Sustainable Rivers Program

Vegetation Resilience and Ecological Modeling Summary Report 2022

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Above: Arrowhead beds at Mile 210 in Pool 26 (USACE photo)

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1 Introduction

Environmental Pool Management (EPM) for Mississippi River Pools 24-26, where the pool is held below full pool during the summer growing season, has shown that ecological conditions can be significantly enhanced for annual emergent aquatic plants production (moist-soil plants). River shoreline and island fringe areas, which are exposed by the lower pool, are consistently revegetated with species such as: arrowhead (*Sagittaria* spp.), smartweed (*Polygonum* spp.), millet (*Echinochloa* spp.), sedges (*Carex* spp.), Amazon sprangletop (*Leptochloa panicoides*), flatsedge (*Cyperus* spp.), etc. Seed production of these plants are valuable for resident and migratory waterbirds and also provide, bank stabilization, nutrient processing, sediment consolidation, invertebrate habitat, egg-laying structure for fish and amphibians, food for aquatic reptiles, cover and nursery habitat for juvenile fish, etc. Past implementation indicates EPM is an effective strategy for enhancing environmental benefits while supporting and maintaining conditions for navigation.

The vegetation resilience and ecological monitoring project consisted of four primary activities during fiscal year 2022. These included several measures of arrowhead populations and corm dynamics, development of ecological parameters for several abundant species, development of a non-EPM water surface elevation dataset, and verification and refinement of model outputs. A summary description of each activity is provided in the following paragraphs and results provided in the following report sections.

Field study of arrowhead resilience. Arrowhead grow from rhizomes, seed, and corms (often referred to as tubers) developed during past growing seasons (Marburger 1993; Sutton 1995). Corms can remain viable for years and dynamics are not wholly understood, though corm densities, positions, and energy content are an important component in arrowhead resilience. We investigated arrowhead resilience as it relates to implementation of EPM. In 2020, known locations of arrowhead were surveyed and a protocol for assessing tuber bioenergetics and abundancies was developed. During the summer of 2021, we utilized three methods to evaluate arrowhead populations and monitor growth and development in future years. These methods were utilized again in fall 2022 to increase our knowledge of arrowhead response and recovery resulting from long duration drawdowns after the historic flood of 2019.

Ecological modeling. An existing ecological model that simulates arrowhead recruitment, vegetative growth, and mortality was expanded to also include millet, smartweed, and waterfowl. Ecological information for millet and smartweed recruitment, growth, biomass including seed production, and mortality was developed in cooperation with SRP and incorporated in the model. Known tuber dynamics were modeled for arrowhead. Ecological information for waterfowl was developed and incorporated in the model for mallards, geese, and swan migration (season, species, and counts) and forage preferences.

Model verification. Finally, we worked with the Sustainable Rivers Program (SRP) to verify model outputs for vegetation and made refinements to ecological information and parameters used in the model. Verification used existing field observations for 2016. Spatial distributions of moist-soil plants as well as plant condition/productivity was considered.

2 Arrowhead corm sampling

2.1 Methods

Arrowhead (*Sagittaria latifolia*) were sampled randomly along transects in an area where it was known to occur previously. A total of 6 samples were gathered at the end of the growing season just before the first frost of fall 2022. Sampling was done in the fall based on lessons learned from the previous year's sample collections throughout the growing season. The number of samples gathered was limited by space to process samples.

Individuals were destructively sampled by excavating individual arrowhead plant root systems within a (0.5 m diameter X 0.5 m depth) 0.1 m^3 of sediment with long-bladed drain spades. Sampling locations were flooded with several inches of water which made root and corm sample collection more challenging to extract. A 0.5 m circle was first cut with a drain spade to approximately 0.5 m deep. Next multiple spades were used to help lift the sediment from the sample plot. The sample area was checked for any portions of the sample that may have broken loose during the transfer and retained. Sediment samples with roots were transferred to labelled collection containers for further processing.

Roots in samples were washed with running water to remove sediment from plant tissues. Roots of other species such as smartweeds, millets, and others were separated from arrowhead roots. Care was taken to extract all arrowhead corms from the samples. Plant parts were then transferred back to a clean collection container, air dried with a fan for 48 hours to prevent mold growth, and dried using a propagation heating mat for 72 hours at approximately 100^{o}F. Samples were measured and weighed after sample drying was completed. Corm weights and dimensions were recorded. Samples gathered contained between 1 and 5 corms. Samples may have contained multiple individuals so corm density would be limited to densities per sample rather than per plant.

2.2 Results

Corm counts, weights, and dimensions were recorded as available (Table 1).

Table 1: Arrowhead sample data per corm, 2022. Eleven corms were collected (mean average of 1.8 corms per sample; two of the six samples did not contain corms).

Sample #	Corm #	Weight (g)	Length 1 (mm)	Length 2 (mm)
1	1	4.7	23.6	33.0
2	1	1.8	18.6	19.2
2	2	0.6	11.2	18.0
2	3	0.4	10.2	14.8
3	1	5.2	28.4	27.1
3	2	1.8	28.1	11.9
4	1	3.8	22.5	25.4
4	2	1.2	21.2	14.3
4	3	0.4	17.3	9.4
4	4	0.4	17.6	13.4
4	5	1.1	29.4	17.9
Overall average (mean)		1.9	20.7	18.6

2.3 Discussion

Corm production and density remained relatively low across sampled plots compared to values found in other regions of the Upper Mississippi River. Two-thirds of samples contained corms; the average number of corms per sample was 1.8. The average weight of sampled corms was 1.9 grams, which is similar to results from 2021 (1.7 grams; USACE 2021). Corm size varied from 0.4 to 5.2 grams and may have been related to timing of formation. The report that summarized 2021 corm sampling efforts noted several biological and environmental factors from the literature that may influence corm production and development in arrowhead, including tradeoffs between sexual reproduction and clonal production and stressors from prior flood events. In fall 2021, arrowhead occurred as individual patches that were distinct, but many patches grew together by fall of 2022. The tradeoff between the type of reproduction and production seems most applicable at Mile 210 due to the tremendous growth in arrowhead extent at that location (Figure 1) which contained around 1 acre of arrowhead intermixed with lower proportions of annual emergent species in fall 2022.

Figure 1: Drone imagery of area with the highest concentration of arrowhead at Mile 210 area (USACE photo). Arrowhead is visible as the darker green and brown broadleaf vegetation outlined in the image.

3 Transect Vegetation Surveys

3.1 Methods

The Illinois Natural History Survey Critical Trends Assessment Protocol for Wetland sites (INHS 2002) was modified to evaluate the plant community in an emergent wetland on Mile 210 area that previously supported extensive beds of arrowhead. Potential areas were screened by elevation and removed if not exposed during typical environmental pool drawdown targets (i.e., stages between 417-419). Random points were generated in 2021 for ten transect locations within this zone (Figure 2; USACE 2021). Transects were revisited in 2022. Each transect was placed along a north bearing. When lying the transect, the tape measure is pulled taut, and laid upon the ground at all points along its length. Herbaceous vegetation is sampled in ¼ m^2 quadrats at an interval of every 2 m along the transect, starting 2 m from the baseline (Figure 3). A total of 10 quadrats are sampled per transect. Quadrats are placed 1 m from the transect on alternate sides, starting on the right at the 2 m point (e.g., the first quadrat covers the area from 2-2.5 m along the transect, at a distance covering 1-1.5 m right of the transect). Average species percent cover by site, frequency of occurrence, species richness, Shannon's Diversity Index, Shannon's equitability Index, and Hill Numbers were calculated.

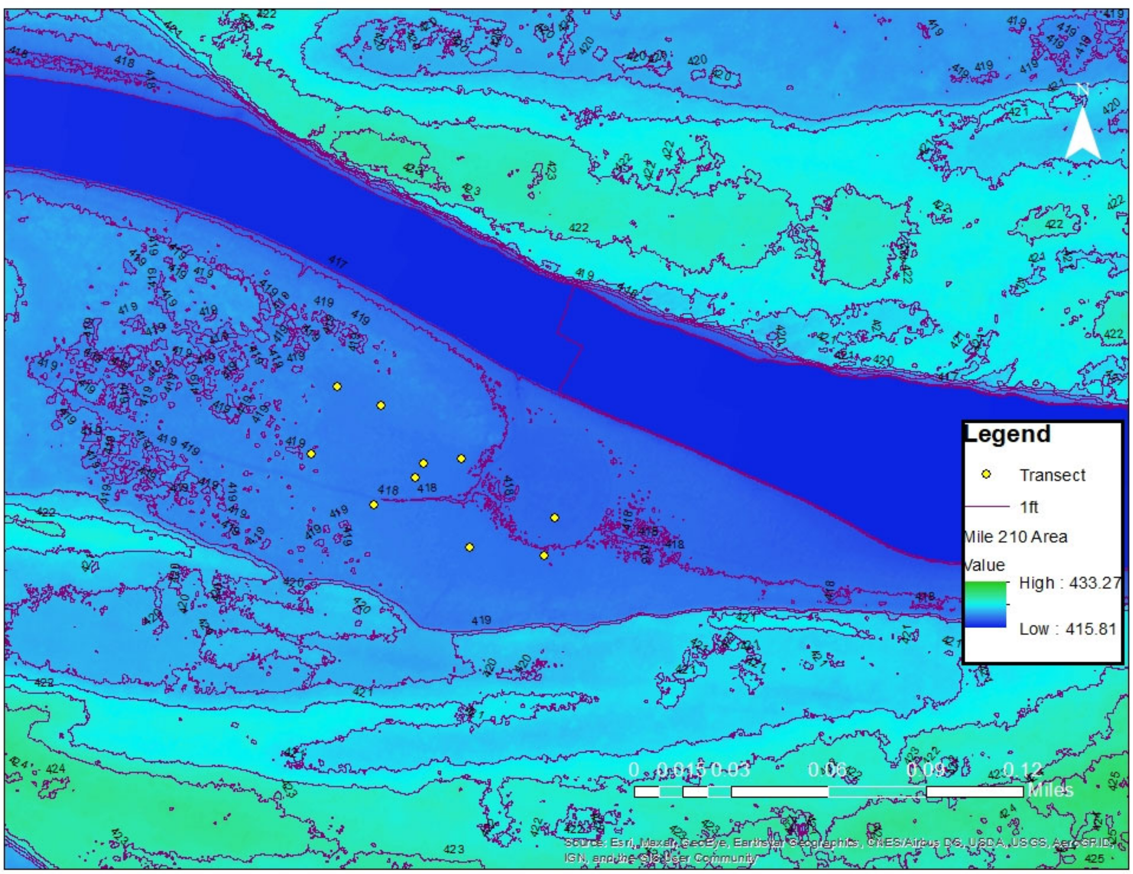

Figure 2: Random transect start locations within Mile 210 area.

Figure 3: Quadrat layout along transect.

Diversity Measures

Hill Numbers are calculated from other diversity indices such as Shannon's Entropy or Simpson's Index and describe the equivalent number of equally common species needed to give the same value of a diversity measure. When these values are plotted as in Figure 7, a comparison of diversity and evenness can be made. When q=0 the value equals overall species richness. When the value of q increases to 1 the effective number equals the inverse of Shannon Entropy and is a balance between richness and species evenness. The value at q=1 gives the approximate number of 'typical' species in the plant community for a given site. When the value of q increases to 2 the effective number equals the inverse of Simpson diversity and there is greater weight given to more abundant species in the plant community. A value at q=2 gives the approximate number of 'very abundant' species in a community (Hill 1973). A value at q= ∞ is equal to the reciprocal of the Berger-Parker Dominance value, which is a measure of the numerical importance of the most abundant species. As the reciprocal of the Berger-Parker Dominance Value (proportional abundance of the commonest species) increases there is an increase in diversity and a reduction in dominance within the community. Taken together, the Hill Numbers below can be used to evaluate species richness and evenness. A shallower slope as q increases from 0 to ∞ reflect greater community evenness, and larger values mean greater overall diversity within the community. Average percent cover, frequency of occurrence, and diversity metrics are plotted in Figures 4-6, respectively.

3.2 Results

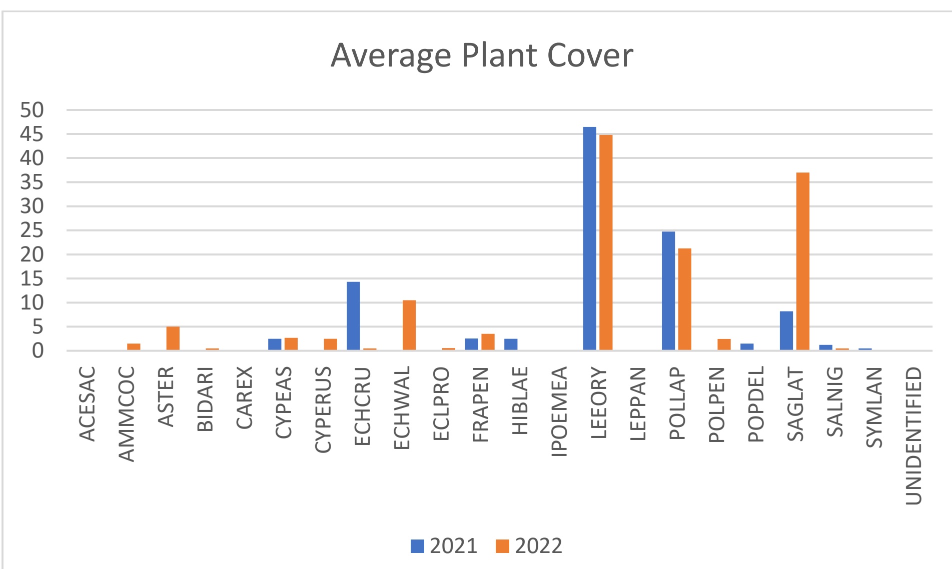

Figure 4: Average percent plant cover at Mile 210 area transects.

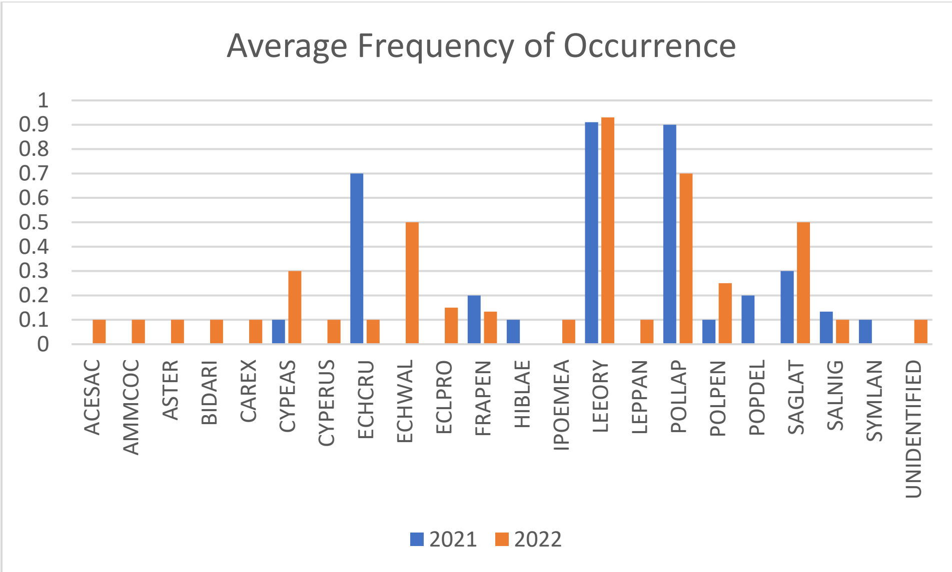

Figure 5: Plant species frequency of occurrence at Mile 210 area transects.

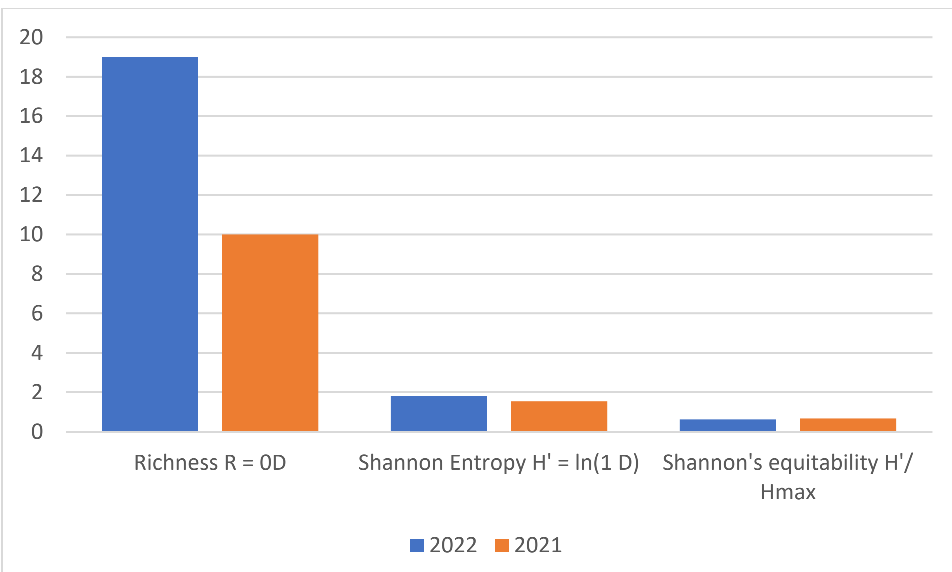

Figure 6: Plant diversity metrics at Mile 210 area transects.

Figure 7: Hill Number diversity measures at Mile 210 area transects.

3.3 Discussion

Average percent cover along transects was greatest for rice cutgrass (*Leersia oryzoides*) followed by arrowhead (*Sagittaria latifolia*), nodding smartweed (*Polygonum lapathifolia*), and millet (*Echinochloa* sp.; Figure 4). Average percent cover for species compared to 2021 were similar for rice cutgrass, smartweed, and millets (overall), but arrowhead increased from 8% to 37% in 2022. The increase in arrowhead extent agrees with a variety of supplemental data and visuals gathered in 2021 (i.e., patch mapping and photos; Figure 8) and drone imagery collected in 2022 (Figure 1).

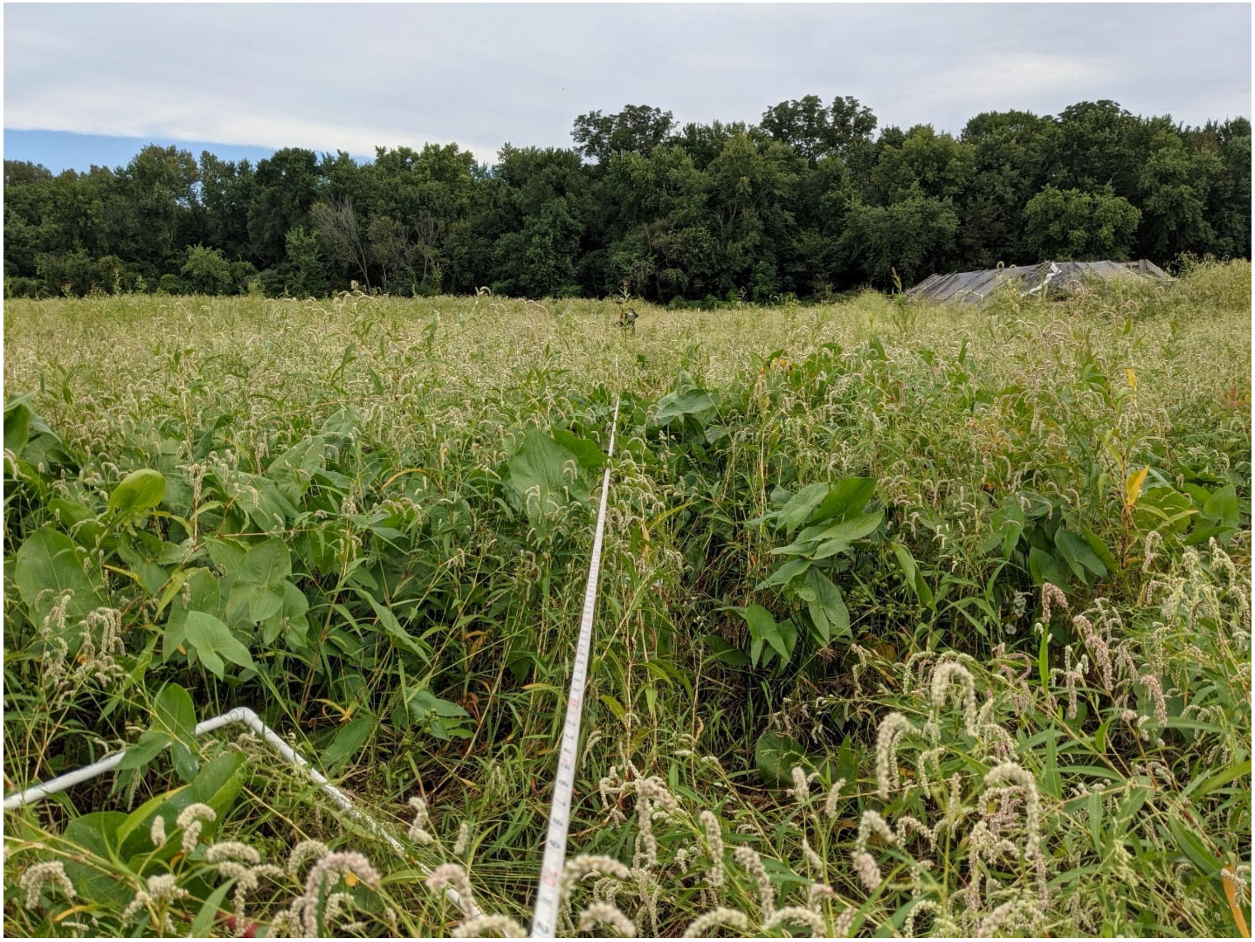

Figure 8: Image of vegetation transect and quadrat frame (plastic pipe, lower left) at Mile 210 area (USACE photo).

Average frequency of occurrence followed similar patterns to percent cover with rice cutgrass having the highest values (Figure 5). This was followed by nodding smartweed which occurred more frequently although at lower average cover values than arrowhead. Arrowhead and millet had the next greatest value for frequency of occurrence being present at 50% of transects. The remaining 15 species occurred at 30% or fewer transect locations.

Overall species richness was 19 in 2022 compared to 10 in 2021 (Figure 6). Additionally, approximately 6 species were abundant in 2022 compared to 4 in 2021 (q=1). Overall, the plant community in 2021 had slightly greater evenness as shown by the more gradual slope in q compared to values in 2022. This pattern was largely driven by the increase in richness in 2022 and that the majority of species encountered occurred at relatively few sites compared to overall patterns in 2021.

3.4 Additional Observations

Woody species such as cottonwood, black willow, and silver maple are increasing their extent at the upper edge of normal pool elevations (Figures 9 and 2). Management considerations that balance long-duration drawdowns which promote perennial emergent wetland species as well as woody species will become more important as backwater areas in Pools 24, 25, and 26 reduce in extent due to sedimentation.

This project has given us an opportunity to revisit the Mile 210 area multiple times throughout the growing season. In both years we sampled vegetation in September during drawdown or near drawdown conditions as well as return visit to sample arrowhead corms in late October shortly after water levels were returned to normal pool elevation in Pool 26. Rapid changes in visual extent of vegetation occurred as grass carp and other invasive carps disturbed the vegetation. The grass carp may disturb the vegetation through herbivory as well as from physically knocking stems down as they swim into emergent wetland vegetation, and silver and bighead carp disturbance would be limited to the latter. In fall of 2022, the visible edge of vegetation above water decreased toward the island bank by nearly 30 m in some areas in just over a week. This could limit the extent of submersed aquatic species when the emergent wetland areas are inundated even shallowly during the growing season.

Figure 9: Drone imagery of higher elevation portion of the Mile 210 emergent wetland area (USACE photo). There has been a gradual increase in woody species over the past decade with scattered trees becoming increasingly common throughout the site.

5 Ecological Model

St. Louis District of the U.S. Army Corps of Engineers worked with SRP to refine ecological parameters for arrowhead (*S. latifolia*) and define comparable ecological parameters for nodding smartweed (*P. lapathifolium*) and Walter's millet (*Echinochloa walterii*). Nodding smartweed was selected due to its abundance in Pools 24, 25, and 26; its relatively early germination period; and its importance as a waterfowl food. Walter's millet was selected due to its periodic abundance, its mid-season germination, and importance as a waterfowl food. For each species information was compiled on germination requirements, biomass production, seed production, size class, growth rates, and senescence.

Waterfowl were also previously added to the model and included three waterfowl taxa with different potential foraging depths. Mallard was selected to represent dabbling ducks due to their abundance in the region, and because the species is often used in other studies as being representative for this group of ducks. Canada Goose was selected as a species with slightly deeper potential foraging depths and also due to its abundance in the region. Finally, Trumpeter Swan was selected to represent a waterfowl species with the maximum average foraging potential in the area and due to its local nonbreeding season abundance in the region. Local IWMM (Integrated Waterbird Monitoring and Management) data from EPM areas were used to develop a bird per acre estimate by calendar date for each species.

Changes were made to enable improved modeling of seasonal transitions for simulated communities. In previous software versions, a single community transitioned to a single different community. That one-to-one constraint was removed, which means communities can now succeed into multiple things. For the Mississippi, this allows vegetative communities like arrowhead (when flooded or at senescence) to succeed into characteristics such as detritus, seed, and corms, which are then tracked independently and are available as variables to help inform other simulated dynamics such as waterfowl behavior.

This combination of ecological parameters and software capability has good potential to simulate vegetation resilience for a variety of management plans. Of particular interest are habitat and forage utilization by migrating waterfowl (especially identification of areas of potential forage that are underutilized due to unsuitable depths), expanding the study area to include more of the river systems within St. Louis District, tracking of caloric content of vegetation and seed produced by EPM, and assessment of different management plans.

6 Conclusion

The assessment of arrowhead resilience and tuber energetics over the past two growing seasons has helped us increase our understanding of arrowhead bed establishment, growth, and spread as a result of multiple long duration drawdowns through environmental pool management. The data gathered has also helped inform development of an ecological model to simulate habitat conditions in response to management. Further refinement and development of that model, which is beyond the scope of the proposed 2022 SRP work, is ongoing.

7 Literature Cited

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