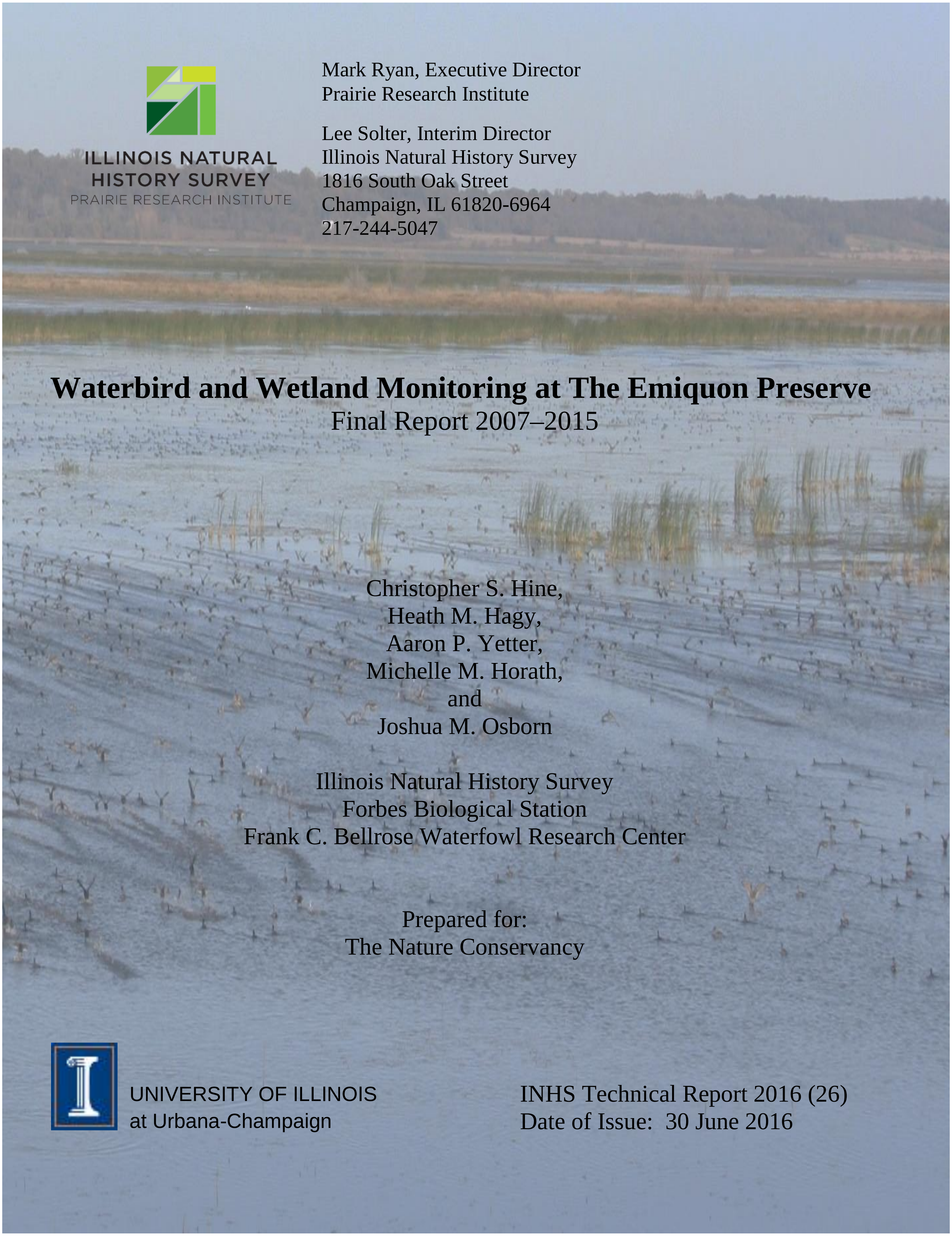

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Waterbird and Wetland Monitoring at The Emiquon Preserve

Final Report 2007–2015

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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 800% since 2007, expanding from 255 ha to 2017 ha in autumn 2015. Aquatic bed vegetation has comprised >50% of Emiquon Preserve since 2009, but important emergent plant communities have declined in recent years as the complex has reached the lake marsh stage due to elevated and stabilized water levels. Waterfowl and other waterbirds visit Emiquon Preserve in great numbers each autumn 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 at Emiquon Preserve, dabbling and diving ducks behaviors are 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 and pied bill grebe, as well as several species of ducks, geese, and other waterbirds. 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 autumn migration, and invertebrate abundance during brood-rearing periods which we assume is related to the transition of Emiquon Preserve into the lake marsh stage. While we acknowledge that different succession phases benefit different guilds of wildlife, we suggest that a drawdown will be necessary to restore some of the emergent vegetation communities and with it 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. For example, 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 autumn 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. Of these, The Nature Conservancy's

Emiquon Preserve (hereafter, Emiquon) is the most substantial effort to date, 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). Indeed, use of wetlands by waterbirds may serve as an indicator of landscape condition or a measure of restoration success (Austin et al. 2001, Gawlik 2006). Therefore, we monitored the response of wetland vegetation and waterbirds to restoration efforts at Emiquon during 2007–2015 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 through brood counts; 3) plant seed and invertebrate biomass to understand energetic carrying capacity for waterfowl during autumn migration and breeding periods; and 4) composition and arrangement of wetland vegetation communities through geospatial cover mapping. 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 waterfowl, other waterbirds, and other common species encountered incidentally by species (Table 1) during primary autumn (early September, mid-October–early January) and spring (mid-February– mid-April) migration periods (Havera 1999). Total counts were conducted aerially during autumn migration in cooperation with the Illinois Natural History Survey's long-term aerial inventories and by ground counts during spring. During ground surveys, birds were counted from fixed, elevated vantage points and during travel between points and effort was made to not double-count individuals. 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 spring counts during 2009 and 2010 which were 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., autumn 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 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. We also calculated UD/ha for nearby Chautauqua National Wildlife Refuge (CNWR) for the period of 1991−2008 as a means to compare waterfowl use at Emiquon to another local wetland of importance that was considered to provide high-quality habitat in most of those years for migrating waterbirds (Havera 1999). During this period, duck use ranged from 133−9,925 UD/ha and averaged 2,632 UD/ha at CNWR.

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 migration (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 (2008–2015; 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).

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 belowground 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 autumn 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 2013–2015 (Stafford et al. 2006, Kross et al. 2008, Stafford et al. 2011). We froze samples in individually labeled bags until processing. Prior to sorting, we thawed core samples at room temperature and soaked them in a 3% solution of hydrogen peroxide (H_2O_2) to dissolve clays (Bohm 1979:117, Kross et al. 2008). We washed samples with water through a #60 (250 μm) sieve and dried for 24 hours at approximately 87°C (Greer et al. 2007, Stafford et al. 2011). We then threshed dried materials over a series of 4−5 sieves (mesh sizes 14 [1.40 mm], 18 [1.00 mm], 35 [500 μm], 45 [355 μm], and 60 [250 μm]) to further separate seeds from debris (Greer et al. 2007). We classified seeds as large if they were retained by the 14, 18 or 35 sieve (e.g., barnyardgrass, smartweed) and small if they remained in the 45 or 60 sieves (e.g., nutgrass, pigweed). We separated all large seeds from debris by hand and weighed to the nearest 0.1 mg. Due to the extensive processing time, we sub-sampled a portion (≥2.5% by mass) of some small seed samples and 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) using PROC MEANS in SAS v9.2 (SAS Institute, Inc., Cary, NC).

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 autumn, 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.

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 autumn 2007–2015. 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 9.3–10.3 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 2013–2015 (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 135 aerial surveys in autumns 2007–2015 (Table 3). The most abundant species encountered were mallards (19%), gadwall (16%), northern pintail (15%) and American green-winged teal (14%). We conducted 79 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%).

Autumn dabbling duck UDs at Emiquon ranged from 1,405,890 in 2007 to 3,965,248 in 2011 and averaged 2,608,787 during 2007–2015 (Fig. 2). 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 2,089,139 during autumn (Fig. 2). Emiquon supported 16–51% ($\bar{x}$ = 28%) of the non-mallard dabbling duck use in the IRV. Autumn 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 autumn 2009. Diving ducks averaged 350,393 UDs at Emiquon, or 23% of the diving duck UDs in the IRV (Fig. 2). Lastly, total ducks averaged 2,967,624 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. 2), despite accounting for an average of only 5.6% of the surveyed wetland area.

Autumn dabbling duck densities at Emiquon ranged from 739 UDs/ha in 2014 to 4,813 UDs/ha in 2007 ($\bar{x}$ = 1,911 UDs/ha, highest in the IRV) during 2007–2015, representing the highest densities in the IRV during 2007, 2010, and 2011, but represented the 8th highest densities in 2013 and 2014. Non-mallard dabbling duck densities averaged 1,509 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 to 6th highest in 2014. Diving duck densities ranged from 21 UDs/ha in 2007 to 438 UDs/ha in 2009 and averaged 188 UDs/ha (2nd in the IRV) during 2007–2015. Finally, total duck density at Emiquon averaged 2,103 UDs/ha (highest in IRV) and ranged from 933 UDs/ha in 2014 to 4834 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 ranged from 453,127 in 2014 to 896,718 in 2009 and averaged 618,211 during 2008–2016 (Fig. 3). 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. 3). 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 3).

Finally, total ducks use peaked in spring 2009 at 1,847,752 UDs and declined to a low of 930,267 UDs in 2015. Across all years, total duck use in spring at Emiquon averaged 1,241,563 UDs (Fig. 3).

Non-Waterfowl Abundance

American coots used Emiquon more than any other species during autumn migration. Use by American coots ranged from 580,668–5,609,688 UDs and averaged 3,076,067 UDs annually. Incredibly, Emiquon hosted nearly all of the coots (93%) using the IRV in 2008 and averaged 67% of the coot use during autumn 2007–2015 (Fig. 4). American white pelicans did not begin using Emiquon during autumn until 2009. With the exception of 2011, pelican use rapidly increased during autumn to a peak of more than 82,000 UDs in 2012 but dropped off to only 16,855 UDs in 2014 (Fig. 5). Double-crested cormorants began using Emiquon in autumn 2008, and like pelicans, their numbers grew steadily. Cormorant use increased from 615 UDs in 2008 to 24,523 UDs in 2011, but dropped significantly (-64%) to 8,860 UDs in autumn 2012. Following the low in 2012, cormorant use recovered to a peak of 39,710 UDs in autumn 2015. Bald eagle use increased from autumn 2007 (12 UDs) to the peak in 2010 (796 UDs), but similar to cormorants, experienced a substantial reduction (-62%) in autumn UDs followed by a recovery to 722 UDs in 2014 (Fig. 5).

Similar to diving ducks, American coot UDs during spring declined sharply following 2009 (1,306,843 UDs) to a low of 202,128 UDs in spring 2013, representing an 85% decline. Nonetheless, coots steadily increased each spring since 2013 to a high of 1,929,112 UDs in 2016 (Fig. 4). 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. 5). 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. 5).

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. 6). 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. 7). 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. 8).

Brood Observations

We recorded more than 800 observations of waterbird broods during spring and summer at Emiquon. Most of the observations were comprised of wood ducks (55%), Canada geese (18%), and mallards (11%). Brood observations increased from 111 in 2008 to 157 in 2012 but declined 66% in 2013 (n = 53) and remained low through 2015 (2013–2015, $\bar{x}$ = 63 observations/year). Observations of wood ducks, Canada geese, and mallards were stable to increasing during 2008–2012 but declined in 2013 and never returned to the pre-2012 level (Fig. 9). Similarly, brood sightings of the state endangered common gallinule increased from 2 in 2011 to 5 in 2012 but declined each subsequent year. Conversely, observations of American coot and pied-billed grebe broods declined sharply following 2009 without recovery (Fig. 10). The age of broods has increased during each spring-summer observation period over the nine years of study, indicating broods were surviving to flight stage (Fig. 11). However, size of duck broods declined slightly between May and August at Emiquon during 2008–2015 indicating mortality during the brood-rearing phase (Fig. 12). The amount of decline in brood size varied among years, but the average size of duck broods declined from 4.3 to 3.5 ducklings between May and August across all years. Mean annual brood densities ranged from 4.4 broods/km^2 to 18.2 broods/km^2 and averaged 11.8 broods/km^2 across all years at Emiquon during 2008–2015. Moreover, average brood size was variable but remained relatively stable during 2008–2015. When we controlled for wetland size and observation area, trends in brood and young densities appeared similar to observations of total broods (Fig. 13).

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. 14). 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 5). 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 165 soil core samples along the Thompson Lake shore during autumn 2007–2015 and 45 soil cores along the shore of Flag Lake during autumn 2013–2015. Moist-soil plant seed density was variable throughout the sampling period, ranging from 235 kg/ha in 2009 to 1,116 kg/ha in 2011 (Fig. 15). Seed abundance at Emiquon exceeded the waterfowl carrying capacity goal (578 kg/ha) of the Upper Mississippi River/Great Lakes Region during 5 out of the 9 years of monitoring. Furthermore, Emiquon surpassed average seed abundance estimates from IDNR wetlands (691 kg/ha) and Chautauqua NWR (790 kg/ha) in only 3 of 9 years. Similar to seed abundance estimates, energetic use days (EUDs) also were variable, ranging from 1,745 EUDs/ha in 2009 to 8,280 EUDs/ha in 2011 (Fig. 15). Moreover, EUDs at Emiquon exceeded those from IDNR sites and Chautauqua NWR in 3 years during the 2007–2015 period.

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 16). 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. 16).

Total energetic carrying capacity for diving ducks during autumn, 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. 16). Total energetic carrying capacity for dabbling ducks during autumn, 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. 16).

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 17).

Wetland Cover Mapping

Spatial coverage of wetland vegetation and associated cover types ranged from 255 ha in 2007 to 2,017 ha in 2015 ($\bar{x}$ = 1,624 ha; Figs 18–26; Table 6). We encountered more than 120 plant taxa during cover mapping. Aquatic bed has been the dominant wetland community at

Emiquon, comprising an average of 46% of the wetland area since 2007 and 55% since 2009 (Figs 27 and 28). Open water ($\overline{x}$ = 20%) was the next largest community at Emiquon, and it increased from 2009 to 2015 (12–25%). Hemi-marsh increased more than eight-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. Persistent emergent vegetation expanded from 33–298 ha, occupying 2–15% ($\overline{x}$ = 10%) 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 very quickly. 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 218 ha ($\overline{x}$ = 90 ha; 7%) following a drawdown in 2010. 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 2007–2015. Occurrence of reed canarygrass ranged from 5 to 48% ($\overline{x}$ = 17%) of the non-persistent emergent polygons (Fig. 29). Eurasian watermilfoil averaged 37% of the aquatic bed, hemi-marsh and persistent emergent polygons combined and ranged from 0% in 2007 to 69% in 2012. Common reed occurred in 0–25% ($\overline{x}$ = 9%) of the combined non-persistent emergent, persistent emergent, and scrub-shrub polygons. Encounters with purple loosestrife and curly pondweed occurred less frequently than other invasive species at Emiquon. Purple loosestrife occurred in an average of 0.8% of the hemi-marsh and wet upland polygons, while curly pondweed averaged 1% of the aquatic bed and hemi-marsh polygons (Fig. 29). Overall, invasive species occurrence ranged from 2% of the total cover map polygons in 2008 to 46% in 2013 ($\overline{x}$ = 25%).

DISCUSSION

Wetland area at Emiquon increased almost 800% from 2007 to 2015 and has undergone a near complete vegetation and cover cycle during this time period. 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 2009–2015. Notably, the area of aquatic bed vegetation grew from just 1% of the wetland area in 2007 to 65.7% in 2009 and remained greater than 50% subsequently. Historically, aquatic bed vegetation, 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.

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

In just 9 years, changes in vegetation structure mirrored an almost complete wetland cycle, including all 4 cover type 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. During 2013–2015, Emiquon entered the degenerating marsh phase, marked by a decline in emergent vegetation, and increase in hemi-marsh vegetation, and a dominance of submersed aquatic vegetation. A combination of factors including high and stabilized water levels, muskrat (*Ondatra zibethicus* L.) herbivory, increasing turbidity from deteriorating vegetation communities or increasing common carp (*Cyprinus carpio*) populations, and other factors contributed to the decline in vegetation cover and increase in open water during the degenerating phase (Bajer et al. 2009). Currently, we believe that Emiquon has transitioned into the lake marsh phase which is characterized by a dominance of submersed and floating-leaved aquatic vegetation and persistent emergent vegetation confined to a narrow band around the perimeter. Eventually, even the submersed aquatic vegetation may decline due to increased turbidity from wave action, increased flocculence of soil, and increased areas of open water (Valk & Davis 1978). A substantial drawdown will be needed to reset the marsh cycle, but drawdowns can also create conditions suitable for rapid expansion of invasive species.

We encountered relatively few invasive or undesirable wetland plant species during wetland mapping; however, we did document areas with curly pondweed, Eurasian watermilfoil, reed canarygrass, and common reed and noted rapid expansions in occurrences of these species between 2009 and 2013. In particular, the proportion of aquatic bed and hemi-marsh polygons containing Eurasian watermilfoil expanded from near 0% in 2008 to near 80% in 2012. While

Eurasian watermilfoil does provide habitat for fish and food for waterbirds, it can compete with native aquatics and should be continuously monitored in case increased prevalence should require management action. Anecdotally, we observed increases in willow (*Salix* spp.) shoots and stands of *Phragmites* spp. following partial drawdowns in the past and caution wetland managers that drawdown timing may influence subsequent response of invasive or undesirable species.

Return of water and wetland vegetation to Emiquon resulted in a rapid response of waterfowl and other waterbirds. Peak abundances of wetland birds typically exceed 200,000 during fall migration at Emiquon Preserve and often comprise more than 25% of the dabbling ducks use days in the Illinois River Valley despite having a wetland area of less than 10% throughout our study years. In particular, aquatic vegetation communities at Emiquon appear to be particularly attractive to dabbling ducks other than mallards and American coots and use typically comprises greater than 25% and 50%, respectively, of use days compared to other locations in the IRV during autumn. Similarly, wetland bird use during spring is substantial, with peak counts typically exceeding 100,000 individuals. In contrast to the autumn, diving ducks typically comprise more than 50% of use days during spring migration.

Although vegetation communities and habitats of waterbirds have changed considerably since 2007, bird guilds have responded differently over time. Diving duck use days during spring have generally declined since 2009, although 2015 represented the third highest total since restoration. Use days for dabbling ducks and total ducks, while variable, have remained relatively constant since restoration while use days of American coots have trended upward in recent years. In contrast, use days of all guilds excepting diving ducks generally increased from autumns 2007 to 2013, but have since decreased. Diving duck use continues to increase annually during autumn, and these trends are likely in response to changing habitat conditions. Increasing and stable water levels since 2013 have resulted in declines in emergent vegetation communities and deeper water which may have reduced foraging habitat quality for dabbling ducks. Moreover, expanded hunting and other recreation on Emiquon may reduce sanctuary area for waterbirds, especially during autumn (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 (1,003,810 UDs) and green-winged teal (784,930 UDs) use at Emiquon in 2011 was the highest recorded at a single location in the IRV since aerial inventories began in 1948 (M. Horath, unpublished data). This is particularly noteworthy as continental population estimates of northern pintails have been below the North American Waterfowl Management Plan (NAWMP) goal (5.6 million) since 1976 (Zimpfer et al. 2012). Moreover, gadwall use of Emiquon averaged 34% of all gadwall use days in the IRV during 2007–2015 and represented as high as 48% of gadwall use in the IRV. Mallards comprised 52−84% of autumn duck UDs at CNWR during 1991–2008, but Emiquon supported a more diverse waterfowl community as mallards comprised only 12−37% of duck UDs during autumns 2007−2015. Moreover, American coot use in autumn 2009 (4,249,563 UDs) was the highest observed for any surveyed location since the inception (1948) of aerial inventories in the IRV (M. Horath, unpublished data) and the autumn 2010 UD estimate was the second highest ever recorded for coots in the IRV, comprising 84% of the coots in the Illinois Valley. Thus, we recommend maintaining diverse vegetation communities that are currently rare in the IRV but attract and support non-mallard duck species.

Further, the diversity of waterfowl species that use Emiquon during migration may be as (or more) useful of an indicator of ecological function than abundance.

During both autumn and spring, Emiquon is used as a foraging habitat by dabbling ducks, diving ducks, and other waterbirds. During the course of the restoration, foraging rates have remained the dominant activity and relatively constant for all ducks and dabbling ducks; however, foraging rates have increased and become the dominant activity since 2013 for diving ducks during spring. Ducks likely consume submersed aquatic vegetation, invertebrates, and natural plant seeds at Emiquon Preserve (Osborn et al. 2016). In fact, we estimated that far more food is likely produced at Emiquon Preserve than is required by the number of birds that forage there during spring and fall migrations. Although the aquatic bed community produced the most energetic use days, energetic use day density is 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 growth and persistence of phytoplankton, zooplankton, and macroinvertebrates. In some years, moist-soil vegetation produces seeds and tubers at levels exceeding management moist-soil wetlands in the region (Bowyer et al. 2005, Soulliere et al. 2007, Stafford et al. 2011), but the total area of moist-soil has decreased to a very small portion of Emiquon Preserve and the hydrologic regime often does not facilitate flooding and access to seeds and tubers during waterbird migration periods.

Emiquon was not only used by migrating waterfowl, but also breeding and post-breeding waterfowl during 2007–2015. Especially during the first 5 years of restoration, broods were abundant; however, brood counts have decreased since 2012, especially pied-billed grebe, wood duck, mallard, and common gallinule. We have also observed decreases in available forage for broods. Invertebrate biomass has declined by 80% since 2008 and was the lowest recorded to data in august 2015. Declines in emergent vegetation communities and adjacent uplands which are used as nesting habitat may explain declines in some species. We are not aware if declines in invertebrate abundance are tied to waterbird brood declines, but the concurrent trends are suggestive of such a relationship.

Over the past several decades, wetland habitat in the IRV has incurred many anthropogenically induced changes and has become less diverse as a result (Mills et al. 1966, Bellrose et al. 1983, Havera 1999, Stafford et al. 2010). Because of these changes, several habitat types 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 habitats 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). Recent abundances 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 vegetation communities, such as submersed aquatic vegetation and hemi-marsh, which are rare in the IRV.

We cannot overemphasize the regional importance of Emiquon to migratory waterbirds, especially when use by some species or guilds were greater in most years than any other aerially surveyed location in the IRV. However, declining trends observed in waterbird abundance, brood counts, invertebrate biomass during summer, and emergent vegetation communities in recent years indicates a decline in wetlands productivity and a transition to the lake marsh phase. We recommend that TNC consider a substantial drawdown during late spring and summer for a period of at least 6 months to perturb vegetation, consolidate sediments, and stimulate primary productivity while monitoring waterbird use and vegetation response.

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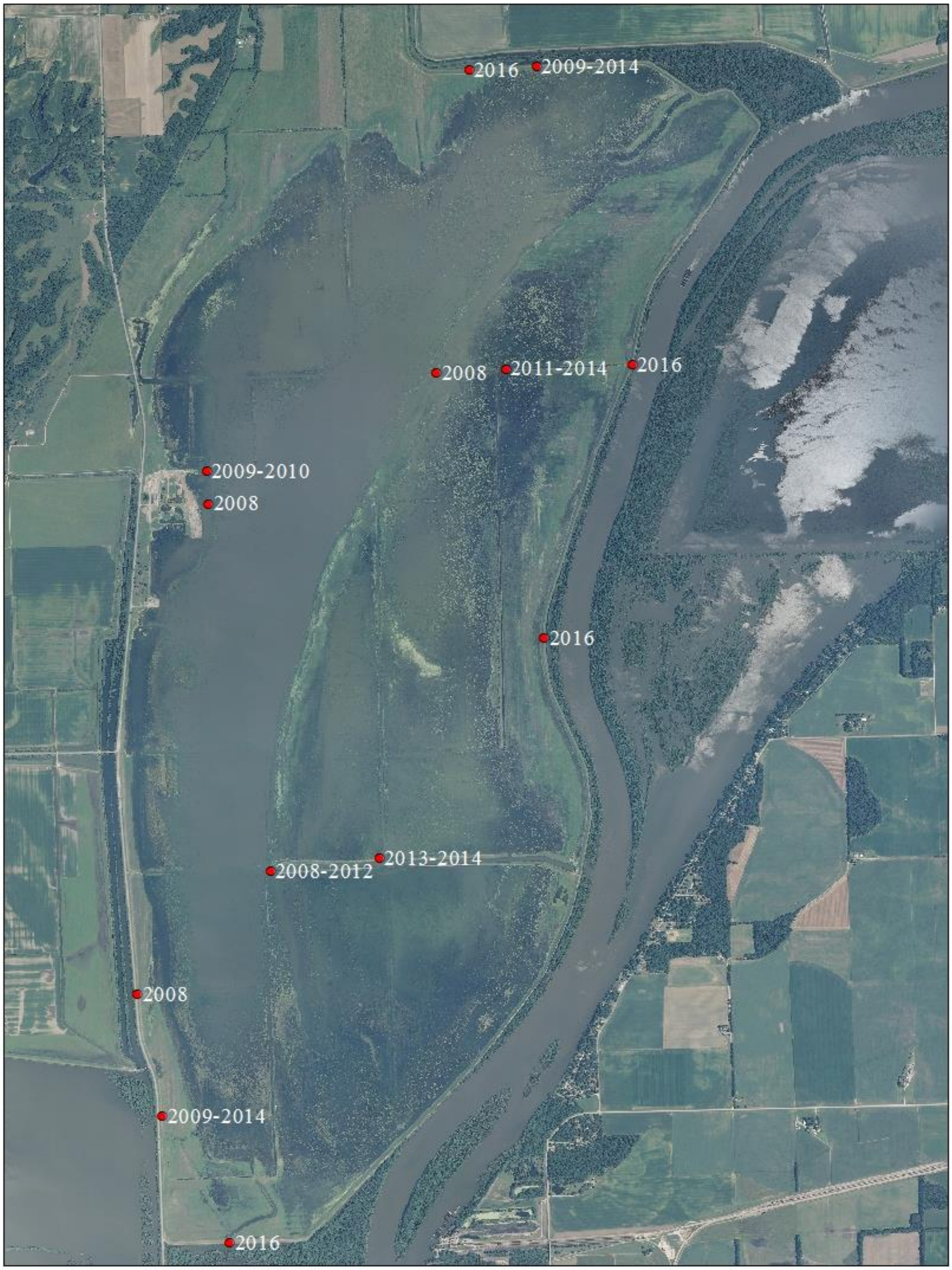


Figure 1. Brood observation locations by year at The Emiquon Preserve, summers 2008–2016. Observation points varied by year due to expanding water levels on the Preserve.

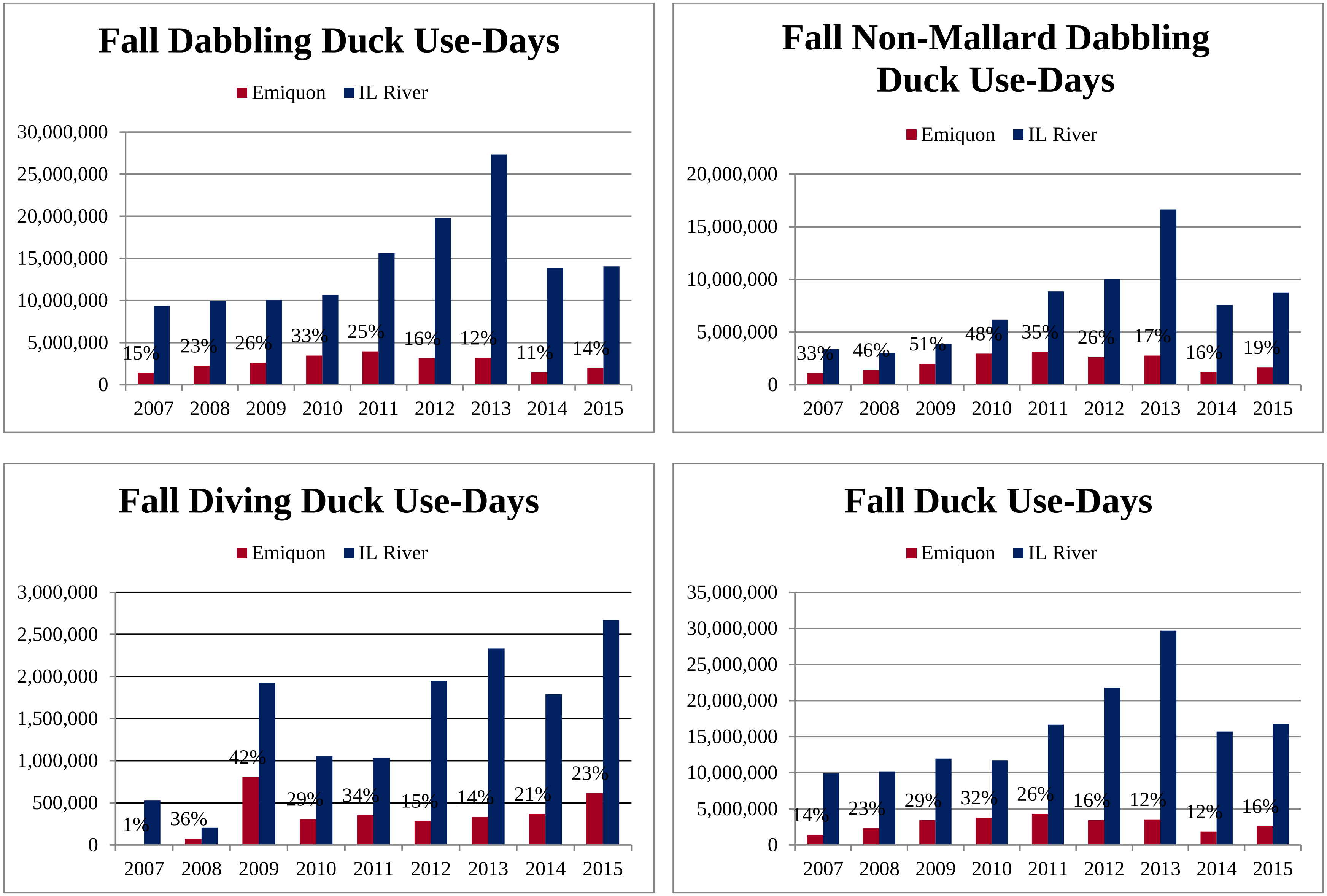


Figure 2. Fall duck use days by guild and the proportion of Illinois River use days occuring at the Emiquon Preserve from aerial inventories during 2007–2015.

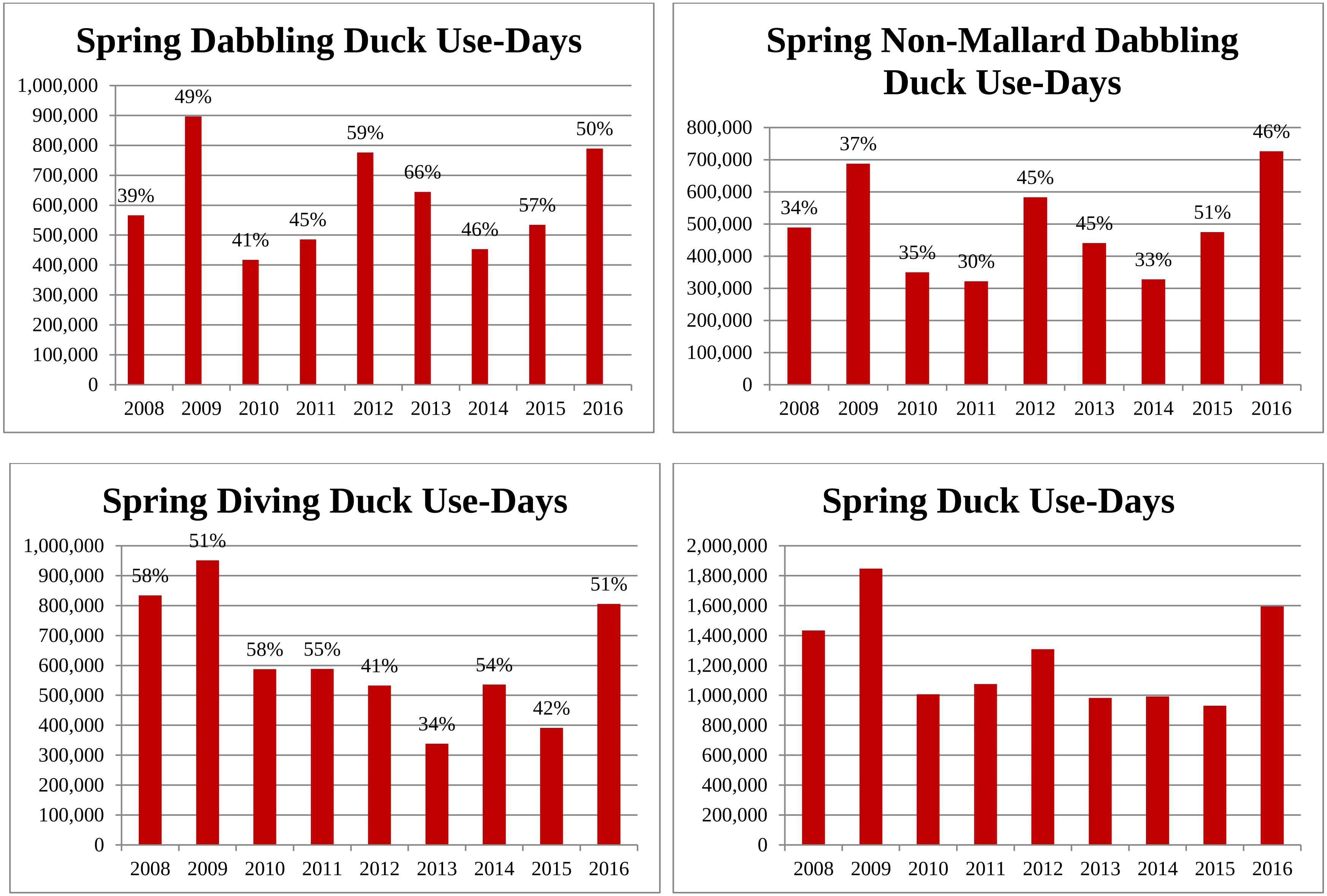
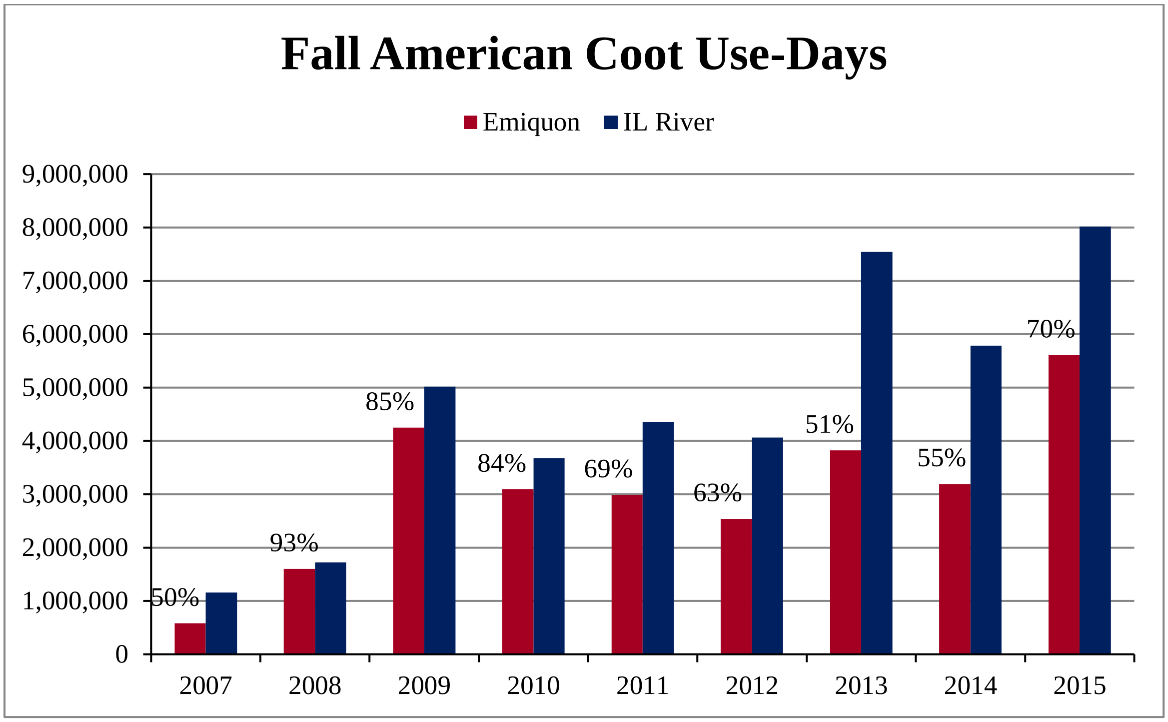


Figure 3. Spring duck use days by guild and their proportion of total duck use days at the Emiquon Preserve from ground inventories during 2008–2016.



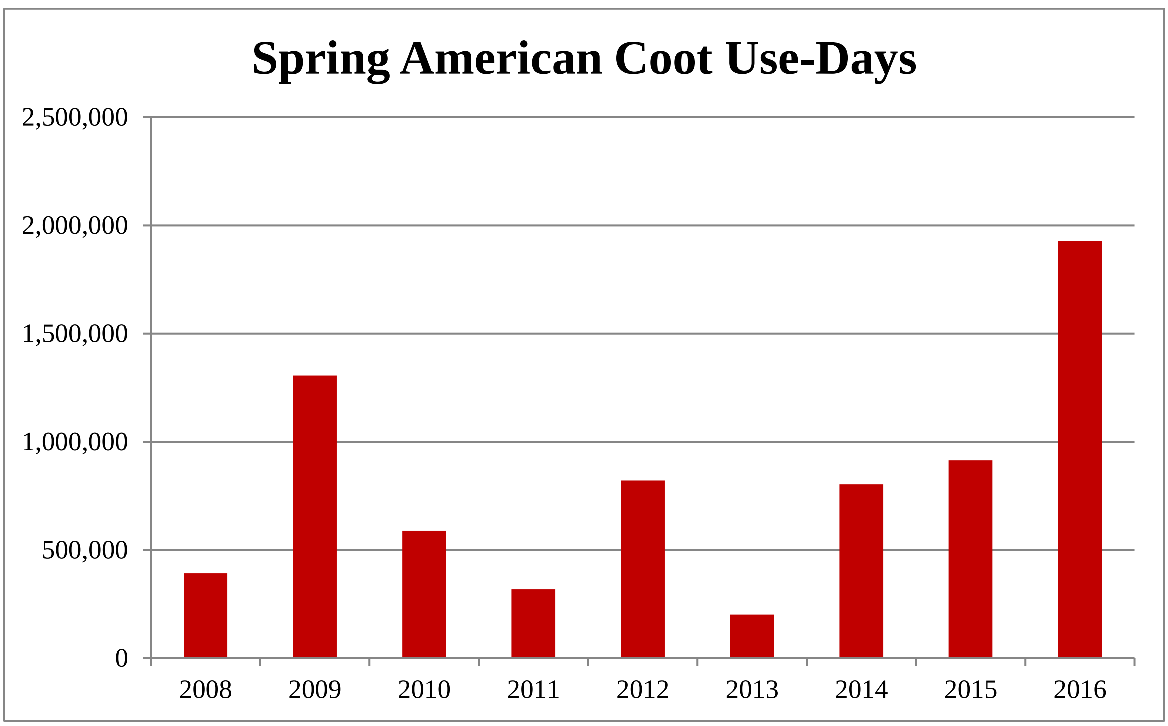
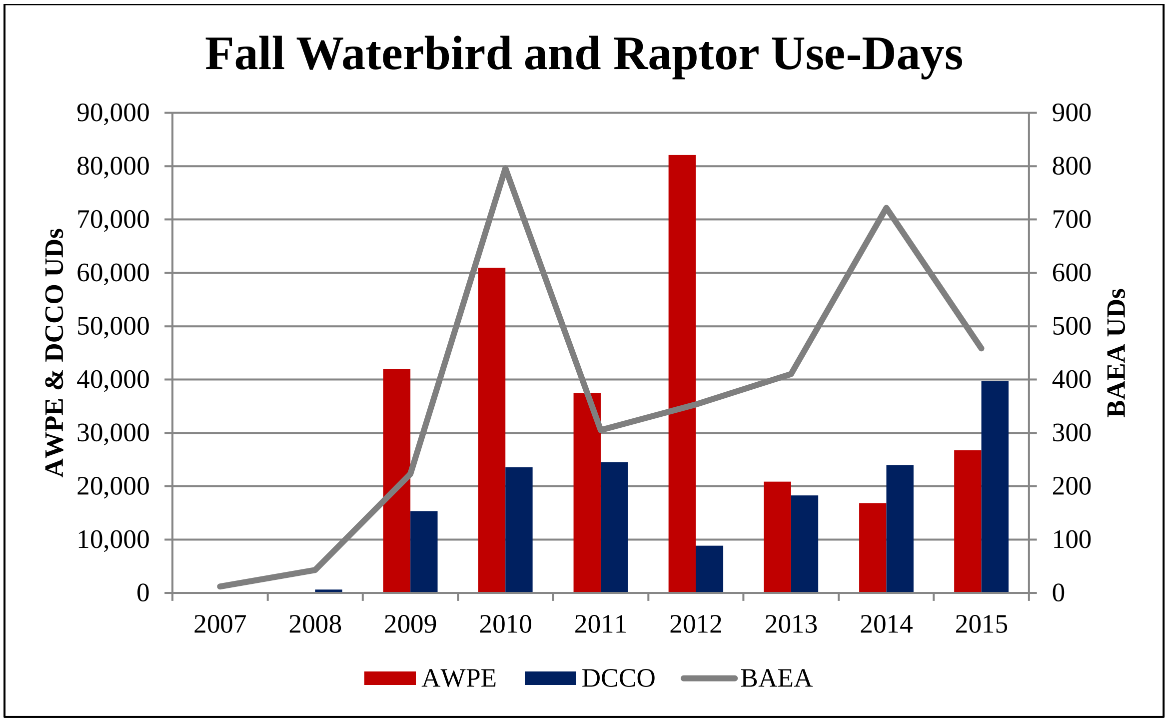


Figure 4. American coot use days and the proportion of Illinois River use days occurring at the Emiquon Preserve during fall aerial inventories 2007–2015 and American coot use days at Emiquon during spring ground inventories 2008–2016.



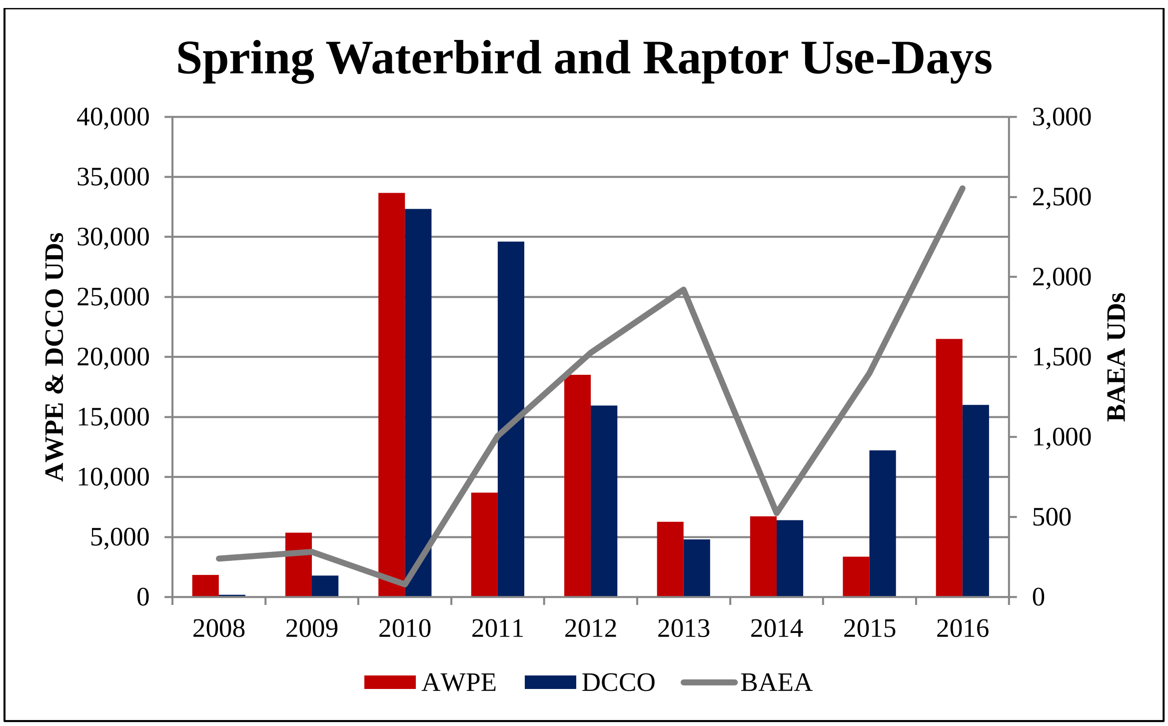


Figure 5. Use days of American white pelicans (AWPE), double-crested cormorants (DCCO), and bald eagles (BAEA) at The Emiquon Preserve during fall aerial inventories (2007–2015) and spring ground inventories (2008–2016).

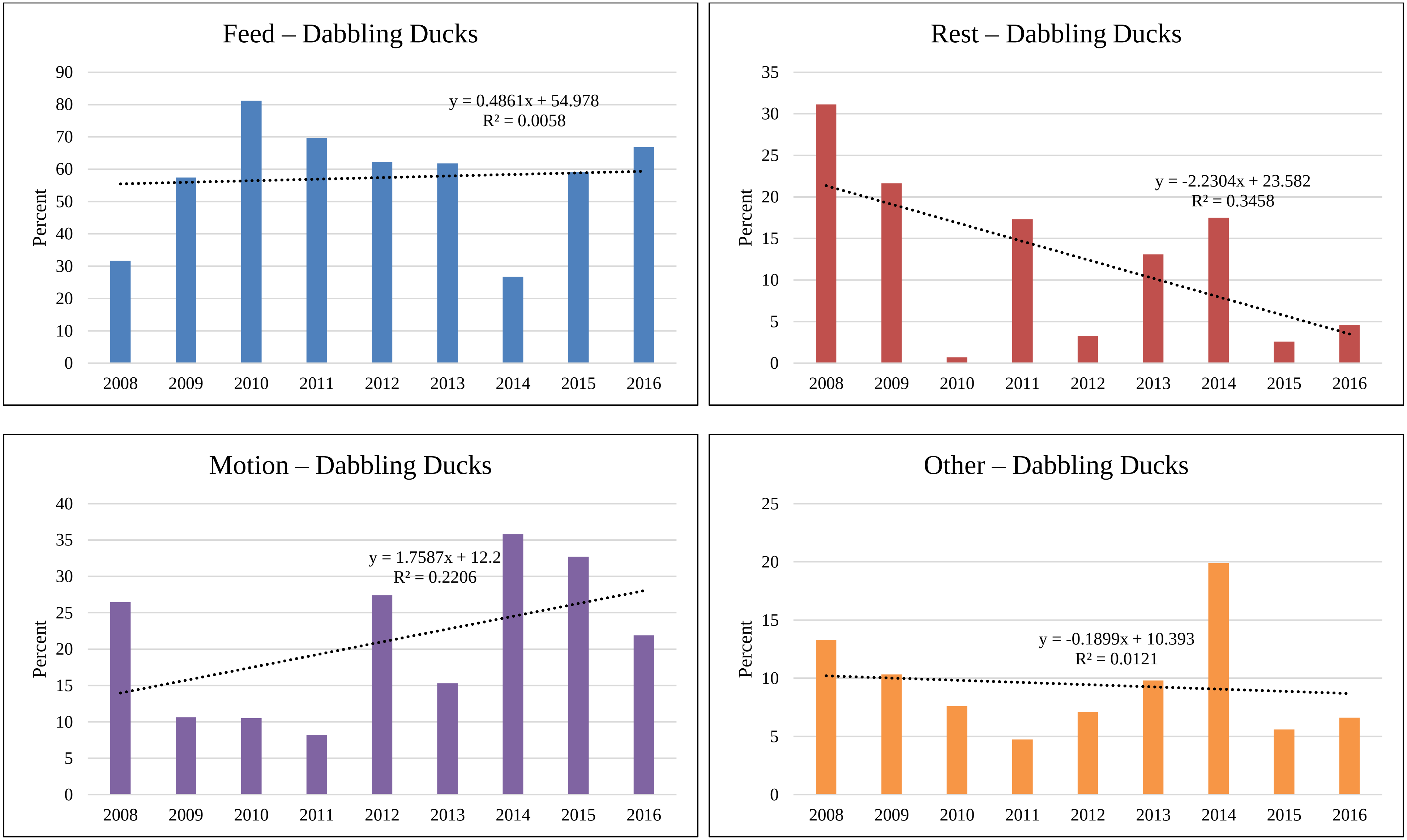


Figure 6. Behaviors of dabbling ducks observed during spring at the Emiquon Preserve 2008–2016.

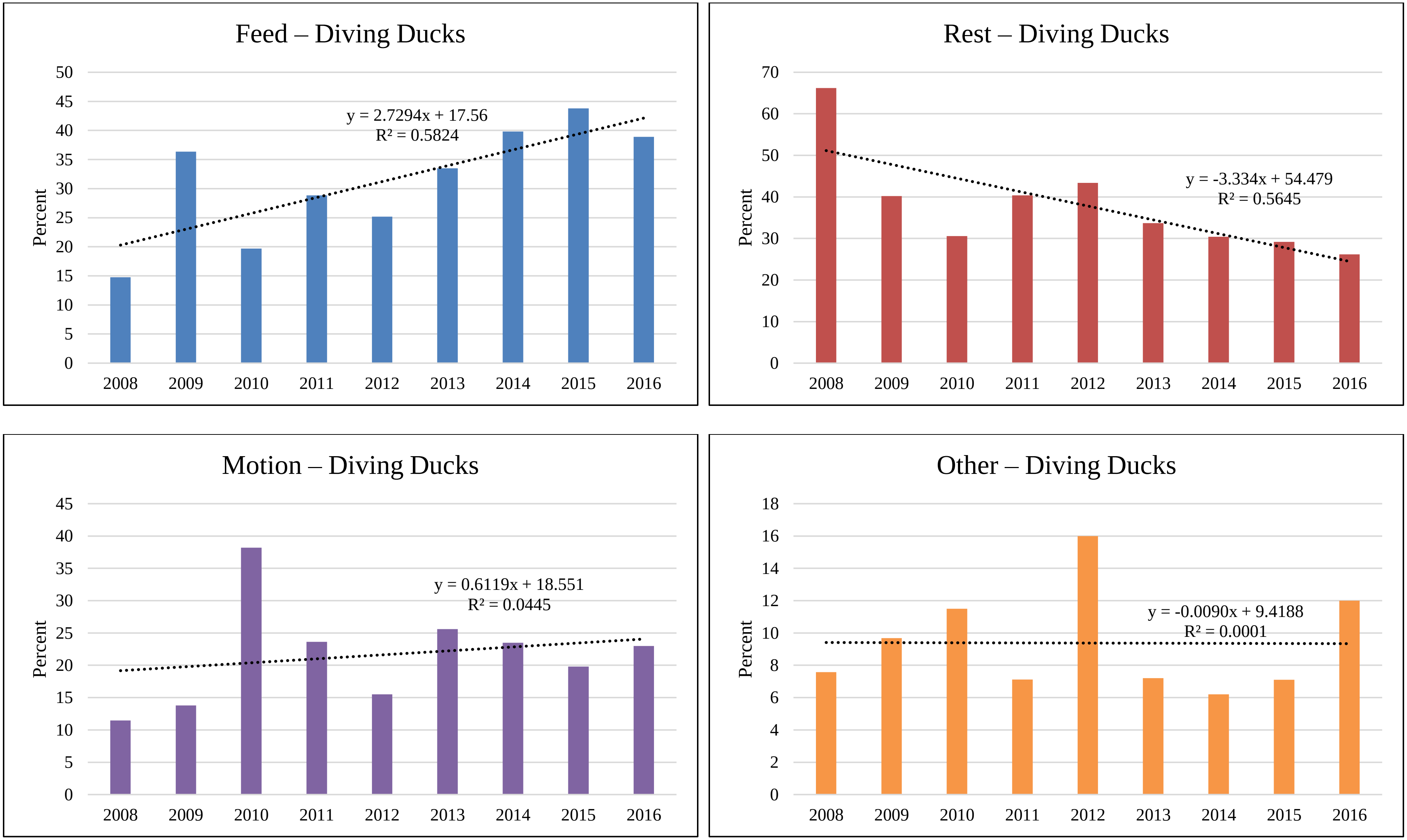


Figure 7. Behaviors of diving ducks observed during spring at the Emiquon Preserve 2008–2016.

Figure 8. Behaviors of all ducks observed during spring at the Emiquon Preserve 2008–2016.

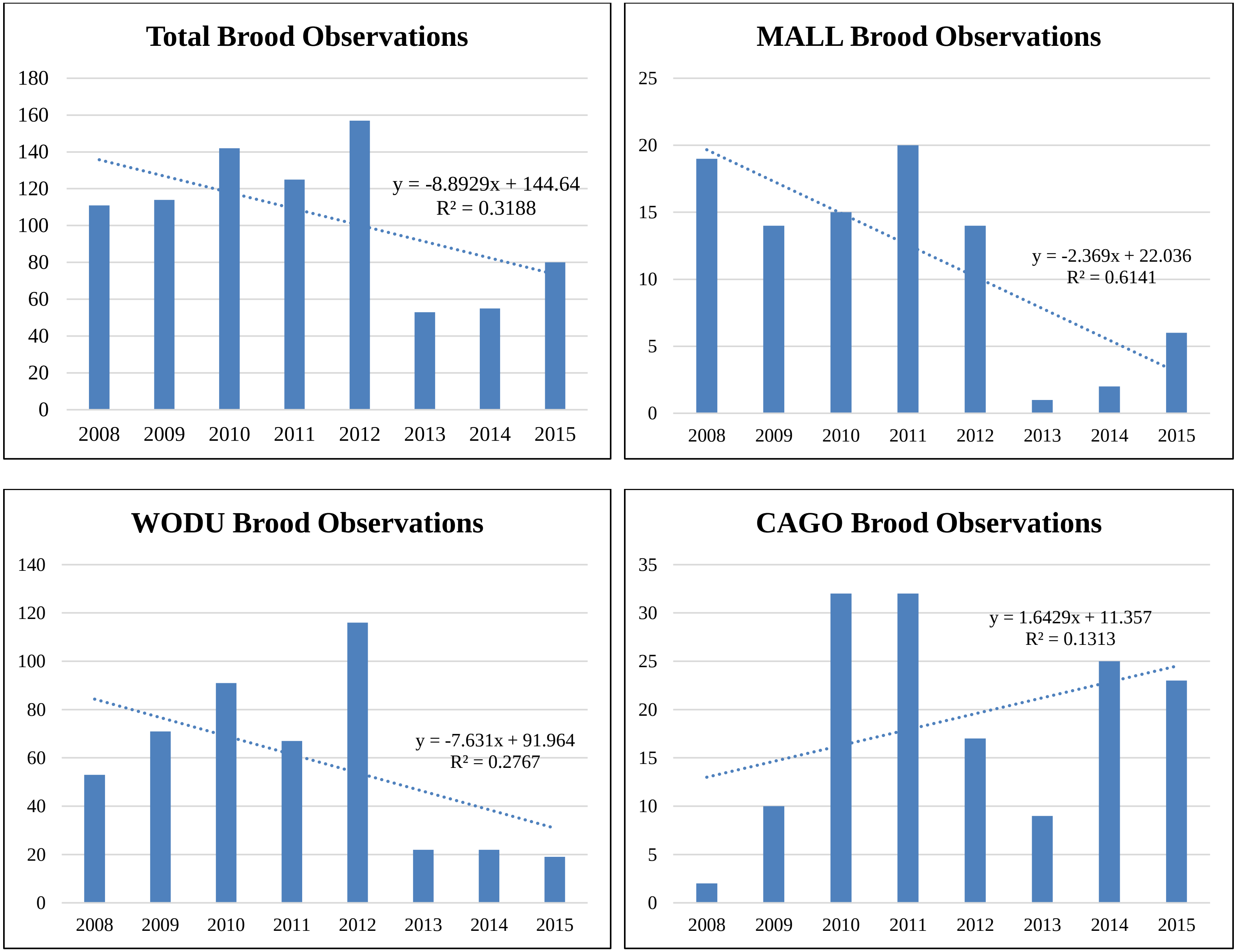


Figure 9. Observations of waterfowl broods during spring and summer at the Emiquon Preserve 2008–2015.

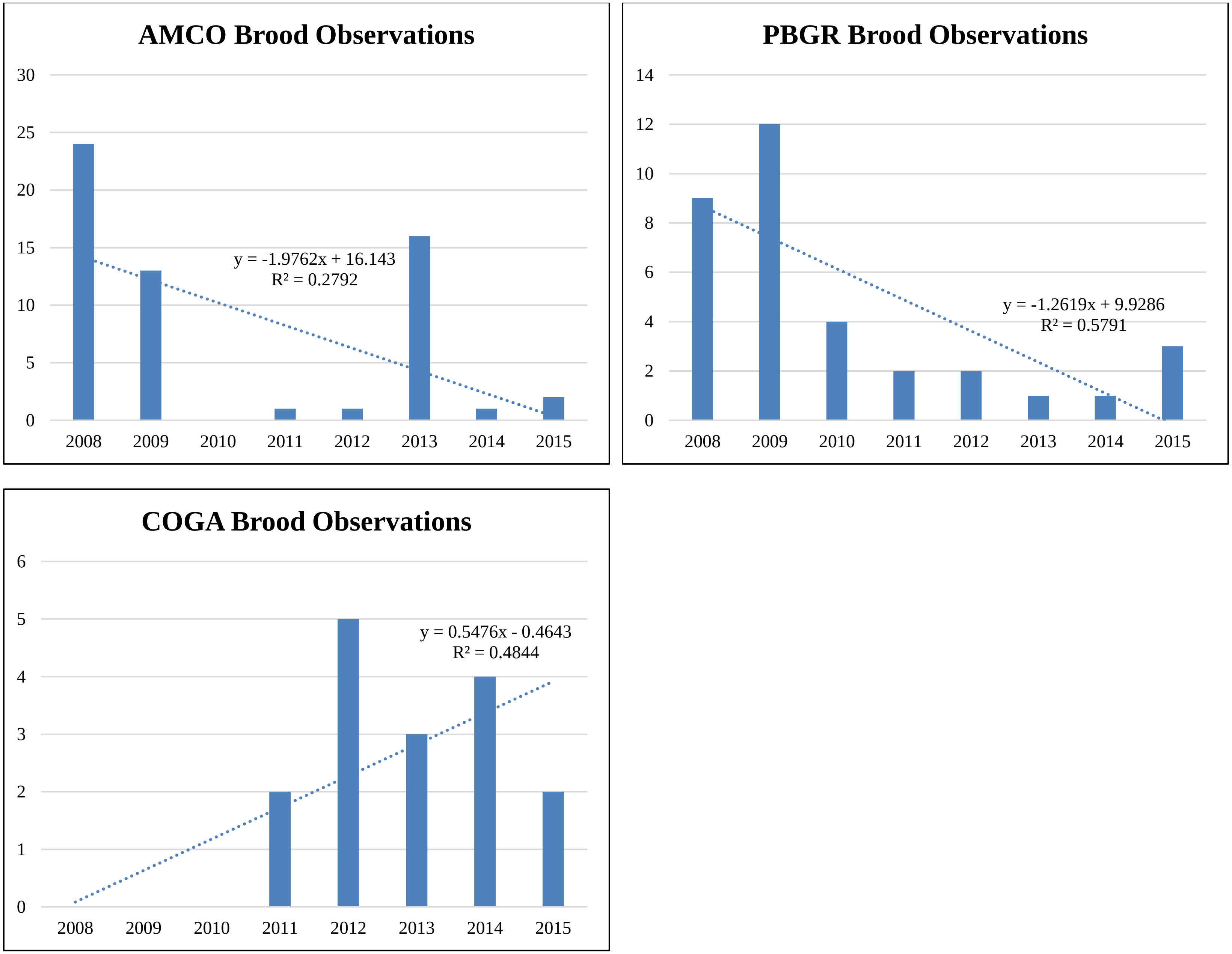


Figure 10. Observations of waterbird broods during spring and summer at the Emiquon Preserve 2008–2015.

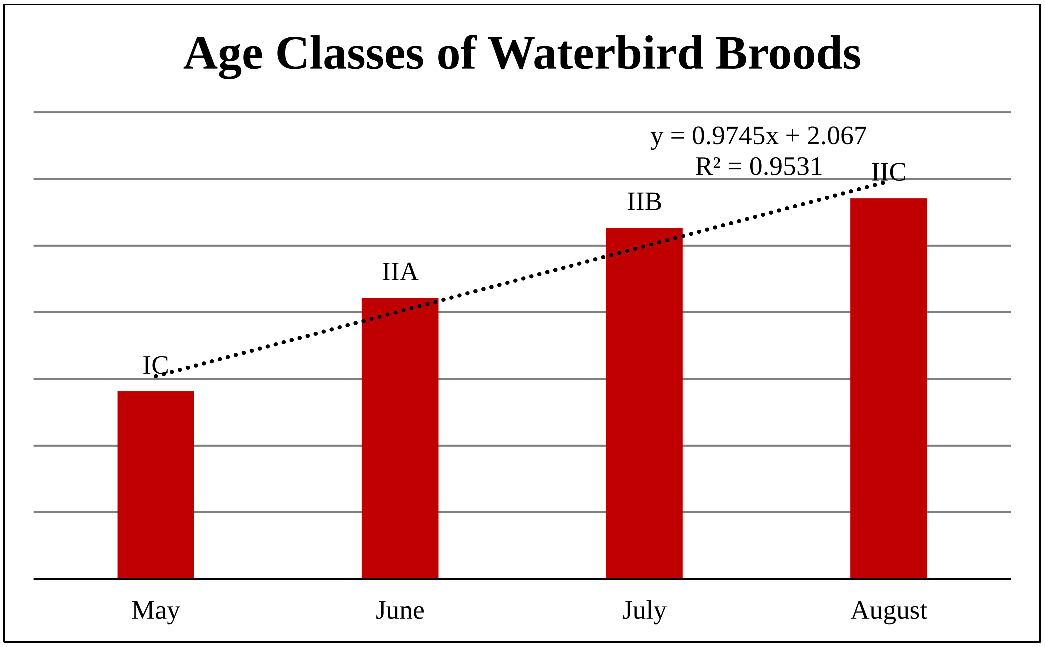


Figure 11. Mean monthly age classes of all waterbird broods observed at the Emiquon Preserve during 2008–2015.

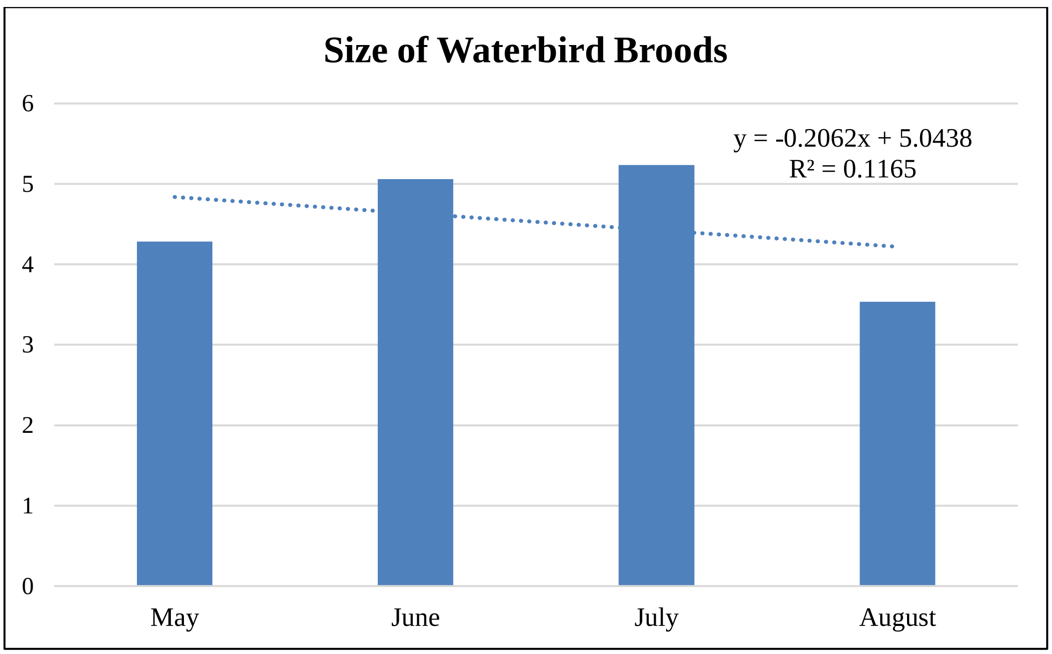


Figure 12. Mean monthly size of waterbird broods observed at the Emiquon Preserve during 2008–2015.

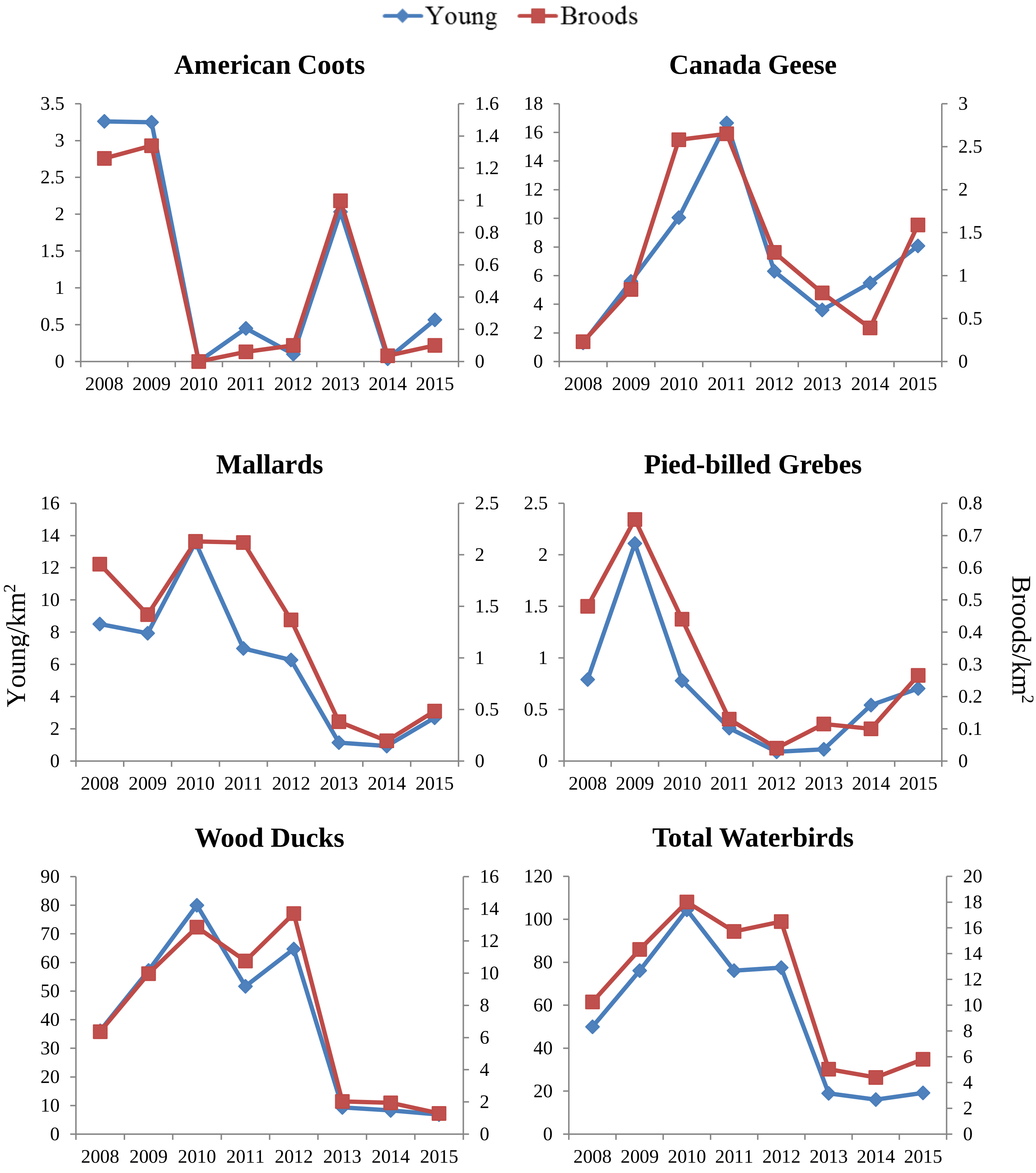


Figure. 13. Mean density of waterbird broods and young at Emiquon Preserve 2008-2015.

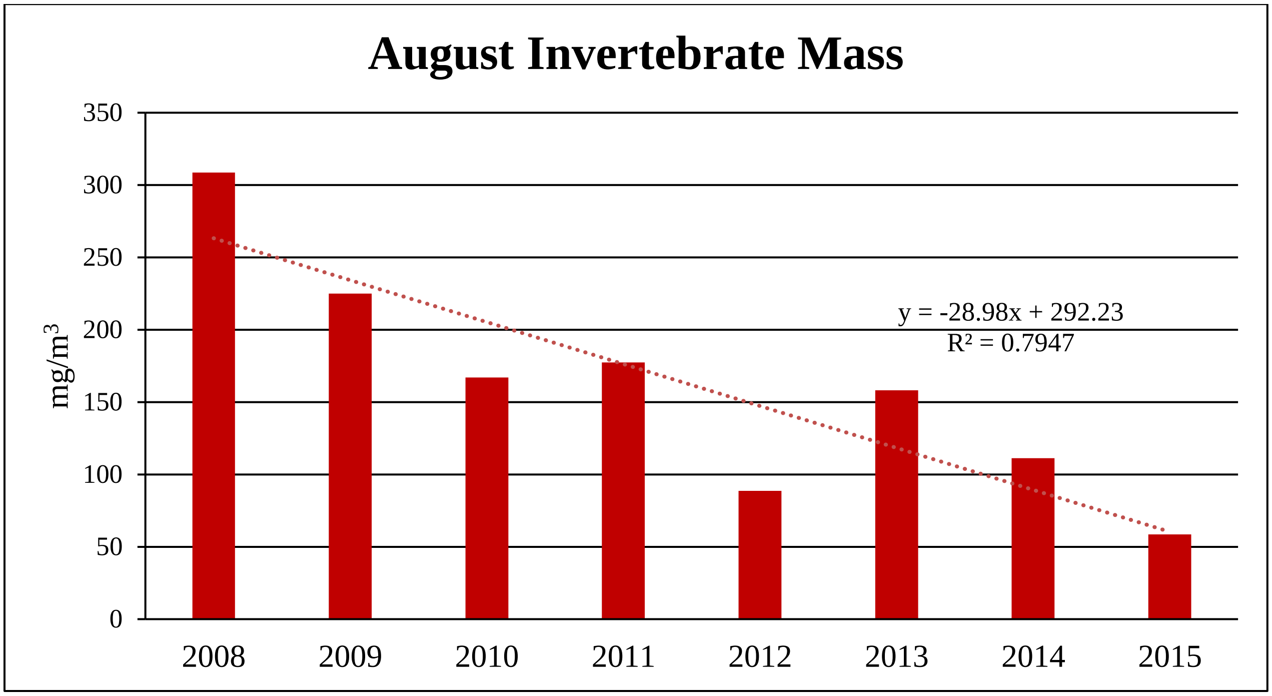
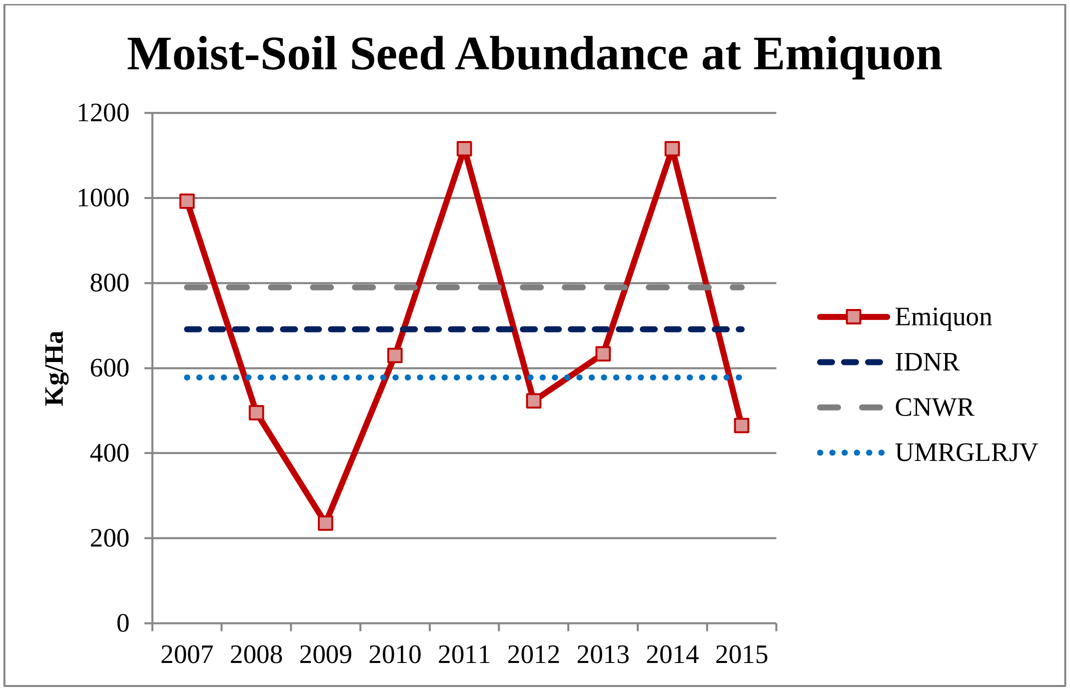


Figure 14. Mean mass of invertebrates collected in August samples at Emiquon Preserve, 2008–2015.



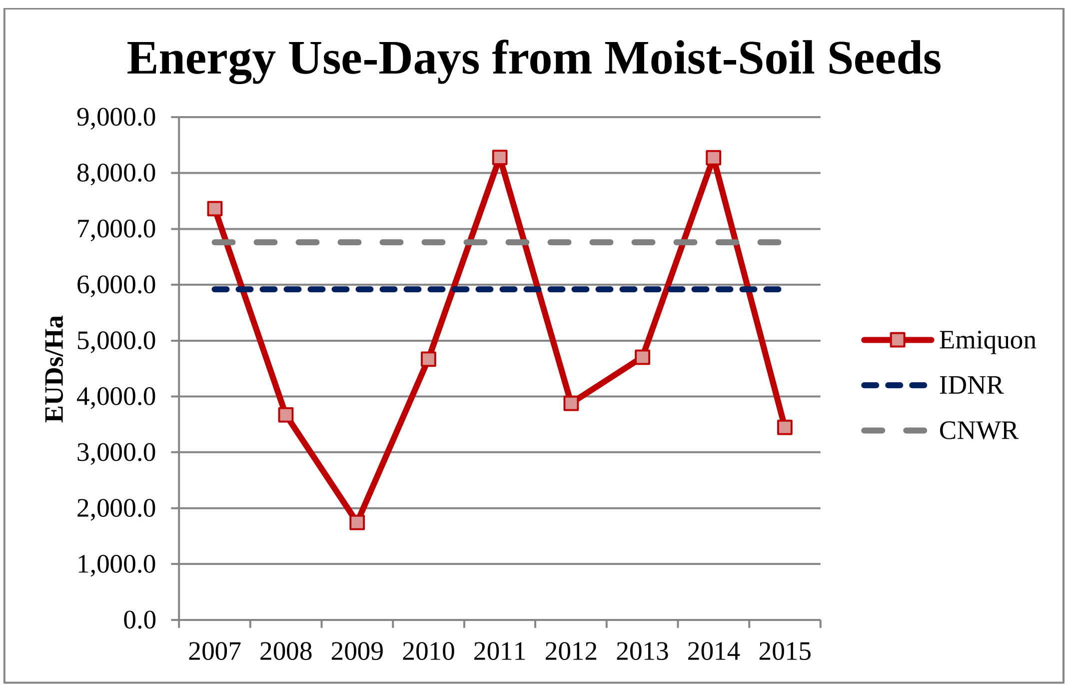


Figure 15. Moist-soil plant seed density and energy use days (EUDs) from moist-soil plants at the Emiquon Preserve compared to estimates (constants) from wetlands at Illinois Department of Natural Resources (IDNR) sites, Chautauqua National Wildlife Refuge (CNWR), and carrying capacity goals of the Upper Mississippi River/Great Lakes Region Joint Venture (UMRGLRJV) of the North American Waterfowl Management Plan.

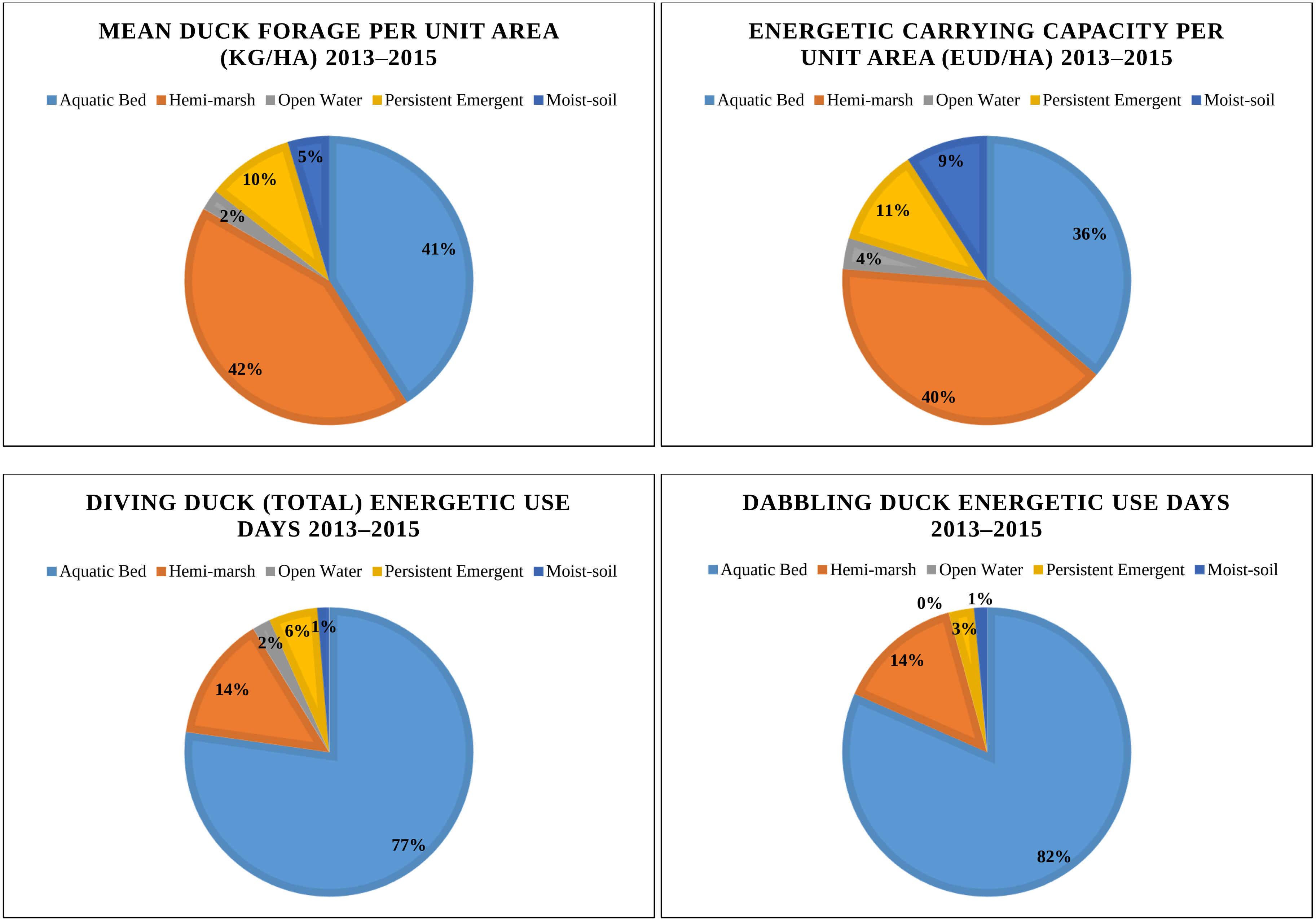


Figure 16. Energetic carrying capacity for diving ducks and dabbling ducks at the Emiquon Preserve, 2013–2015.

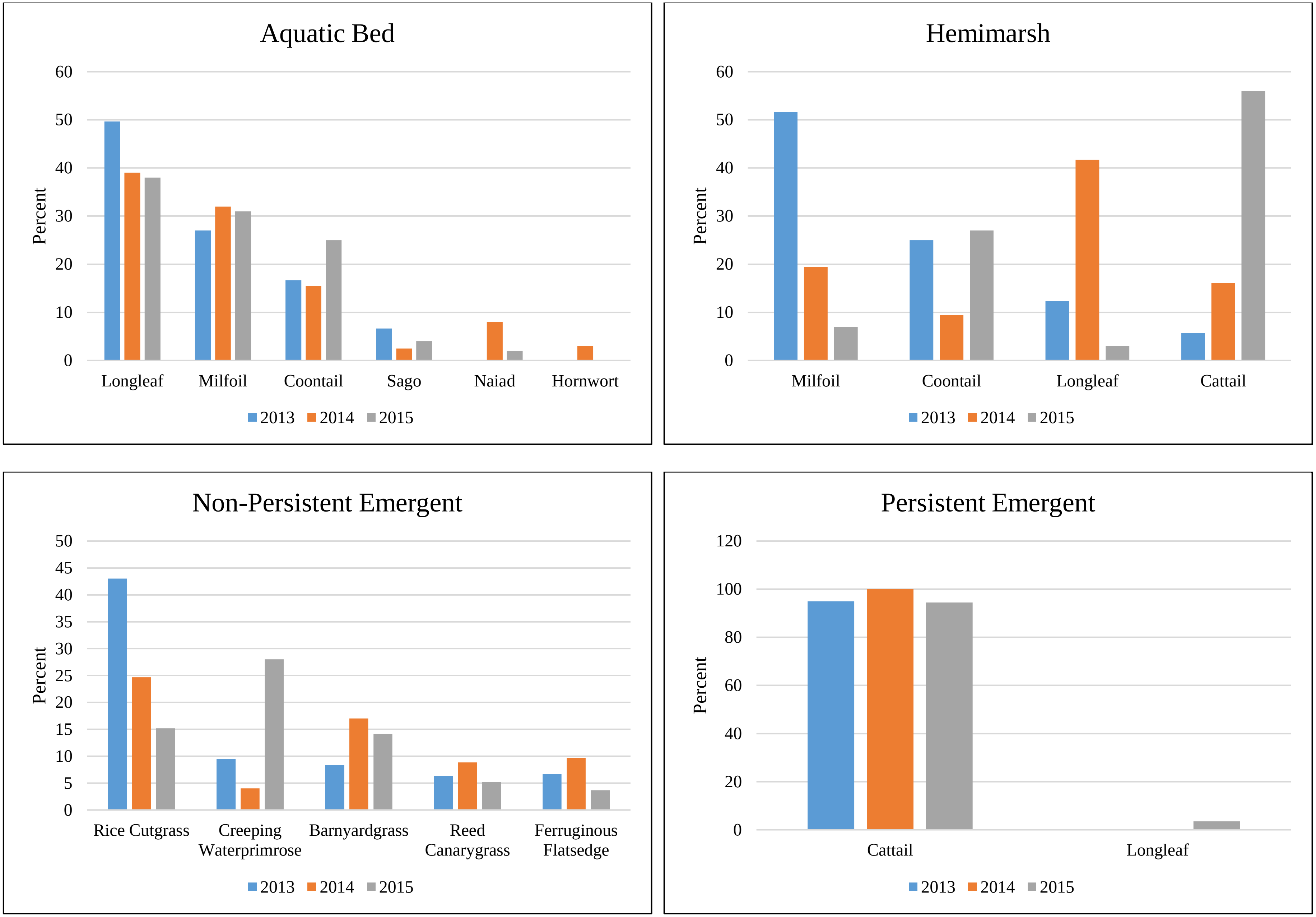


Figure 17. Species composition (%) of the major vegetation communities at Emiquon Preserve, 2013–2015.

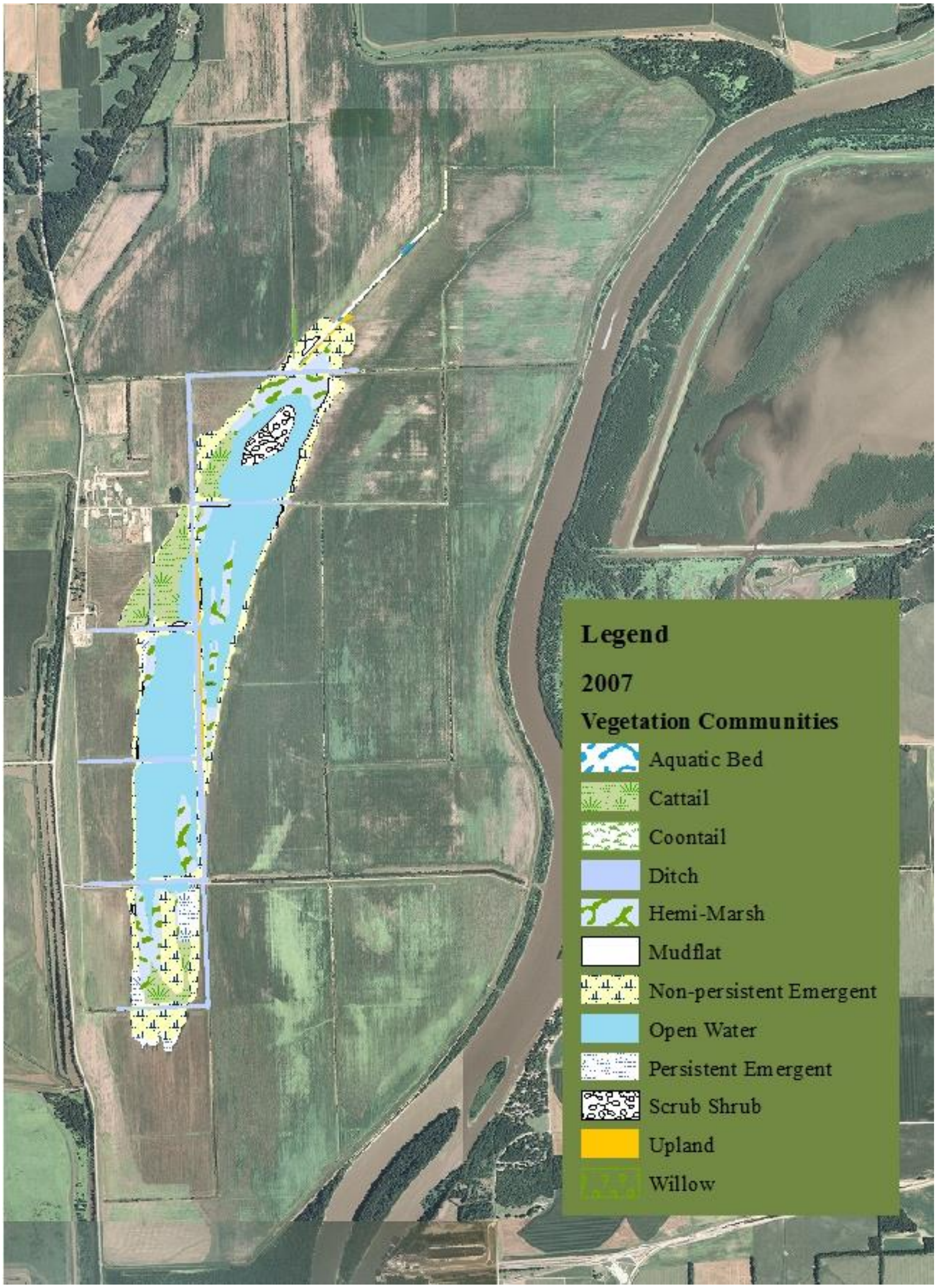


Figure 18. Wetland vegetation map of The Emiquon Preserve (255 ha), 7–8 November 2007.

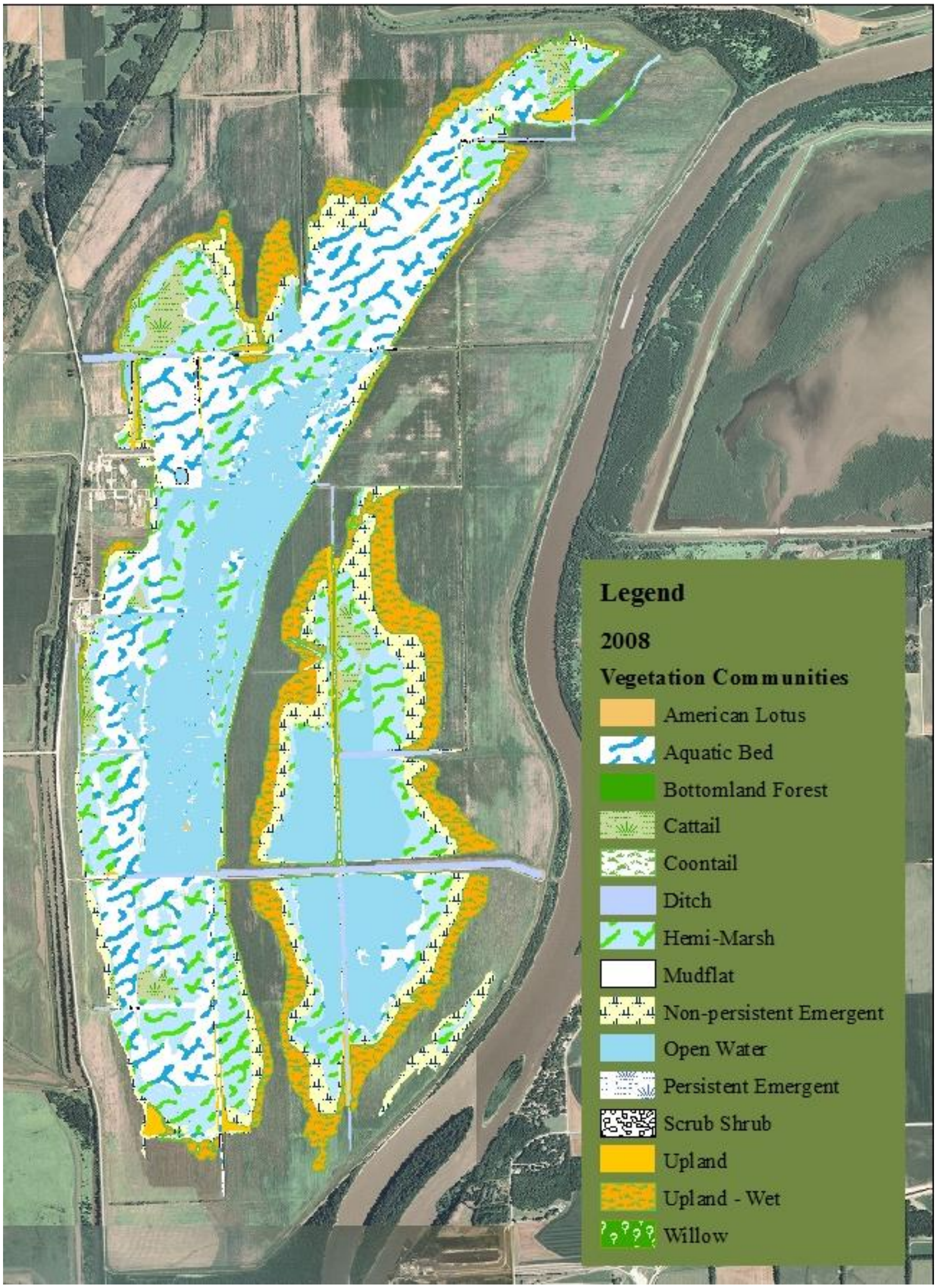


Figure 19. Wetland vegetation map of The Emiquon Preserve (1,077 ha), 11–18 September 2008

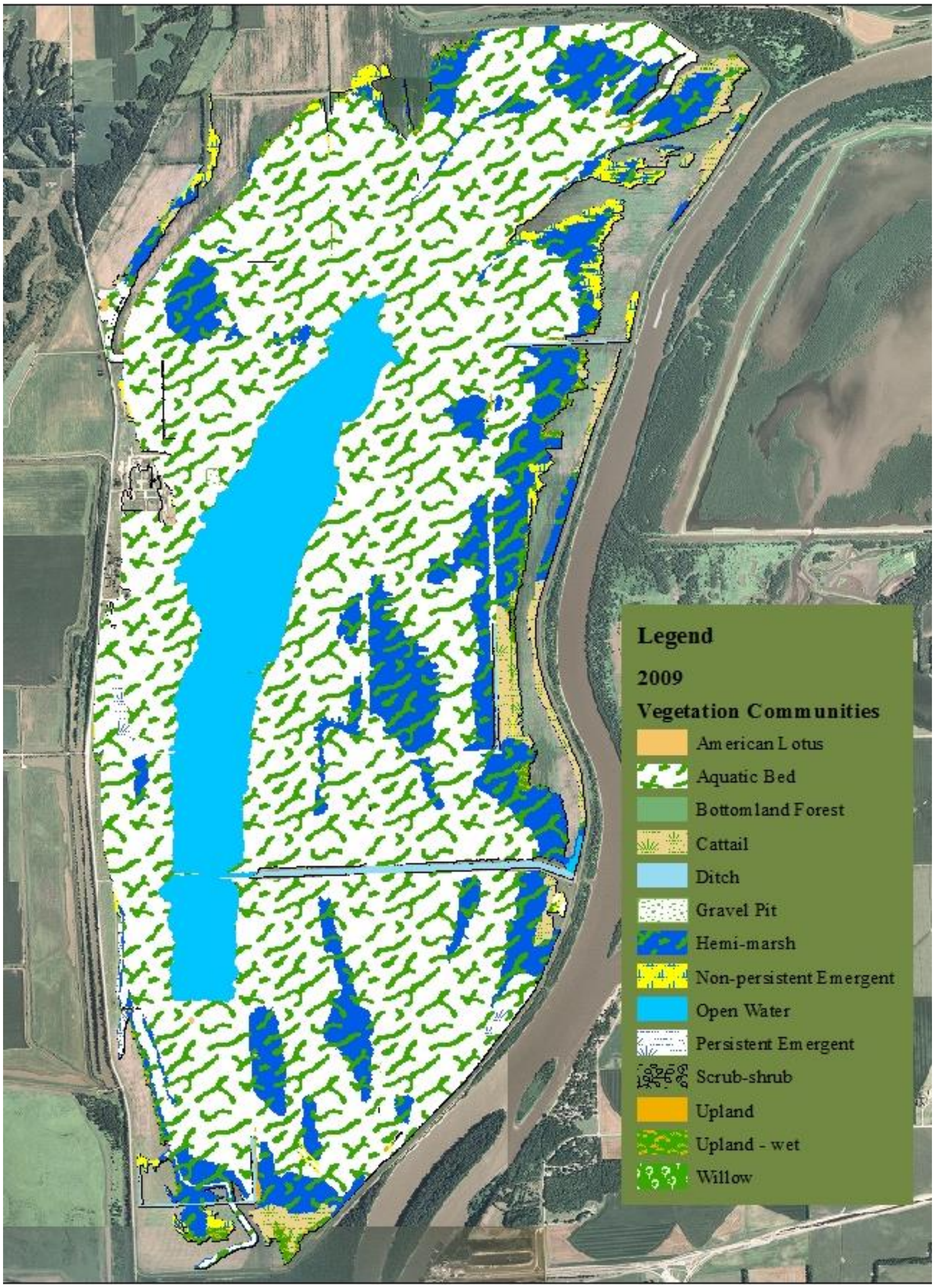


Figure 20. Wetland vegetation map of The Emiquon Preserve (1,804 ha), 15–23 September 2009.

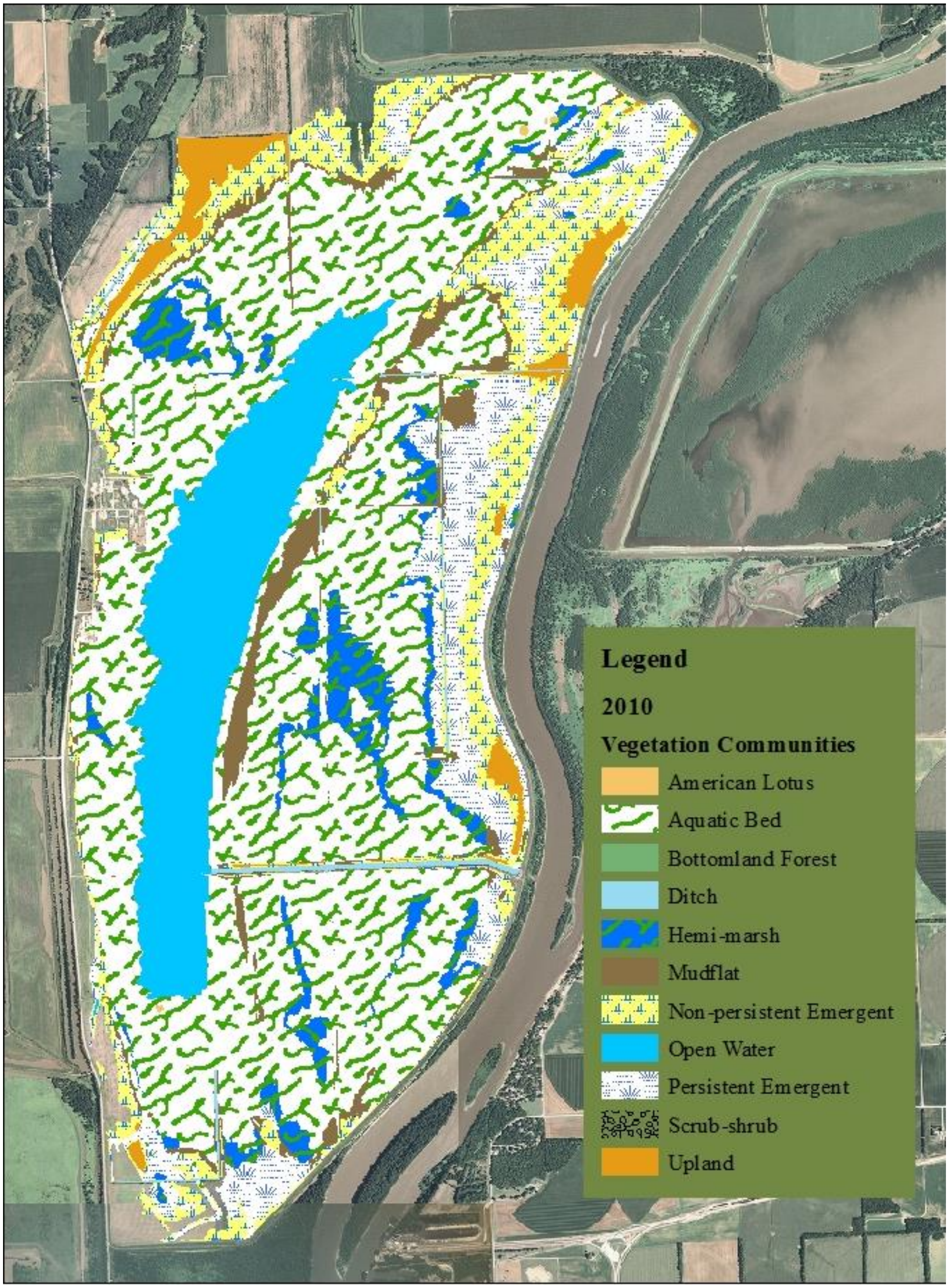


Figure 21. Wetland vegetation map of The Emiquon Preserve (1,974 ha), 8–20 September 2010.

Figure 22. Wetland vegetation map of The Emiquon Preserve (1,821 ha), 13 September–24 October, 2011.

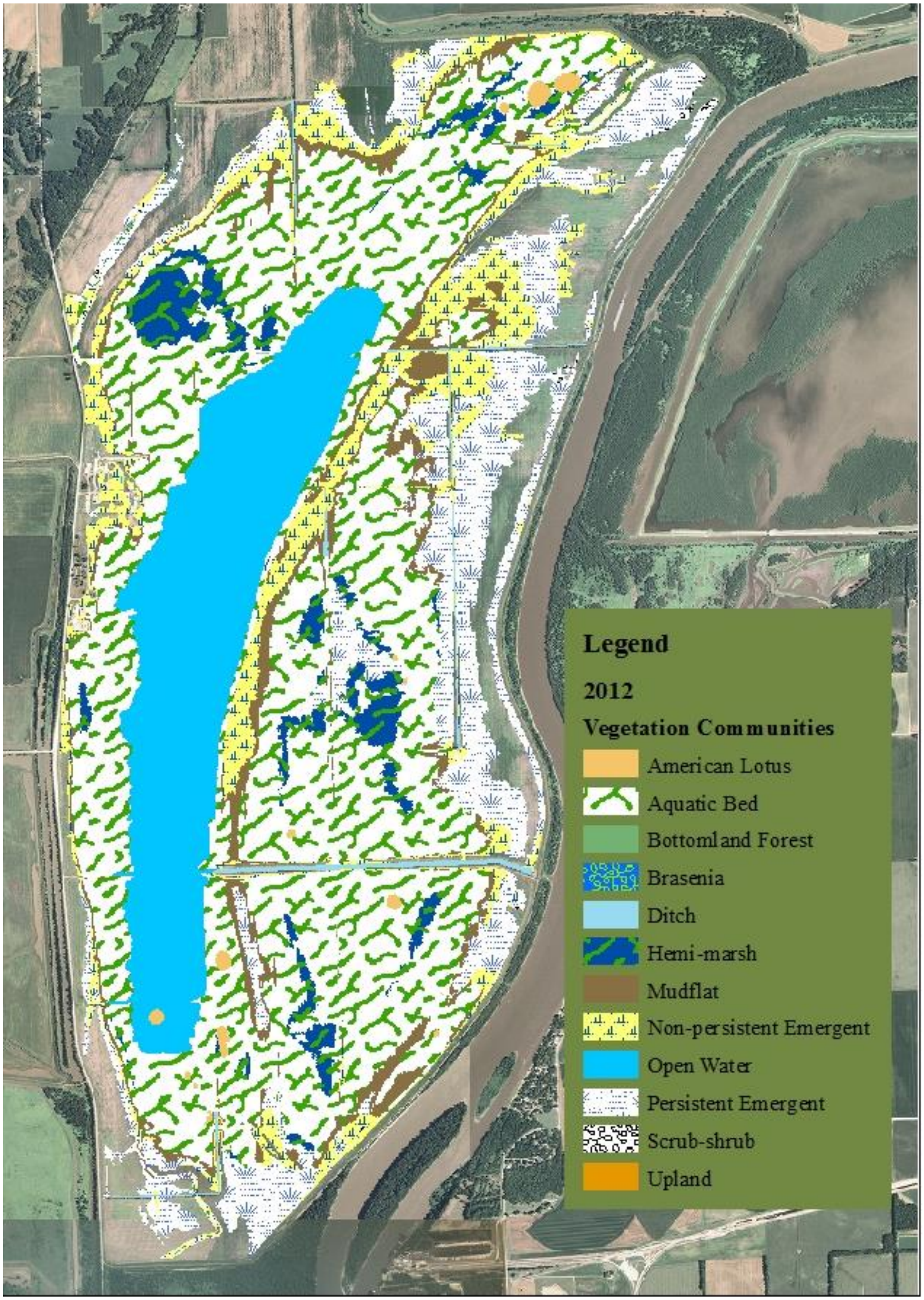


Figure 23. Wetland vegetation map of The Emiquon Preserve (1,782 ha), 10–17 September, 2012.

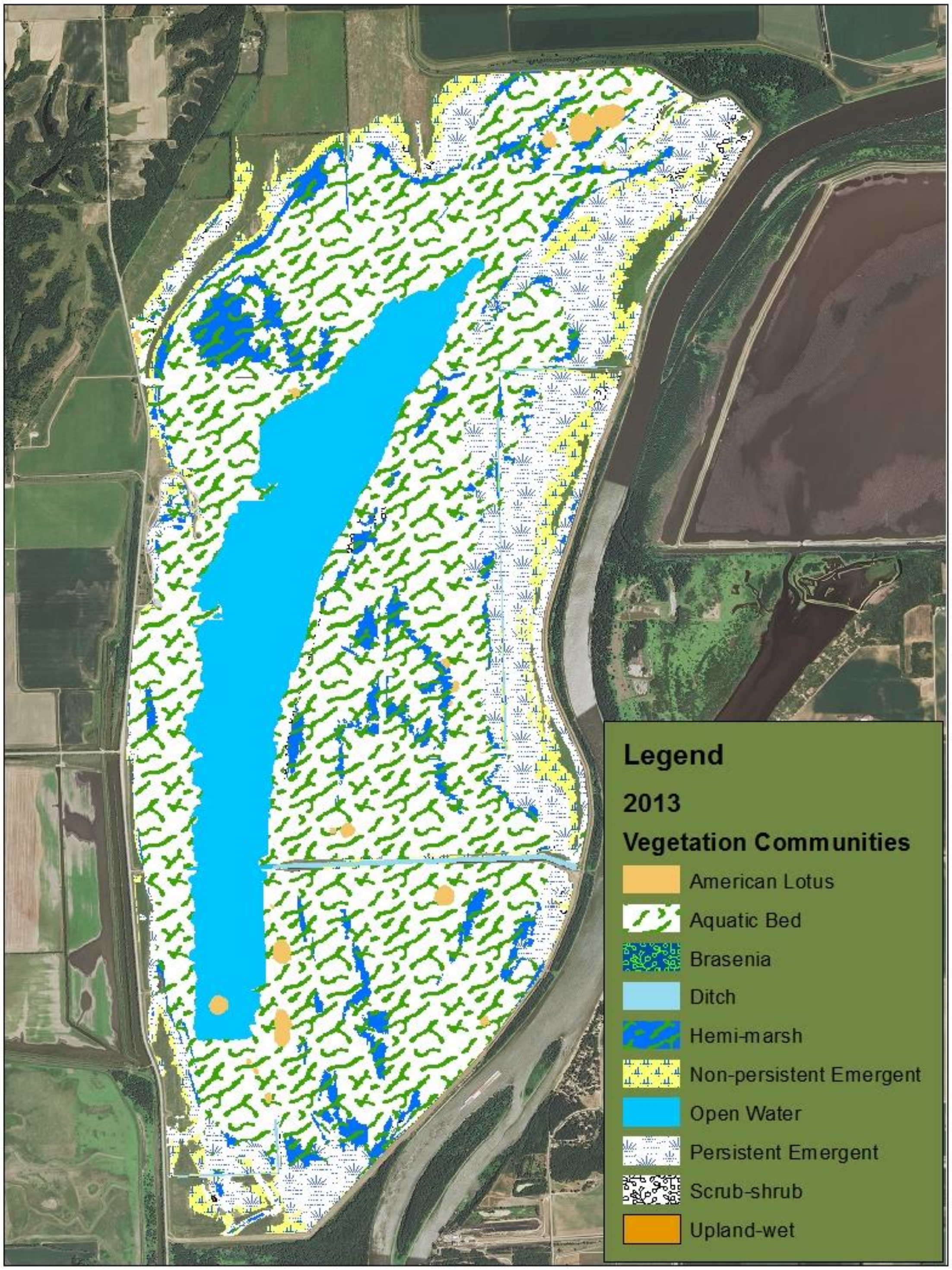


Figure 24. Wetland vegetation map of The Emiquon Preserve (1,944 ha), 23 August–6 September, 2013.

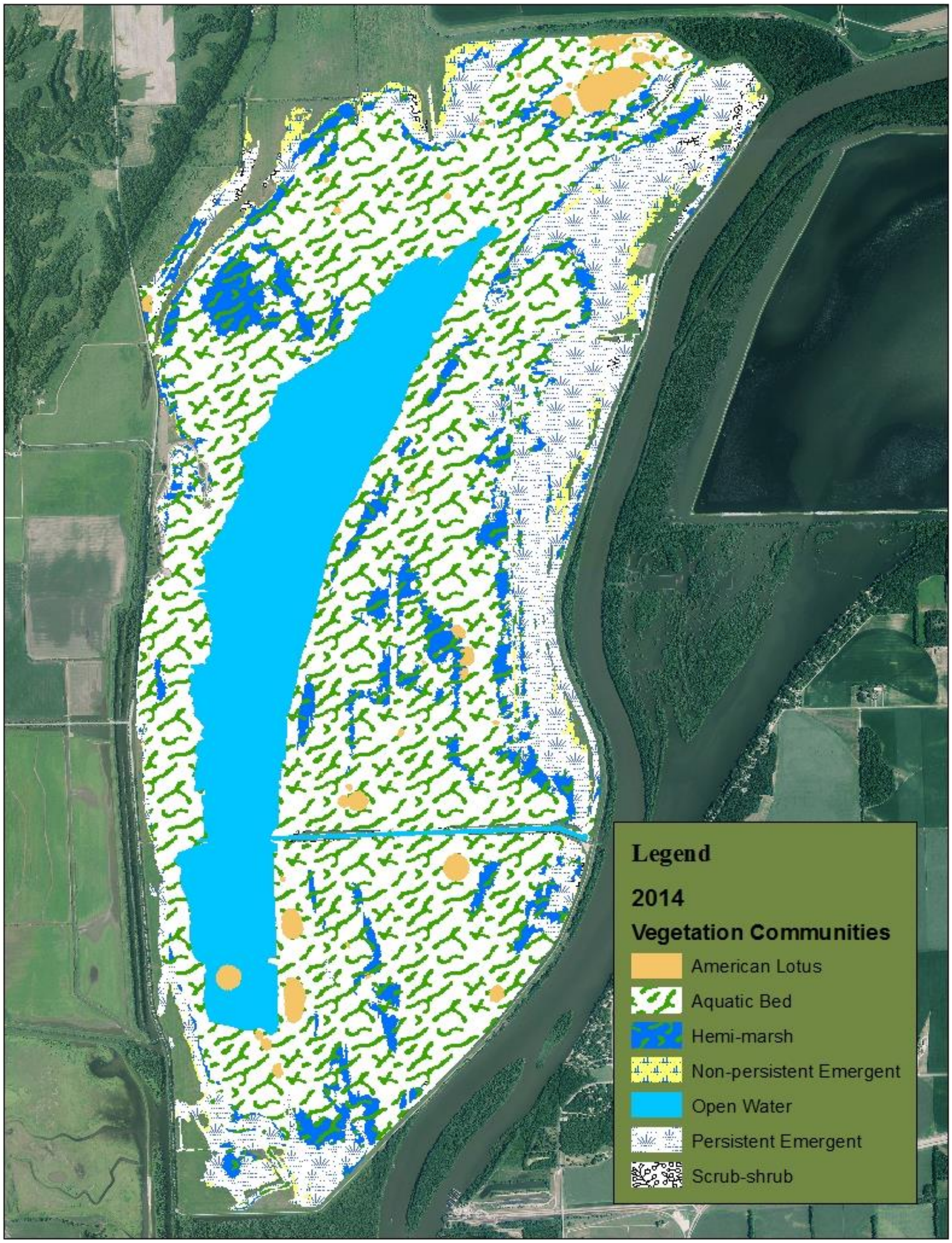


Figure 25. Wetland vegetation map of The Emiquon Preserve (1,944 ha), 4–16 September, 2014.

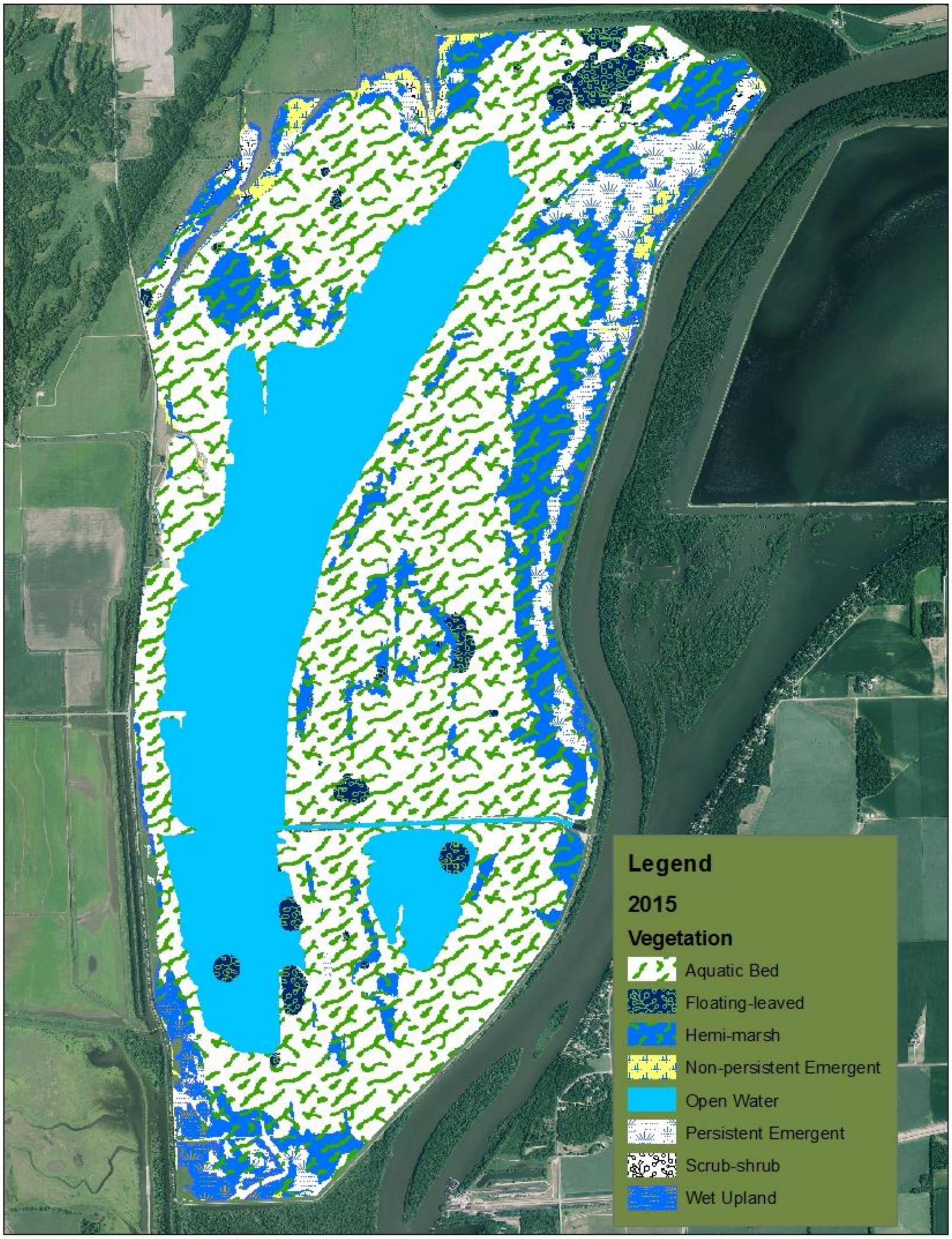


Figure 26. Wetland vegetation map of The Emiquon Preserve (2,017 ha), 14–21 September, 2015.

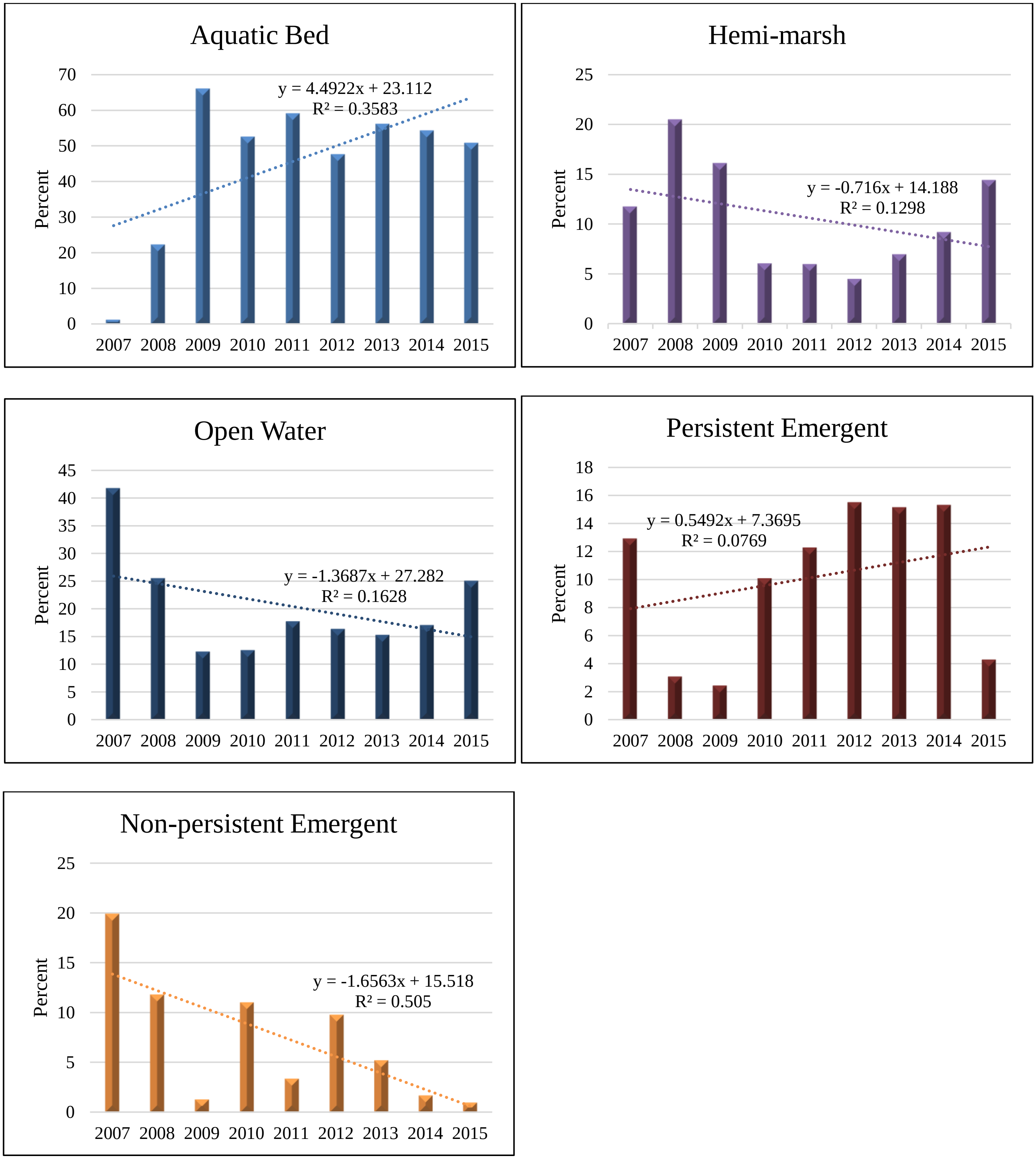


Figure 27. Trends in vegetation community composition (%) at Emiquon Preserve, 2007–2015.

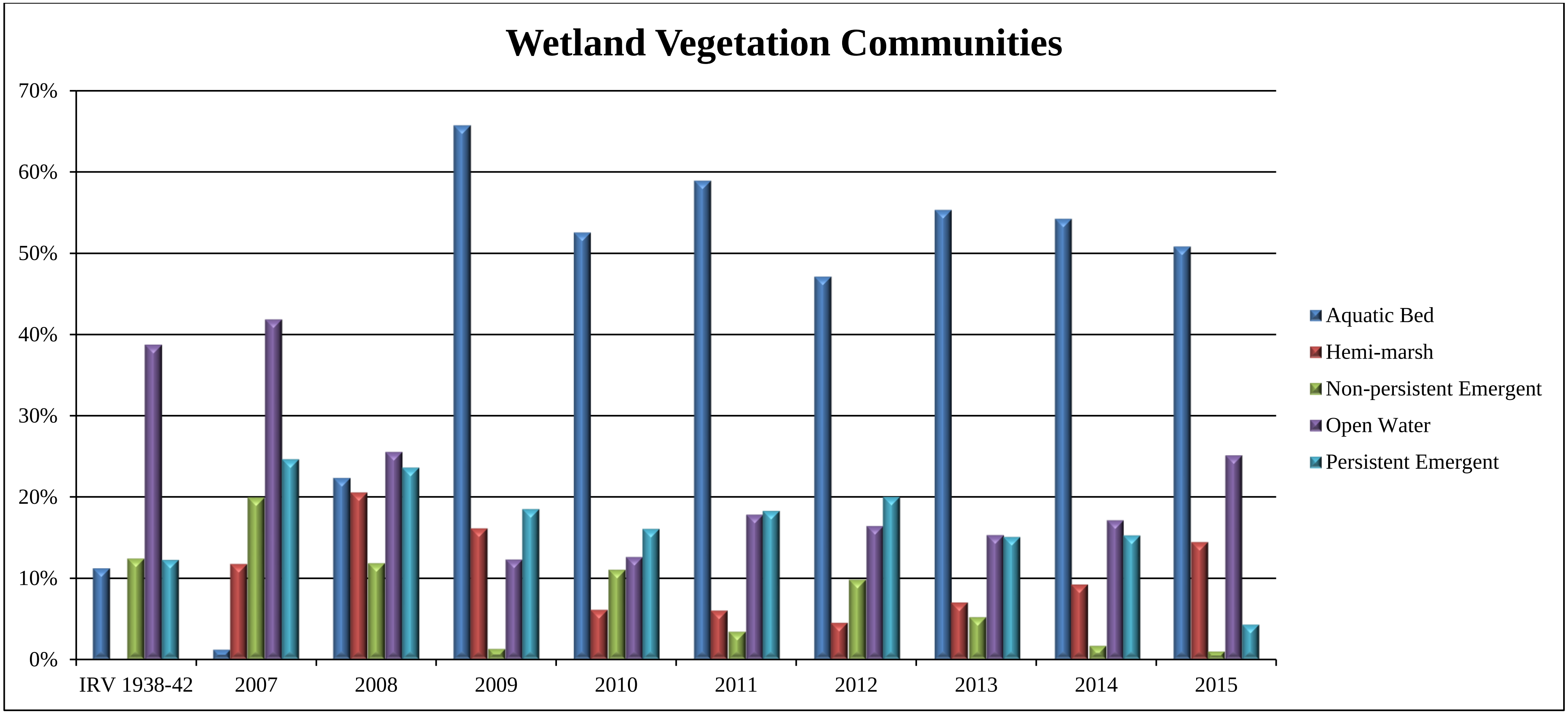


Figure 28. Proportional coverage of wetland vegetation communities at the Emiquon Preserve during early fall 2007–2015 and those historically present in the IRV wetlands (1938–1942).

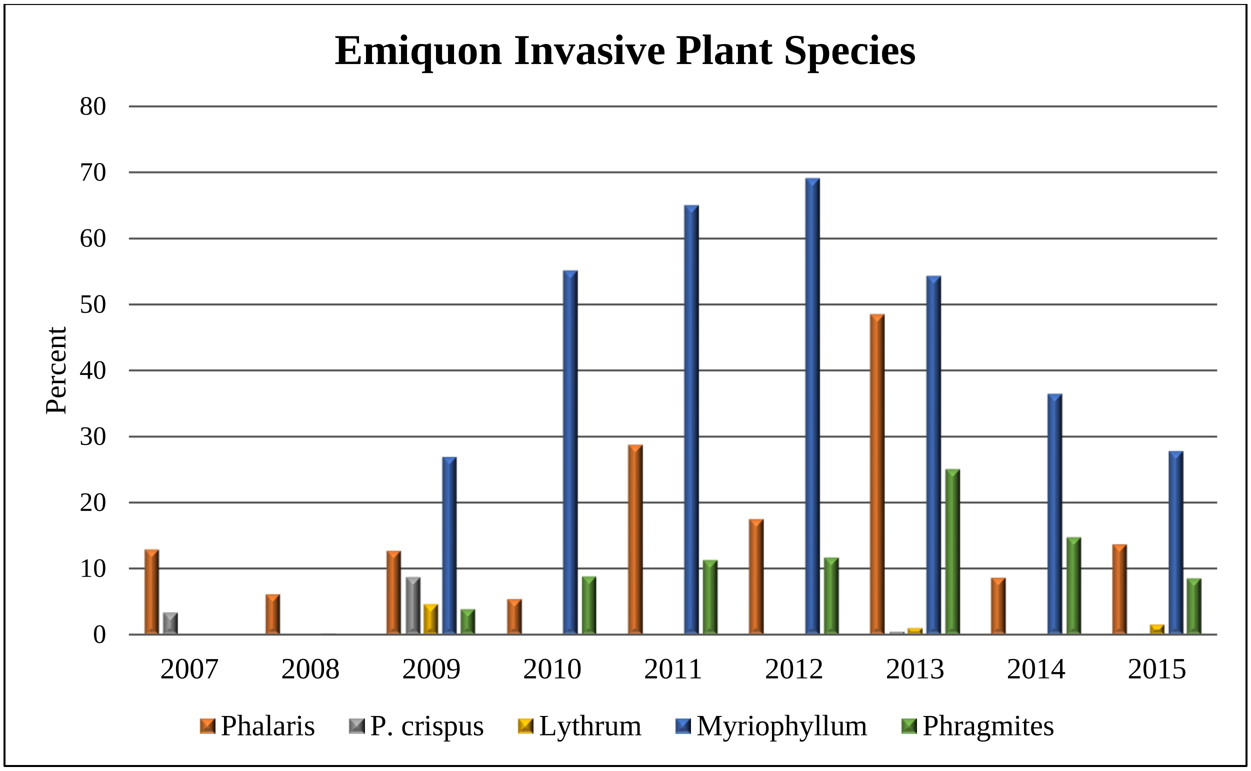


Figure 29. Proportion of cover map polygons containing invasive species encountered at Emiquon Preserve, 2007–2015.

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

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

Table 1. Continued.

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

Table 2. Plant species encountered during wetland covermapping at The Emiquon Preserve, 2007−2015.

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.
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*
Dogbane	*Apocynum* spp.

Table 2. Continued.

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

Table 2. Continued.

Common Name	Scientific Name
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*
Pigweed	*Amaranthus* spp.
Plantain	*Plantago* spp.
Pokeweed	*Phytolacca* spp.
Prairie Cordgrass	*Spartina pectinata*
Prickly Sida	*Sida spinosa*
Purple Loosestrife	*Lythrum salicaria*
Ragweed	*Ambrosia* spp.
Rattlesnake Master	*Eryngium yuccifolium*
Red-rooted Nutgrass	*Cyperus erythrorhizos*
Reed Canarygrass	*Phalaris arundinacea*
Ribbonleaf Pondweed	*Potamogeton epihydrus*
Rice Cutgrass	*Leersia oryzoides*
River Birch	*Betula nigra*
River Bulrush	*Scirpus fluviatilis*
Rush	*Juncus* spp.
Sagittaria (Arrowhead)	*Sagitarria* spp.
Sago Pondweed	*Stuckenia pectinata*
Sallow Sedge	*Carex lurida*
Scouring Rush	*Equisetum hyemal affinis*
Shattercane	*Sorghum bicolor*
Silver Maple	*Acer saccharinum*
Small Pondweed	*Potamogeton Pusillis*
Smooth Brome	*Bromus inermis*
Softstem Bulrush	*Schoenoplectus Tabernaemontani*
Sowthistle	*Sonchus* spp.
Spikerush	*Eleocharis* spp.
Sprangletop	*Leptochloa fascicularis*
Spurge	*Euphorbia* spp.
Straw-colored Flatsedge	*Cyperus strigosus*

Table 2. Continued.

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

Table 3. Abundances of waterfowl and waterbirds observed during fall aerial inventories at Emiquon Preserve, 2007–2015.

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
Total	**N**	2,595,475	384,980	48,740	2,021,545	3,050,634	2,979,345	6,029,979
	Proportion	43.0%	6.4%	0.8%	33.5%	50.6%	49.4%	100.0%

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%	23.3%	18.7%	22.5%	32.3%	67.7%	

Table 5. 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 5. 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 5. 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 5. 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 6. Area (ha) of vegetation communities at The Emiquon Preserve during fall, 2007–2015.

Habitat Category	2007	2008	2009	2010	2011	2012	2013	2014	2015
Aquatic Bed	2.6	238.1	1,185.7	1,036.3	1,071.7	839.5	1,091.9	1,054.8	1,024.3
Bottomland Forest	0.0	0.2	0.8	1.0	1.0	0.2	0.0	0.0	0.0
Cattail	25.5	33.1	38.1	N/A[a]	N/A[a]	N/A[a]	N/A[a]	N/A[a]	N/A[a]
Coontail	0.4	2.6	N/A[b]	N/A[b]	N/A[b]	N/A[b]	N/A[b]	N/A[b]	N/A[b]
Ditch	18.7	15.4	12.2	14.0	11.6	13.6	11.5	0.0	0.0
Floating-leaved[c]	0.0	0.1	0.6	1.0	4.2	9.0	17.1	35.0	47.0
Hemi-marsh	29.9	220.5	290.4	119.8	109.3	80.7	135.4	178.6	290.1
Mudflat	3.5	0.0	0.0	83.2	11.8	93.4	0.0	0.0	0.0
Non-persistent Emergent	50.7	127.3	23.6	217.7	61.5	174.4	101.3	33.7	21.1
Open Water	106.4	275.1	221.3	248.7	323.5	292.4	298.2	332.9	505.9
Persistent Emergent	7.4	0.2	6.2	199.0	223.3	276.2	294.3	297.7	86.3
Scrub Shrub	6.9	1.4	1.7	0.3	2.3	2.7	10.9	11.3	6.1
Upland	2.7	14.7	1.1	53.1	0.2	0.2	0.0	0.0	0.0
Upland - Wet	0.0	147.9	16.1	N/A	N/A	N/A	0.1	0.0	36.4
Willow	0.2	0.7	0.1	N/A[d]	N/A[d]	N/A[d]	N/A[d]	N/A[d]	N/A[d]
Total Area	254.7	1,077.2	1,803.9	1,974.1	1,820.6	1,782.3	1,943.6	1,944.2	2,017.0

[a] Cattail was included with persistent emergent or hemi-marsh in 2010.

[b] Coontail was included with the aquatic bed category in 2009.

[c] Includes lotus and watershield

[d] Willow was included with scrub-shrub or bottomland forest in 2010.

Appendix A. Conservation targets and Key Ecological Attributes (KEAs) of The Nature Conservancy at The Emiquon Preserve during 2007−2016 for waterbird and wetland monitoring objectives with observed values good (green), fair (yellow), or poor (red) relative to desired ranges.

Key Ecological Attribute	Indicator	Desired range			Results									
		Good	**Fair**	**Poor**	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Waterbird Habitat Quality	Fall Dabbling Duck Use Days	IRV ranking 1–5 (>1,132 UD/ha)	IRV ranking 5–10 (289–1,131 UD/ha)	IRV ranking <10 (<289 UD/ha)	4,813	2,035	1,418	1,773	2,131	1,722	1,611	739	960	TBD
	Fall Other Dabbling Duck Use Days	IRV ranking 1–5 (>493 UD/ha)	IRV ranking 5–10 (88–492 UD/ha)	IRV ranking <10 (<88 UD/ha)	3,821	1,261	1,082	1,507	1,680	1,438	1,391	598	805	TBD
	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	TBD
	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	TBD
	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	TBD
	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	TBD
	Spring Diving Duck Use Days	IRV ranking 1–12 (>120 UD/ha)	IRV ranking 13–28 (40–120 UD/ha)	IRV ranking <28 (<40 UD/ha)	–	336	383	236	237	214	156	216	158	399
	Spring Dabbling Duck Use Days	>486 UD/ha	486–376 UD/ha	<376 UD/ha	–	513	487	213	261	426	325	228	260	391
	Spring Other waterbird Use Days	>469 UD/ha	469–346 UD/ha	<346 UD/ha	–	358	713	334	192	470	107	411	456	975
	Duck Foraging Rates	>50%	30–50%	<30%	–	22	46	58	53	51	45	36	50	57
	Moist-soil Plant Seed Production	≥800 kg/ha	578–779 kg/ha	<578 kg/ha	1,132	547	256	733	1,246	591	565	1,115	465	TBD
Waterbird Production	Waterbird Brood Density	>10 broods/km2 peak	5–9 broods/km2 peak	<5 broods/km2 peak	–	22	24	28	25	29	19	6	10	TBD
	Waterbird (Non-waterfowl) Brood Species Richness	>5 species	3–5 species	<3 species	–	3	2	1	3	3	3	3	4	TBD
	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	TBD
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	TBD
	Cattail, river bulrush, bur reed dominance	Single species <50% of emergent coverage	–	Single species >50% of emergent coverage	>50%[a]	>50%[a]	>50%[a]	>50%[a]	>50%[a]	>50%[a]	>50%[a]	>50%[a]	>50%[a]	TBD
Community Composition (Moist-soil Vegetation)	Non-woody invasives	<50% goldenrod, cocklebur, etc.	–	>50% goldenrod, cocklebur, etc.	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]	<50%[a]	TBD
	Woody encroachment	<25% coverage of woody invasives	–	>25% coverage of woody invasives	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]	<25%[a]	TBD
	Forb and grass coverage	Forbs ≥10% coverage	–	Forbs <10% coverage	–	–	–	–	–	–	19	19	38	TBD

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