9 years of observation (Fig. 9). Courtship and antagonistic behaviors comprised only 2.5% of dabbling duck activities in spring at Emiquon. Unlike dabbling ducks, diving ducks spent most of their time resting (38%), followed by feeding (31%), locomotion (22%), and self-maintenance (9%) behaviors (Fig. 10). Few social activities (0.8%) were observed in diving ducks during spring at Emiquon; although, some courtship behavior could have been masked by locomotion (e.g., multiple males swimming with a single female). Overall, ducks utilized Emiquon primarily for foraging and resting behaviors (Fig. 11).

Waterbird Productivity

Brood Observations

We recorded 1,350 observations of waterbird broods at Emiquon during spring and summer 2008–2018. We averaged 123 brood observations per year (range, 53–198 broods), and documented 12 breeding bird species. Most of the observations were comprised of wood ducks (50%), Canada geese (21%), and mallards (10%). Brood observations increased from 111 in 2008 to 157 in 2012 but declined 66% in 2013 (n = 53). Subsequently, brood observations recovered to a peak in 2017 (n = 198 observations). Observations of Canada geese and mallards were stable to increasing during 2008–2018 despite declines recorded during 2013–2015 (Fig. 12). Brood sightings of the state endangered common gallinule were first documented in 2011 and peaked in 2012 and 2017 (n = 5). Conversely, observations of American coot and pied-billed grebe broods declined sharply following 2009 and did not recover with the exception of 2013 when American coot broods increased to 16 (Fig. 13). Mute swan broods were first observed at Emiquon in 2015. Since then, mute swans have averaged 30.2 broods/year and comprised 20% of the brood observations during 2015–2018. The age of broods has increased during each spring-summer observation period over the 11 years of study, indicating broods were surviving to flight stage (Fig. 14). However, size of waterbird broods declined slightly between

May and August at Emiquon during 2008–2018, indicating that some mortality occurred during the brood-rearing phase (Fig. 15). The amount of decline in brood size varied among years, but the average size of broods declined from 4.5 to 3.6 ducklings between May and August across all years. Overall, average brood size remained relatively stable during 2008–2018. Mean annual brood densities ranged from 4.4 broods/km^2 to 45.8 broods/km^2 and averaged 16.1 broods/km^2 across all years at Emiquon. When we controlled for wetland size and observation area, trends in brood and young densities appeared similar to observations of total broods (Fig. 16).

Upland Nesting Ducks

We conducted 45 chain-drag nest searches over 6 grassland tracts covering 87 ha during spring and summer (19 April–25 July), 2017–2019. We found 144 nests of 2 duck species (mallard [*n* = 142], blue-winged teal [*n* = 2]; Fig. 2, Table 6). We estimated the first nest was initiated (i.e., first egg laid) on 8 April in 2017, while nest initiation occurred on 12 and 13 April in 2018 and 2019, respectively. Furthermore, the last nests terminated on 10 July in 2017 and 12 July, 2018 and 19 July 2019. Overall nest density in 2017 averaged 0.4 nest/ha (range; 0.1–1.5 nest/ha) with peak nest density occurring in the west prairie tract (0.9 nest/ha) on 15 June (Fig. 17). Mean nest density increased in 2018 ($\bar{x}$ = 0.6 nest/ha) with peaks occurring on 4 May, 10 May, and 31 May in the west prairie (0.7 nest/ha). Nest density in 2019 ($\bar{x}$ = 0.2 nest/ha; range, 0.02–1.17 nests/ha) declined 67% from 2018 and was the lowest observed at Emiquon. Nest density peaked (0.7 nest/ha) in 2019 on the south levee on 23 May. Nest survival in 2017 ranged from 0.07% – 11.7% ($\bar{x}$ = 5.7%) with the highest nest survival occurring in prairie 3 (Table 6). Nest survival in 2018 averaged 14.1% (range; 0.3% – 100%) with the highest nest survival occurring in the south levee (100%, *n* = 1), prairie 3 (41.1%, *n* = 4), and the west prairie (28.2%, *n* = 11). Finally, nest survival in 2019 ($\bar{x}$ = 3.3%) was the lowest observed at Emiquon, ranging from 0.6% on the south levee to 16.7% in the Butt Tract.

Marsh Birds

We conducted 502 waterbird nest surveys in hemi-marsh and dense persistent emergent vegetation communities at Emiquon during early June–late July, 2013–2018. We found 284 active waterbird nests (includes incidental nests) comprised mostly of common gallinule (*n* = 56), American coots (*n* = 52), least bitterns (*n* = 47), black-necked stilts (*n* = 46), and black-crowned night herons (*n* = 35; Fig. 18). Annual nest survival estimates across all species, years and vegetation communities averaged 50.9%. Nest survival (species with >1 nest) was highest for pied-billed grebes ($\bar{x}$ = 85.1%), least bitterns ($\bar{x}$ = 58.0%), and black-crowned night herons ($\bar{x}$ = 52.7%; Fig. 19). The hemi-marsh community exhibited the highest nest survival ($\bar{x}$ = 51.3%), while the persistent emergent community had slightly higher nest densities ($\bar{x}$ = 1.3 nests/ha). Annual waterbird nest densities averaged 1.2 nests/ha (range, 0.6 – 2.0 nests/ha) across all species and vegetation communities (Table 7). When extrapolated to the hemi-marsh and dense persistent emergent communities combined, we estimated Emiquon averaged 429 waterbird nests annually during 2013–2018.

Aquatic Invertebrates

We collected 420 sweep-net samples in August during 2008–2015 and total invertebrate biomass available to broods averaged 162 mg/m^3. Mean invertebrate biomass declined dramatically from 309 mg/m^3 in 2008 to 59 mg/m^3 in 2015 (Fig. 20). We identified 96 taxa with Cladocera ($\bar{x}$ = 80%), Copepoda ($\bar{x}$ = 68%), Oligochaeta ($\bar{x}$ = 62%) occurring in most samples. Physidae ($\bar{x}$ = 45.7 mg/m^3), Planorbidae ($\bar{x}$ = 30.9 mg/m^3), and Aeshnidae ($\bar{x}$ = 17.6 mg/m^3) accounted for the greatest biomass per unit volume (Table 8). There was no difference in invertebrate biomass between Thompson ($\bar{x}$ = 109.2 mg/m^3) and Flag ($\bar{x}$ = 109.3 mg/m^3) lakes from samples taken in August during 2013–2015.

Moist-soil Plant Seeds

We collected 210 soil core samples along the Thompson Lake shore during fall 2007–2018 and 90 soil cores along the shore of Flag Lake during fall 2013–2018. Moist-soil plant seed density was variable throughout the sampling period, ranging from 235 kg/ha in 2009 to 2,032 kg/ha in 2018 (Fig. 21). Seed abundance at Emiquon exceeded the waterfowl carrying capacity goal (578 kg/ha) of the Upper Mississippi River/Great Lakes Region during 8 out of the 12 years of monitoring. Furthermore, Emiquon surpassed average seed abundance estimates from IDNR wetlands (691 kg/ha) and Chautauqua NWR (790 kg/ha) in 6 of 9 years. Similar to seed abundance estimates, energetic use days (EUDs) also were variable, ranging from 1,745 EUDs/ha in 2009 to 15,076 EUDs/ha in 2018 (Fig. 21). Moreover, EUDs at Emiquon exceeded those from IDNR sites and Chautauqua NWR in 6 years during the 2007–2018 period. Emiquon attained the energetic carrying capacity goal for moist-soil seeds (1 million EUDs) in only 2 years.

Energetic Carrying Capacity

We collected 280 benthic core and box samples from aquatic bed, hemi-marsh, persistent emergent, and open water during 29 September–9 October, 2013–2015. Hemi-marsh ($\bar{x}$ = 6,852 kg/ha; 5,757–7,997 kg/ha) produced the greatest amount of waterfowl forage per unit area, followed by aquatic bed ($\bar{x}$ = 6,624 kg/ha; 6,350–7,128 kg/ha), persistent emergent ($\bar{x}$ = 1,579 kg/ha; 1,046–2,113 kg/ha), and open water ($\bar{x}$ = 386 kg/ha; 234–588 kg/ha; Fig 22). Likewise, the hemi-marsh community provided the greatest energetic carrying capacity per unit area with a mean of 24,044 EUDs/ha ($\bar{x}$ = 17,899–34,141 EUDs/ha), followed by aquatic bed ($\bar{x}$ = 21,807

EUDs/ha; 19,824–23,348), persistent emergent ($\bar{x}$ = 6,649 EUDs/ha; 5,162–8,687 EUDs/ha), and open water ($\bar{x}$ = 2,094 EUDs/ha; 1,543–2,480 EUDs/ha; Fig. 22).

Total energetic carrying capacity for diving ducks during fall, including that from moist-soil seeds, averaged 30,517,374 EUDs (26,817,878–34,152,212 EUDs). Aquatic bed ($\bar{x}$ = 23,546,430 EUDs; 21,645,857–25,447,002 EUDs) contributed the most overall forage, followed by hemi-marsh ($\bar{x}$ = 4,260,557 EUDs; 2,423,585–6,097,529 EUDs), persistent emergent ($\bar{x}$ = 1,667,065 EUDs; 749,926–1,815,099 EUDs), and open water ($\bar{x}$ = 626,622 EUDs; 513,700–1,142,155 EUDs; Fig. 22). Total energetic carrying capacity for dabbling ducks during fall, including moist-soil seeds, averaged 20,037,282 EUDs (13,317,405–25,217,383 EUDs). Similar to energetic carrying capacity values for diving ducks, aquatic bed ($\bar{x}$ = 16,355,758 EUDs; 11,650,284–19,355,727) produced the most overall energy for dabbling ducks, followed by hemi-marsh ($\bar{x}$ = 2,827,217; 1,108,645–5,443,929), persistent emergent ($\bar{x}$ = 568,605 EUDs; 277,385–1,088,243 EUDs), and open water ($\bar{x}$ = 5,231 EUDs; 2,209–8,615 EUDs; Fig. 22).

During 2013–2015, the aquatic bed community was dominated by longleaf pondweed ($\bar{x}$ = 42%), Eurasian watermilfoil ($\bar{x}$ = 30%), coontail ($\bar{x}$ = 19%), and sago pondweed ($\bar{x}$ = 4%; Fig. 17). The hemi-marsh community was primarily comprised of Eurasian watermilfoil ($\bar{x}$ = 26%), cattail ($\bar{x}$ = 26%), coontail ($\bar{x}$ = 20%), and longleaf pondweed ($\bar{x}$ = 19%). Rice cutgrass ($\bar{x}$ = 28%) was the dominant species in the non-persistent emergent vegetation community at Emiquon, followed by creeping waterprimrose ($\bar{x}$ = 14%), barnyardgrass ($\bar{x}$ = 13%), reed canarygrass ($\bar{x}$ = 7%), and ferruginous flatsedge ($\bar{x}$ = 7%). The persistent emergent community was comprised of nearly all cattail ($\bar{x}$ = 96%; Fig 23).

Plant and Seed Emigration

We sampled seeds and plant material emigrating from Emiquon on 4 dates during 13 July – 15 November, 2016 and 6 dates during 14 August – 2 October, 2017. We identified 28 seed taxa and 10 plant taxa moving through the water control structure (Table 9). Mean seed emigration was 0.24 mg/m^3 (range, 0.00 – 1.48 mg/m^3), comprised mostly of *Potamogeton* (0.17 mg/m^3), *Setaria* (0.03 mg/m^3), *Najas* (0.02 mg/m^3), and *Ludwigia* (0.01 mg/m^3) species. Aquatic plants emigrating from Emiquon averaged 8.81 mg/m^3 (range, 0.01 – 52.20 mg/m^3). *Ceratophyllum* (4.05 mg/m^3), *Myriophyllum* (1.81 mg/m^3), *Najas* (1.53 mg/m^3), and *Potamogeton* (1.09 mg/m^3) were the most abundant plant species moving through the water control structure.

Soil Characteristics

We collected 45 soil cores at random locations within the moist-soil, hemi-marsh, aquatic bed, and floating-leaved vegetation communities and in open water during early September – early October, 2016–2018. Water depths at sampling locations ranged from 0 – 225 cm with secchi readings ranging from 4 – 115 cm (Table 10). Mean water depth and transparency declined 79% and 73%, respectively during 2016–2018. Soil bulk density ranged from 0.5 – 1.4 g/cm^3 ($\bar{x}$ = 0.9 g/cm^3) and declined 7% during the monitoring period (Fig. 24). Percent organic matter ranged from 2.8 – 11.4% and averaged 5.6%. Mean organic matter declined 0.2% during 2016–2018. Soil consolidation estimates at core sites averaged 6.7 cm (range, 0.2 – 14.5 cm) and declined 27% from 2016–2018.

Wetland Cover Mapping

Spatial coverage of wetland vegetation and associated cover types ranged from 255 ha in 2007 to 2,022 ha in 2016 ($\bar{x}$ = 1,716 ha; Figs 25–36; Table 11). We encountered more than 120 plant taxa during cover mapping. Aquatic bed has been the dominant wetland community at

Emiquon, comprising an average of 43% of the wetland area since 2007 and 49% since 2009 (Figs 37 and 38). Open water ($\overline{x}$ = 22%) was the next largest community at Emiquon, and it increased 12–28% during 2009–2018. Hemi-marsh increased more than nine-fold from 2007–2009, but declined 72% during 2009–2012. From 2012–2015 hemi-marsh increased to 14% of the area, although this was attributed to cattails dying and creating openings in dense persistent emergent vegetation. Since 2016, hemi-marsh averaged only 5% of the wetland area. Persistent emergent vegetation expanded from 33–298 ha, occupying 2–15% ($\overline{x}$ = 11%) of the wetland area during 2007–2014. Conversely, the area of persistent emergent declined sharply (-71%) in 2015 to only 86 ha (4%) as large stands of cattails died. Persistent emergent vegetation averaged 7% of Emiquon during 2015–2018. Finally, the area of non-persistent emergent vegetation at Emiquon was variable during the monitoring period. Non-persistent vegetation ranged from 21 ha during high water in 2015 to 868 ha ($\overline{x}$ = 146 ha; 9%) following a drawdown in 2018. Annual variation in the amount of non-persistent emergent vegetation is largely due to the extent and timing of drawdowns.

Encounters with invasive species were variable at Emiquon during 2007–2018. Occurrence of reed canarygrass ranged from 5 to 48% ($\overline{x}$ = 17%) of the non-persistent emergent, persistent emergent, and scrub-shrub polygons (Fig. 39). Eurasian watermilfoil averaged 38% of the aquatic bed, hemi-marsh and persistent emergent polygons combined and ranged from 0% in 2007 to 69% in 2012. Common reed peaked at 25% in 2012 and averaged 9% of the combined non-persistent emergent, persistent emergent, scrub-shrub, and hemi-marsh polygons during 2007–2018. Encounters with purple loosestrife and curly pondweed occurred less frequently than other invasive species at Emiquon. Purple loosestrife occurred in an average of 0.6% of the hemi-marsh, non-persistent emergent, and wet upland polygons, while curly pondweed averaged <2% of the aquatic bed and hemi-marsh polygons (Fig. 39).

DISCUSSION

Wetland area at Emiquon increased almost 700% from 2007 to 2016 and, including the drawdown of 2016–2018, has undergone a near complete vegetation cycle (van der Valk and Davis 1978). Initially, nonpersistent emergent vegetation and open water comprised the dominant cover types, but persistent emergent, hemi-marsh, and aquatic bed vegetation communities comprised more than 70% of cover types during 2008–2016. Notably, the area of aquatic bed grew from just 1% of the wetland area in 2007 to 65.7% in 2009 and remained greater than 50% subsequently, other than during the drought of 2012 (48%) and the managed drawdown in 2018 (12%). Historically, aquatic bed, including submersed and floating-leaved vegetation, comprised approximately 25% of lakes and wetlands in the IRV, but recent studies have indicated that it has been eliminated from most of the IRV and portions of the Mississippi River corridor south of Pool 13 (Moore et al. 2010, Stafford et al. 2010). Floating-leaved and submersed aquatic vegetation provide important habitats for waterbirds, fish, and other wildlife and are an important component of the restoration success at Emiquon Preserve. While Emiquon produced an abundance of submersed aquatic vegetation, the contribution of this vegetation type to the Illinois River was minimal during the 2016 and 2017.

Hine et al. (2016) described the rapid expansion of aquatic plant communities at Emiquon during the initial 3 years of restoration and the tradeoffs in plant communities resulting from hydrologic scheme. Generally, expansion of non-persistent emergent and persistent emergent communities followed partial drawdowns as mudflats and shallow areas were colonized. Wet years with stable or increasing water levels favored the expansion of aquatic bed and hemi-marsh communities. Hydrology was probably the key factor influencing vegetation community structure and cover and the increased water management capabilities should allow better control and manipulation of wetland cover types. (Low and Bellrose, 1944, Bellrose et al., 1983, Fredrickson & Taylor, 1982).

During 2007–2018, changes in vegetation structure mirrored a complete wetland cycle, including all 4 vegetative phases, 1) dry marsh, 2) regenerating marsh, 3) degenerating marsh and 4) lake marsh. (Weller & Spatcher, 1965, Weller & Fredrickson, 1973, van der Valk & Davis, 1978). During 2007 and prior, Emiquon existed in the dry marsh phase and was dominated by mudflats and non-persistent emergent vegetation. During 2008–2012 as water returned, Emiquon transitioned into the regenerating phase characterized by a termination of emergent plant germination and conditions favorable for submersed and floating-leaved aquatic vegetation. Emiquon entered the degenerating marsh phase, marked by a decline in emergent vegetation and a dominance of submersed aquatic vegetation during 2013–2015. A combination of factors including high and stabilized water levels, muskrat (*Ondatra zibethicus* L.) herbivory, increasing turbidity from deteriorating vegetation or possibly increasing common carp (*Cyprinus carpio*) and grass carp (*Ctenopharyngodon idella*) populations, likely contributed to the decline in vegetation cover and increase in open water during the degenerating phase (Bajer et al. 2009). We believe Emiquon was transitioning into the lake marsh phase characterized by a dominance of submersed and floating-leaved aquatic vegetation with persistent emergent vegetation restricted to the perimeter of the wetland. As the lake marsh phase progresses, even the submersed aquatic vegetation declines due to increased turbidity from wave action, increased flocculence of soil, and increased areas of open water (van der Valk & Davis 1978). A substantial drawdown was needed to reset the marsh cycle, thus TNC reduced the surface water elevation at Emiquon by more than 2 m during 2016–2018. Most of the wetland area of Emiquon in 2018 had re-entered the dry marsh phase dominated by non-persistent emergent vegetation (i.e., moist-soil [45%]), while aquatic bed was reduced to only 12% of the area. The drawdown is ongoing and its influence on wetland vegetation communities is yet to be determined.

Organic matter of wetland sediments at Emiquon was very low compared to those reported prior to drawdown at Big Muskego Lake in Wisconsin (>40%; James et al. 2001). Furthermore, soil bulk density was much greater at Emiquon than soil density estimates prior to and following drawdown at Big Muskego Lake (<0.1–0.2 g/cm^3). We found no change in soil bulk density ($\overline{x}$ = 0.9 g/cm^3) across years. 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, and our values were less than half of that reported by James et al. (2001). We did detect decreases in penetrometer readings at core sites, suggesting that some soil consolidation had occurred. Our data suggest that accumulation of organic matter in the wetland substrates of Emiquon was minimal during the first 10 years of restoration.

We encountered relatively few invasive or undesirable wetland plant species during wetland mapping; however, we documented areas with curly pondweed, Eurasian watermilfoil, reed canarygrass, common reed, and purple loosestrife and noted rapid expansions in occurrences of some of these species from 2009–2013. In particular, the proportion of aquatic bed and hemi-marsh polygons containing Eurasian watermilfoil expanded from near 0% in 2008 to near 70% in 2012. While Eurasian watermilfoil does provide habitat for fish and food for waterbirds, it can compete with native aquatics and should be monitored in case increased prevalence should require management actions. Common reed was first encountered at Emiquon in 2009 and peaked in 2013 (25%), but was reduced to 7% of the covermap polygons in 2018. While still prevalent on the preserve, the recent reduction in encounters with common reed and few encounters with purple loosestrife throughout restoration are likely evidence of TNC's diligence in controlling these species. We observed an increase in woody encroachment (i.e., willow and cottonwood) in the wetland area and an upswing in reed canarygrass encounters in 2018. Similarly, we observed increases in reed canarygrass encounters during or directly following low water years (i.e., 2011, 2013, and 2018). Timing and extent of drawdowns certainly influences subsequent response of invasive or undesirable species; thus, continued vigilance of these species is strongly encouraged during and directly following drawdown.

Return of water and wetland vegetation to Emiquon resulted in a rapid response of waterfowl and other waterbirds. Peak abundances of wetland birds at Emiquon typically exceed 100,000 during fall migration with peaks surpassing 200,000 in some years. Emiquon hosted an average of 18% of the dabbling duck and total duck use days in the IRV despite comprising only 6% of the wetland area surveyed throughout the monitoring period. Furthermore, aquatic vegetation communities at Emiquon appear to be particularly attractive to non-mallard dabbling ducks and American coots, as their use of Emiquon represented greater than 25% and 50% of the fall use days in the IRV, respectively. Similarly, wetland bird use during spring is substantial, with peak counts typically near 100,000 or more individuals. In contrast to fall (11%), diving ducks typically comprise more than 50% of duck use days during spring migration.

Although vegetation communities and habitats of waterbirds have changed considerably since 2007, bird guilds have responded differently over time. Total duck and diving duck use days during spring have generally declined since 2009 with diving ducks reaching lows during 2018 and 2019. Use days for dabbling ducks and non-mallard dabbling ducks, while variable, have remained relatively constant since restoration. American coot use days have trended upward, although coot use days reached the lowest observed in spring 2019; however, coot abundance was low throughout the IRV in spring 2019. Fall use days of all guilds have generally remained stable during 2007–2018, while use days of all guilds in the IRV have shown increasing trends, especially use-days of diving ducks. Fall use days of American coots have exhibited an increasing trend across all years of restoration at Emiquon as have use days of coots in the IRV. Undoubtedly, Emiquon has influenced the fall population of American coots in the IRV throughout restoration. Some downward trends in waterbird use days are likely in response to changing habitat conditions described above as well as the 2016–2018 drawdown which reduced habitat availability for some guilds. Moreover, weather and river conditions have likely influenced waterbird use at Emiquon. Early freezes and late ice-out with Illinois River flooding in the spring have also played a role in reduced waterbird use observed at Emiquon in recent years. Furthermore, expanded hunting and other recreation on Emiquon likely reduced sanctuary for waterbirds, especially during fall (Hagy et al. 2016).

In contrast to other wetland habitats available in the IRV, Emiquon is likely disproportionately important to a few species that select natural plant communities for forage and habitat, such as green-winged teal, northern pintail, and gadwall. For instance, northern pintail use (1,003,810 UDs) at Emiquon in 2011 was the highest and green-winged teal use (784,930 UDs) was second highest recorded at a single location in the IRV since aerial inventories began in 1948 (M. Horath and A. Yetter, unpublished data). This is particularly noteworthy as continental population estimates of northern pintails have been below the North American Waterfowl Management Plan (NAWMP) goal in most years since the mid-1970s (USFWS 2018). Moreover, gadwall use of Emiquon averaged 34% of all gadwall use days in the IRV during falls, 2007–2018 and represented up to 48% of gadwall use in the IRV. Furthermore, American coot use in fall 2015 (5,609,688 UDs) was the highest observed for any surveyed location since the inception (1948) of aerial inventories in the IRV (M. Horath and A. Yetter, unpublished data), and the fall 2016 UD estimate (5,547,603 UDs) was the second highest ever recorded for coots in the IRV, comprising 80% of the coots in the Illinois Valley. Thus, we recommend maintaining a wetland complex which supports vegetation communities that are currently rare in the IRV but attract and support diverse waterbird populations. Further, the diversity of waterbird species that use Emiquon during migration may be as (or more) useful of an indicator of ecological function than abundance.

During both fall and spring, Emiquon is used as a foraging habitat by dabbling ducks, diving ducks, and other waterbirds. During the course of restoration, foraging behaviors have remained the dominant activity and relatively constant for all ducks and dabbling ducks; however, foraging rates have increased and become the dominant activity for diving ducks during spring since 2013. Ducks likely consume submersed aquatic vegetation, invertebrates, and natural plant seeds at Emiquon Preserve (Osborn et al. 2016). In fact, we estimated that the energetic carrying capacity at Emiquon Preserve duck use during spring and fall migrations. Although the aquatic bed community produced the most energetic use days, energetic use day density was greatest in hemi-marsh vegetation communities. Hemi-marsh communities contain a mix of submersed and emergent aquatic plants that provide food directly through seed and vegetative production and indirectly through substrate for phytoplankton, zooplankton, and macroinvertebrates. In some years, moist-soil vegetation produced seeds and tubers at levels exceeding managed moist-soil wetlands in the region (Bowyer et al. 2005, Soulliere et al. 2007, Stafford et al. 2011), but until recently, the spatial extent of moist-soil vegetation at Emiquon was small in most years, and the hydrologic regime often did not facilitate flooding and access to seeds and tubers during waterbird migration periods. The expansion of non-persistent emergent vegetation in 2018 demonstrated Emiquon's capability of producing phenomenal amounts of moist-soil seed (>2,000 kg/ha), providing an important forage for a number of waterbird species.

Emiquon also provided breeding and post-breeding waterbird habitat during 2007–2018. Total brood observations have exhibited an upward trend across all years, despite low observations during 2013–2015. Observations of mallard broods, while variable, have remained relatively stable across years. Broods of Canada geese and the state endangered common gallinule have increased during the monitoring period, as well as non-native mute swans, which have exhibited the most dramatic increase of any species in recent years at Emiquon. Conversely, observations of some species, such as pied-billed grebes and American coots, were most abundant early in restoration but declined after 2009 and have remained low. Furthermore, wood duck broods have shown a slight downward trend over all years, particularly since the peak in 2012, despite being the most abundant species observed. Fluctuations in emergent vegetation communities may explain variability in observations of some species. Waterbird broods, especially 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). 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.

Marsh bird nest surveys allowed us to further evaluate waterbird productivity at Emiquon. Emiquon has supported breeding Illinois endangered species such as, common gallinules, black-crowned night herons, and American bitterns, as well as the Illinois threatened least bittern. Marsh bird nest abundance at Emiquon has been variable over the years with a downward trend since the peak in 2016. Likewise, overall nest survival has decreased since 2013. The observed declines in nest abundance and survival may be attributable to changes in the persistent emergent vegetation communities, especially during the drawdown years of 2016–2018. For comparison, 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 (0.3 nests/ha), and coot nest survival at Emiquon (51%) was lower than that reported in southeast Idaho (72%; Austin and Buhl 2011). Nest density of least bitterns at Emiquon (1.0 nest/ha) was greater than nest densities in western New York (0.1 nest/ha), while nest survival of least bitterns at Emiquon (58%) fell within the range observed in New York (46 – 80%; Lor and Malecki 2006).

Chain drags for upland nesting ducks during 2017–2019 indicated the nesting period at Emiquon (8 Apr–19 Jul) was 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. Annual duck nest densities at Emiquon ranged from 0.2–0.6 nests/ha ($\bar{x}$ = 0.4 nest/ha) for individual tracts. Several studies in the prairie pothole region of north-central South Dakota during 1968–1973 reported higher 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 ($\bar{x}$ = 8%) was lower than that 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 during 2017–2019 (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. Abundance and species composition of the mammalian community may be limiting recruitment of upland nesting ducks at Emiquon.

Over the past several decades, wetlands in the IRV have incurred many anthropogenic changes that have decreased heterogeneity (Mills et al. 1966, Bellrose et al. 1983, Havera 1999, Stafford et al. 2010). Several vegetation communities have been lost or nearly so in IRV wetlands, especially submersed (e.g., sago pondweed) and floating-leaved aquatic vegetation (e.g., American lotus; Stafford et al. 2010). The loss of these specific communities has been associated with regional declines in duck species that are considered foraging specialists when compared to the mallard; particularly diving ducks (e.g., lesser scaup) and non-mallard dabbling ducks (e.g., gadwall). Diving ducks were historically abundant throughout the IRV but declined drastically during the 1950s following the loss of their preferred foraging habitats and foods (Mills et al. 1966). Responses of diving ducks, non-mallard dabbling ducks, and American coots and the overall diversity of wetland-dependent wildlife emphasized the importance of Emiquon in providing wetland communities, such as submersed aquatic vegetation and hemi-marsh, which are rare in the IRV.

Emiquon's regional importance to migratory waterbirds was evident during the first 12 years of monitoring, especially when use by some species or guilds were greater in most years than any other aerially-surveyed location in the IRV. However, recent negative trends observed in waterbird abundance, brood counts, invertebrate biomass during summer, and emergent vegetation communities indicate a decline in wetland productivity. The current drawdown at

Emiquon is intended to reverse these declining trends by resetting the vegetation cycle, consolidating sediments, and stimulating primary productivity. Our monitoring of vegetation communities and waterbird populations will continue to assess the full impact of drawdown in subsequent years.

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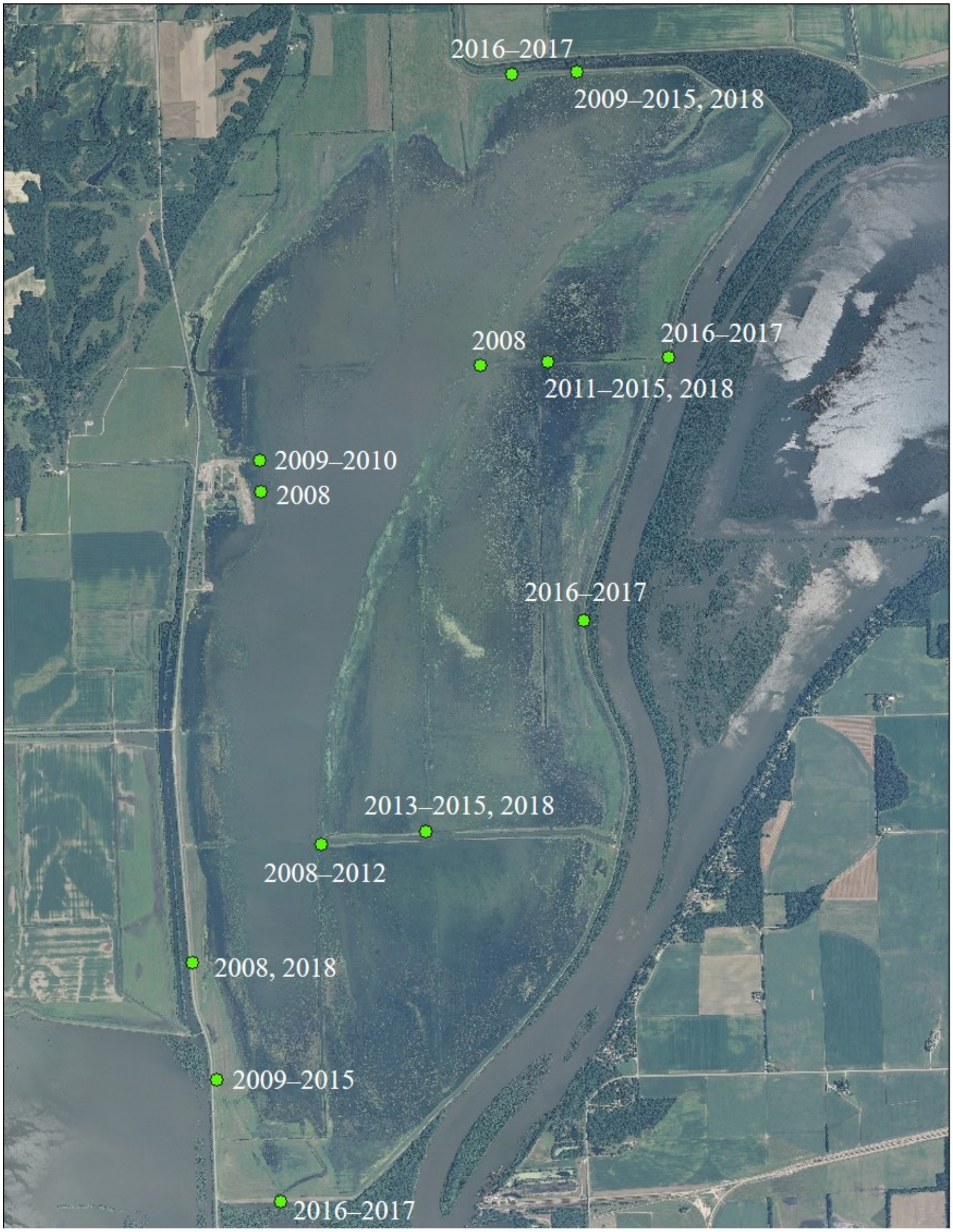


Figure 1. Brood observation locations by year at The Emiquon Preserve, summers 2008–2018. Observation points varied by year due to changing water levels on the Preserve.

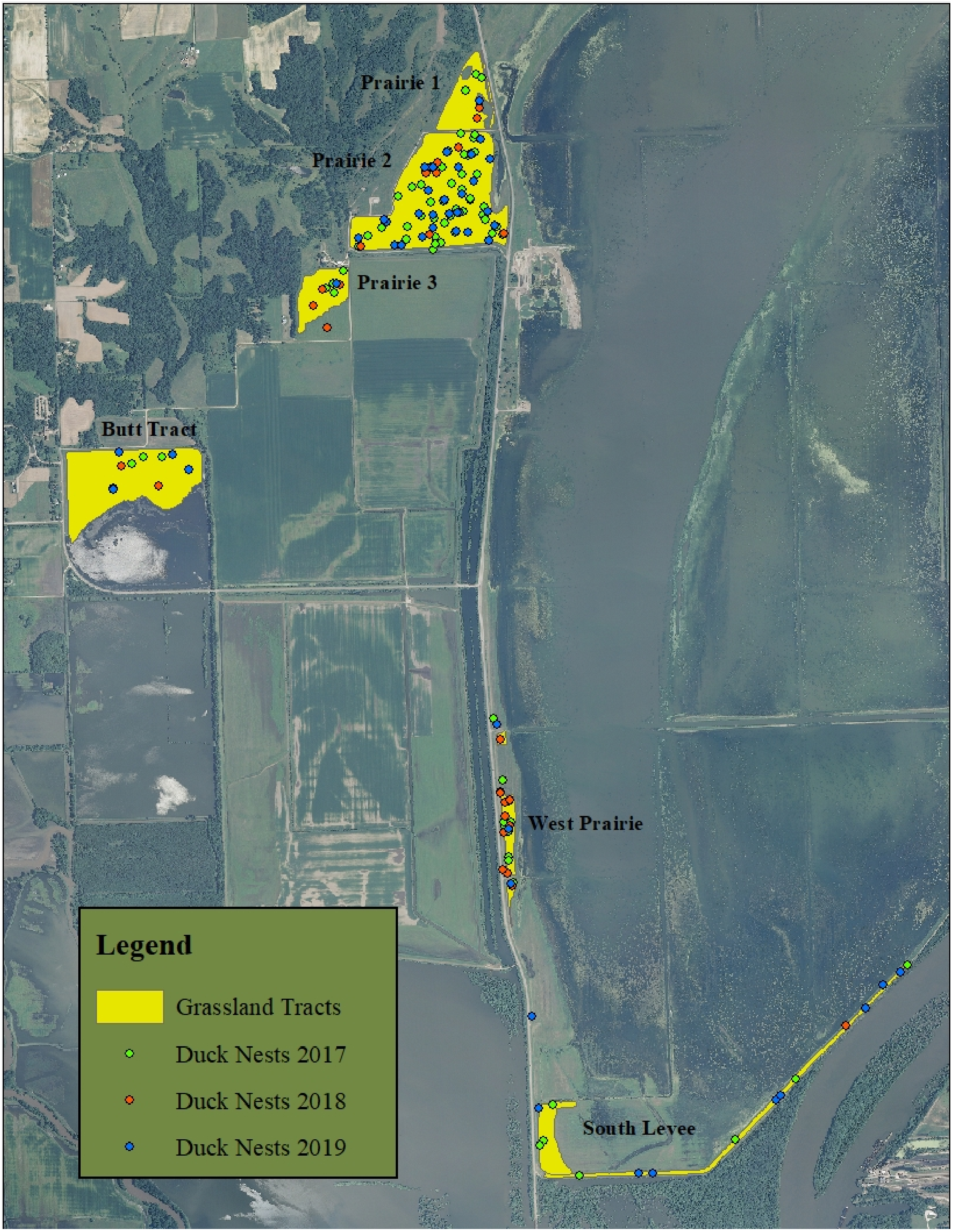


Figure 2. Grassland tracts searched and locations of duck nests found during weekly chain drags at The Emiquon Preserve, 2017–2019.

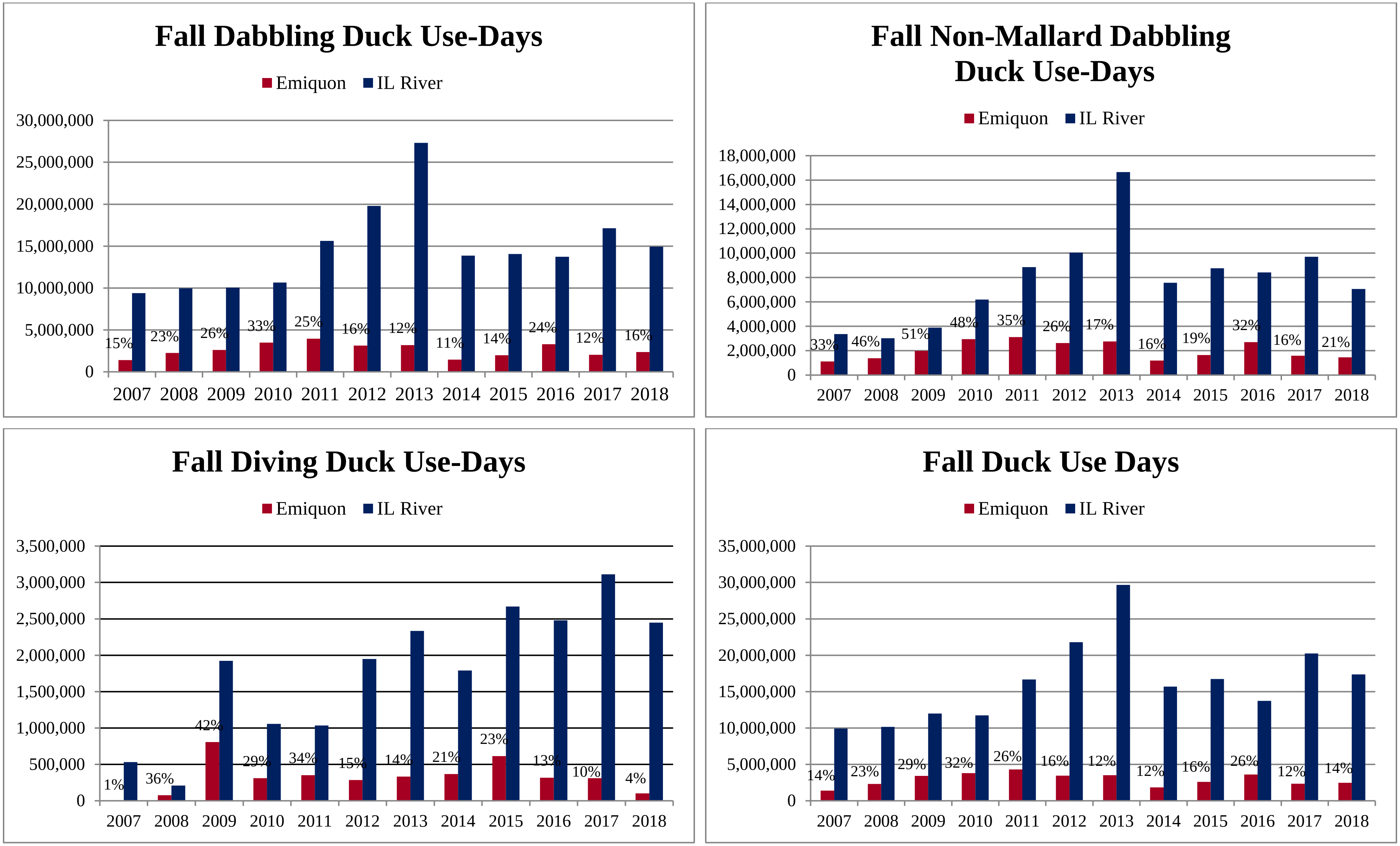


Figure 3. Fall duck use days by guild and the proportion of Illinois River use days occuring at the Emiquon Preserve from aerial inventories during 2007–2018.

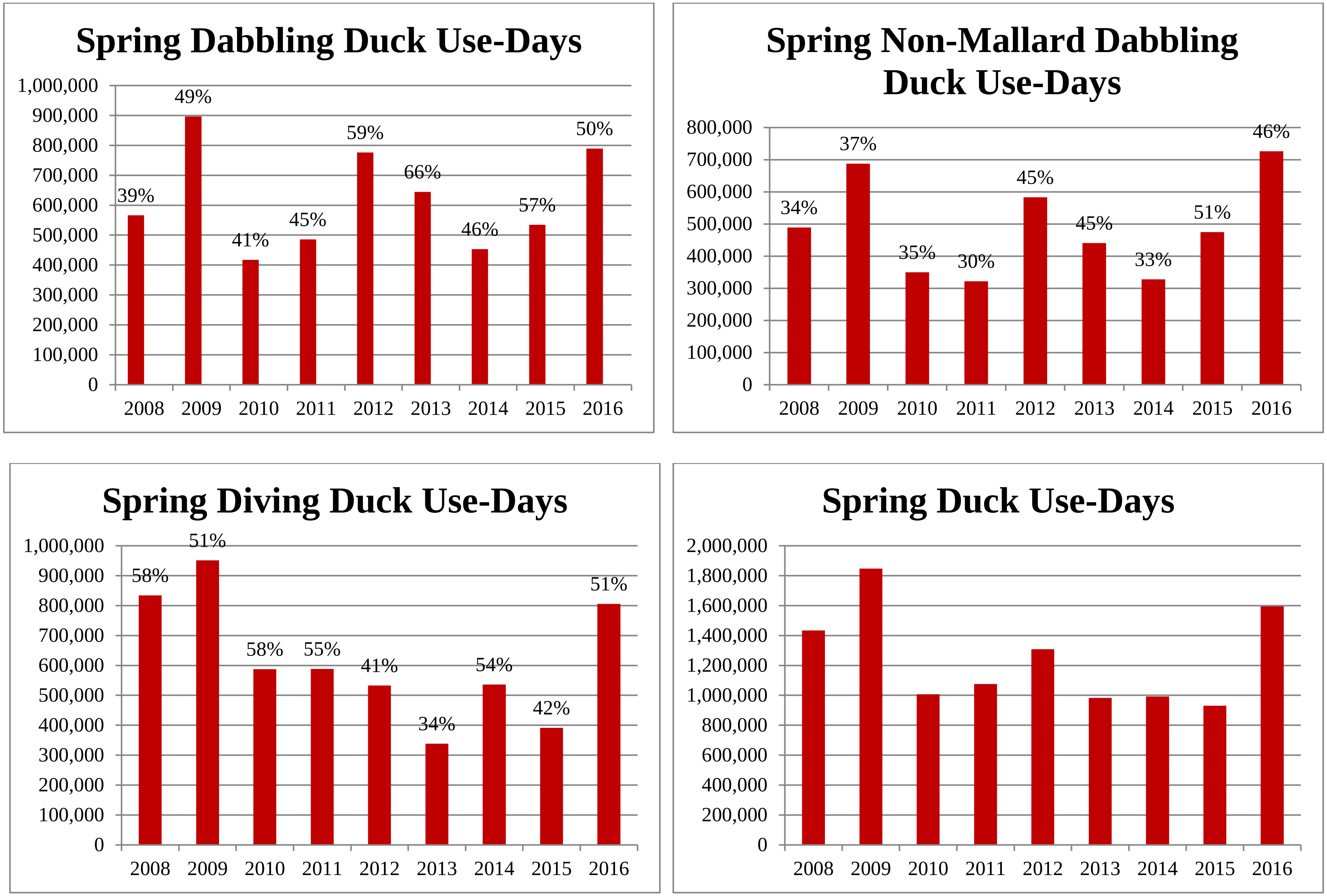


Figure 4. Spring duck use days by guild and their proportion of total duck use days at the Emiquon Preserve from ground inventories during 2008–2016.

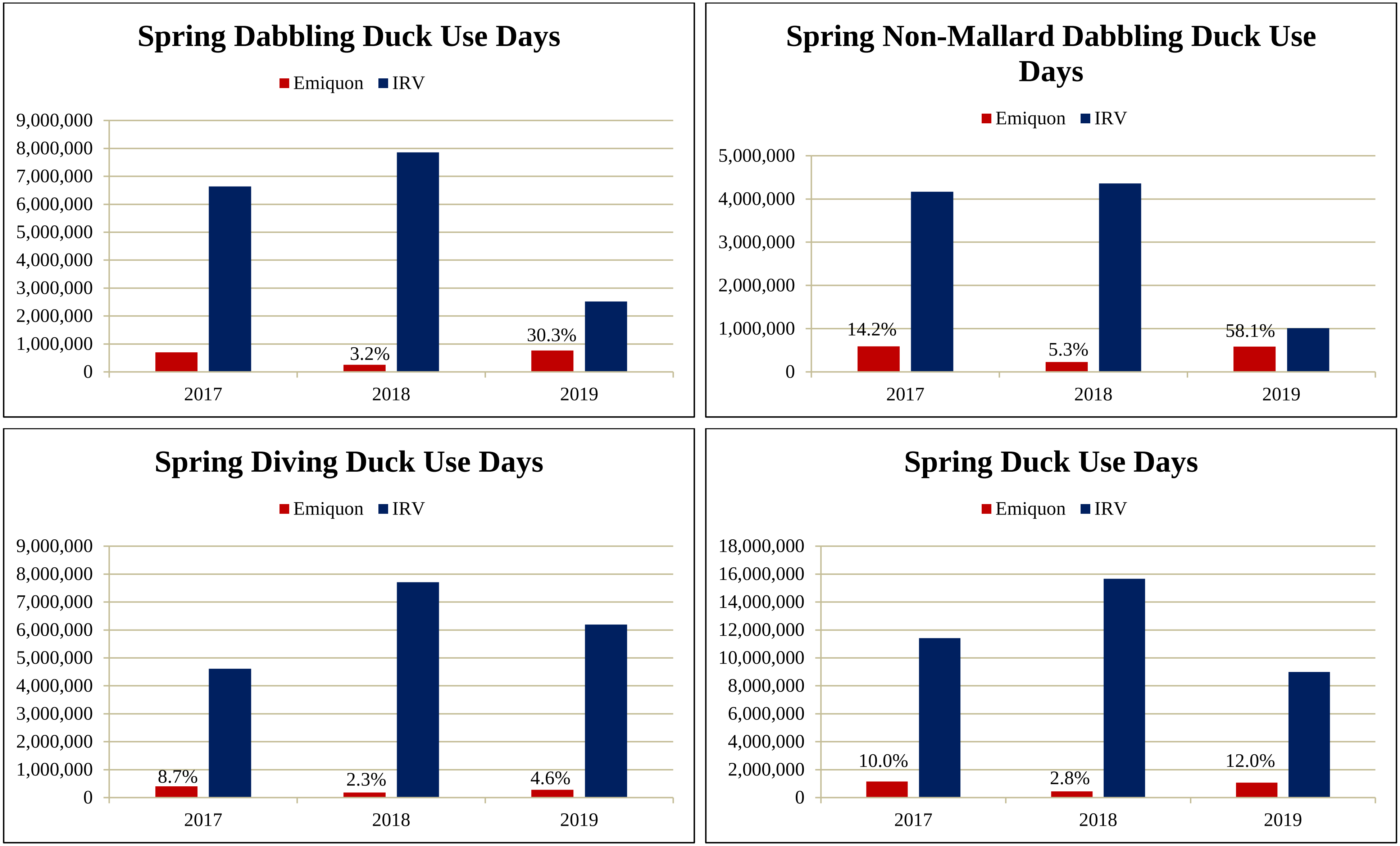
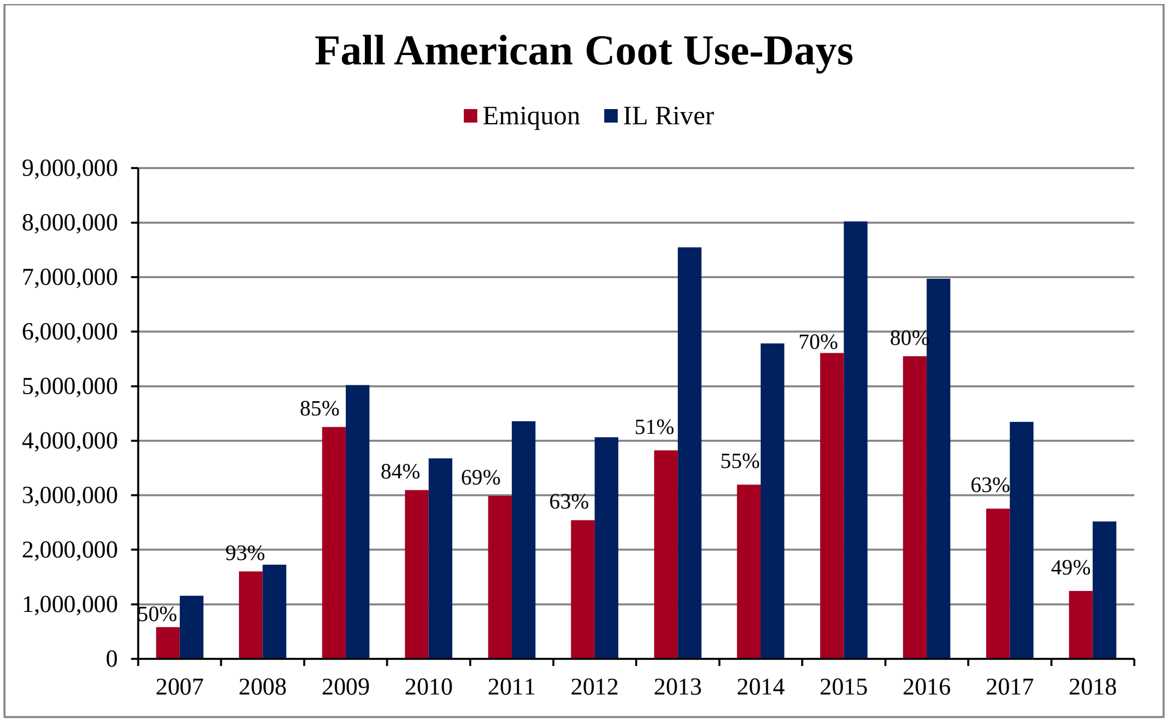


Figure 5. Spring duck use days by guild and their proportion of total duck use days at the Emiquon Preserve from aerial inventories during 2017–2019.



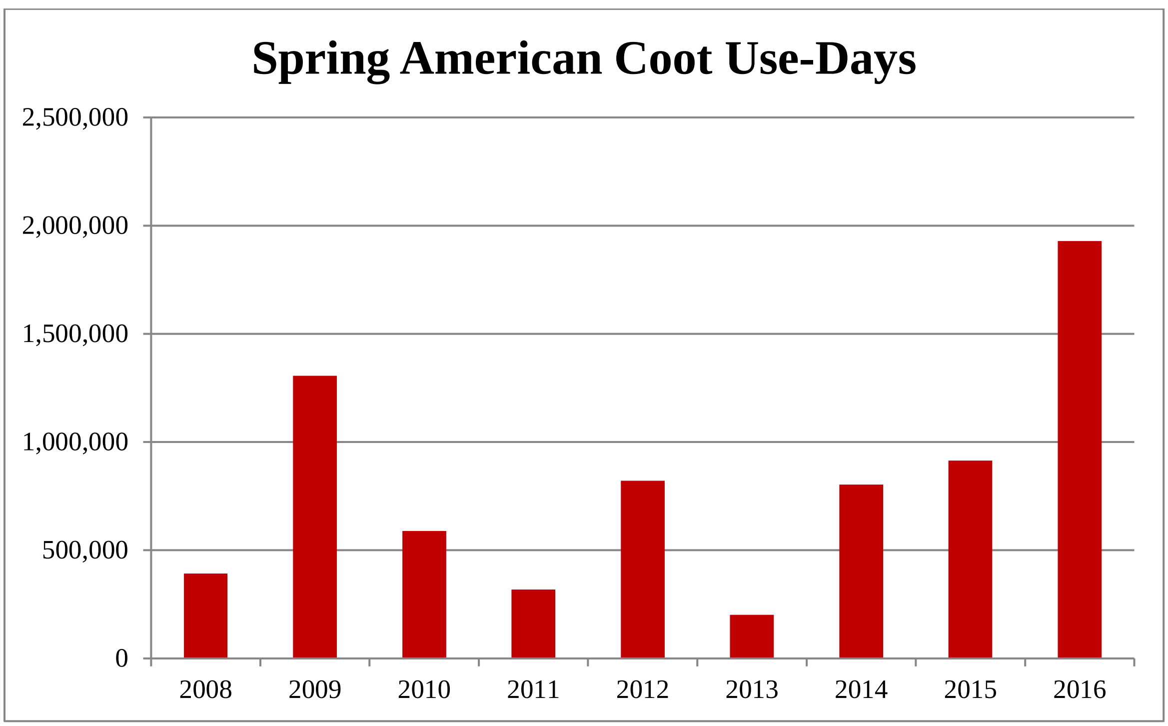
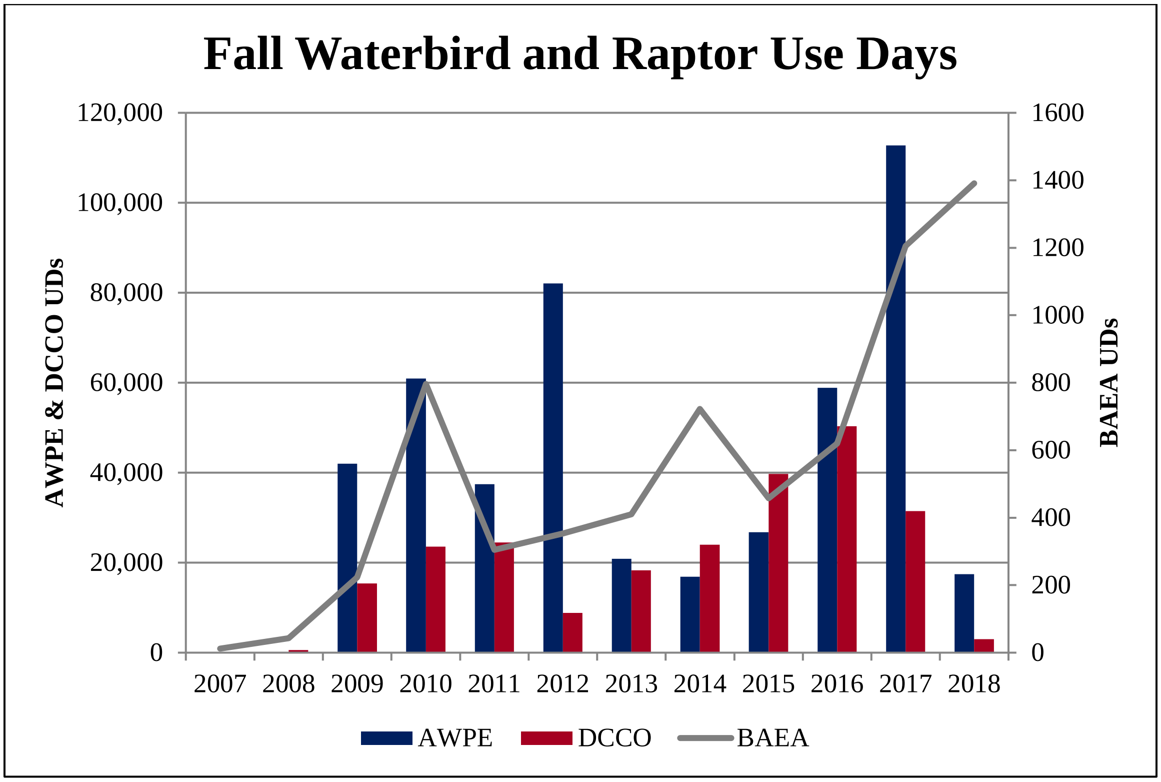


Figure 6. American coot use days and the proportion of Illinois River use days occurring at the Emiquon Preserve during fall aerial inventories 2007–2018 and American coot use days at Emiquon during spring ground inventories 2008–2016.



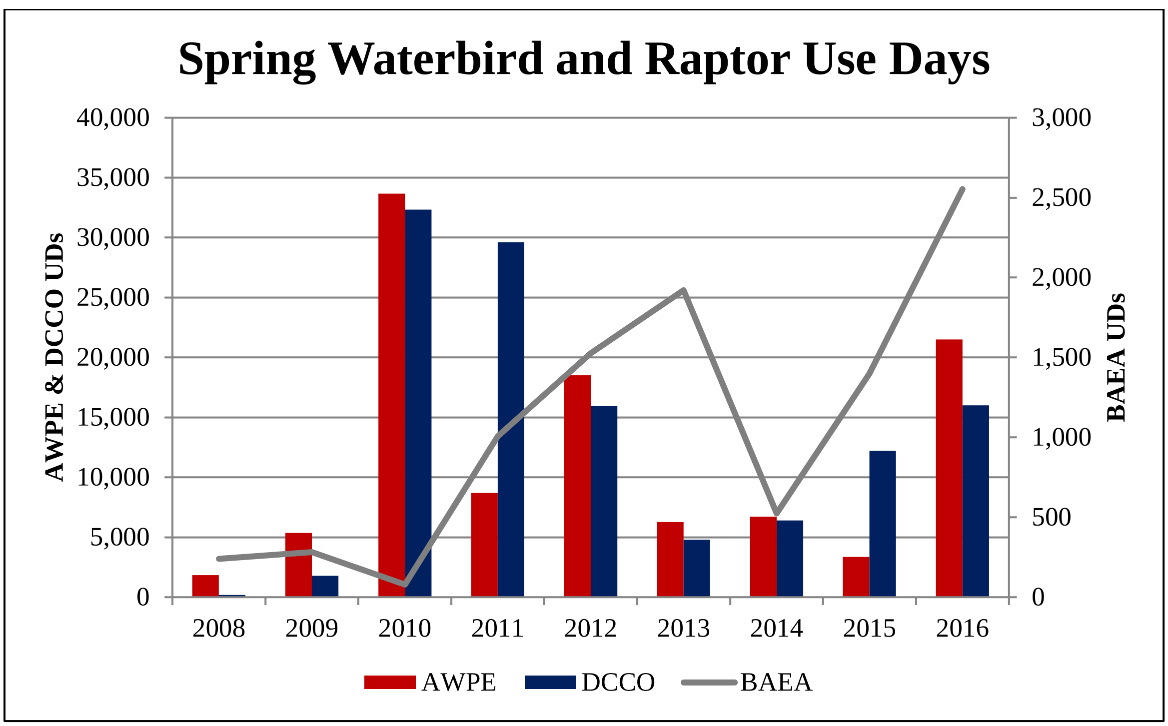


Figure 7. Use days of American white pelicans (AWPE), double-crested cormorants (DCCO), and bald eagles (BAEA) at The Emiquon Preserve during fall aerial inventories (2007–2018) and spring ground inventories (2008–2016).

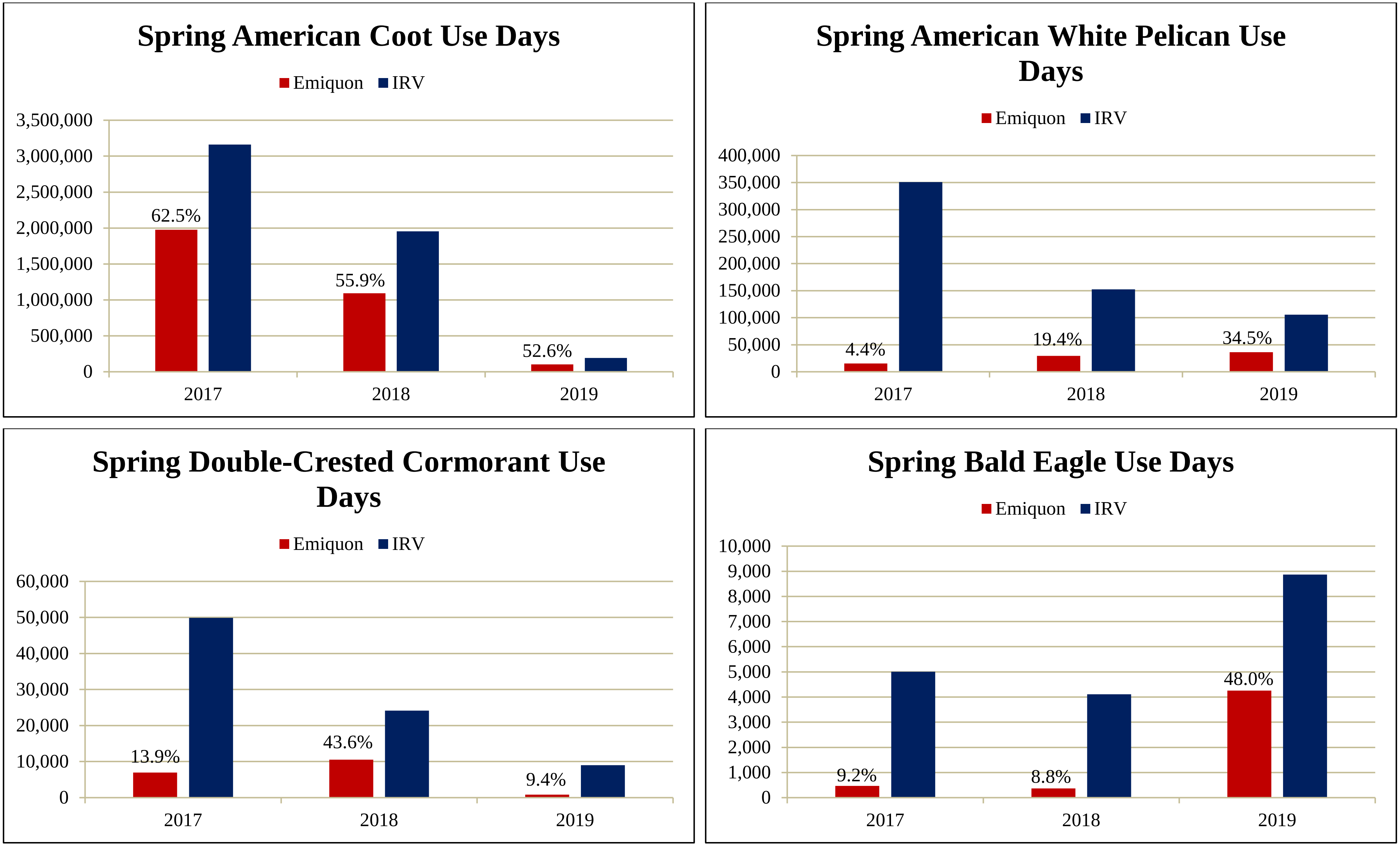


Figure 8. Waterbird and bald eagle use days and the proportion of Illinois River use days occurring at the Emiquon Preserve during spring aerial inventories 2017–2019.

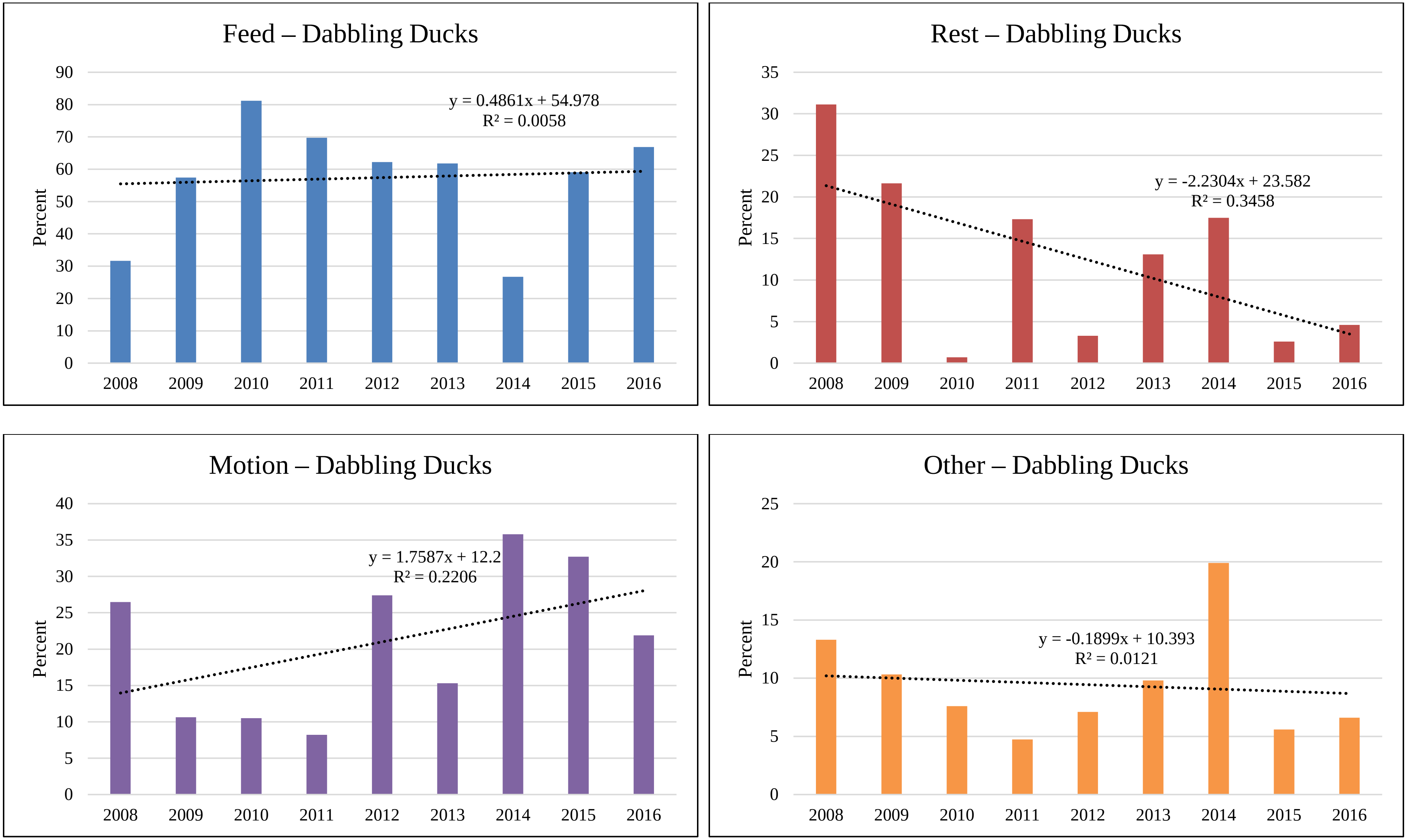


Figure 9. Behaviors of dabbling ducks observed during spring at the Emiquon Preserve 2008–2016.

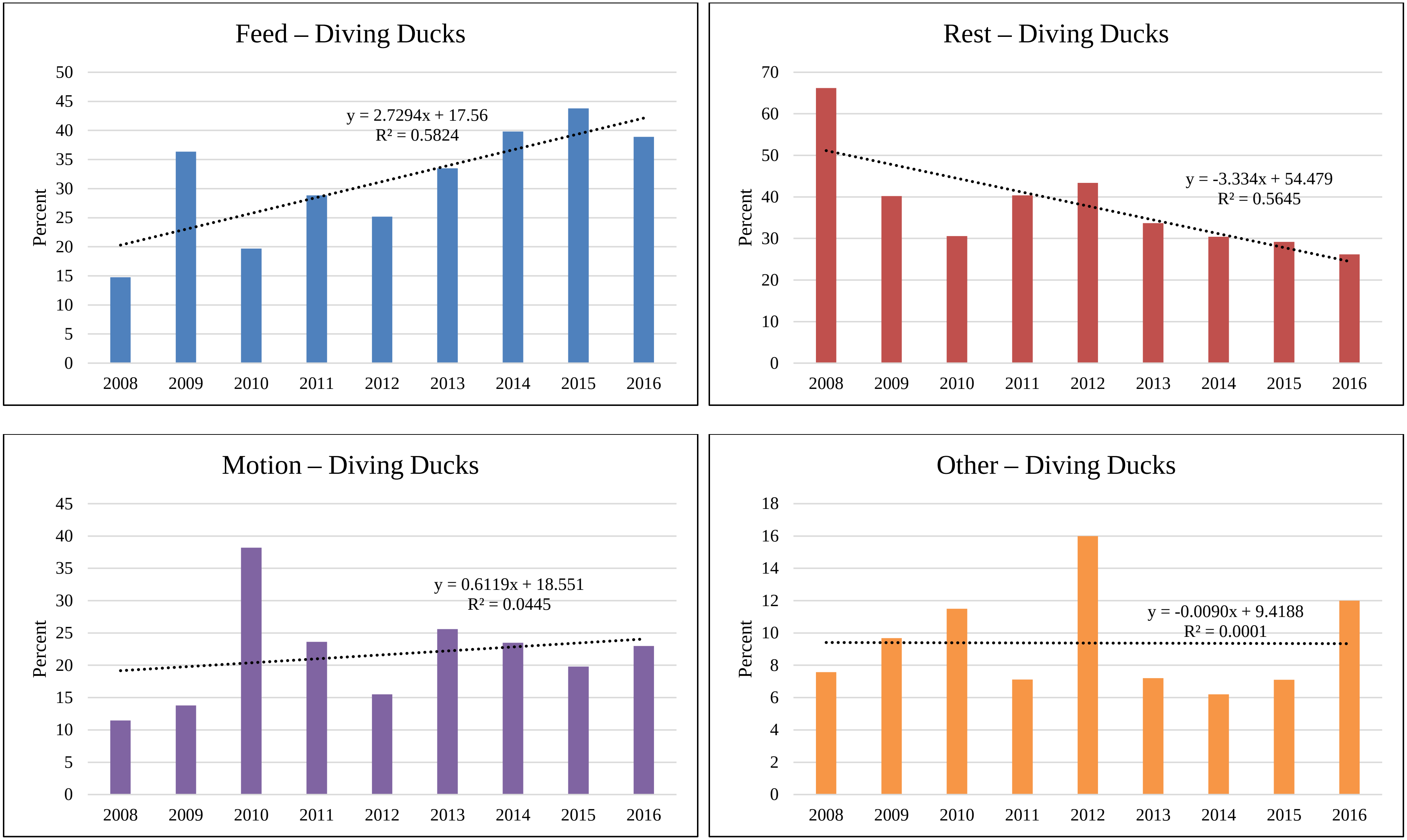


Figure 10. Behaviors of diving ducks observed during spring at the Emiquon Preserve 2008–2016.

Figure 11. Behaviors of all ducks observed during spring at the Emiquon Preserve 2008–2016.

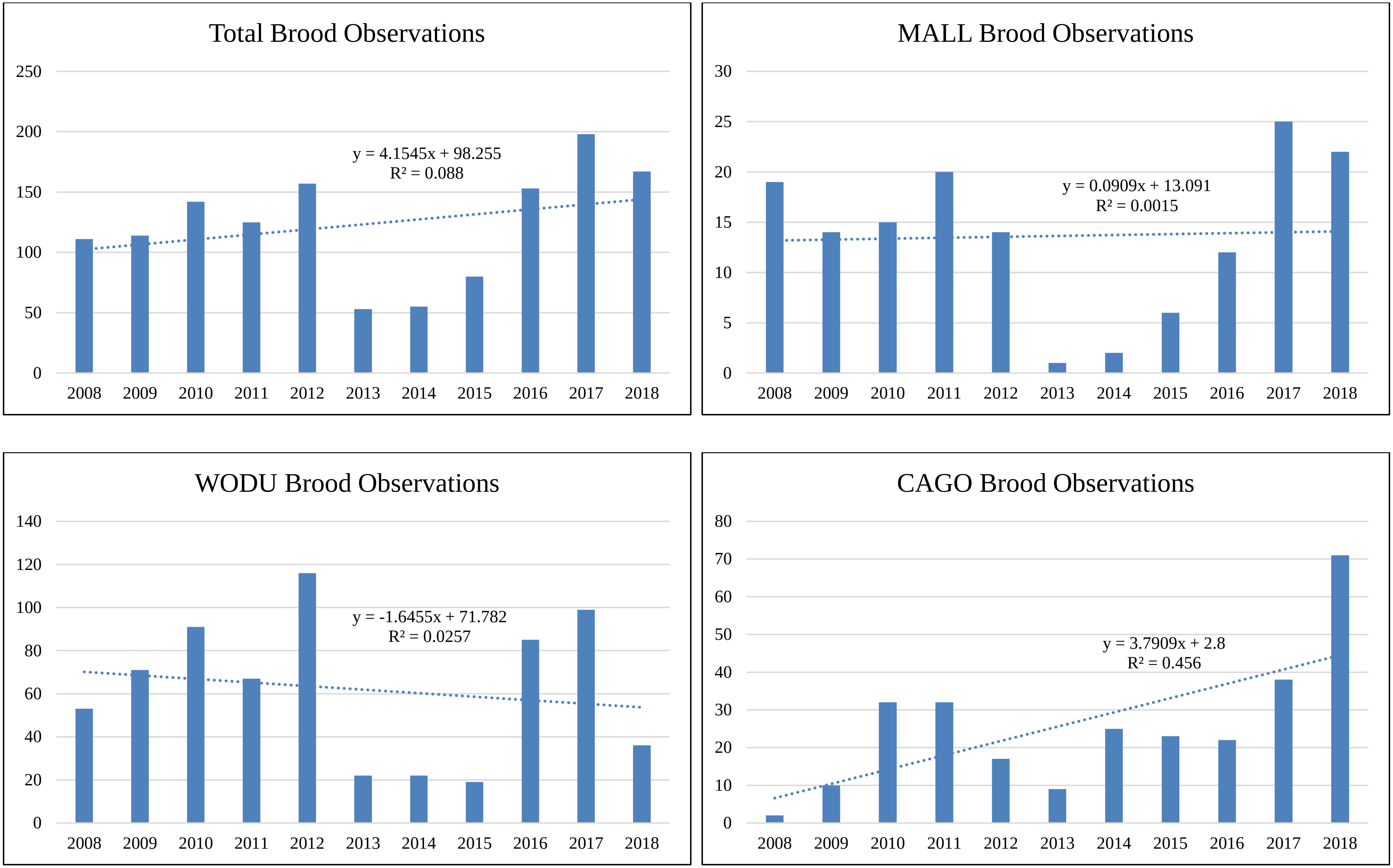


Figure 12. Observations of waterfowl broods during spring and summer at the Emiquon Preserve 2008–2018.

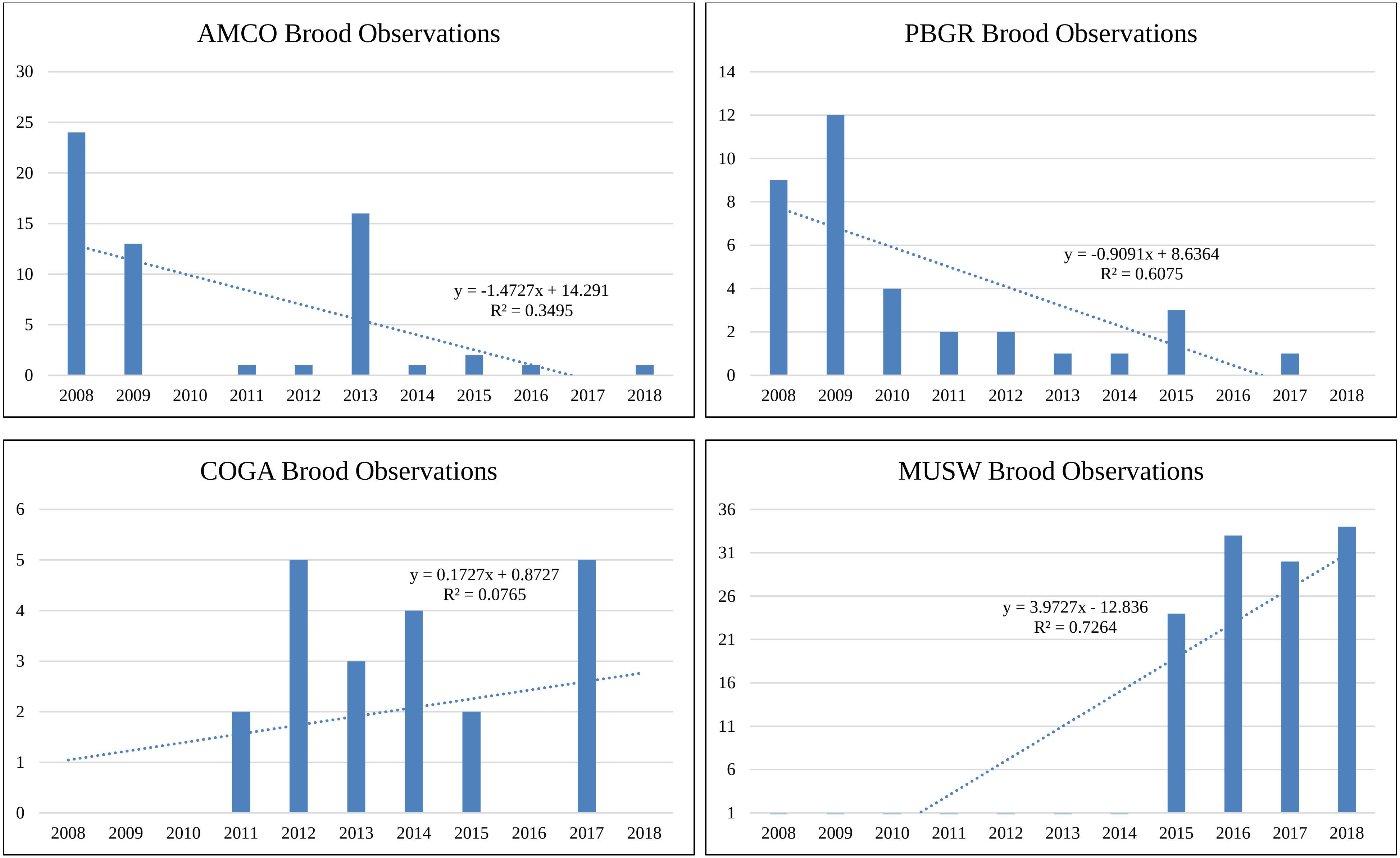


Figure 13. Observations of waterbird broods during spring and summer at the Emiquon Preserve 2008–2018.

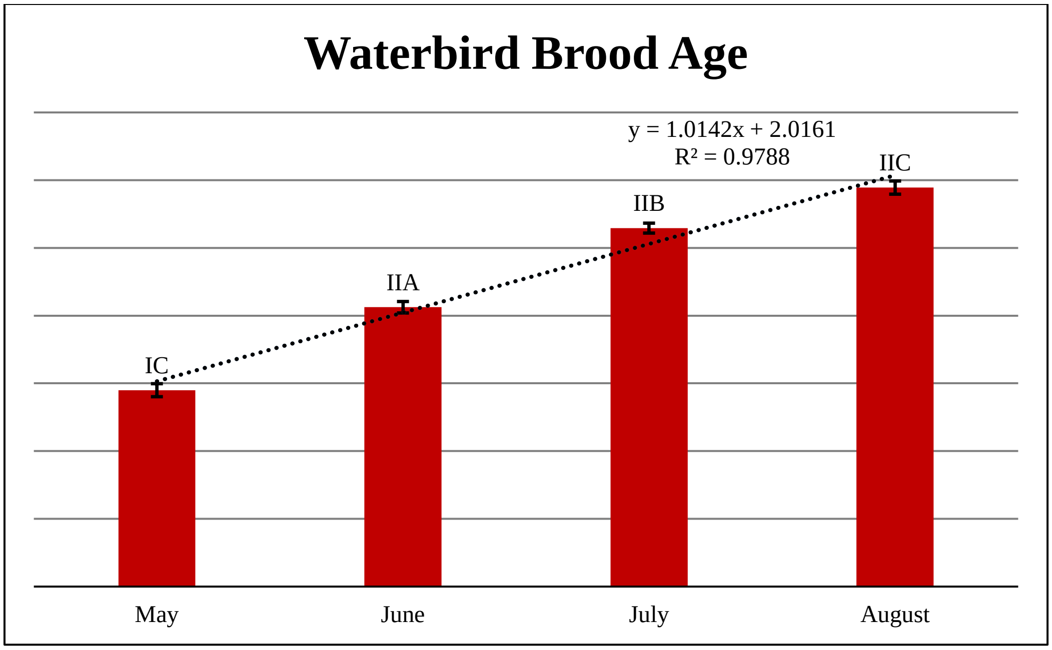


Figure 14. Mean monthly age classes of all waterbird broods observed at the Emiquon Preserve during 2008–2018.

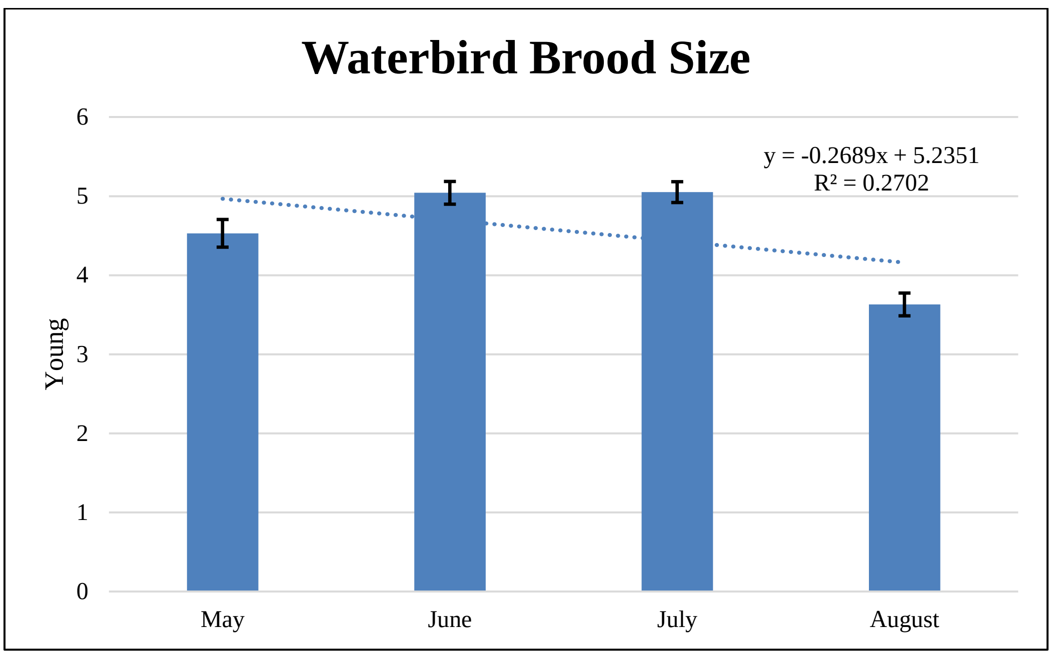


Figure 15. Mean monthly size of waterbird broods observed at the Emiquon Preserve during 2008–2018.

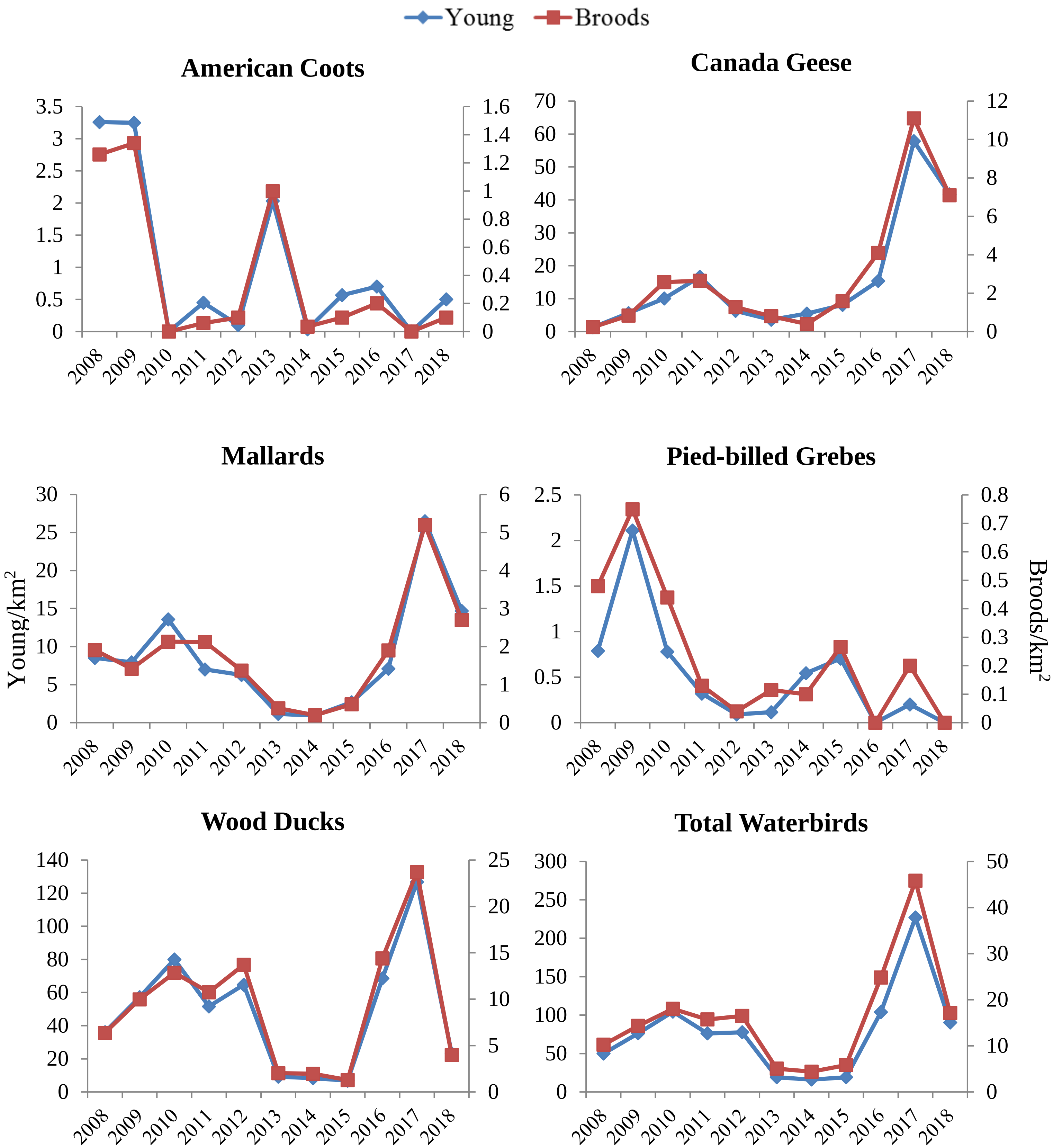
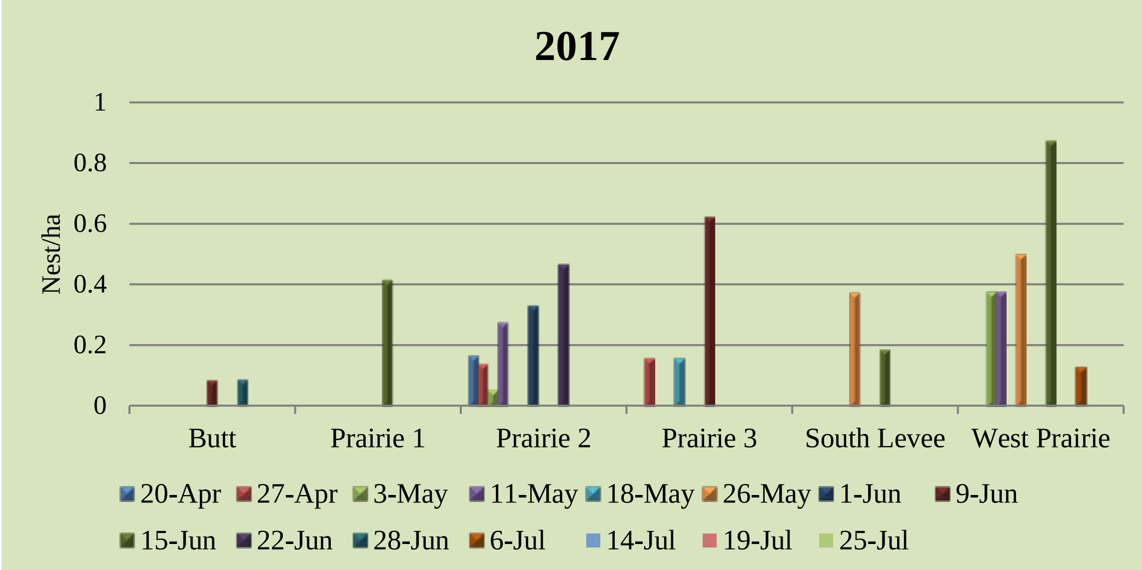
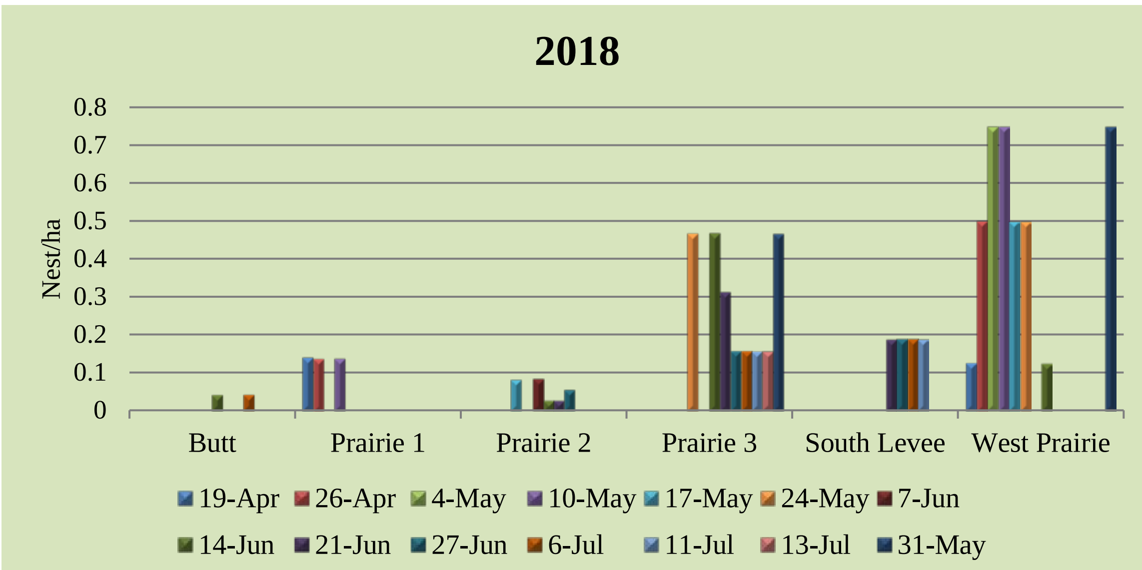


Figure. 16. Mean density of waterbird broods and young at Emiquon Preserve 2008-2018.





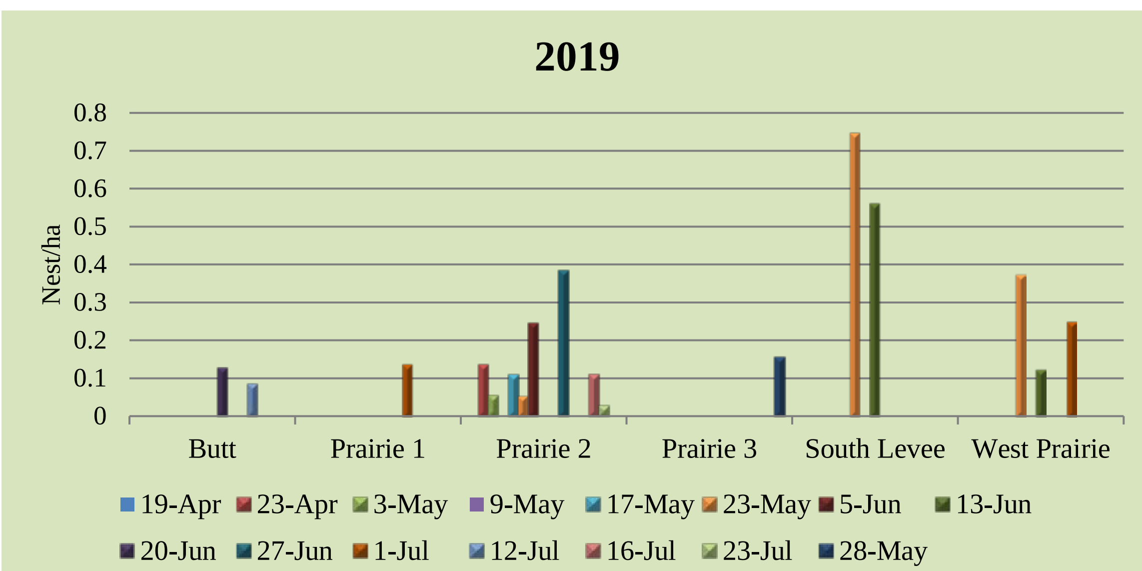


Figure 17. Weekly duck nest densities derived from chain drags of six grassland tracts at The Emiquon Preserve during 20 April–25 July, 2017, 19 April–20 July, 2018, and 19 April–23 July, 2019 (C).

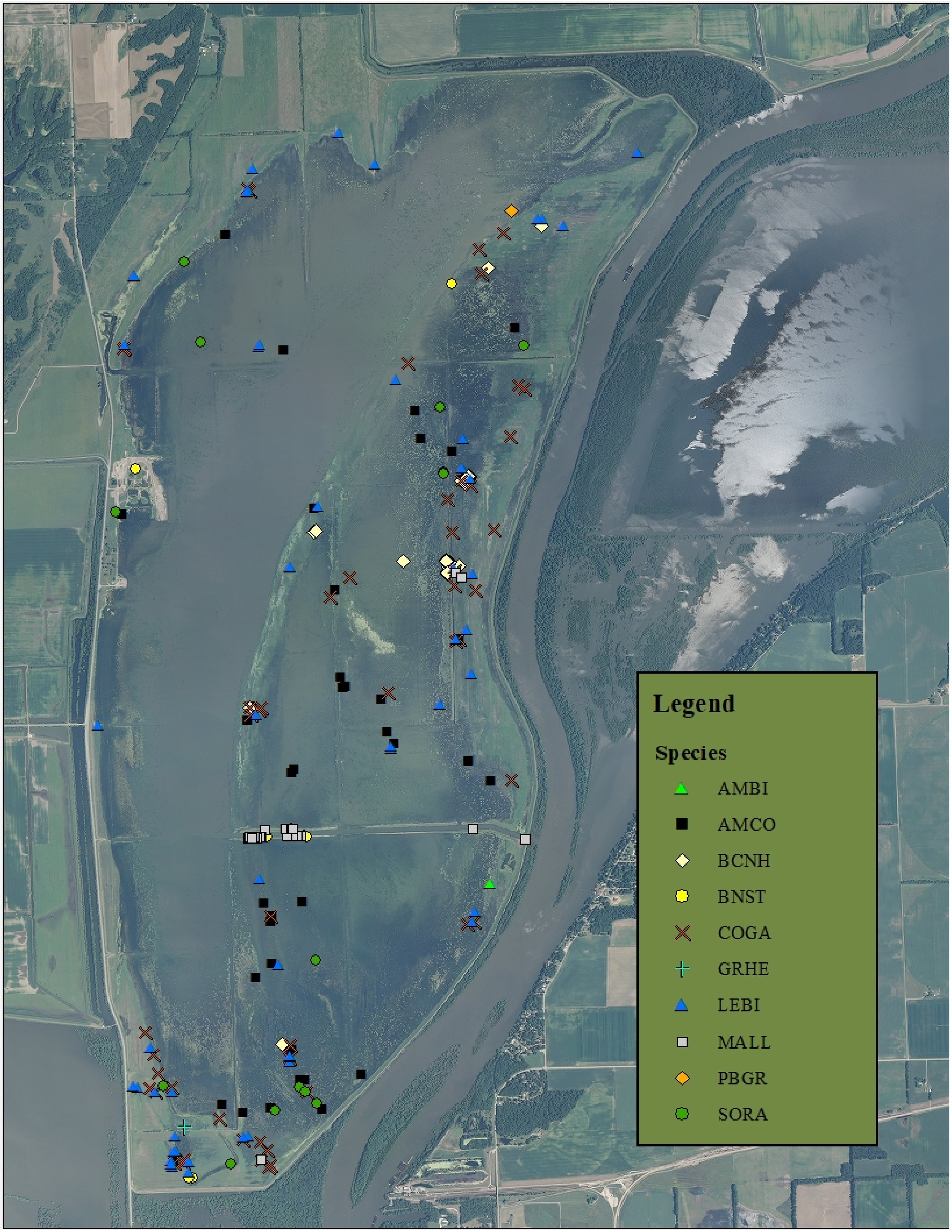


Figure 18. Locations of waterbird nests found during searches of hemi-marsh and dense persistent emergent vegetation communities at The Emiquon Preserve, 2013–2018.

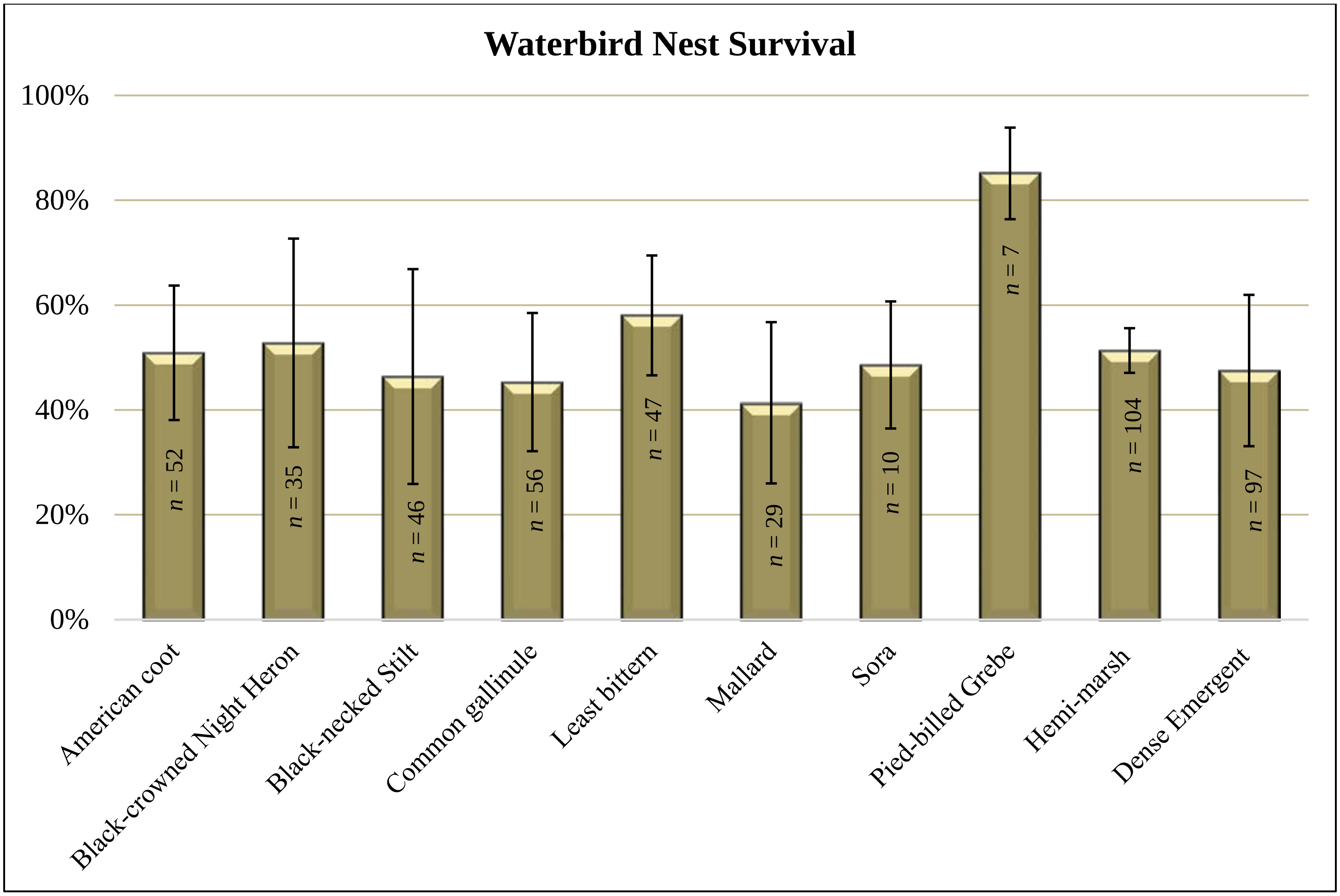


Figure 19. Mean (±SE) survival estimates of waterbird nests found during random plot (25-m radius) searches and incidentally at the Emiquon Preserve, 2013–2018.

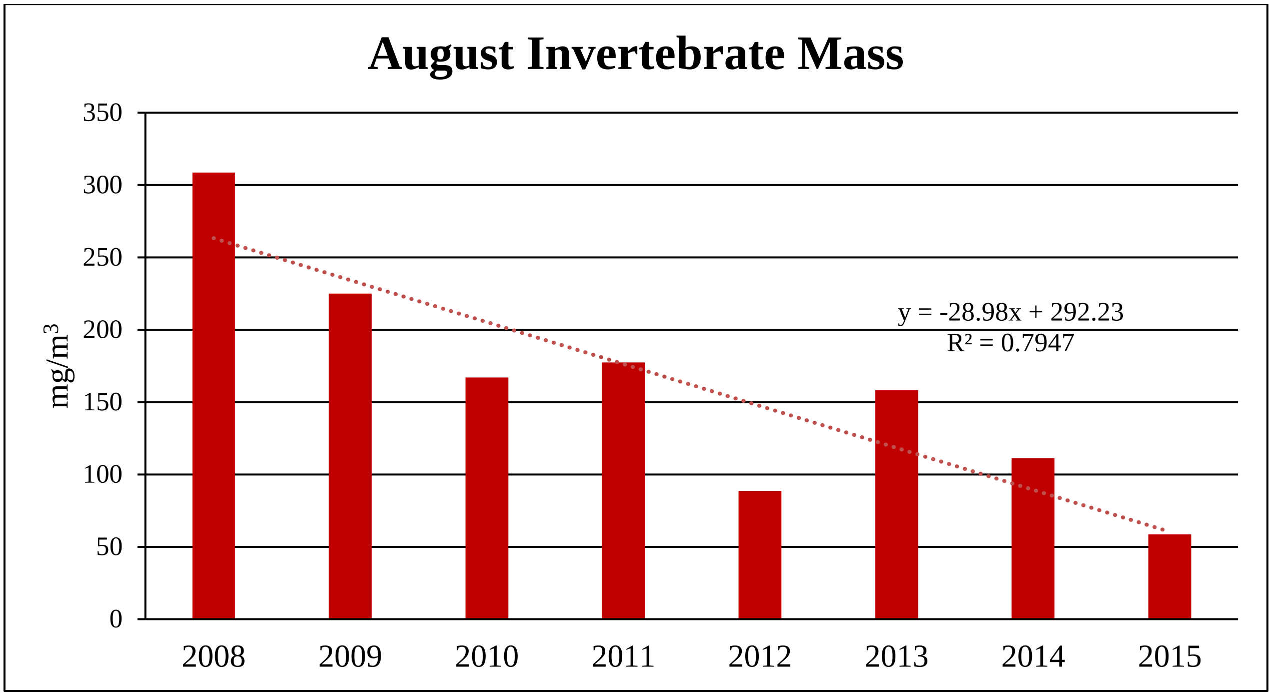
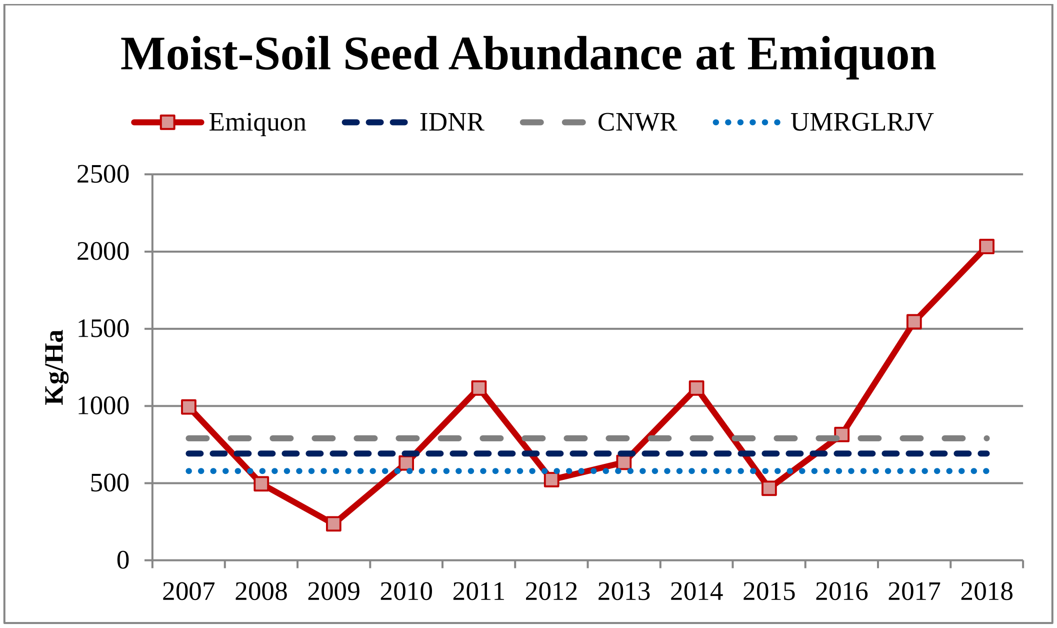


Figure 20. Mean density of aquatic invertebrates collected at Emiquon Preserve during August, 2008–2015.



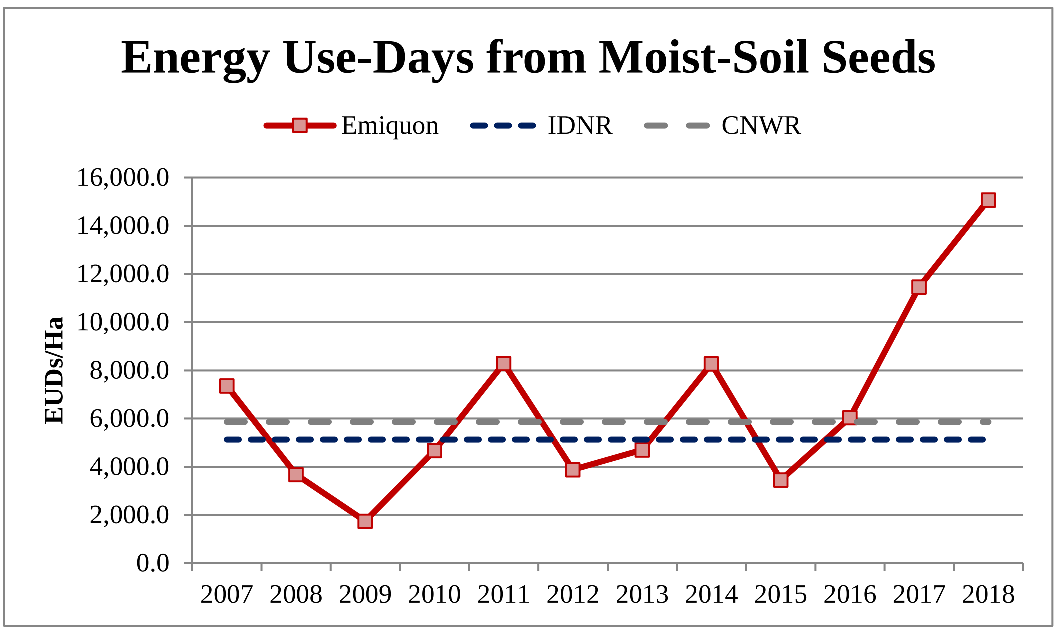


Figure 21. Moist-soil plant seed density and energy use days (EUDs) from moist-soil plants at the Emiquon Preserve compared to estimates (constants) from wetlands at Illinois Department of Natural Resources (IDNR) sites, Chautauqua National Wildlife Refuge (CNWR), and carrying capacity goals of the Upper Mississippi River/Great Lakes Region Joint Venture (UMRGLRJV) of the North American Waterfowl Management Plan.

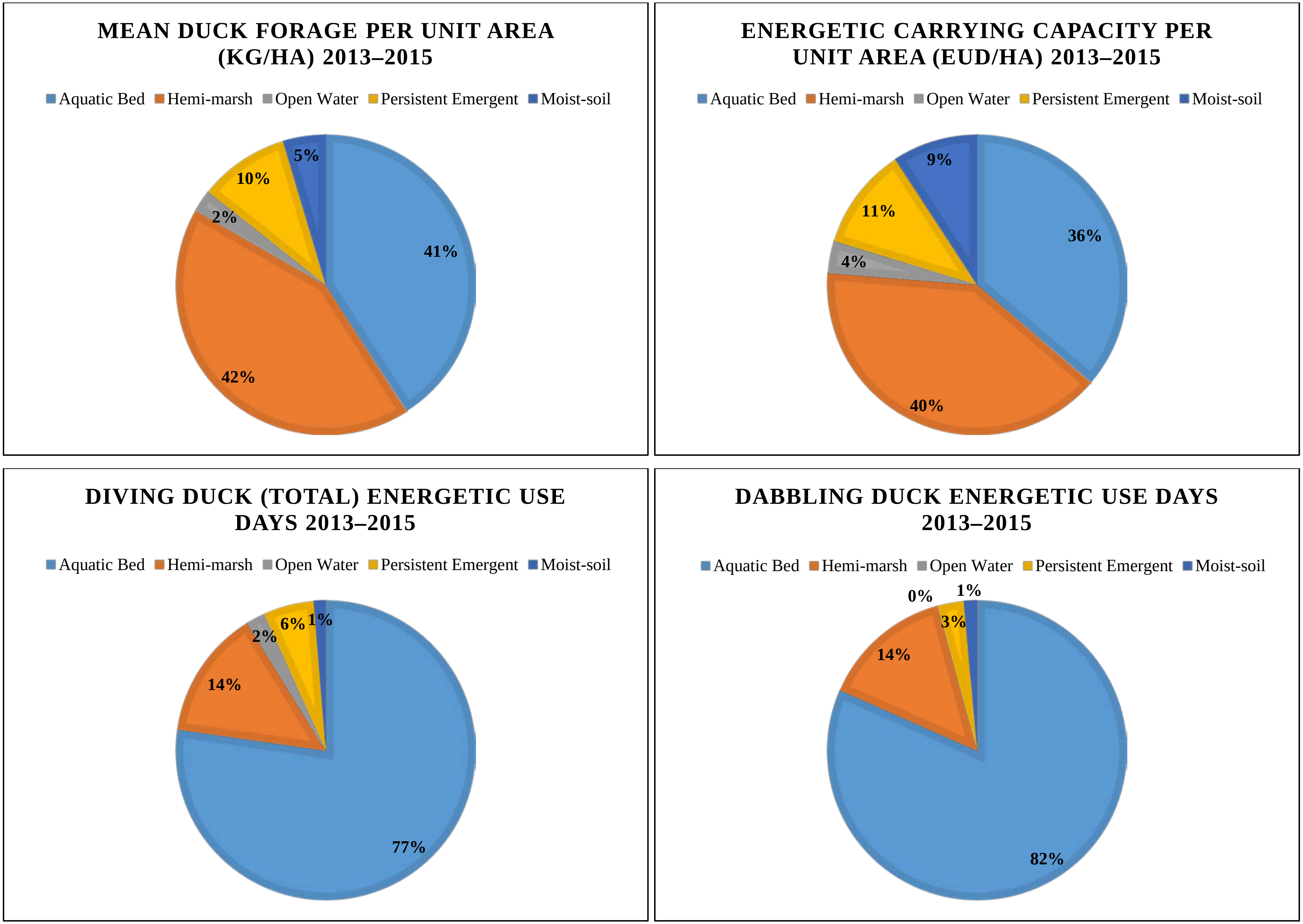


Figure 22. Energetic carrying capacity for diving ducks and dabbling ducks at the Emiquon Preserve, 2013–2015.

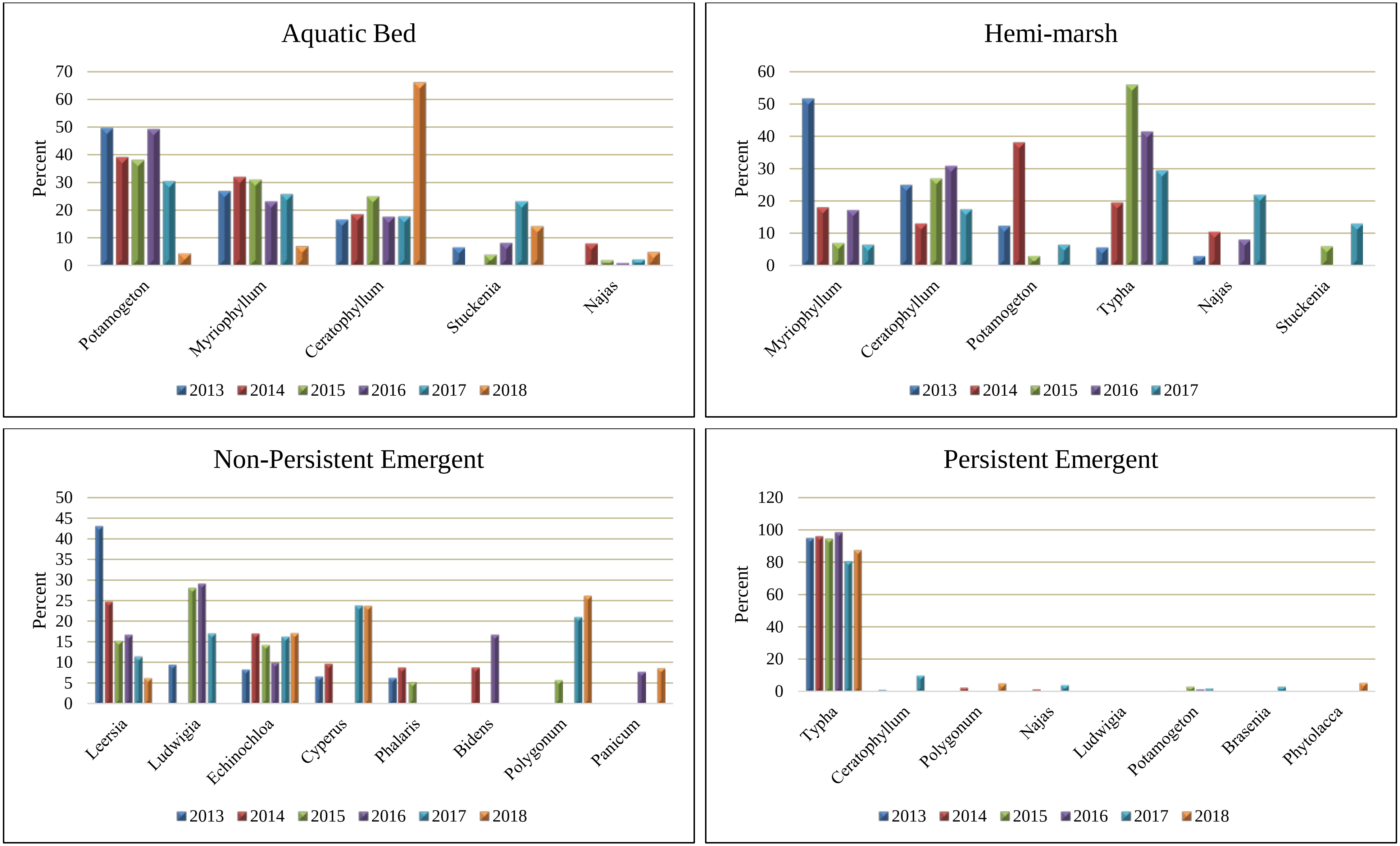


Figure 23. Species composition (%) of the major vegetation communities at Emiquon Preserve, 2013–2018.

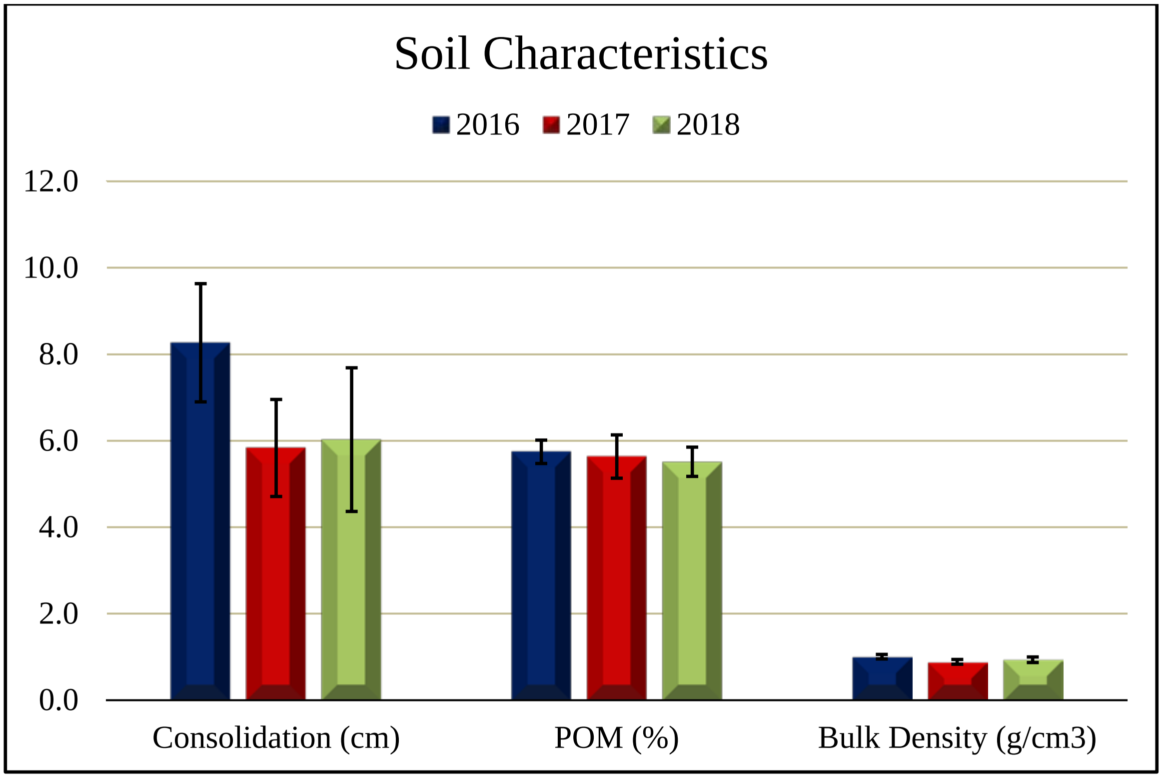


Figure 24. Mean soil penetrometer (consolidation), particulate organic matter, and soil density estimates from 15 random core samples collected annually at Emiquon Preserve during falls, 2016–2018.

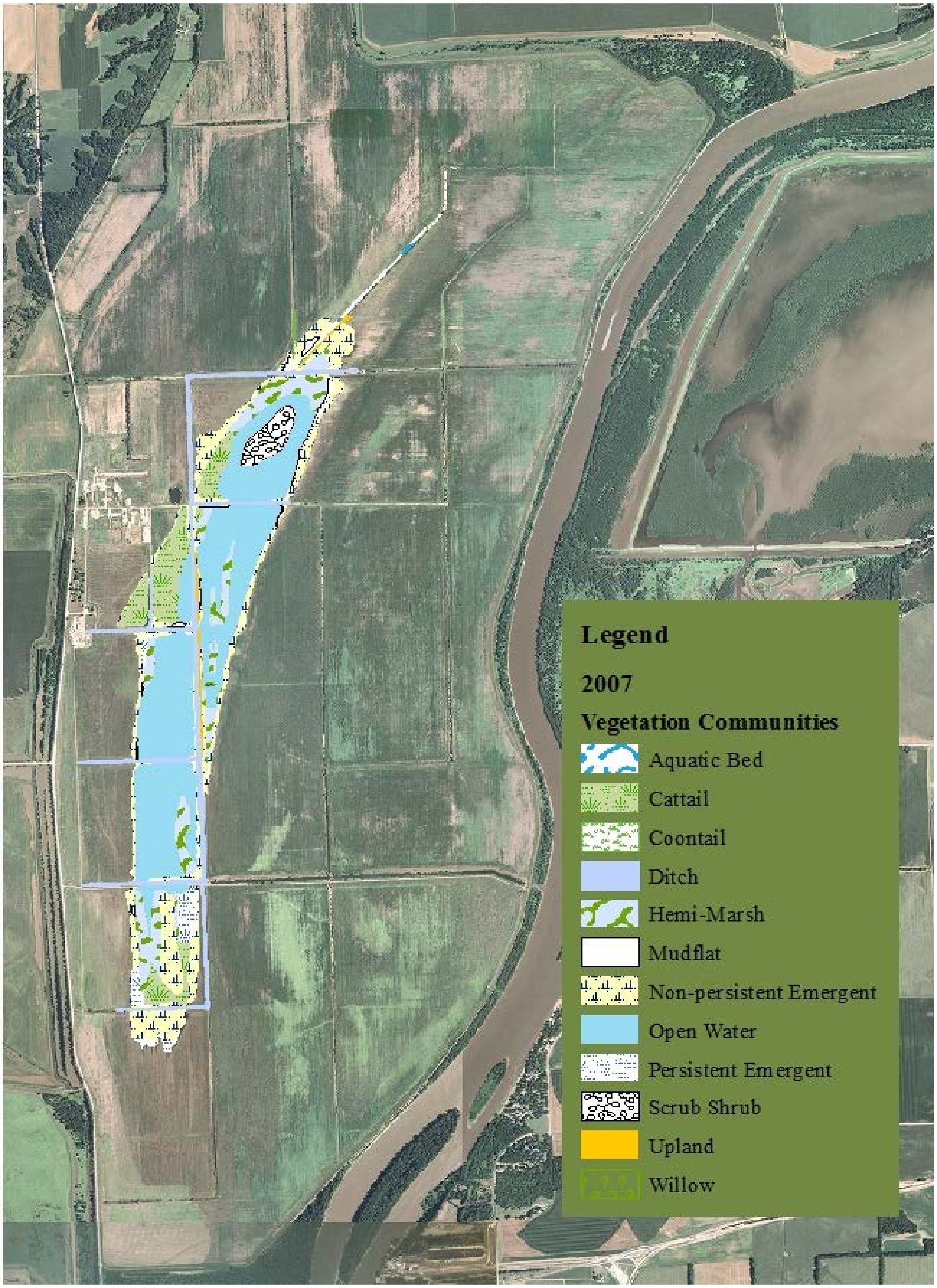


Figure 25. Wetland vegetation map of The Emiquon Preserve (255 ha), 7–8 November 2007.

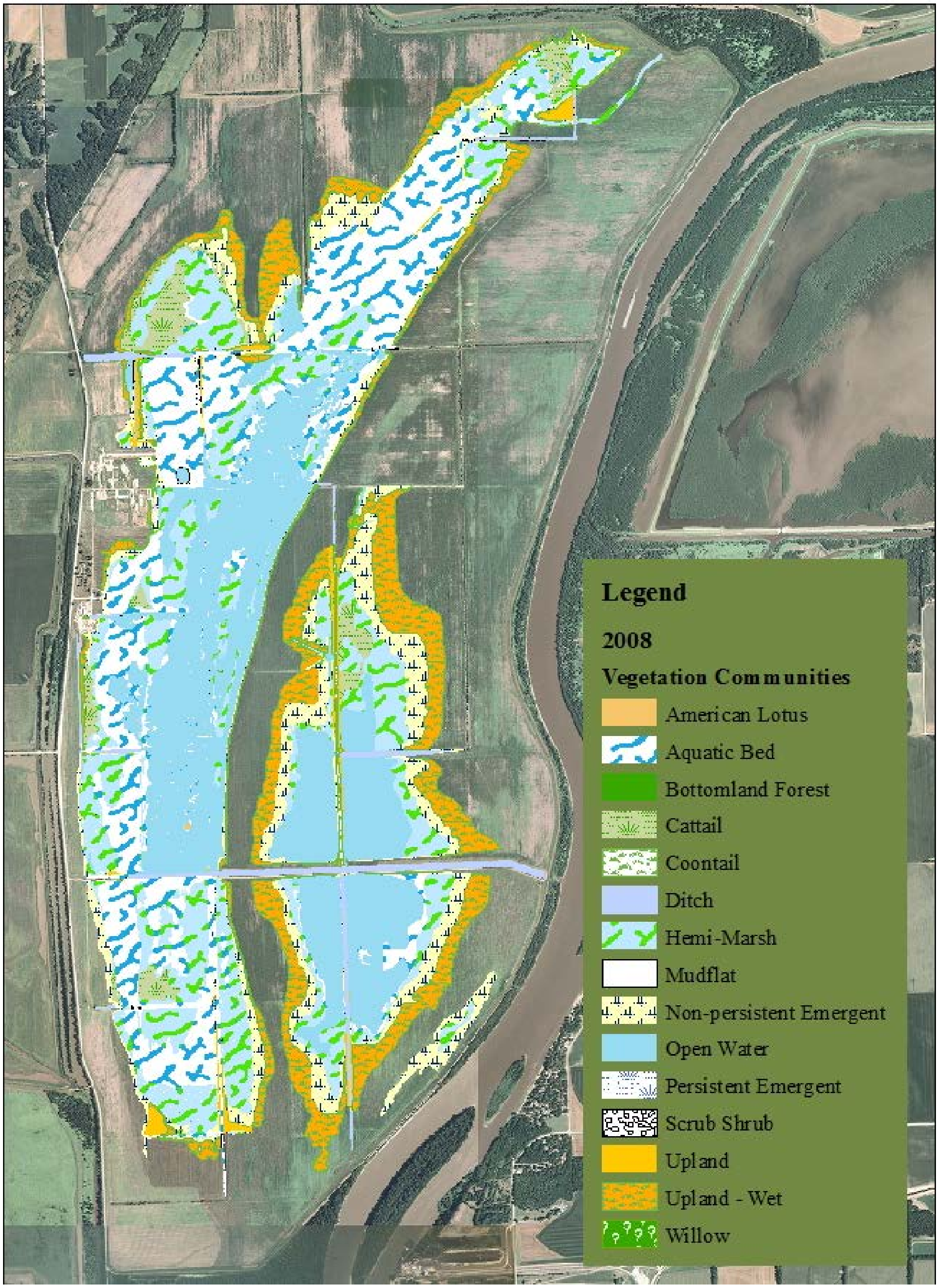


Figure 26. Wetland vegetation map of The Emiquon Preserve (1,077 ha), 11–18 September 2008

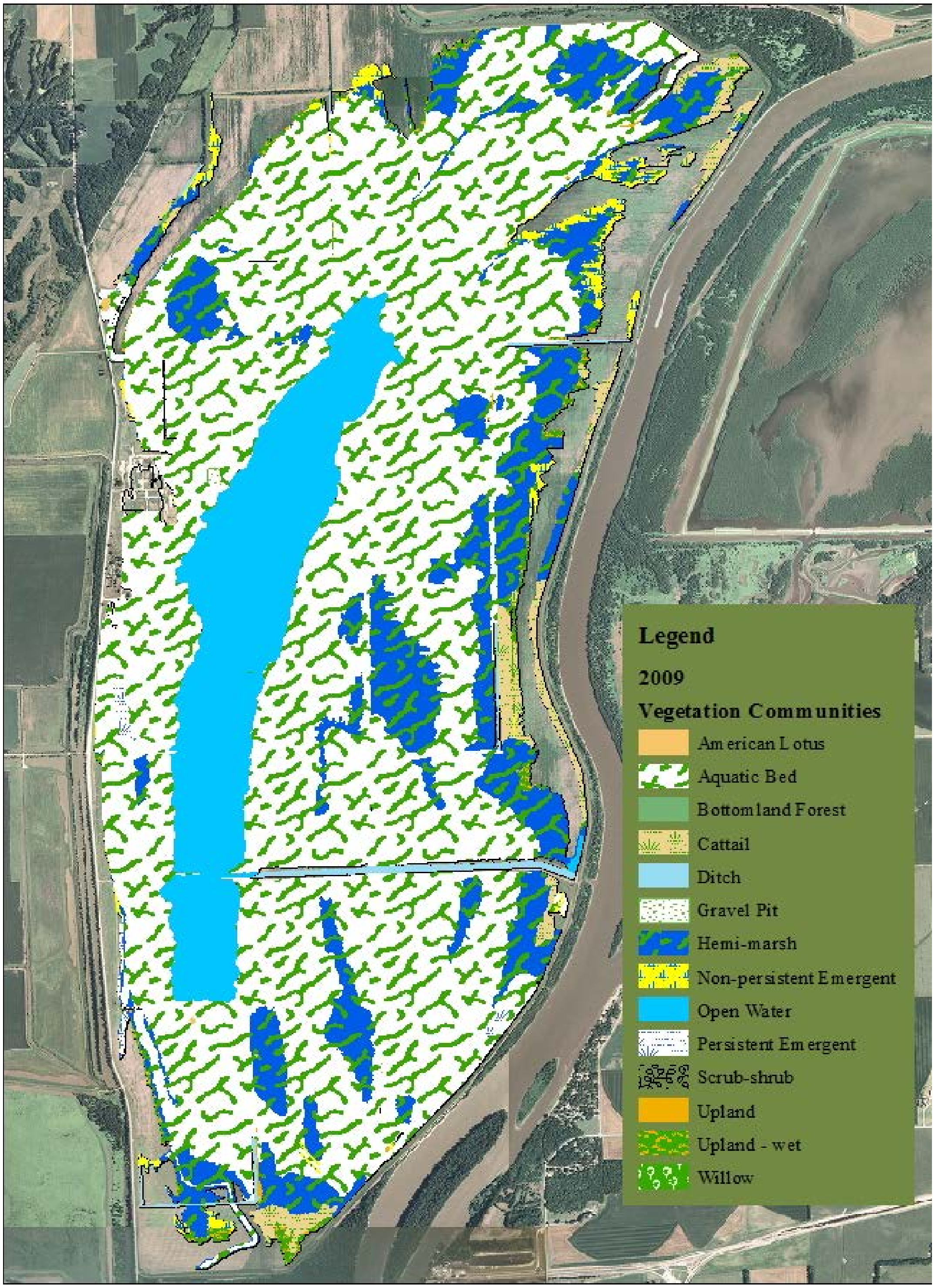


Figure 27. Wetland vegetation map of The Emiquon Preserve (1,804 ha), 15–23 September 2009.

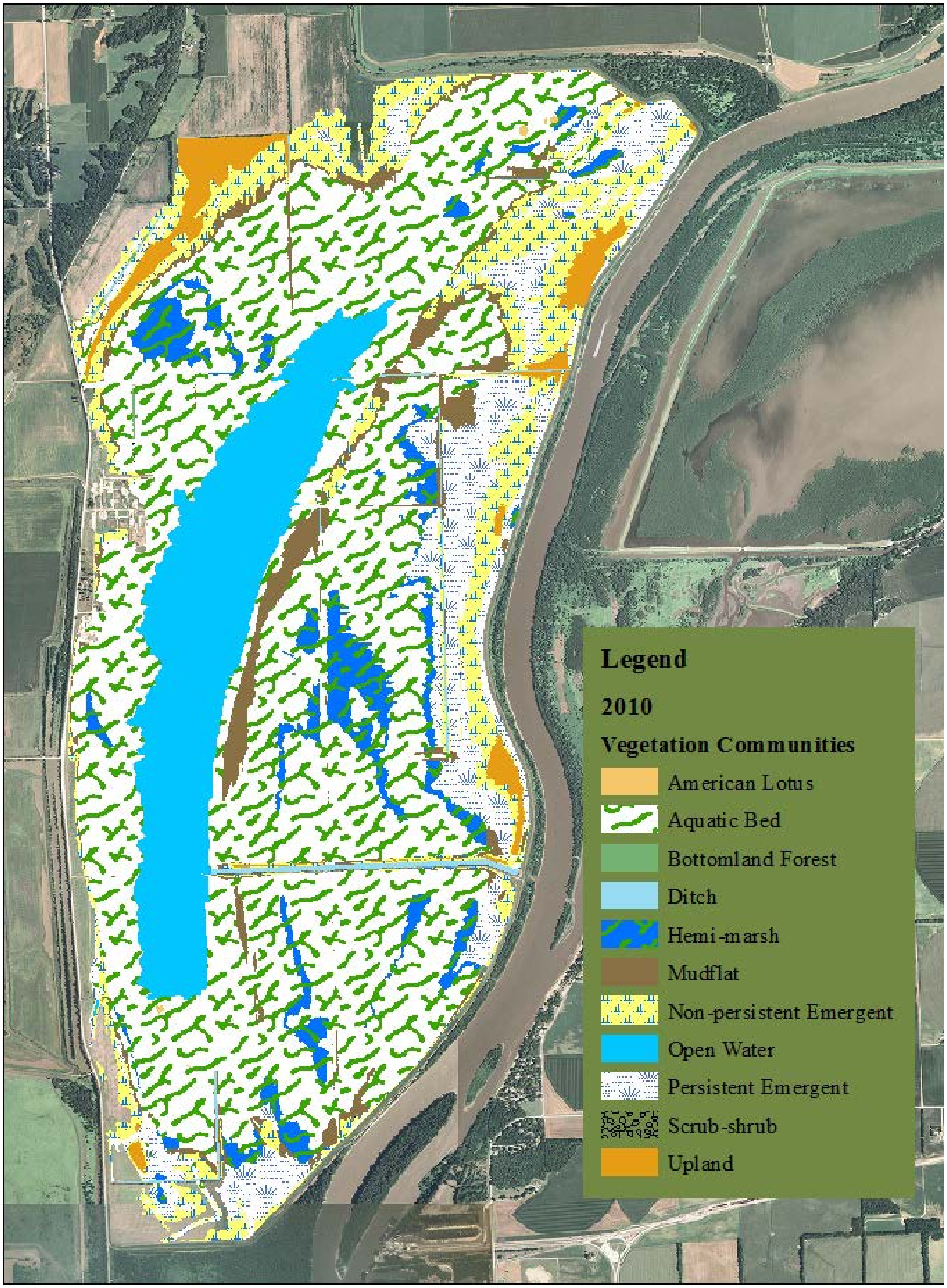


Figure 28. Wetland vegetation map of The Emiquon Preserve (1,974 ha), 8–20 September 2010.

Figure 29. Wetland vegetation map of The Emiquon Preserve (1,821 ha), 13 September–24 October, 2011.

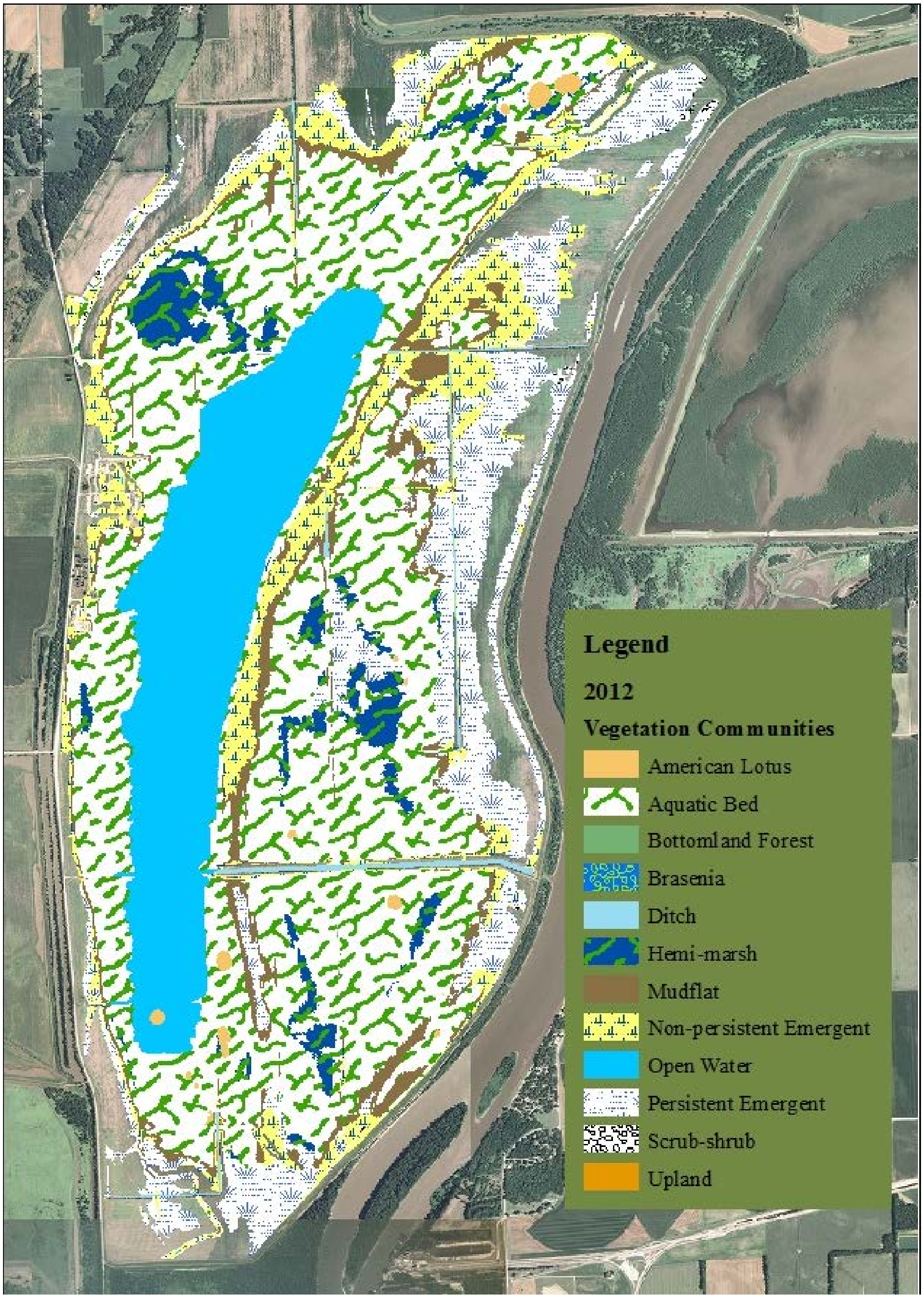


Figure 30. Wetland vegetation map of The Emiquon Preserve (1,782 ha), 10–17 September, 2012.

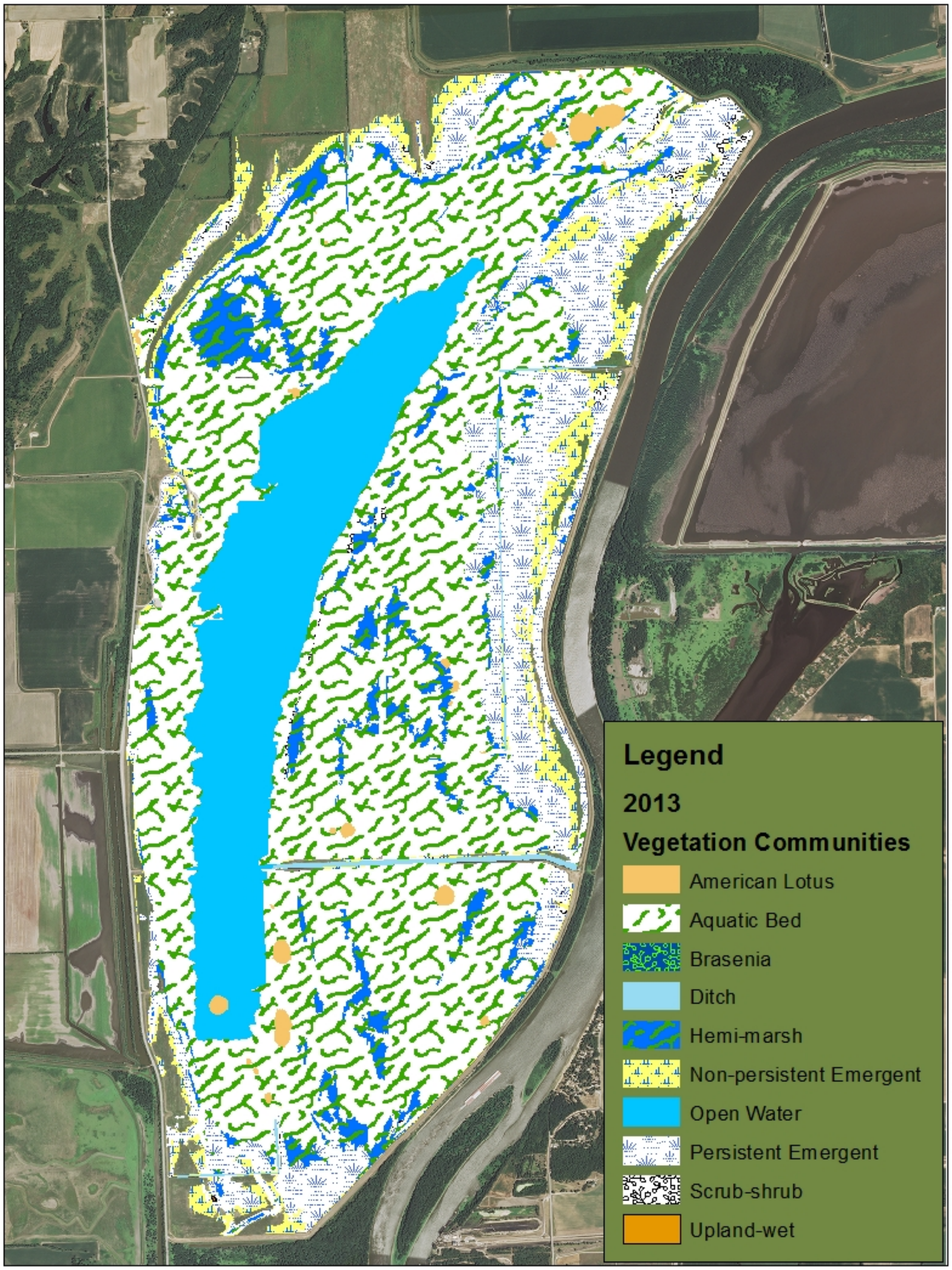


Figure 31. Wetland vegetation map of The Emiquon Preserve (1,944 ha), 23 August–6 September, 2013.

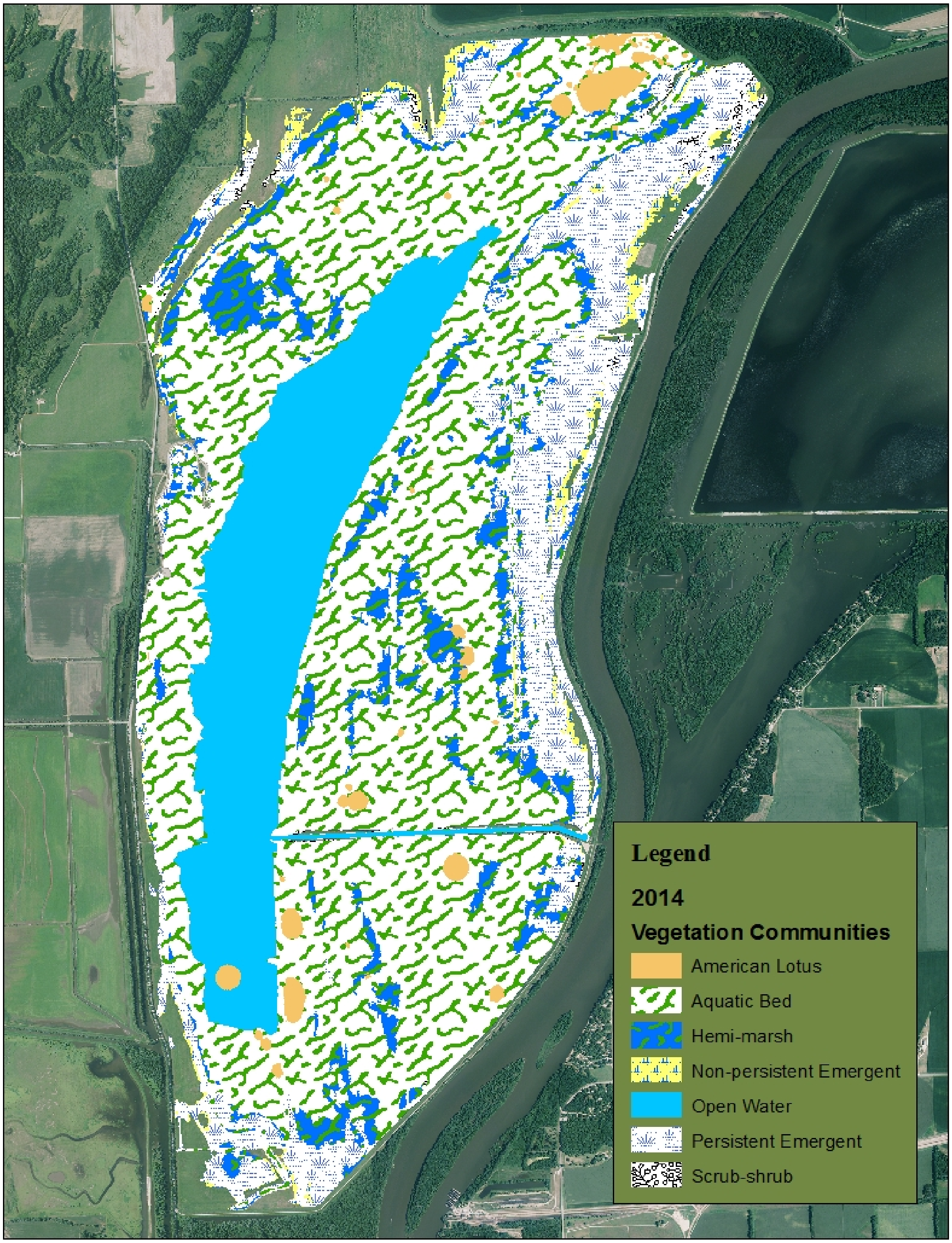


Figure 32. Wetland vegetation map of The Emiquon Preserve (1,944 ha), 4–16 September, 2014.

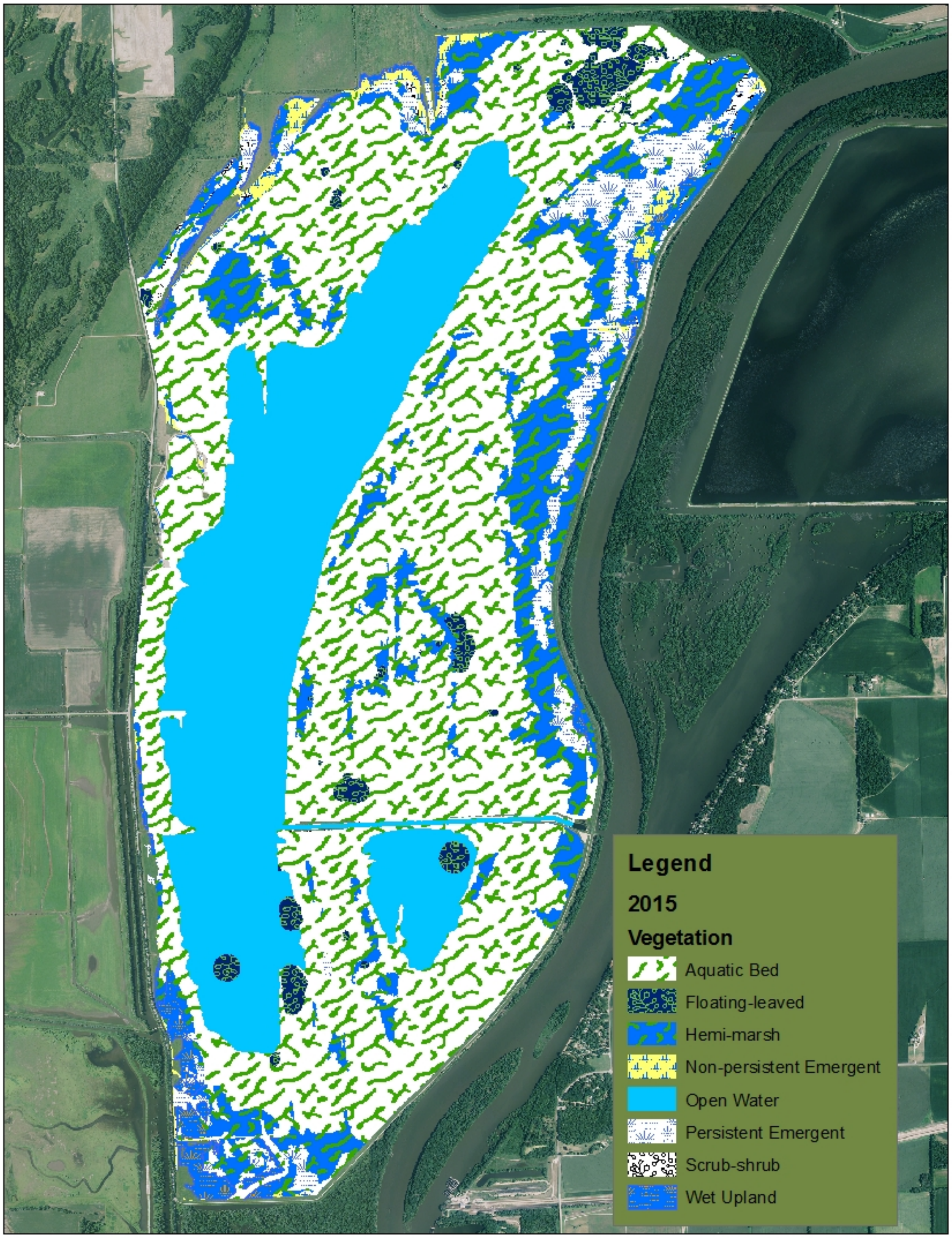


Figure 33. Wetland vegetation map of The Emiquon Preserve (2,017 ha), 14–21 September, 2015.

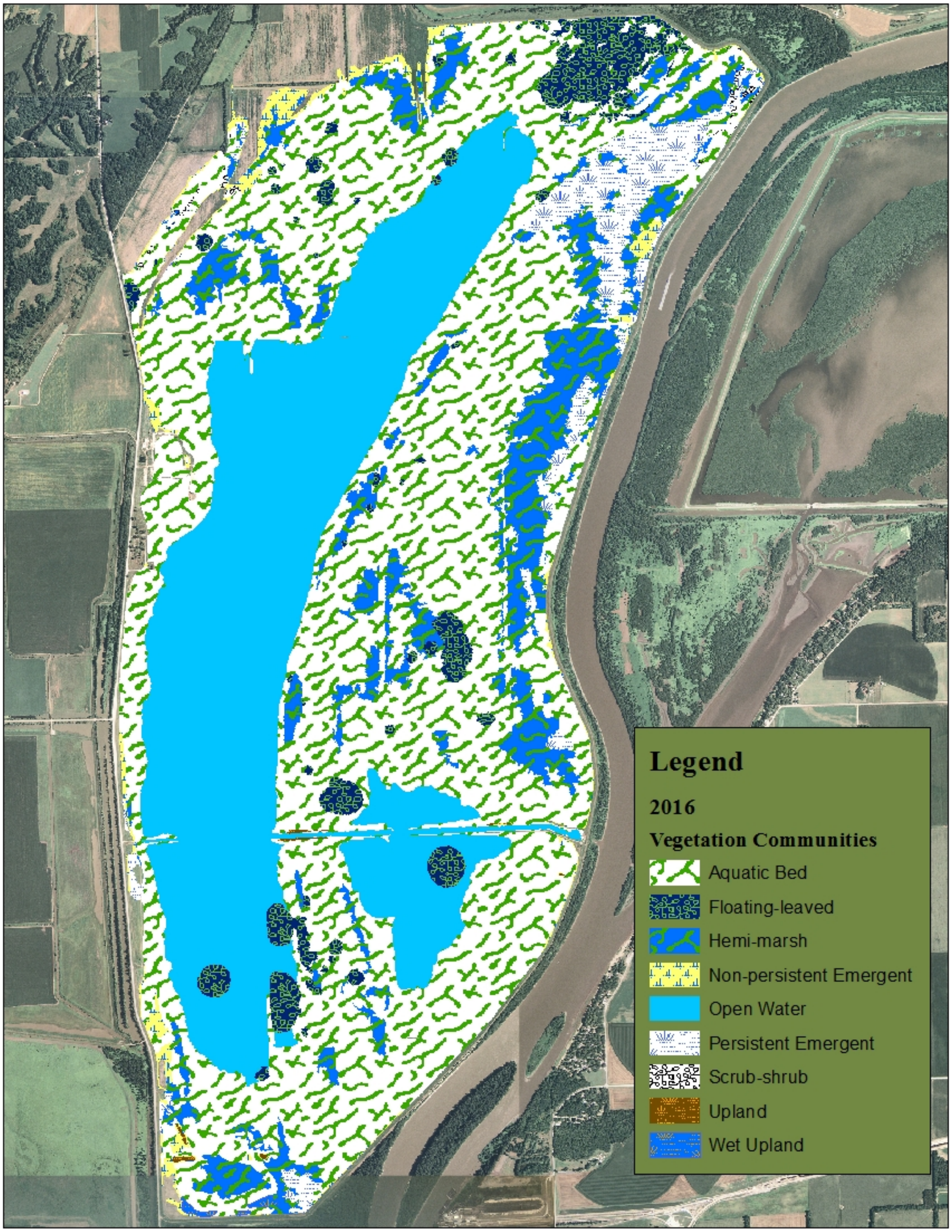


Figure 34. Wetland vegetation map of The Emiquon Preserve (2,021.7 ha), 14–20 September, 2016.

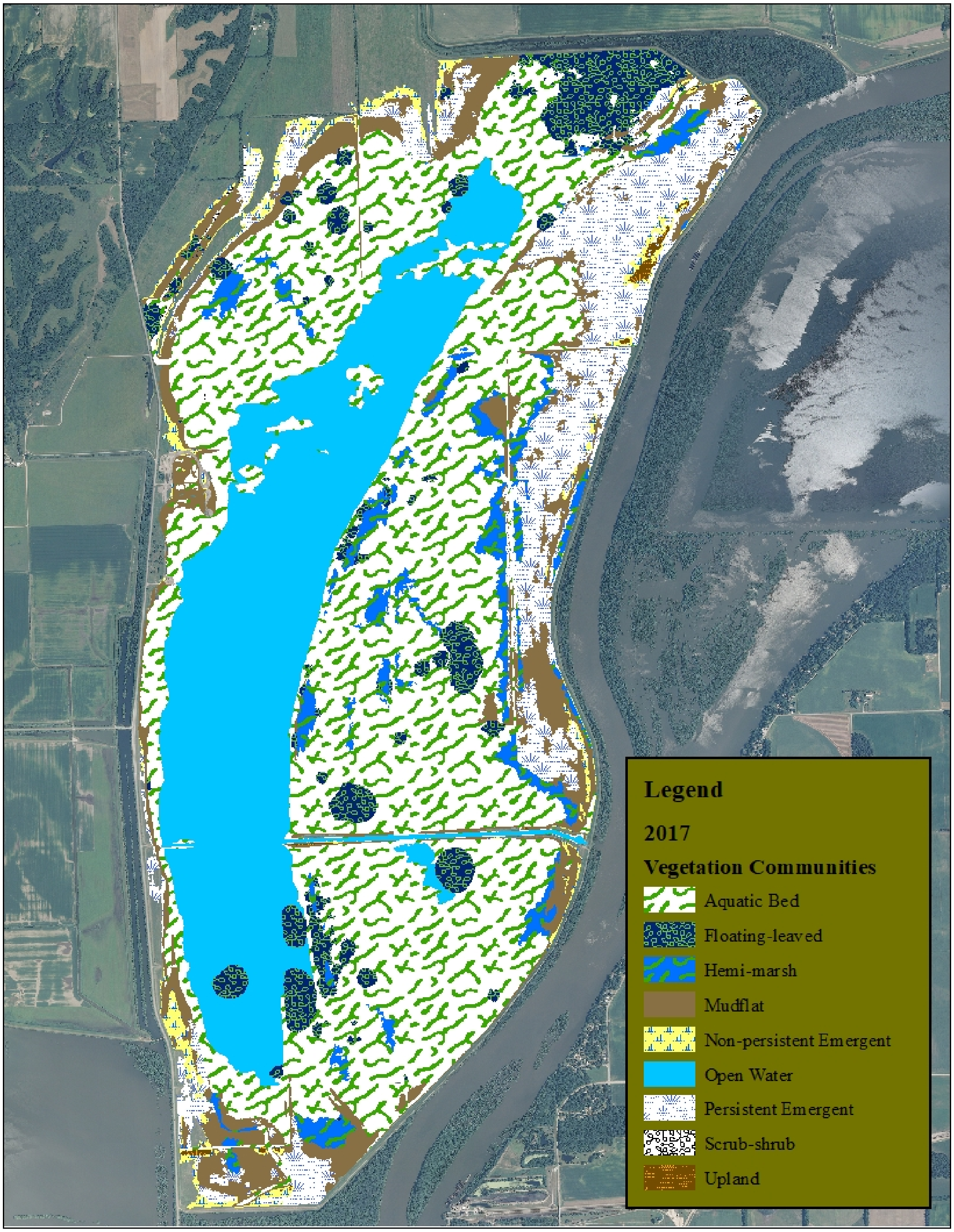


Figure 35. Wetland vegetation map of The Emiquon Preserve (2,010.7 ha), 12–21 September, 2017.

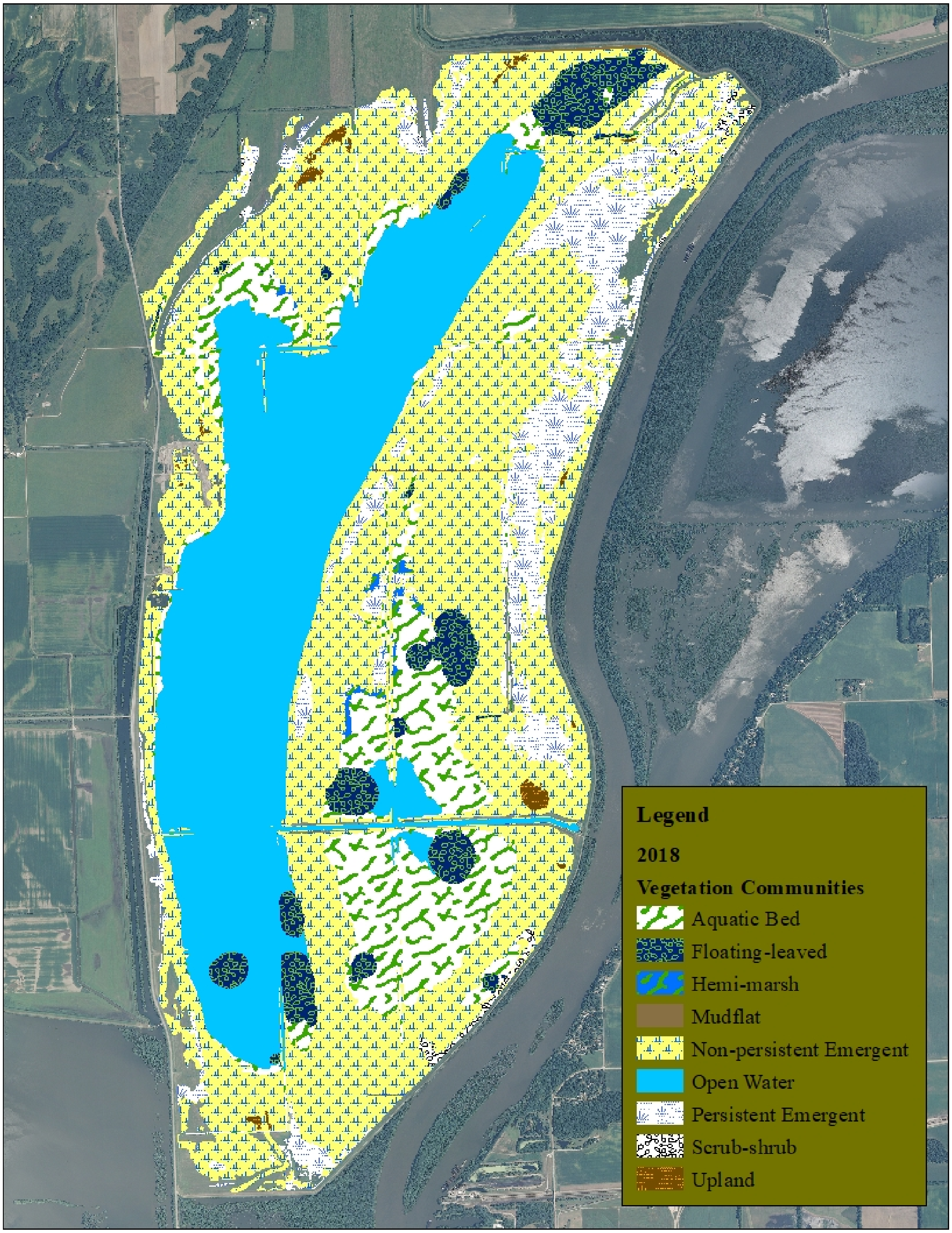


Figure 36. Wetland vegetation map of The Emiquon Preserve (1,938.4 ha), 18 September–9 October, 2018.

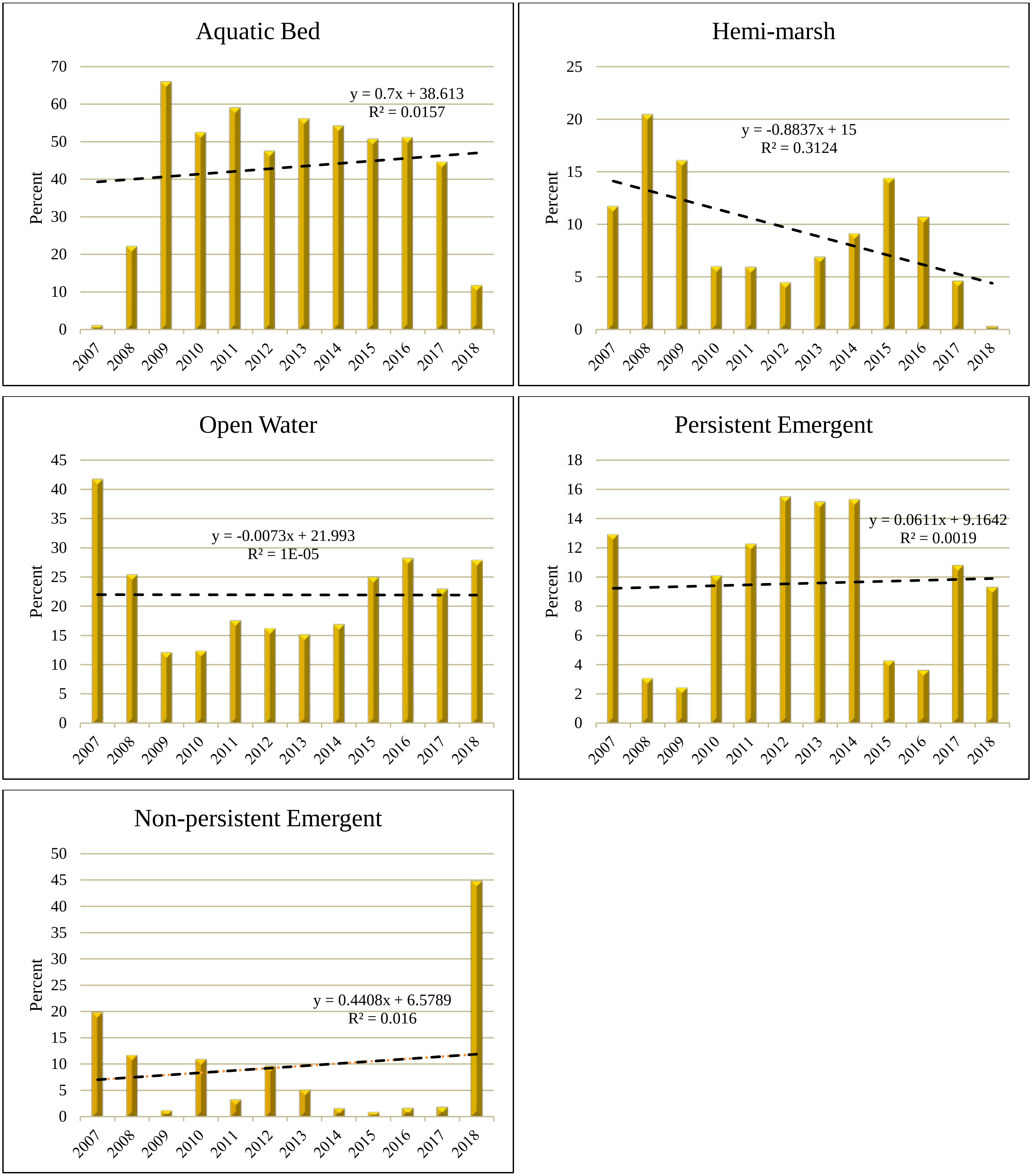


Figure 37. Trends in vegetation community composition (%) at Emiquon Preserve, 2007–2018.

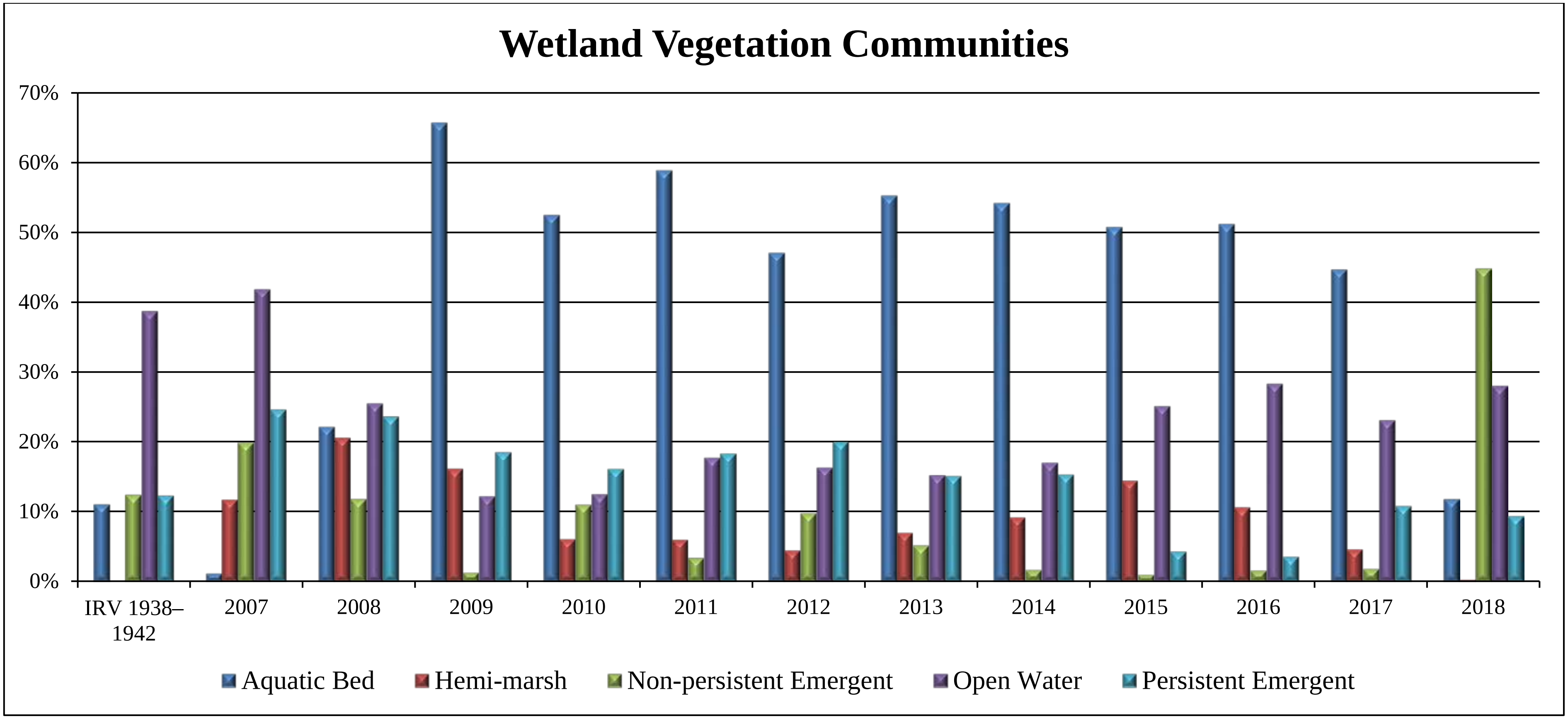


Figure 38. Proportional coverage of wetland vegetation communities at the Emiquon Preserve during early fall 2007–2018 and those historically present in the Illinois River valley (1938–1942).

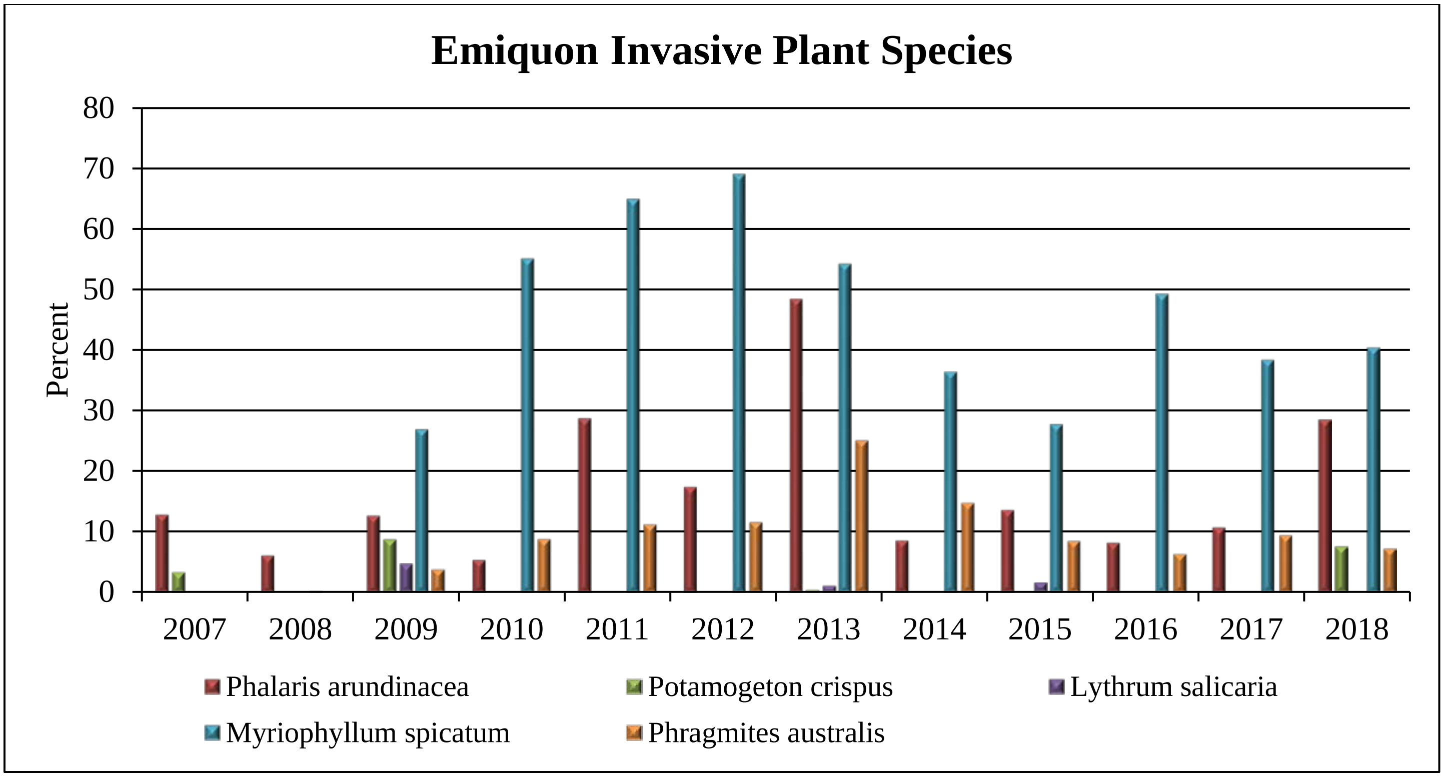


Figure 39. Proportion of cover map polygons containing invasive species encountered at Emiquon Preserve, 2007–2018.

Table 1. Avian species observed during monitoring activities at The Emiquon Preserve, 2007–2018.

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, 2007−2018.

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*
Water Stargrass	*Heteranthera dubia*
WhiteTurtlehead	*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. Abundances of waterfowl and waterbirds observed during fall aerial inventories at Emiquon Preserve, 2007–2018.

Year	Day	Dabbling ducks	Diving ducks	Geese	Non-mallard dabbling ducks	Total waterfowl	Total waterbirds	Total birds
2007	9/4	5,500	0	0	5,100	5,500	100	5,600
	9/10	19,900	0	0	17,860	19,900	200	20,100
	9/26	24,220	0	85	19,670	24,305	6,000	30,305
	10/12	14,645	0	145	11,925	14,791	1,260	16,051
	10/23	17,230	0	0	11,710	17,230	10,570	27,800
	10/29	21,255	0	45	18,275	21,300	25,900	47,200
	11/13	8,510	490	10	6,630	9,010	4,410	13,420
	11/23	5,645	0	0	3,415	5,649	5,280	10,929
	11/27	8,680	0	20	1,815	8,700	2,095	10,795
	12/4	0	0	0	0	0	0	0
	12/18	0	0	0	0	0	10	10
	12/26	0	0	55	0	55	0	55
	1/9	3,060	0	3,710	200	6,770	0	6,770
2008	9/2	8,400	0	95	8,000	8,495	550	9,045
	9/9	2,875	0	100	2,800	2,975	1,800	4,775
	9/16	3,690	0	0	2,965	3,690	4,965	8,655
	10/13	14,910	0	10	12,780	14,920	21,320	36,240
	10/20	33,625	0	10	29,445	33,635	48,000	81,635
	10/28	46,720	2,070	0	35,895	48,790	41,400	90,190
	11/3	39,015	3,800	0	34,805	42,815	32,285	75,100
	11/10	49,570	680	0	27,820	50,250	29,750	80,000
	11/18	46,030	2,855	100	13,095	49,005	5,895	54,900
	11/25	19,850	400	0	5,250	20,250	1,450	21,700
	12/2	17,220	710	50	1,700	17,980	350	18,330
	12/22	0	0	0	0	0	0	0
	12/29	110	0	600	0	710	0	710
	1/5	0	0	120	0	130	0	130
2009	9/2	11,720	0	10	11,485	11,730	2,020	13,750
	9/9	8,280	0	40	6,860	8,320	5,700	14,020
	9/14	4,675	0	20	3,630	4,695	2,340	7,035
	10/13	25,330	1,050	265	22,705	26,645	26,655	53,300
	10/20	41,290	5,260	160	35,980	46,710	59,755	106,465

Table 3. Continued.

Year	Day	Dabbling ducks	Diving ducks	Geese	Non-mallard dabbling ducks	Total waterfowl	Total waterbirds	Total birds
2009	11/2	39,720	12,420	10	34,050	52,150	87,410	139,560
	11/11	46,665	16,420	5	30,645	63,123	96,920	160,043
	11/23	39,310	17,310	200	24,960	56,820	87,350	144,170
	12/1	23,105	25,175	1,060	11,150	49,340	14,070	63,410
	12/7	9,960	10,990	125	5,180	21,279	27,550	48,829
	12/15	0	0	0	0	10	120	130
	12/21	0	110	0	0	115	100	215
	12/28	0	0	5	0	30	0	30
	1/4	0	0	0	0	0	0	0
2010	9/8	24,150	0	150	22,260	24,300	2,825	27,125
	9/14	30,570	0	125	28,080	30,695	4,520	35,215
	9/20	30,380	0	95	26,900	30,475	5,435	35,910
	10/11	45,640	3,300	245	40,090	49,185	64,545	113,730
	10/18	48,775	2,000	140	41,045	50,915	60,170	111,085
	10/25	46,850	5,525	650	39,815	53,025	92,770	145,795
	11/2	42,325	7,065	460	35,260	49,860	95,960	145,820
	11/8	55,240	6,830	800	46,035	62,872	19,595	82,467
	11/16	53,810	4,880	635	46,310	59,352	20,485	79,837
	11/23	19,880	5,765	535	12,120	26,180	6,670	32,850
	12/3	2,800	2,280	70	1,200	5,360	715	6,075
	12/14	5	150	0	0	155	0	155
	12/28	0	0	0	0	0	0	0
	1/3	0	0	0	0	300	0	300
2011	8/30	9,750	0	235	8,940	10,002	565	10,567
	9/6	13,985	0	80	11,990	14,065	660	14,725
	9/12	17,705	0	60	15,495	17,765	500	18,265
	9/22	23,055	0	80	19,960	23,135	4,710	27,845
	10/10	48,105	500	370	44,410	48,985	21,330	70,315
	10/17	61,400	500	285	57,580	62,185	92,510	154,695
	10/24	80,755	9,420	810	71,135	90,985	136,035	227,020
	11/1	80,505	8,320	205	68,250	89,030	86,540	175,570
	11/15	44,415	8,165	930	25,655	53,550	6,205	59,755
	11/21	22,205	9,355	50	11,925	31,860	1,800	33,660

Table 3. Continued.

Year	Day	Dabbling ducks	Diving ducks	Geese	Non-mallard dabbling ducks	Total waterfowl	Total waterbirds	Total birds
2011	11/30	10,200	2,090	100	1,100	12,501	840	13,341
	12/7	17,395	1,790	250	555	19,475	415	19,890
	12/12	16,800	700	900	400	18,950	1,125	20,075
	12/23	1,550	1,350	2,660	300	6,010	500	6,510
	12/28	1,730	770	2,875	420	6,625	350	6,975
	1/4	400	200	305	0	1,385	600	1,985
2012	9/6	39,475	0	20	38,425	39,495	4,310	43,805
	9/10	23,040	0	60	22,270	23,110	6,890	30,000
	9/20	35,695	0	320	33,925	36,020	20,360	56,380
	9/27	23,570	0	570	20,250	24,140	41,750	65,890
	10/15	54,170	8,580	1,385	49,190	64,135	94,345	158,480
	10/29	30,940	775	100	24,475	31,815	16,960	48,775
	11/8	17,120	2,400	20	13,665	19,710	3,465	23,175
	11/13	15,555	2,660	20	4,330	18,576	1,865	20,441
	11/20	15,930	4,535	0	10,130	21,340	5,080	26,420
	11/26	25,045	4,175	10	18,175	29,860	5,335	35,195
	12/6	25,935	1,700	610	20,130	29,156	3,100	32,256
	12/12	15,540	5,815	355	4,490	22,781	10	22,791
	12/19	14,080	2,090	16,585	8,565	34,245	1,910	36,155
	12/27	135	125	0	10	276	35	311
	1/2	0	0	400	0	502	0	502
	1/8	400	0	1,070	0	1,985	0	1,985
2013	9/3	7,565	0	35	6,935	7,600	1,875	9,475
	9/13	9,485	0	110	8,625	9,602	4,945	14,547
	9/25	28,660	0	185	27,050	28,848	25,810	54,658
	10/14	53,795	825	150	50,530	54,772	109,270	164,042
	10/23	64,800	1,500	200	61,200	66,512	113,840	180,352
	10/28	101,500	5,850	525	89,320	107,885	101,755	209,640
	11/8	45,510	19,950	5	33,300	65,507	28,080	93,587
	11/14	4,935	1,895	10	4,110	6,950	1,230	8,180
	11/19	5,400	8,620	80	4,850	14,275	865	15,140
	11/27	6,770	2,350	60	235	9,330	125	9,455
	12/6	8,080	900	150	30	9,418	55	9,473

Table 3. Continued.

Year	Day	Dabbling ducks	Diving ducks	Geese	Non-mallard dabbling ducks	Total waterfowl	Total waterbirds	Total birds
2013	12/12	0	100	5	0	120	0	120
	12/19	425	10	15	0	505	0	505
	12/23	10	25	0	0	135	0	135
	12/30	0	25	0	0	495	0	495
	1/8	0	0	10	0	835	0	835
2014	9/3	8,530	0	50	8,330	8,584	1,200	9,784
	9/11	9,520	0	25	9,470	9,553	2,185	11,738
	9/16	6,825	0	30	6,700	6,870	4,435	11,305
	9/23	5,200	0	15	5,080	5,225	22,380	27,605
	10/16	21,400	1,920	40	21,300	23,370	119,630	143,000
	10/20	25,930	1,375	315	22,595	27,625	75,585	103,210
	10/29	21,480	5,985	60	18,815	27,525	58,310	85,835
	11/5	60,265	33,870	0	47,285	94,137	33,950	128,087
	11/12	6,700	4,370	15	4,400	11,245	5,435	16,680
	11/20	12,335	890	0	20	13,239	15	13,254
	11/25	6,410	550	0	135	7,305	10	7,315
	12/3	210	595	0	0	1,355	0	1,355
	12/9	50	150	10	0	815	0	815
	12/17	170	545	15	70	2,520	5	2,525
	12/29	660	2,030	1,060	0	5,201	20	5,221
	1/5	0	10	35	0	146	0	146
2015	8/31	5,105	0	70	4,500	5,206	4,030	9,236
	9/9	11,820	0	10	11,585	11,857	7,020	18,877
	9/16	7,790	0	100	7,050	7,914	24,715	32,629
	9/21	13,730	0	25	13,240	13,774	34,140	47,914
	10/14	33,210	3,905	30	29,295	37,177	93,785	130,962
	10/22	49,035	6,590	310	45,260	55,986	133,610	189,596
	10/26	30,275	10,085	200	26,910	40,580	129,015	169,595
	11/2	18,890	15,190	35	16,090	34,130	152,470	186,600
	11/9	23,530	8,710	10	20,905	32,364	54,485	86,849
	11/24	7,805	8,345	10	2,230	16,286	6,225	22,511
	12/3	5,570	4,400	175	1,870	10,686	11,010	21,696
	12/8	5,200	6,000	275	2,850	12,377	8,605	20,982

Table 3. Continued.

Year	Day	Dabbling ducks	Diving ducks	Geese	Non-mallard dabbling ducks	Total waterfowl	Total waterbirds	Total birds
2015	12/15	9,360	6,170	480	3,250	16,438	5,010	21,448
	12/22	2,360	4,135	145	2,060	7,405	6,910	14,315
	12/29	465	1,850	235	305	2,603	6,415	9,018
	1/5	985	1,710	740	700	4,197	3,520	7,717
2016	8/31	8,090	0	70	7,835	8,175	8,965	17,140
	9/6	10,485	0	230	10,090	10,730	3,750	14,480
	9/14	24,240	0	210	21,290	24,480	30,295	54,775
	9/20	26,685	0	30	23,765	26,755	30,475	57,230
	10/10	23,810	1,020	70	22,275	24,925	129,695	154,620
	10/18	35,100	2,925	745	33,150	38,800	159,200	198,000
	10/24	40,400	3,380	275	39,390	44,071	59,470	103,541
	11/1	39,585	4,865	540	34,010	44,995	69,070	114,065
	11/7	52,060	9,025	100	42,040	61,190	82,655	143,845
	11/14	57,720	5,645	250	40,575	63,620	51,175	114,795
	11/21	32,670	5,635	275	27,530	38,605	11,690	50,295
	11/29	40,375	4,510	2,250	31,000	47,275	17,540	64,815
	12/7	17,390	2,825	235	9,760	20,675	2,020	22,695
	12/12	14,150	1,030	650	1,700	16,050	3,750	19,800
	12/21	1,185	20	990	55	2,365	5	2,370
	12/27	1,170	1,020	2,145	0	5,130	0	5,130
	1/5	300	0	2,040	0	2,565	10	2,575
2017	9/6	8,395	0	405	7,970	8,870	5,405	14,275
	9/14	6,460	0	745	6,100	7,320	8,190	15,510
	9/21	4,340	0	185	4,085	4,610	17,450	22,060
	9/27	10,655	0	330	9,590	11,075	43,055	54,130
	10/20	46,860	1,805	415	44,435	49,100	74,950	124,050
	10/26	50,400	7,515	1,050	46,200	58,975	85,550	144,525
	10/31	23,800	4,880	320	20,750	29,005	48,135	77,140
	11/10	13,680	3,140	820	8,000	17,700	11,065	28,765
	11/13	32,425	7,410	1,680	22,855	42,215	8,205	50,420
	11/22	5,320	2,770	3,030	2,610	11,440	350	11,790
	11/29	3,845	2,255	770	2,140	7,495	280	7,775
	12/7	8,050	1,160	1,090	1,200	10,925	200	11,125

Table 3. Continued.

Year	Day	Dabbling ducks	Diving ducks	Geese	Non-mallard dabbling ducks	Total waterfowl	Total waterbirds	Total birds
2017	12/14	17,670	5,905	6,805	1,620	32,245	50	32,295
	12/19	11,515	2,260	6,370	1,510	21,980	205	22,185
	12/26	350	1,010	1,400	0	4,267	5	4,272
	1/3	0	0	0	0	0	0	0
2018	9/4	9,005	0	540	8,905	9,570	270	9,840
	9/12	7,470	0	65	7,360	7,565	745	8,310
	9/21	11,360	0	265	11,000	11,640	2,405	14,045
	9/27	13,840	0	335	13,670	14,205	15,335	29,540
	10/12	12,390	600	510	11,260	13,510	25,555	39,065
	10/18	32,450	1,060	1,665	26,225	35,180	49,505	84,685
	10/24	50,930	1,095	1,830	44,450	53,855	46,400	100,255
	11/2	27,935	775	1,730	25,620	30,440	17,655	48,095
	11/9	31,990	3,100	220	22,990	35,315	3,700	39,015
	11/14	21,770	2,605	1,015	15,550	25,870	500	26,370
	11/20	14,105	650	265	5,300	15,460	115	15,575
	11/29	14,805	25	2,600	2,700	17,660	0	17,660
	12/7	15,105	110	10,900	405	27,430	0	27,430
	12/11	5,700	5	1,105	10	6,990	0	6,990
	12/17	13,150	430	5,760	1,410	21,040	5	21,045
	1/3	20,620	300	18,800	1,200	42,630	0	42,630
	1/10	13,120	200	54,350	620	68,965	0	68,965
Total	**N**	3,580,400	477,945	187,215	2,743,750	4,285,587	4,104,395	8,389,982
	%	83.5[a]	11.2[a]	4.4[a]	32.7[a]	51.1[b]	48.9[b]	

[a]Proportion of total waterfowl

[b]Proportion of total birds

Table 4. Abundances of waterfowl and waterbirds observed during spring ground counts at Emiquon Preserve, 2008–2016.

Year	Date	Diving Ducks	Dabbling Ducks	Non-mallard dabbling ducks	Geese	Total Waterbirds	Total Waterfowl	Total Birds
2008	2/19	429	277	157	172	17	1,089	1,106
	2/27	397	112	27	392	13	932	945
	3/10	39,275	21,694	14,605	409	2,214	64,637	66,851
	3/17	21,482	5,762	5,470	26	7,828	27,717	35,545
	3/24	18,442	17,710	17,439	16	14,151	36,168	50,319
	4/4	9,261	7,494	7,205	6	7,614	16,761	24,375
	4/7	4,342	8,660	8,575	11	9,934	13,014	22,948
	4/14	10,107	13,324	13,244	6	20,071	23,437	43,508
2009	2/10	722	9,559	4,472	20,631	7	30,914	30,921
	2/17	9,277	15,665	3,340	25,231	204	50,208	50,412
	3/3	15,420	6,580	2,743	1,070	1,193	23,098	24,291
	3/13	19,179	11,083	10,287	13,186	17,258	43,581	60,839
	3/19	16,945	16,522	15,801	7,682	29,468	41,174	70,642
	3/26	25,530	16,072	15,893	1,545	58,110	43,165	101,275
	4/7	14,017	21,416	21,156	420	30,064	35,863	65,927
	4/14	5,327	15,028	14,942	346	31,318	20,788	52,106
2010	3/3	648	85	10	175	1	922	923
	3/10	3,996	4,225	1,588	13,879	1,180	22,329	23,509
	3/23	27,867	14,078	11,884	57	26,535	42,056	68,591
	4/8	10,187	12,734	12,120	7	19,835	22,932	42,767
	4/20	2,388	6,477	6,276	26	12,191	8,904	21,095
2011	2/18	350	2,214	79	5,145	22	8,204	8,226
	2/24	1,312	5,186	848	39,488	47	46,746	46,793
	3/2	5,407	9,767	3,412	103,074	478	119,095	119,573
	3/11	12,042	10,139	5,734	12,785	5,877	36,985	42,862
	3/16	14,955	5,936	3,987	397	9,658	21,872	31,530
	3/24	19,792	11,765	10,762	196	12,086	31,910	43,996

Table 4. Continued.

Year	Date	Diving Ducks	Dabbling Ducks	Non-mallard dabbling ducks	Geese	Total Waterbirds	Total Waterfowl	Total Birds
2011	3/31	14,288	12,291	11,388	38	11,831	26,718	38,549
	4/7	8,661	8,937	7,918	41	8,454	17,756	26,210
	4/14	2,034	2,315	1,913	44	3,906	4,533	8,439
2012	2/17	2,594	4,939	1,430	2,671	320	16,169	16,489
	2/22	4,352	5,782	1,981	5,621	810	18,956	19,766
	3/1	10,453	11,556	6,150	41,341	4,391	65,803	70,194
	3/9	15,795	19,126	15,037	71,031	15,624	106,058	121,682
	3/15	8,927	28,456	24,905	9,390	19,564	46,880	66,444
	3/23	10,282	17,008	15,126	412	28,741	27,733	56,474
	3/29	6,425	9,551	7,124	143	21,119	16,129	37,248
	4/3	2,909	9,166	8,083	117	19,885	12,218	32,103
	4/11	1,445	5,966	4,649	71	17,491	7,495	24,986
	4/19	559	2,119	1,788	62	8,683	2,758	11,441
2013	2/13	2,621	7,961	1,779	68,297	72	80,785	80,857
	2/22	61	284	167	238	33	765	798
	2/28	443	1,189	385	693	84	2,518	2,602
	3/7	2,221	10,131	4,276	5,813	463	19,942	20,405
	3/15	7,721	10,807	6,411	11,411	3,049	30,525	33,574
	3/21	8,065	11,089	8,455	6,093	1,801	26,643	28,444
	3/27	9,834	28,359	21,530	5,228	7,029	44,207	51,236
	4/3	6,667	10,324	8,858	107	7,887	17,272	25,159
	4/11	5,525	11,765	11,026	86	8,763	17,393	26,156
	4/17	4,698	12,305	11,674	216	10,838	17,243	28,081
2014	2/18	0	0	0	45	5	64	69
	2/24	0	0	0	0	6	0	6
	3/7	288	315	0	13,695	16	14,670	14,686
	3/13	6,443	459	236	6,372	1,267	14,106	15,373
	3/20	22,050	9,284	7,445	50,425	11,600	83,422	95,022

Table 4. Continued.

Year	Date	Diving Ducks	Dabbling Ducks	Non-mallard dabbling ducks	Geese	Total Waterbirds	Total Waterfowl	Total Birds
2014	3/28	14,089	16,501	9,534	720	31,521	31,884	63,405
	4/5	18,877	23,991	20,322	133	32,780	43,019	75,799
	4/10	8,155	7,725	6,240	362	26,565	16,256	42,821
	4/17	1,569	1,254	1,084	142	13,122	2,969	16,091
2015	2/13	348	26	0	20,525	10	21,549	21,559
	2/20	630	11	11	4,358	39	5,627	5,666
	2/27	602	30	15	3,815	12	5,070	5,082
	3/4	560	24	24	3,945	106	4,856	4,962
	3/13	5,437	2,159	1,695	82,773	1,374	90,852	92,226
	3/20	7,881	7,111	3,645	4,065	5,512	19,076	24,588
	3/27	11,291	15,228	11,405	2,369	14,198	28,902	43,100
	4/1	16,924	27,727	27,069	1,050	49,865	45,712	95,577
	4/10	8,198	15,695	15,245	541	39,968	24,442	64,410
	4/16	2,901	7,541	7,488	96	15,450	10,555	26,005
	4/23	669	4,196	4,155	55	13,413	4,931	18,344
2016	2/17	887	1,333	161	39,882	34	43,674	43,708
	2/26	3,730	2,798	1,752	7,176	2,612	16,255	18,867
	3/2	17,829	11,439	8,612	22,678	9,082	53,841	62,923
	3/11	27,701	23,691	23,229	569	63,694	52,062	115,756
	3/18	31,434	40,426	36,944	287	59,622	72,174	131,796
	3/23	13,985	14,826	14,497	285	47,118	29,096	76,214
	4/1	3,761	7,922	7,834	137	43,082	11,841	54,923
	4/7	6,362	5,502	5,462	87	20,679	11,974	32,653
	4/15	3,172	4,427	4,175	110	21,685	7,743	29,428
	4/21	2,881	5,926	5,826	137	23,812	8,982	32,794
Total	**N**	684,330	768,557	618,214	742,376	1,066,461	2,236,604	3,303,065
	%	20.7[a]	23.3[a]	18.7[a]	22.5[a]	32.3[b]	67.7[b]	

[a]Proportion of total waterfowl

[b]Proportion of total birds

Table 5. Abundances of waterfowl and waterbirds observed during spring aerial inventories at Emiquon Preserve, 2017–2019.

Year	Date	Diving Ducks	Dabbling Ducks	Non-mallard dabbling ducks	Geese	Total Waterbirds	Total Waterfowl	Total Birds
2017	2/14	3,970	2,500	1,750	5,435	600	17,165	17,765
	2/21	15,160	37,305	27,800	58,020	12,150	111,170	123,320
	3/3	2,450	5,470	4,470	4,210	34,400	12,210	46,610
	3/9	6,945	13,680	12,630	360	42,740	21,050	63,790
	3/16	8,625	9,405	8,905	1,285	54,610	19,630	74,240
	3/28	5,970	9,855	9,405	440	49,490	16,315	65,805
	4/16	1,630	1,045	1,005	55	8,970	2,760	11,730
2018	2/26	2,830	1,975	870	4,830	2,835	12,455	15,290
	3/8	855	3,865	3,515	19,240	7,415	24,010	31,425
	3/15	5,880	9,065	7,965	475	26,850	15,565	42,415
	3/22	7,170	7,000	6,700	1,510	41,700	15,815	57,515
	3/28	4,080	6,330	6,130	800	41,225	11,260	52,485
	4/10	2,770	3,100	3,000	120	15,940	5,995	21,935
	4/17	295	570	510	680	3,880	1,565	5,445
	4/26	290	1,015	960	115	3,090	1,515	4,605
2019	2/27	3,600	10,300	3,200	105,700	50	121,125	121,175
	3/4	2,755	100	0	141,100	0	144,080	144,080
	3/11	1,100	5,905	805	276,910	675	284,990	285,665
	3/18	24,215	26,265	23,690	29,085	3,800	83,060	86,860
	3/26	1,210	22,465	21,465	1,425	3,665	25,360	29,025
	4/8	670	9,685	9,610	430	4,895	10,900	15,795
Total	**N**	176,415	314,845	262,120	1,236,426	628,070	1,754,396	2,382,465
	%	10.1[a]	17.9[a]	14.9[a]	70.5[a]	26.4[b]	73.6[b]	

[a]Proportion of total waterfowl

[b]Proportion of total birds

Table 6. Duck nest survival estimates (95% CI) derived from chain-dragged grassland tracts at The Emiquon Preserve, 2017–2019.

	2017				2018				2019			
Tract	*n*	ŝ	LCL	UCL	*n*	ŝ	LCL	UCL	*n*	ŝ	LCL	UCL
Butt	4	0.0020	0.6842	0.9824	2	0.0027	0.6368	1.0432	4	0.1670	0.8795	1.0179
Prairie 1	3	0.0007	0.6098	1.0031	2	0.0064	0.6846	1.0396	1	0.0658	0.7782	1.0679
Prairie 2	42	0.0643	0.8978	0.9471	7	0.0034	0.7329	0.9594	29	0.0397	0.8742	0.9447
Prairie 3	5	0.1167	0.8716	1.0059	4	0.4111	0.9389	1.0095	1	0.0391	0.7392	1.0790
South Levee	3	0.0046	0.7007	1.0067	1	1.0000	1.0000	1.0000	7	0.0056	0.7615	0.9557
West Prairie	13	0.1051	0.8975	0.9743	11	0.2816	0.9347	0.9921	5	0.0120	0.7779	0.9782
Total	70	0.0567	0.8991	0.9390	27	0.1410	0.9189	0.9691	47	0.0327	0.8757	0.9329

Table 7. Waterbird nest density and abundance estimates from random plot searches in hemi-marsh and dense persistent emergent vegetation communities at the Emiquon preserve, 2013–2018.

	2013		2014		2015		2016		2017		2018		Average			
Vegetation Community/Species	Nest Density	Nest Abundance	Nest Density	Nest Abundance	Nest Density	Nest Abundance	Nest Density	Nest Abundance	Nest Density	Nest Abundance	Nest Density	Nest Abundance	Nest Density	SE	Nest Abundance	SE
Hemi-marsh																
AMCO	0.42	33.69	0.41	55.17	0.00	0.00	0.36	104.44	0.41	87.78	0.00	0.00	0.27	0.08	46.84	17.91
COGA	0.00	0.00	0.00	0.00	0.19	34.32	0.44	127.64	0.81	175.56	1.13	105.71	0.43	0.19	73.87	29.85
LEBI	0.00	0.00	0.31	41.38	0.10	17.16	0.58	168.26	0.31	65.83	0.57	52.85	0.31	0.10	57.58	24.19
BNST	0.00	0.00	0.00	0.00	0.00	0.00	0.07	19.97	0.00	0.00	0.00	0.00	0.01	–	3.33	–
MALL	0.00	0.00	0.00	0.00	0.00	0.00	0.07	19.97	0.20	43.89	0.00	0.00	0.05	0.03	10.64	7.41
SORA	0.00	0.00	0.31	41.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	–	6.90	–
UNKN	0.00	0.00	0.51	68.96	0.10	17.16	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.08	14.35	11.27
Total	0.42	33.69	1.53	206.88	0.38	68.65	1.52	440.27	1.73	373.06	1.70	158.56	1.21	0.26	213.52	66.65
Persistent Emergent																
AMCO	0.31	84.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	–	14.07	–
COGA	0.00	0.00	0.13	37.47	0.15	44.59	1.27	109.60	0.42	31.16	0.07	16.29	0.34	0.19	39.85	15.40
LEBI	0.10	28.13	0.51	149.89	0.75	222.97	2.55	220.07	0.42	31.16	0.07	16.29	0.73	0.38	111.42	40.06
BCNH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	16.29	0.01	–	2.71	–
SORA	0.31	84.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	–	14.07	–
UNKN	0.00	0.00	0.38	112.41	0.30	89.19	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.07	33.60	21.46
Total	0.71	196.93	1.02	299.77	1.20	356.75	3.82	329.67	0.85	62.31	0.22	48.87	1.30	0.52	215.72	55.28
Overall	0.65	230.62	1.18	506.65	0.89	425.40	2.05	769.94	1.51	435.37	0.67	207.43	1.16	0.22	429.23	83.82

Table 8. Abundance (mg/m^3, dry mass) and percent occurrence of aquatic invertebrates collected at The Emiquon Preserve, 2008–2015.

Taxa	2008[a]		2009[a]		2010[a]		2011[a]		2012[a]		2013[b]		2014[b]		2015[b]	
	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%
Acari									0.2	53.3	0.1	40	0.3	56.4	0.7	70.0
Aeshnidae					18.9	5.0	0.1	1.7	0.0	6.7	17.1	12.5				
Amphipoda	1.1	35.0	1.2	56.7	1.6	55.0	0.5	40.0	2.8	73.3	2.0	65	5.1	79.5	3.5	70.0
Aphididae									0.4	35.0	0.2	25	0.9	35.9	0.0	22.5
Arachnida					0.0	23.3	0.0	1.7	0.0	1.7	0.3	7.5				
Araneae											0.2	30	0.2	25.6	0.0	17.5
Baetidae larvae			0.5	15.0	0.8	35.0	0.0	3.3	0.4	43.3	0.3	27.5	0.3	30.8	0.4	37.5
Baetidae nymph	0.8	18.3	0.2	8.3	0.3	6.7										
Belostomatidae					2.0	5.0							0.2	2.6	0.4	5.0
Braconidae															0.0	2.5
Bryozoa													2.2	17.9		
Caenidae adult	0.7	61.7	0.0	1.7	6.7	56.7	2.4	63.3	7.8	86.7	1.8	65	1.1	71.8	3.0	95.0
Caenidae larvae			0.6	45.0												
Caenidae nymph			0.1	20.0	0.8	8.3										
Ceratopogonidae larvae	0.7	33.3	0.0	23.3	0.7	46.7	0.4	46.7	0.1	45.0	0.4	52.5	1.2	74.4	0.1	32.5
Ceratopogonidae pupae			0.0	6.7	0.0	16.7										
Chaoboridae									0.0	1.7			0.0	5.1		
Chironomidae adult	0.3	6.7	0.0	18.3	0.3	6.7	2.4	70.0	1.2	78.3	1.7	95	1.7	100.0	1.9	97.5
Chironomidae larvae	6.1	81.7	6.6	90.0	6.9	65.0										
Chironomidae pupae	0.0	11.7	0.9	18.3	0.3	16.7										
Chrysomelidae larvae			0.0	3.3												
Cladocera	6.3	86.7	1.9	95.0	7.4	90.0	1.0	95.0	0.5	96.7	0.5	100	0.4	92.3	1.7	80.0
Coenagrionidae larvae			1.0	35.0	3.7	60.0	1.7	55.0	4.7	71.7	4.0	85	1.6	76.9	0.7	52.5
Coenagrionidae nymph	0.5	36.7	0.8	16.7	0.1	6.7										
Collembola					0.0	3.3	0.0	11.7	0.1	13.3	0.1	72.5	0.1	35.9		
Copepoda	0.8	91.7	0.5	80.0	0.2	61.7	0.3	73.3	0.2	70.0	0.7	100	0.5	89.7	1.4	72.5
Corduliidae													0.0	2.6		
Corixidae	0.7	26.7	4.2	60.0	4.8	31.7	0.4	16.7	0.7	20.0	0.1	10	0.0	5.1	0.0	2.5
Corydalidae															0.5	2.5

Table 8. Continued.

Taxa	2008[a]		2009[a]		2010[a]		2011[a]		2012[a]		2013[b]		2014[b]		2015[b]	
	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%
Culicidae Larvae	0.0	5.0			0.0	8.3	0.0	6.7	0.1	21.7	0.2	42.5	0.1	17.9	0.1	27.5
Curculionidae adult			0.0	1.7							0.0	5	0.6	28.2		
Diptera											0.0	5				
Dolichopodidae											0.0	17.5				
Dytiscidae adult	0.2	8.3	0.1	20.0	2.8	5.0	0.1	48.3	0.1	38.3	2.5	52.5	0.4	41.0	0.0	10.0
Dytiscidae larvae	0.5	25.0	0.0	23.3	0.4	31.7										
Elmidae adult			0.0	1.7	0.0	1.7			0.0	1.7	0.0	7.5	0.2	12.8	0.1	10.0
Empididae									0.0	1.7	0.0	2.5				
Ephemeridae													0.0	2.6		
Ephydridae pupae			0.0	1.7	0.0	1.7			0.0	1.7	0.0	5			0.1	2.5
Formicide											0.0	5				
Gerridae							0.0	1.7	0.0	3.3			0.0	2.6		
Glossiphonidae	0.5	20.0			0.1	6.7	0.2	6.7	0.3	13.3	0.3	12.5	0.3	12.8	0.7	45.0
Gomphidae									0.0	1.7					0.0	2.5
Haliplidae adult	0.6	5.0	0.7	10.0	0.0	3.3	0.0	3.3	0.0	6.7	0.9	25	0.3	7.7	0.1	12.5
Haliplidae larvae	0.7	26.7	0.4	16.7	0.3	18.3										
Haliplidae nymph			0.0	1.7												
Hebridae			0.0	1.7					0.0	3.3	0.0	15				
Heteroceridae adult					0.0	1.7					0.1	5				
Hirudinea			0.5	23.3	2.0	5.0										
Homoptera							0.2	13.3								
Hydra	0.1	26.7	0.2	41.7	0.0	18.3	0.2	46.7	0.2	60.0	0.4	75	0.2	56.4	0.2	62.5
Hydrachnida	0.2	45.0	0.2	58.3	0.1	35.0	0.2	56.7								
Hydrophilidae adult	1.5	3.3	0.1	8.3	0.1	1.7	0.9	16.7	0.7	20.0	10.0	47.5	0.2	23.1	0.1	7.5
Hydrophilidae larvae	0.6	16.7	0.4	20.0	0.0	11.7										
Hydroptilidae larvae			0.0	1.7	0.0	10.0					0.0	5	0.0	2.6	0.0	5.0
Hydroptilidae pupae					0.0	1.7										
Hydroscaphidae adult			0.0	1.7												
Hymenoptera							0.0	3.3	0.0	8.3						

Table 8. Continued.

Taxa	2008[a]		2009[a]		2010[a]		2011[a]		2012[a]		2013[b]		2014[b]		2015[b]	
	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%
Isopoda	0.0	1.7														
Lepidoptera											0.0	2.5				
Leptoceridae larvae	0.1	11.7	0.1	6.7	0.2	13.3	0.1	11.7	0.4	20.0	0.0	10	0.0	5.1	0.1	7.5
Leptoceridae pupae					0.0	1.7										
Leptophlebiidae															0.0	2.5
Libellulidae larvae	0.8	1.7	0.1	6.7	8.9	33.3	0.9	30.0	7.5	26.7	4.7	75	2.0	61.5	1.6	57.5
Libellulidae Nymph	0.2	8.3														
Lymnaeidae	4.6	31.7	0.3	11.7			0.0	1.7			0.5	5			0.0	2.5
Mesoveliidae	0.1	13.3	0.0	30.0	0.7	20.0	0.1	35.0	0.1	23.3	0.1	5	0.1	30.8	0.2	35.0
Muscidae									0.0	1.7						
Naucoridae									0.2	1.7						
Noteridae adult					0.0	1.7										
Nematoda			0.0	11.7	0.0	5.0	0.0	8.3	0.0	16.7	0.1	57.5	0.0	46.2	1.7	17.5
Noteridae adult					0.6	1.7					0.1	15	0.7	23.1	0.0	15.0
Notonectidae			0.0	1.7	0.4	3.3			0.3	3.3	0.3	5	0.3	2.6	0.1	2.5
Oligochaeta	2.6	60.0	4.5	96.7	0.3	56.7	1.6	65.0	1.3	81.7	9.2	100	7.2	100.0	2.3	97.5
Ostracoda			0.0	6.7	0.0	13.3	0.0	5.0	0.0	16.7	0.0	12.5	0.1	43.6	0.0	2.5
Physidae	72.0	61.7	72.3	81.7	6.7	61.7	27.9	60.0	8.1	48.3	57.4	100	4.9	51.3	9.6	42.5
Planaria											0.0	5				
Planariidae									0.2	18.3						
Planorbidae	20.4	46.7	55.3	38.3	4.7	21.7	21.9	50.0	1.0	35.0	37.6	77.5	14.6	61.5	9.1	22.5
Platyhelminthes	0.4	20.0														
Pleidae			0.0	3.3	0.4	40.0	0.3	40.0	0.1	23.3	0.6	40	0.7	48.7	1.0	60.0
Pseudoscorpion					0.0	1.7										
Psychodidae											0.0	2.5	0.0	2.6		
Ptiliidae													0.0	2.6		
Pyralidae larvae					0.3	20.0	1.5	28.3	0.4	23.3	0.2	30	0.6	35.9	0.6	20.0
Pyralidae pupae					0.3	5.0										
Rotifer											0.1	35	0.0	25.6	0.0	5.0

Table 8. Continued.

Taxa	2008[a]		2009[a]		2010[a]		2011[a]		2012[a]		2013[b]		2014[b]		2015[b]	
	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%	mg/m^3	%
Saldidae							0.1	10.0								
Scelionidae			0.0	1.7	0.0	1.7										
Sciomyzidae larvae			0.0	1.7			0.0	1.7			0.0	2.5	0.0	5.1		
Scirtidae													0.0	2.6		
Sphaeriidae									0.0	1.7	0.0	2.5	0.5	7.7	0.0	2.5
Stratiomyidae larvae	1.2	30.0	1.5	15.0	0.4	21.7	1.6	26.7	0.0	5.0	2.3	30	0.2	30.8	0.2	20.0
Tabanidae									0.0	1.7						
Tetragnathidae											0.7	10			2.2	27.5
Thysanoptera									0.0	10.0						
Tipulidae											0.0	2.5	0.1	7.7		
Trichoptera											0.0	2.5				
Turbellaria			0.1	16.7	0.5	20.0	0.0	8.3			0.0	20			0.0	12.5
Unknown					0.0	1.7							0.3	51.3	0.0	2.5
Unknown Coleoptera			0.0	1.7					0.0	1.7						
Unknown Diptera			0.1	5.0	0.0	1.7	0.0	3.3	0.0	5.0						
Unknown Hemiptera					0.0	1.7			0.0	3.3						
Unknown Tricoptera					0.0	3.3										
Valvatidae															10.2	2.5
Veliidae									0.1	5.0	0.0	17.5	0.0	30.8	0.2	37.5
Viviparidae											0.0	2.5				

[a] Includes invertebrates collected in all 3 sampling periods (April, June, August).
[b] Invertebrates collected in August samples only.

Table 9. Abundance (mg/m^3, dry mass) and percent occurrence of plants and seeds emigrating from The Emiquon Preserve through the water-control structure, July–November, 2016 and August–October, 2017.

Taxa	Biomass (mg/m3)[a]		Percent Occurrence	
	2016	2017	2016	2017
Seeds				
Ambrosia spp.	0.00	<0.01	0.0	4.5
Carex lupulina	0.00	<0.01	0.0	4.5
Ceratophyllum demersum	0.00	0.01	0.0	4.5
Chenopodium spp.	0.00	<0.01	0.0	4.5
Echinochloa spp.	0.00	<0.01	0.0	4.5
Echinochloa walteri	<0.01	0.00	5.9	0.0
Eupatorium spp.	0.00	<0.01	0.0	4.5
Ludwigia peploides	<0.01	0.01	11.8	36.4
Medicago spp.	0.00	<0.01	0.0	4.5
Morus spp.	0.00	<0.01	0.0	9.1
Najas flexilis	<0.01	0.00	5.9	0.0
Najas guadalupensis	0.00	<0.01	0.0	4.5
Najas minor	0.03	<0.01	11.8	4.5
Panicum spp.	0.00	<0.01	0.0	4.5
Poa spp.	0.00	<0.01	0.0	4.5
Polygonum lapathafolium	<0.01	0.00	5.9	0.0
Polygonum spp.	<0.01	0.00	11.8	0.0
Potamogeton nodosus	0.02	0.00	11.8	0.0
Potamogeton pusillus	0.06	0.00	5.9	0.0
Potamogeton spp.	0.05	0.20	41.2	59.1
Portulaca oleracea	<0.01	<0.01	5.9	4.5
Rumex crispus	<0.01	<0.01	5.9	13.6
Setaria	0.02	0.03	41.2	63.6
Trifolium spp.	0.00	<0.01	0.0	9.1
Zanichellia palustris	0.00	<0.01	0.0	4.5
Total Seeds	0.22	0.25		
Plants				
Ceratophyllum demersum	0.45	6.83	47.1	95.5
Ludwigia peploides	0.00	0.03	0.0	4.5
Myriophyllum spicatum	4.07	0.06	76.5	50.0
Najas flexilis	0.76	0.00	41.2	0.0
Najas guadalupensis	0.01	0.05	29.4	63.6
Najas minor	3.37	0.04	70.6	50.0
Potamogeton pusillus	1.91	0.25	29.4	18.2
Stuckenia pectinata	0.00	0.04	0.0	4.5
Zanichellia palustris	0.00	<0.01	0.0	9.1
Total Plants	10.79	7.28		

Table 10. Soil and water characteristics at random locations within Thompson and Flag lakes to assess the effects of drawdown at The Emiquon Preserve during falls, 2016–2018.

		Water Depth[a]			Water Transparency[a]			Soil Compaction[a]			POM[b]			Bulk Density[c]		
Location	Community	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
Thompson	Moist-soil	3.0	0.0	0.0	3.0	N/A	N/A	10.0	2.0	1.0	5.0	11.4	4.5	0.8	0.6	1.0
Flag	Aquatic Bed	216.0	113.0	62.0	65.0	70.0	22.0	14.5	9.0	18.0	7.3	6.0	6.6	0.9	0.7	0.7
Flag	Floating-leaved	145.0	53.0	4.0	145.0	28.0	4.0	1.5	2.0	1.5	6.8	4.0	6.0	0.9	0.9	1.0
Thompson	Open Water	135.0	220.0	161.0	40.0	38.0	35.0	2.5	6.0	14.5	4.6	5.7	6.4	1.0	0.7	0.6
Thompson	Aquatic Bed	111.0	15.0	0.0	111.0	15.0	N/A	16.0	9.0	14.0	7.0	6.0	7.1	0.7	0.8	0.5
Flag	Mudflat	38.0	0.0	0.0	38.0	N/A	N/A	3.5	1.5	0.7	6.4	7.1	6.1	0.8	0.8	1.1
Flag	Aquatic Bed	188.0	81.0	34.0	81.0	70.0	15.0	8.0	7.0	10.0	5.2	5.5	6.1	1.3	1.0	0.7
Flag	Aquatic Bed	168.0	71.0	24.0	86.0	71.0	24.0	8.0	6.0	14.0	6.8	5.1	7.0	0.8	1.0	0.6
Thompson	Aquatic Bed	113.0	11.0	0.0	86.0	11.0	N/A	17.0	13.5	0.2	4.1	3.4	2.8	1.3	1.1	1.1
Flag	Hemi-marsh	106.0	15.0	0.0	106.0	15.0	N/A	8.5	13.0	0.3	6.8	5.6	5.4	1.1	0.7	1.3
Flag	Moist-soil	0.0	0.0	0.0	N/A	N/A	N/A	1.0	0.5	2.0	5.6	4.4	6.1	1.1	1.2	1.0
Flag	Persistent Emergent	52.0	0.0	0.0	43.0	N/A	N/A	6.0	1.0	1.7	5.0	7.3	6.0	0.9	0.7	1.0
Flag	Aquatic Bed	137.0	42.0	0.0	113.0	42.0	N/A	7.0	2.0	1.5	5.9	4.3	4.8	1.3	1.2	1.0
Thompson	Aquatic Bed	225.0	119.0	72.0	115.0	85.0	27.0	15.0	10.0	9.0	5.2	4.9	4.8	1.1	1.3	1.4
Thompson	Floating-leaved	86.0	23.0	0.0	86.0	23.0	N/A	5.5	5.0	2.0	4.3	4.0	3.0	1.2	0.9	1.0
	$\bar{x}$	123.1	50.9	23.8	79.9	42.5	21.2	8.3	5.8	6.0	5.7	5.6	5.5	1.0	0.9	0.9
	SE	17.3	16.0	11.6	10.3	8.1	4.3	1.4	1.1	1.7	0.3	0.5	0.3	0.1	0.1	0.1

Table 11. Area (ha) of vegetation communities at The Emiquon Preserve during fall, 2007−2018.

Community	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	$\bar{x}$	SE
Aquatic Bed	3.1	240.8	1,191.6	1,037.3	1,076.1	848.5	1,091.9	1,054.8	1,024.3	1,034.9	898.8	231.8	811.2	117.5
Bottomland Forest	0.0	0.2	0.8	1.0	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1
Ditch	18.7	15.4	12.2	14.0	11.6	13.6	11.5	0.0	0.0	0.0	0.0	0.0	8.1	2.1
Hemi-marsh	29.9	220.5	290.4	119.8	109.3	80.7	135.4	178.6	290.1	215.4	93.4	5.4	147.4	26.9
Mudflat	3.4	0.0	0.0	83.2	11.8	93.4	0.0	0.0	0.0	0.0	172.7	2.4	30.6	16.1
Non-persistent Emergent	50.7	127.3	23.6	217.7	61.5	174.4	101.3	33.7	21.1	33.3	37.1	867.9	145.8	68.2
Open Water	106.4	275.1	222.2	248.7	323.5	292.4	298.2	332.9	505.9	572.1	464.5	542.7	348.7	41.0
Persistent Emergent	32.9	33.3	44.2	199.0	223.3	276.2	294.3	297.7	86.3	73.4	217.5	181.2	163.3	29.9
Scrub-Shrub	7.0	2.1	1.8	0.3	2.3	2.7	10.9	11.3	6.1	3.8	2.3	9.1	5.0	1.1
Upland	2.6	14.7	1.1	53.1	0.2	0.2	0.0	0.0	0.0	1.3	4.1	9.1	7.2	4.4
Upland-wet	0.0	147.9	16.1	0.0	0.0	0.0	0.1	0.0	36.4	1.9	0.0	0.0	16.9	12.3
Total Area	254.7	1,077.2	1,804.0	1,974.1	1,820.6	1,782.3	1,943.6	1,944.2	2,017.0	2,021.7	2,010.7	1,938.4	1,715.7	152.2

Appendix A. Conservation targets and Key Ecological Attributes (KEAs) of The Nature Conservancy at The Emiquon Preserve during 2007−2019 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	2018	2019
Waterbird Habitat Quality	Fall Duck Use Days (Dabblers & Divers)	IRV ranking 1–5 (>2,000 UD/ha)	IRV ranking 5–10 (1,500–2,000 UD/ha)	IRV ranking <10 (<1,500 UD/ha)	4,834	2,104	1,857	1,931	2,323	1,893	1,780	933	1,271	1,753	1,147	1,248	–
	Relative Fall Duck Use Days (Dabblers & Divers)	>Top 5 IRV Lakes Average UD/ha	–	<Top 5 IRV Lakes Average UD/ha	151%	45%	17%	74%	45%	-10%	-38%	-50%	-18%	-8%	-54%	-49%	–
	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	1,197	–
	Fall Non-Mallard 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	738	–
	Relative Fall Non-Mallard Dabbling Duck Use Days	>Top 5 IRV Lakes Average UD/ha	–	<Top 5 IRV Lakes Average UD/ha	250%	132%	105%	108%	88%	45%	-25%	-37%	-2%	8%	-37%	-11%	–
	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	640	–
	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	51	–
	Relative Fall Diving Duck Use Days	>Top 5 IRV Lakes Average UD/ha	–	<Top 5 IRV Lakes Average UD/ha	-80%	115%	32%	36%	27%	-43%	-51%	7%	-17%	-49%	-64%	-87%	–
	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	208	–
	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	630	–
	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	120	158
	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	129	387
	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	544	70
	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	634	1,115	465	814	1,544	2,032	–
	Moist-soil ECC	>1 million DEDs	500K−1 million DEDs	<500K DEDs	373,159	467,741	41,138	1,016,633	509,246	676,445	476,333	278,882	72,808	201,119	424,940	13,084,200	–
	Total ECC	>3.5 million DEDs	1.7–3.5 million DEDs	<1.7 million DEDs	–	–	–	–	–	–	34 million	27 million	30 million	–	–	–	–
Waterbird Production	Waterbird Brood Density	>17 broods/km2 peak	15–17 broods/km2 peak	<15 broods/km2 peak	–	22	24	28	25	29	19	6	10	56	66	25	–
	Waterbird (Non-waterfowl) Brood Species Richness	>5 species	3–5 species	<3 species	–	3	2	1	3	3	3	3	4	1	2	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	0.5	–
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	5	0.3	–
	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]	95%	96%	94%	98%	80%	87%	–
Community Composition (Moist-soil Vegetation)	Native Versus Exotic Species	<10% cumulative composition of exotics	–	>10% cumulative composition of exotics	<10%[a]	<10%[a]	<10%[a]	<10%[a]	<10%[a]	<10%[a]	0.4%	0.8%	0.7%	0.0%	0.7%	2.8%	–
	Non-woody Invasives	<50% goldenrod, cocklebur, etc.	–	>50% goldenrod, cocklebur, etc.	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]	16%	16%	36%	29%	18%	5%	–
	Woody Encroachment	<25% coverage of woody invasives	–	>25% coverage of woody invasives	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]	0%	0.3	0%	0%	0%	3%	–
	Forb and Grass Coverage	Forbs ≥10% coverage	–	Forbs <10% coverage	–	–	–	–	–	–	19	19	38	53	43	38	–

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

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