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# An Assessment of Aquatic Invasive Plants in the Illinois River: water hyacinth surveillance, mapping, persistence, and potential seed dispersal

## Annual Progress Report

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**Annual Report – Final FY2015**

# EXECUTIVE SUMMARY

**<u>Project Title</u>: An Assessment of Aquatic Invasive Plants in the Illinois River: water hyacinth surveillance, mapping, persistence, and potential seed dispersal**

**<u>Objectives</u>**:

1. Documenting the current distribution of mature water hyacinth plants in the Illinois River/CAWS corridor and comparing with historical records and sightings.
2. Comparing seed densities and frequencies in seed banks and dispersal in areas where dense colonies of water hyacinth occur and non-occupied areas (i.e., control) in the main Illinois River channel and associated backwaters.
3. Concurrently assessing the temporal and spatial overlap between recurring stands of water hyacinth and the presence of their seeds in their underlying seed bank
4. Developing and evaluating a rapid aerial survey technique to detect and map locations of water hyacinth along the Illinois River

Water hyacinth (*Eichhornia crassipes*) is becoming a reoccurring problem in the Illinois River – Chicago Areas Waterway System (CAWS), but the current extent and potential for future intensification are largely unknown in this system. Regular reoccurrence of water hyacinth represents a significant threat to the recreation, fisheries, and wildlife resources, economy, and ecological processes of both the Great Lakes and the Illinois & Mississippi River systems. We conducted aerial surveillance flights and boat surveys of floating-leaved vegetation with visual signatures of water hyacinth from Hennepin, IL to Joliet, IL along the Illinois River twice during the summer and fall 2014. We collected sediment cores in random sites throughout the Dresden and Starved Rock reaches, and at water hyacinth bed locations. We collected and assessed diets of 26 Common Carp (*Cyprinus carpio*) to determine evidence of water hyacinth seed presence. We discovered a total of 14 water hyacinth beds in 2014. We located five beds of water hyacinth while conducting aerial surveillance, and an additional nine water hyacinth beds via ground surveillance yielding a 35.7% detection rate of water hyacinth beds. We found water hyacinth seed densities were greatest beneath water hyacinth beds and least in random samples. We determined that frequency of water hyacinth seed (whole or partial) in common carp diets was 30.8% of the total carp assessed while mean seed density was 1.7 seeds/carp. We determined that although water hyacinth seeds are present in the seed bank and within dispersal vectors (i.e., common carp), water hyacinth in Illinois likely relies on annual reintroduction as seed germination rates were extremely low.

**<u>Project Title</u>: An Assessment of Aquatic Invasive Plants in the Illinois River: water hyacinth surveillance, mapping, persistence, and potential seed dispersal**

**Introduction**

Water hyacinth (*Eichhornia crassipes*) is an invasive aquatic macrophyte native to Lower Amazonia, Brazil, South America (Penfound and Earle, 1948). Water hyacinth forms dense mats on the surface of slow-moving waterways and backwaters, restricting commercial and recreation traffic, outcompeting native emergent and submerged plants, and affecting natural biogeochemical and evapotranspiration cycles (Penfound and Earle 1948, Rai and Datta Munshi 1979). Large, leathery "sail-like" leaves with swollen petioles allow water hyacinth to be blown through the water with ease, and a new colony can be created from a single propagule (Bock, 1969). Water hyacinth beds are easily disturbed by water current, wind, or wave action, spreading plants to new localities within the system (Burton, 2005).

Water hyacinth is becoming a reoccurring problem in the Illinois River – Chicago Areas Waterway System (CAWS), but the current extent and potential for future intensification are largely unknown in this system. Regular reoccurrence of water hyacinth represents a significant threat to the recreation, fisheries, and wildlife resources, economy, and ecological processes of both the Great Lakes and the Illinois & Mississippi River systems. Considering the scale and density to which water hyacinth mats can grow, it can be extremely problematic and costly to control. Several methods are commonly used to mitigate issues associated with large beds, including biological, chemical, mechanical, and integrated control methods. Because water hyacinth has the potential to substantially degrade aquatic and wetland resources wherever it becomes established, proactive management of biomass and prevention are the best methods of control (Gopal, 1987; Villamagna and Murphy, 2010). Risk assessment, surveillance, and control of aquatic invasive plants like water hyacinth relies on a firm understanding of the factors controlling its establishment and dispersal.

## Methods

### *Study Area*

The study area is located along the upper Illinois Waterway (Figure 1), including sections of the Illinois, Des Plaines, and Kankakee rivers and the Chicago Area Waterway System (CAWS). The Illinois River proper is formed at the confluence of the Des Plaines and Kankakee Rivers and consists of the upper Peoria reach, Starved Rock reach, Marseilles reach, Dresden reach, and Brandon Road reach (river miles 208–291; Fig. 1). Search areas included the main channel, connected and disconnected backwaters, sloughs, marinas, and other slack-water areas in or near the river floodplain where water hyacinth may be present. We also conducted surveys outside of the main study area, in areas neighboring the survey route and where hyacinth was likely to grow (e.g., golf course ponds).

### ***Surveillance***

*Aerial surveys* - Flights for surveillance of floating-leaved vegetation and water hyacinth occurred from Hennepin, IL to Joliet, IL along the Illinois River during August and October 2014 – a period when hyacinth has been previously reported to occur in the Dresden Reach. Aerial surveys were conducted using a 1971 Piper Arrow low-winged aircraft traveling at approximately 130 mph and 200 ft. altitude. During each aerial survey prior to vegetation assessments, we flew over areas of known size (i.e., athletic fields) at surveillance altitudes to provide surveyors with a reference size to ensure accurate estimations of bed size. During low-altitude surveys, two observers were seated on the same side of the aircraft and communicated locations of beds and size (front and rear seating; Cook and Jacobson 1979). We searched water surfaces for floating-leaved vegetation including the main channel, off-channel, connected and disconnected wetlands and lakes within the 100-year floodplain, marinas, and other slack-water areas in or near the river floodplain within the study area where water hyacinth may have been present. We marked the locations of hyacinth beds and plant colonies having visual signatures resembling water hyacinth with a GPS waypoint. Once a colony was located and marked, observers discussed vegetation identity until an agreement was reached, with the airplane circling multiple times to ensure accuracy.

*Ground Surveys* — We conducted a complete search of all accessible areas from the river and adjacent floodplain by foot and boat within one week of aerial surveys to estimate aerial detection probability. During ground-truthing, we visited all aerially-marked waypoints by boat to verify aerial species identifications and bed size estimates (Everitt et al. 1999). Ground surveys also covered all accessible backwaters, sloughs, and the main navigation channel of the Illinois River. Ground surveys were extensive, and we assumed that detection was 100%. Aggregations of plants were deemed a "bed" based on occurrence of at least a 21.5 $ft^2$ patch of water hyacinth plants separated by water from another bed.

***Biomass Sampling***

During October at each established water hyacinth bed, we collected three random replicate 1.25 $ft^2$ samples of water hyacinth using a modified Gerking box sampler (hereafter: box sampler; Downing and Anderson 1985, Sychra and Adamek 2010). To reduce the possibility of altering seed production or effects of water hyacinth beds, a bed was not box sampled if it was small and a significant portion would have been removed. Multiple water hyacinth plants connected by stolons which lay outside the box sampler edges were separated, and only plants that laid completely within the box sampler area were collected. After collection, samples were placed in secure, plastic containers for transport. In a lab, samples were rinsed with tap water to remove soil, inorganic debris, or other aquatic macrophytes. Water hyacinth plants were dried to a constant weight at 80°C for 48 hours and weighed to the nearest 0.01 g (Downing and Anderson 1985).

***Seed Bank Sampling***

*Core and Sweep Samples* — In 2014 I collected two sets of benthic core samples and water column sweep samples at 1) random sites and 2) water hyacinth bed sites. Random site samples were obtained during October throughout the entire Dresden and Starved Rock reaches. I took three replicate samples at each of 30 random sites in each respective reach. Random sites were generated using ArcMap 10.2.2 (ESRI, Redlands, California, USA) within location polygons (Dresden Reach, Starved Rock Reach, etc.) which were created in ArcMap using aerial imagery. I obtained three randomly-placed cores and three vertical sweep net samples within 5 m of each site; homogenized the three samples in a Wildco (Yulee, Florida, USA) sieve bucket with 500-um aperture screen; rinsed excess soil and detritus from samples; and placed the remaining material into Ziploc bags for transport to a laboratory. I collected five sediment cores and five vertical sweep net samples at each water hyacinth bed. All individual sediment cores and sweep net samples were combined and processed as previously described. At water hyacinth bed sites, I also measured the overall bed size and calculated area ($ft^2$).

Subsequently in a laboratory, all sediment core and sweep net samples were rinsed through 500-um apertures screens; air dried; and sub-sampled by 25% to reduce processing time (Hagy et al. 2011, Stafford et al. 2011). Samples weighing <10 g were processed completely. Seeds were removed by hand from samples, identified by microscopy to species or lowest possible taxonomical unit, dried at 80°C for 24 hours, and weighed to the nearest 0.1 mg. The number of and biomass of seeds was corrected for processing and recovery bias using sizespecific correction factors (Hagy et al. 2011).

*Fish Sampling* — We collected common carp (*Cyprinus carpio*) throughout the Dresden reach of the Illinois River twice during September and October. We used AC and DC boat-mounted electroshocking techniques to obtain 26 common carp. Emphasis was placed on electroshocking hyacinth beds, and fish shocked directly from a water hyacinth bed were labeled accordingly. Immediately after capture, fish were placed on ice until the entire digestive tract (anus – mouth) was removed and preserved with 10% formalin in a laboratory (<3 hours; Garcia-Berthou 2001) (Institutional Animal Care and Use Committee Protocol #12049; Wild Fish Population Studies). Later in a laboratory, all contents including seeds, invertebrates, and vegetation were removed from the digestive tract, identified to species or lowest possible taxonomical unit, dried at 70°C, and weighed to the nearest 0.1 mg (Colle et al. 1978).

**Results**

*Surveillance and Biomass Sampling* — In 2014, we located free-floating water hyacinth plants in the DuPage River on 5 August, but no water hyacinth beds were located until 1 October 2014, when we located 5 water hyacinth beds aerially and an additional 9 water hyacinth beds via ground surveillance (totaling 1,980.6 $ft^2$ in size). Water hyacinth beds were located in both the Des Plaines River ($n$ = 7) and the DuPage River ($n$ =7; a tributary of the Des Plaines River). Free-floating water hyacinth vegetative propagules were located throughout the Dresden reach 2014 and were typically discovered downstream of water hyacinth beds. Box samples of water hyacinth bed biomass were collected at 9 of 14 beds in 2014 due to the small size of water hyacinth beds. We calculated the total dried biomass of water hyacinth beds in the Dresden reach in 2014 to be 36.1 kg. Water hyacinth mean bed size was 13.1 $m^2$ ± 4.0 ($n$ = 14) in 2014.

On October $2^{nd}$, Illinois Department of Natural Resources (IDNR) personnel alerted us to a water hyacinth sighting in Lake Springfield (39.671396, -89.666282; Springfield, IL). An electrofishing crew collected all plants observed (5) and removed them from the lake. No further sightings in Lake Springfield have come to our attention. All water hyacinth sightings and locations have been reported to the Early Detection and Distribution Mapping System (EDDMapS; www.eddmaps.org), a website which maps and documents distributions of invasive species.

*Sediment Core Samples* — We found water hyacinth seed to be present in 100% of all sediment cores taken at from water hyacinth beds ($n$ = 13), and 43% of random sediment cores throughout the Dresden reach ($n$ = 30). Water hyacinth beds had the highest mean seed density (1,112.7 ± 265.1 seeds/ft$^2$; Table 1). Water hyacinth beds located in the Des Plaines River had a mean seed density (1,606.4 ± 430.5 seeds/ft$^2$; $n$ = 7) that was greater than the DuPage River water hyacinth bed sediment cores (626.2 ± 180.1 seeds/ft$^2$; $n$ = 6; Table 1). Random sediment cores in the Dresden reach in 2014 ($n$ = 30) had a lesser mean seed density (252.1 ± 82.4 seeds/ft$^2$) than water hyacinth beds (Table 1). We found no water hyacinth seeds in Starved Rock reach random sediment cores ($n$ = 30; Table 1).

*Sweep Net Samples* — In 2014, no water hyacinth seeds were collected in sweep net samples in the Dresden reach random samples ($n$ = 30) or Starved Rock reach sweep net samples ($n$ = 30). Water hyacinth seeds were collected in sweep net samples from water hyacinth beds ($n$ = 11; 1.9 ± 1.1 seeds/ft$^2$), but seeds were only present in sweep net samples from water hyacinth beds in the Des Plaines River ($n$ = 6; 3.4 ± 1.9 seeds/ft$^2$) and none were collected in DuPage River water hyacinth beds ($n$ = 5).

*Seeds in Common Carp stomachs*

Electrofishing techniques were used to collect 26 common carp during fall 2014. Contents of the digestive tracts have been assessed for the presence of water hyacinth seeds. We calculated that 23% of all carp had whole water hyacinth seed present, and 23.1% had water hyacinth seed evidence (i.e., seed casing or seed fragments) present within the digestive tract, totaling 30.8% of all carp processed showing evidence of water hyacinth seed consumption (Table 2). We calculated that 75% of carp collected within a water hyacinth bed ($n$ = 4) had whole water hyacinth seeds present in the digestive tract and an additional 75% had partial or broken water hyacinth seeds (Table 2). We calculated that 13.6% of carp collected at random locations within the Dresden Reach ($n$ = 22) contained whole water hyacinth seeds and 13.6% contained partial or nonviable water hyacinth seed, totaling 22.7% of carp collected from random locations showing evidence of water hyacinth seed consumption (Table 2).

*Aerial surveillance*

We conducted two aerial surveys of the upper Illinois River during fall 2014. We mapped floating leaved aquatic vegetation with visual characteristics resembling water hyacinth and estimated species composition and size of the plant colony. Plant colony species composition error rate describes the percent of aerial observations of species composition that differed from ground-truthed species compositions. A negative error rate means estimates are greater from the plane than was actually present on the water, whereas a positive error rate means that estimates from the air were lower than measured by boat surveys. For example, we found a 100% error rate when estimating percent species composition of white water lily (*Nymphaea odorata*) because we located one bed from the air and designated the bed 100% white water lily, but ground surveys indicated that 1% of the bed was water hyacinth in addition to white water lily. However, in this example, we correctly identified that white water lily was present and the dominant form of vegetation cover in the bed, but misclassified 1% of the vegetation coverage; thus, the effect size of our error rate was actually quite small.

We located 24 floating-leaved plant colonies in the Dresden reach during 5 flights. Plant colony species composition error rates showed high variation. We estimated a 28.6% error rate for creeping water primrose (*Ludwigia peploides*), whereas for water hyacinth we estimated only a 14.3% error rate (Table 3). We estimated a 100% plant colony species composition error rate for white water lily, broadleaf arrowhead (*Sagittaria latifolia*), and pickerelweed (*Pontederia chordata*). We estimated a plant colony species composition error rate of 40.0% for American lotus (*Nelumbo lutea*). Species identification error rate for creeping water primrose (-5.57%; SE = 5.74; $n$ = 7), water hyacinth (0.14%; SE = 0.38; $n$ = 7), white water lily (-1.00%; $n$ = 1) and American lotus (7.80%; SE = 8.05, $n$ = 5) were all relatively low, meaning that our overall accuracy was quite high and we had few species misidentifications of significant size (Table 3). Estimated species error rates for both broadleaf arrowhead (-90.0%; $n$ = 1) and pickerelweed (90.0%; $n$ = 1) were high, but only occurred within one bed where both species were present (Table 3). We identified 5 of 14 water hyacinth beds aerially (35.7%).

**Discussion**

The Dresden reach of the Illinois River is the only location in Illinois to host an annually reoccurring water hyacinth population, at least for the last 4-5 years. Invasion is likely due to the re-introduction of vegetative water hyacinth plants annually, but may be exacerbated by the discovery of water hyacinth seeds in the seed bank. It is well understood that water hyacinths main reproductive strategy is asexual (i.e., vegetative), and secondarily sexual reproduction, although sexual reproduction may have a reduced frequency in temperate populations (Barrett

1980). Flowering water hyacinth was observed from August-October of 2014 in the Dresden reach, and capsules containing seeds were observed during peak seed fecundity months.

Mean water hyacinth seed density and biomass was greater in 2014 than 2013. Greater estimates in 2014 may be attributable to an increase in water hyacinth bed numbers and spatial distribution, even though total size of water hyacinth beds was greater in 2013. Water hyacinth seed density and biomass was greatest from samples collected from directly beneath water hyacinth beds during sampling conducted in September and October when water hyacinth seed fecundity should be highest annually. Water hyacinth seed density and biomass was secondarily greatest in historically infested locations (i.e., Big Basin, Treats Island, and Big Basin Marina). The presence of water hyacinth seeds in random samples throughout the Dresden reach, although in low densities and biomass, provides evidence of dispersal of water hyacinth seeds, potentially presenting risk of future infestations. Core samples from random sites showed that 90.1% of water hyacinth seeds collected occurred downriver of at least one water hyacinth bed, suggesting that hydrochory may be an important mechanism of water hyacinth seed dispersal in the Illinois River. Attempted germination studies of water hyacinth seeds from the Dresden reach have yielded near 0% germination of more than 200 seeds (VonBank et al., unpublished data) following similar methods as Barrett (1980; 87.5% germination success) which may indicate that water hyacinth seeds produced in the Dresden reach are non-viable or environmental conditions are not favorable, thus greatly reducing the risk of potential future infestations via seedling establishment.

We found seeds in the digestive tracts of common carp collected from directly beneath water hyacinth, as well as from carp collected away from the water hyacinth bed. Common carp (*Cyprinus carpio*) frequently ingest seeds when foraging (Balon, 1995; Hossain et al., 2001) and are known to increase germination post-digestion (Pollux et al., 2006). Pending verified viability of water hyacinth seeds in the Illinois River, water hyacinth seed dispersal by fish has the potential to amplify the infestation of water hyacinth throughout the upper and lower reaches of the Illinois River.

Aerial surveillance for water hyacinth proved to be successful, but could be improved. Our correct identification of water hyacinth suggests that surveillance for this plant from the air is a practical endeavor. Estimations of plant colony species composition were moderately successful, but can also likely be improved. Species identification of water hyacinth was very accurate from the air, and error rates associated with the misidentification of water hyacinth were low. High species identification errors (i.e., *Sagittaria latifolia* and *Pontederia chordata*) can be attributed to small sample sizes. Aerial surveillance of water hyacinth is a time efficient method, but small beds or those occurring under tree canopies, as we noted in the DuPage River, may be missed during aerial surveys. An assessment of costs associated with aerial surveillance (i.e., contracted flight costs, staff salary, vehicle mileage, etc.) as compared to costs associated to ground surveillance (i.e., lodging, staff salary, fuel, etc.) indicated that both methods are similar in costs, however due to a 35.7% detection rate of water hyacinth beds aerially, ground surveillance may be a more effective method of surveillance if staff and funding are available.

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# FIGURES

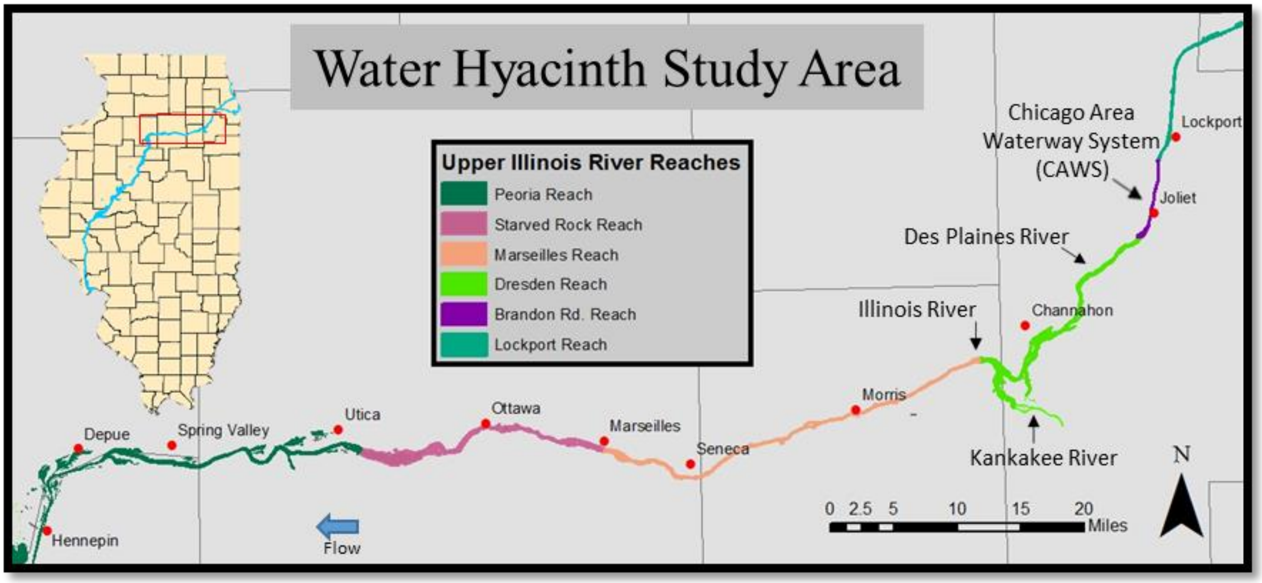


**Figure 1**. The upper Illinois River, Chicago Area Waterway System, associated tributaries common names of river reaches between dams, cities adjacent to the river, and flow direction.

# TABLES

**Table 1.** Water hyacinth seed density (m²; $\bar{x}$, SE) and seed biomass (kg/ha, $\bar{x}$, SE) in sediment core samples by year, site type, site name, and sample size.

| | | | | Density | | Biomass | |
|---|---|---|---|---|---|---|---|
| **Year** | **Site Type** | **Site Name** | ***n*** | $\bar{x}$ | **SE** | $\bar{x}$ | **SE** |
| 2014 | Random | Dresden Reach | 30 | 2,713.7 | 887.0 | 1.9 | 0.8 |
| | | Starved Rock Reach | 30 | 0.0 | – | 0.0 | – |
| | Water Hyacinth Bed | Des Plaines River | 7 | 16,673.9 | 4,450.8 | 25.2 | 6.8 |
| | | Du Page River | 6 | 6,496.5 | 1,860.4 | 9.8 | 2.9 |

**Table 2.** Frequency of occurrence of water hyacinth seeds in the digestive tracts of common carp by sampling period, location, and seed presence type. Whole seeds included one or more completely intact seeds, seed evidence included fragments of water hyacinth seed, and total seed presence is the presence of whole seeds, seed evidence, or both.

| Sampling Period | Carp Collection Location | *n* | Whole Seed(s) | Seed Evidence | Total Seed Presence |
|---|---|---|---|---|---|
| Fall 2014 / Year 2 Total[b] | Water Hyacinth Bed | 4 | 75.0% | 75.0% | 75.0% |
| | Random | 22 | 13.6% | 13.6% | 22.7% |
| | Total | 26 | 23% | 23.1% | 30.8% |

[b] Year 2 is defined as data from fall 2014.

**Table 3.** Percent error of plant colony species composition of aerially mapped floating-leaved aquatic vegetation. A negative error rate correlates to estimating a higher percent of that species from the plane than was actually present on the water. A positive error rate means that estimates from the air were lower than was actually present. Plant colony species composition error rate is the actual percentage difference (i.e., the effect size) of aerial species composition estimates from ground truth species compositions.

| Aerial Error Rate Type | *Ludwigia peploides* | *Nymphaea odorata* | *Eichhornia crassipes* | *Sagittaria latifolia* | *Pontederia chordata* | *Nelumbo lutea* |
|---|---|---|---|---|---|---|
| Plant Colony Species Composition | 28.6% | 100.0% | 14.3% | 100.0% | 100.0% | 40.0% |
| Species | -5.57% | -1% | 0.14% | -90% | 90% | 7.80% |