UPPER MISSISSIPPI RIVER SYSTEM
ENVIRONMENTAL MANAGEMENT PROGRAM
POST-CONSTRUCTION
PERFORMANCE EVALUATION REPORT
2010

FOR

SWAN LAKE
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

US Army Corps
of Engineers
St. Louis District

ALTON POOL
ILLINOIS RIVER MILES 13.3 – 5.0
CALHOUN COUNTY, ILLINOIS

ACKNOWLEDGEMENTS

Many individuals of the St. Louis District, U.S. Army Corps of Engineers; the U.S. Fish and Wildlife Service; and the Illinois Department of Natural Resources, Illinois Natural History Survey, and Southern Illinois University contributed to the development of this Post-Construction Performance Evaluation for the Swan Lake Rehabilitation and Enhancement Project. These individuals are listed below:

ST. LOUIS DISTRICT, CORPS OF ENGINEERS

PROJECT MANAGER:	Brian Markert
ENGINEER COORDINATOR:	Ron Dieckmann, P.E.
ECOLOGIST/REPORT PREPARER	Donovan Henry

U.S. FISH AND WILDLIFE SERVICE

REFUGE MANAGER:	John Mabery
ASSISTANT REFUGE MANAGER:	Curt McMurl
WILDLIFE BIOLOGIST	Ken Dalrymple
FISHERY BIOLOGIST	Greg Connover
FISHERY BIOLOGIST	Nate Caswell
FISHERY BIOLOGIST	Colby Wrasse

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

MISSISSIPPI RIVER STATE FISH AND WILDLIFE AREA SITE MANAGER:	Kim Postlewait
FISHERY BIOLOGIST	Butch Atwood

ILLINOIS NATURAL HISTORY SURVEY

DIRECTOR GREAT RIVERS FIELD STATION:	John Chick
RESEARCH ASSISTANT	Thomas Timmerman
RESEARCH ASSISTANT	Chad Dolan
RESEARCH ASSISTANT	James Lamer

SOUTHERN ILLINOIS UNIVERSITY CARBONDALE

DIRECTOR FISHERIES AND ILLINOIS AQUACULTURE CENTER AND DEPARTMENT OF ZOOLOGY	James Garvey
ASST. PROFESSOR WATERFOWL/WETLAND ECOLOGY	Mike Eichholz
RESEARCHER AND FISHERY BIOLOGIST	Ronald Brooks
RESEARCH ASSISTANT	Laura Csoboth
RESEARCH ASSISTANT	Kelly Baerwaldt
RESEARCH ASSISTANT	Douglas Schultz
RESEARCH ASSISTANT	Darin Grulkowski
RESEARCH ASSISTANT	Randy Smith
RESEARCH ASSISTANT	Erin Hotchkiss
RESEARCH ASSISTANT	Brett Tevini
RESEARCH ASSISTANT	Darrin Martin

EXECUTIVE SUMMARY

General. The design of the Swan Lake Project was to provide the physical conditions necessary for creating a wide spectrum of strategies for waterfowl and fisheries management. Sedimentation, lack of water level control, and wind fetch at the site were contributing to the direct loss of fish and wildlife habitat and a decrease in fish and wildlife habitat quality. As stated in the Definite Project Report, the Swan Lake HREP was undertaken to address these three primary problems.

Purpose. The purposes of this Performance Evaluation Report (PER) are as follows:

1. Summarize the performance of the project with respect to project goals and objectives as stated in the Definite Project Report (DPR)
2. Summarize the monitoring results
3. Summarize the project operation and maintenance requirements
4. Summarize project modifications through adaptive management
5. Review the site management plan for possible revisions
6. Review engineering performance criteria to aid in design of future projects
7. Summarize recommendations and conclusions

Project Goals. The specific goals as stated in Definite Project Report (DPR) were to:

1) Restore aquatic macrophyte beds and associated invertebrate communities for the benefit of migratory waterfowl
2) Provide habitat for over winter survival of fish
3) Provide habitat for spawning and rearing of fish
4) Increase the overall habitat value for waterfowl and fishes

Observations, Conclusions, and Recommendations.

<u>Project Performance Monitoring.</u> Pre- and post-project monitoring, both qualitative and quantitative, by each of the involved agencies, was performed in accordance with the Monitoring and Performance Evaluation Matrix from the original DPR (Appendix A). Monitoring and performance evaluation was conducted by the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, Illinois Department of Natural Resources, Illinois Natural History Survey and Southern Illinois University Carbondale. The period of data collection covered in this report includes the pre-project monitoring (pre-1991), quantitative and qualitative post-project monitoring through 2006, and anecdotal information through the summer of 2009.

<u>Evaluation of Project Objectives.</u> Monitoring activities and discussions with USFWS and Corps personnel involved with operation and maintenance at the Swan Lake HREP have resulted in the following general conclusions regarding project features that may affect future project design:

a) Substantially reduce future lake sedimentation: Sediment inputs into Swan Lake may have been retarded by the Swan Lake HREP measures during the three years of post-project monitoring. However, this is a short time period to evaluate long term impacts, and it is a commonly held understanding that sedimentation is still significantly affecting Swan Lake. The post-project evaluation likely failed to capture the large deltas forming near the tributary inputs in Lower and Middle Swan. Additional long-term monitoring would be necessary to identify actual sediment accumulation from outside inputs into Swan Lake, and the effects of the Swan Lake HREP measures.

b) Maintain stable water conditions during the growing season: The water control structures in Swan Lake can effectively maintain stable water conditions, particularly during years that weather and Illinois River water levels cooperate. Periodic inundation from Illinois River flooding or heavy rainfall on the hillside watershed during the growing season can hinder the ability to keep the site dewatered. The approach to water level management may have to be more opportunistic and maximize drawdown periods during dry years.

c) Provide the ability to solidify the lake bottom: The project measures were successful in providing the ability to dewater Swan Lake, thereby providing the ability to solidify the lake bottom. However, re-suspension and deposition of sediments by wind generated waves is still a major obstacle in achieving the goals of the Swan Lake HREP. The accretion rates of the flocculent sediment, especially in Lower Swan Lake, continue to impede habitat enhancement. Post-project analyses suggest that the ability to dewater the project area has the potential to substantially harden Swan Lake sediments, thereby achieving the desired results.

d) Enhance wave control: Creation of island groups had a slight impact in reducing wave height and resuspension of sediments in Middle Swan, but in Lower Swan, the island complexes did not significantly alter wave height or the rate of sediment deposition from the pre-project to the post-project monitoring. Preliminary wind/wave models indicated that additional islands may be viable solution to the wind fetch issues on Lower and Middle Swan Lakes. However, additional island construction would be extremely costly, particularly if large islands or large numbers of islands need to be built to be successful.

e) Form smaller independently-managed lake units: The interior lake closure divides Swan Lake into two compartments, Middle (1,200 acres) and Lower (1,400 acres) Swan Lakes, and has been successful in allowing for independent management objectives of both compartments. Lower Swan is currently managed for annual dewatering with a thorough drawdown every two to three years to consolidate sediments and promote the establishment of aquatic vegetation and aquatic invertebrates. Middle Swan is managed for a complete drawdown every four years and partial dewatering on subsequent years.

f) Provide areas of deep water: Nearly all the deep water habitat created by dredging has been lost due to sedimentation. Deep water habitat could be created again by re-dredging the same areas, dredging in areas where sediment suspension and deposition are lowest, or dredging to create more islands that would reduce wind fetch and wave activity. Access to the areas of deeper water remaining in Middle Swan during winter months may still promote the over winter survival of fishes, however the persistent sedimentation issues throughout Swan Lake will likely prevent the maintenance or creation of sustainable deep water habitats until abated.

g) Allow free movement of fishes between river and lake during late fall/early winter period: Providing the opportunity for fish to migrate between Lower Swan Lake and the Illinois River was successful. Based on the telemetry study and targeted sampling of the stop-log fish passage structure, there appears to be minimal impact on the immigration and emigration of fishes common to Swan Lake when the water control structure is open. However, fishes did not utilize Lower Swan for refuge in late fall/early winter to the extent expected. Depths in Lower Swan are insufficient for complete thermal stratification, but pockets of deep water may still provide some functioning overwinter habitat in Middle Swan.

h) Buffer impact of cold water and ice: During times of typical winter discharges, the riverside dike and water control structures successfully shield Swan Lake from cold flowing water and ice found in the Illinois River. However, the shallow waters of Lower Swan experience volatile fluctuations in water temperature caused by diel fluctuations in air temperature and mixing from wind during winter months.

Evaluation of Project Goals. Post-construction monitoring was conducted to quantify the physical and biological response to the project features and adaptive management procedures.

a) Restore aquatic macrophyte beds and associated invertebrate communities for benefit of migratory waterfowl: In Upper Swan/Fuller Lake, submersed and rooted floating vegetation remained established with similar species composition when comparing pre- and post-project monitoring. In Middle Swan, establishment of aquatic vegetation was minimal in post-project, in contrast to the presence of several species in pre-project surveys. Lower Swan also had seven species established in pre-project surveys, but virtually no submersed aquatic or rooted floating vegetation in post-project monitoring. However, the establishment of emergent and submersed aquatic vegetation may be achieved in Lower and Middle Swan Lake with the current, more frequent draw down schedule that will help reduce turbidity and consolidate sediments. The remaining limiting factor to establishing aquatic vegetation in Swan Lake is the frequency and duration of flooding from the Illinois River on wet years or during wet weather cycles. Changes in invertebrate abundance between pre- and post-HREP were variable between habitat types and seasons, but there was an increase in invertebrate abundance during late spring, when some species of waterfowl appear to increase their dependence on invertebrates, having a positive influence on both dabbling and diving ducks.

b) Provide habitat for over winter survival of fish: During the post-HREP monitoring, no seasonal increases in abundance of any fish species were observed during fall that would indicate individuals were seeking overwintering habitat in Swan Lake. The shallow windswept Lower Swan Lake is unsuitable for overwintering habitat due to the extreme temperature volatility making physiological acclimation and preferred temperature selection difficult. The slightly deeper habitat found in Middle Swan Lake is likely more suitable for maintaining overwintering habitat, and telemetered fishes accessed this area during the post-HREP study.

c) Provide habitat for spawning and rearing of fish: The enhanced ability to provide stable water conditions for spawning and rearing of fishes, while allowing for fish passage, was achieved with the riverside dike and stop log structures. However, turbidity and sedimentation continue to impact the available spawning and nursery habitat. The more opportunistic drawdown schedule now being employed should continue to improve consolidation of sediments, decrease turbidity, and promote the establishment of aquatic macrophytes, all of which will improve the overall spawning and rearing habitat in Swan Lake. The tradeoff to improving and maintaining spawning and nursery habitat in Swan Lake requires the more frequent drawdown schedule, which precludes fishes from recruiting in the lake during dewatered years. But with a less frequent dewatering schedule, turbidity and sedimentation will continue to degrade the available spawning and nursery habitat, and reduce recruitment potential during years the lake is not dewatered.

d) Increase overall habitat value for waterfowl and fish: The density of diving and dabbling ducks increased in Swan Lake when comparing pre- and post-HREP numbers. This may have been in part due to an increase in the continent-wide waterfowl populations, however, ducks were foraging successfully in Middle Swan Lake and likely gaining energy for reproduction in spring and migration in fall. The ability to maintain and manipulate water levels in Middle and Lower Swan Lake while allowing for fish passage was successful. Both native and exotic species were observed passing through the stop log structures in the post-HREP sampling. The habitat in Lower Swan Lake is largely unsuitable for overwinter survival of fishes, but Swan Lake continues to provide important spawning and rearing habitat for fishes based on post-construction sampling efforts. The explosion of the Asian carp populations has impacted design, operation, adaptive management, resource management, and some environmental benefits of the Swan Lake HREP. Future management objectives for native fish populations in Swan Lake will also have to include impacts by the Asian carps.

Project Operation and Maintenance. At this time the O & M manual is still under preparation. Operation and maintenance has been conducted in accordance with the project goals and objectives. Adaptive management strategies have been developed, coordinated, and deployed in an ongoing effort to improve project design and function. The water control structures are being operated and maintained correctly. Regular site inspections by the Refuge Manager have resulted in proper coordination and corrective maintenance actions. As project goals are met or amended through adaptive management processes, the operations and maintenance manual will be finalized for the USFWS site manager.

Swan Lake HREP Performance Evaluation Points of Contact							
U.S. Army Corps of Engineers, St. Louis District							
Name	**Position**	**Address**	**City**	**State**	**Zip**	**Phone**	**Email**
Brian Markert	Project Manager	1222 Spruce St	St. Louis	MO	63103	314-331-8455	Brian.J.Markert@usace.army.mil
Ron Dieckmann	Hydraulic Engineer	1222 Spruce St	St. Louis	MO	63103	314-331-8363	Ronald.J.Dieckmann@usace.army.mil
U.S. Fish and Wildlife Service							
Name	**Position**	**Address**	**City**	**State**	**Zip**	**Phone**	**Email**
John Mabery	Refuge Manager	HC 82, Box 107 (Hagen Road)	Brussels	IL	62013	618-883-2524	John_Mabery@fws.gov
Curt McMurl	Assistant Refuge Manager	HC 82, Box 107 (Hagen Road)	Brussels	IL	62013	618-883-2524	Curt_McMurl@fws.gov
Ken Dalrymple	Wildlife Biologist	HC 82, Box 107 (Hagen Road)	Brussels	IL	62013	618-883-2524	Kenneth_Dalrymple@fws.gov
Illinois Department of Natural Resources							
Kim Postlewait	Site Manager	RR 1 Box 182	Grafton	IL	62037	(618)376-3303	kim.postlewait@illinois.gov

TABLE OF CONTENTS

List of Appendices

List of Figures

List of Tables

POST-CONTRUCTION
PERFORMANCE EVALUATION REPORT
2009

FOR

SWAN LAKE
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

UPPER MISSISSIPPI RIVER SYSTEM
ENVIRONMENTAL MANAGEMENT PROGRAM

ALTON POOL, ILLINOIS RIVER MILES 13.3 – 5.0
CALHOUN COUNTY, ILLINOIS

1. INTRODUCTION

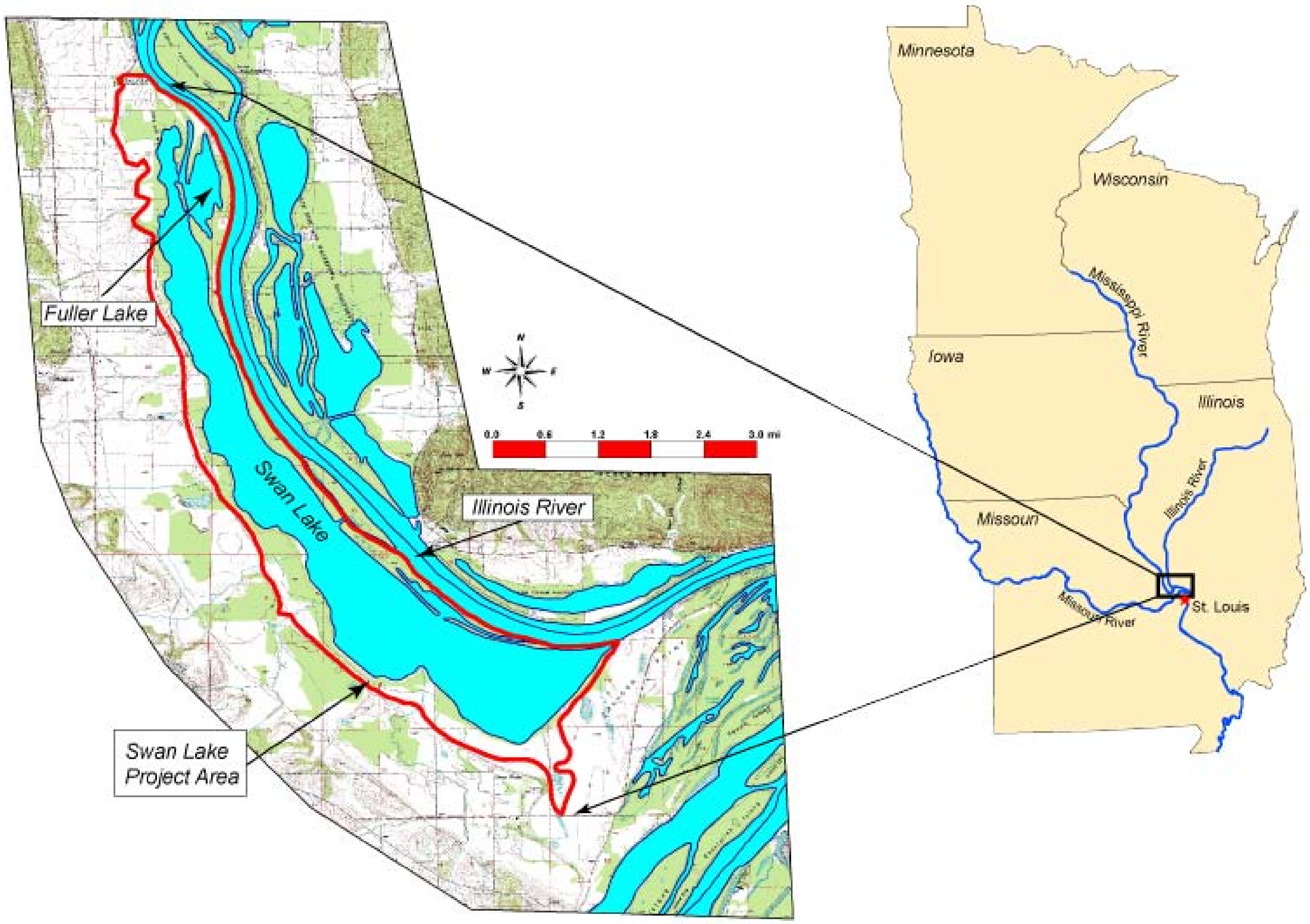
The Swan Lake Habitat Rehabilitation and Enhancement Project (HREP) is part of the Upper Mississippi River System (UMRS) Environmental Management Program (EMP). The project is located in Calhoun County, Illinois, on the right descending bank of the Illinois River, between river miles 13.3 and 5.0 (Figure 1). The project is operated by the U.S. Fish and Wildlife Service and the Illinois Department of Natural Resources. The project is located in the Calhoun Division of the Two Rivers National Wildlife Refuge and the Illinois Department of Natural Resources Fuller Lake Management Area.

Swan Lake is bottomland lake approximately 2,900 acres in size with an average depth between 3 and 3.5 feet. This water body constitutes a significant portion of the backwater habitat in the Upper Mississippi River Valley and the Illinois River. This is the largest backwater complex in Pool 26 of the Mississippi River and one of the largest on the Illinois River. Bottomland lake habitat such as Swan Lake has significantly declined over the last century and the remaining backwater lakes are severely degraded due to sedimentation and altered hydrology for navigation and flood control. With the construction of Lock and Dam 26, water levels in the lower Illinois River were raised and stabilized. This also raised the water levels in Swan Lake, resulting in permanent inundation of a much larger area. The bottomland hardwoods adapted for wet-dry cycles were lost due to the prolonged flooding, and the sluggish backwater habitat quickly filled with sediment resulting in increased turbidity eradicating the aquatic vegetation. The goal of the Swan Lake HREP is to restore some of the more natural processes and ecological attributes to the area.

a. **Purpose**. The purposes of this Performance Evaluation Report (PER) are as follows:
    1. Summarize the performance of the project with respect to project goals and objectives as stated in the Definite Project Report (DPR)
    2. Summarize the monitoring results
    3. Summarize the project operation and maintenance requirements
    4. Review the site management plan for possible revisions
    5. Review engineering performance criteria to aid in design of future projects

b. **Scope**. This report summarizes available monitoring data, inspection records, and field observations made by the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, Illinois Department of Natural Resources, Illinois Natural History Survey and Southern Illinois University Carbondale. The period of data collection covered in this report includes the pre-project monitoring (pre-1991) to summer of 2009.

Figure 1. Swan Lake Project Area.



c. Project References.

(1) Garvey, et. al. 2007. Swan Lake habitat rehabilitation and enhancement project: post-project monitoring of water quality, sedimentation, vegetation, invertebrates, fish communities, fish movement, and waterbirds. Final Report prepared for U. S. Army Corps of Engineers, St. Louis District. Fisheries & Illinois Aquaculture Center and Department of Zoology, Southern Illinois University at Carbondale.

(2) Theiling, C. H., R. J. Maher, and J. K. Tucker. 2000. Swan Lake habitat rehabilitation and enhancement project pre-project biological and physical response monitoring final report. Report prepared for the United States Army Corps of Engineers, St. Louis District. Illinois Natural History Survey, Great Rivers Field Station, Brighton, IL. 130 pp.

(3) U. S. Army Corps of Engineers. 1991. Swan Lake rehabilitation and enhancement project, pool 26, Illinois River, Calhoun County, Illinois. Upper Mississippi River System Environmental Management Program Definite Project report (SL-5). USACOE, St. Louis District, St. Louis, MO.

(4) Heitmeyer, M. E. and K. Westphall. 2007. An evaluation of ecosystem Restoration and management options for the Calhoun and Gilbert Lake Division of Two Rivers National Wildlife Refuge. Gaylord Memorial Laboratory Special Publication No. 13. University of Missouri – Columbia. 79 pp.

2. PROJECT GOALS AND OBJECTIVES

a. General. The design of the Swan Lake Project was to provide the physical conditions necessary for creating a wide spectrum of strategies for waterfowl and fisheries management. The specific goals as stated in Definite Project Report (DPR) were to: 1) Restore aquatic macrophyte beds and associated invertebrate communities for the benefit of migratory waterfowl; 2) Provide habitat for over winter survival of fish; 3) Provide habitat for spawning and rearing of fish; and, 4) Increase the overall habitat value for waterfowl and fishes. In order to achieve these goals, sedimentation, lack of water level control, and wind fetch at the site needed to be addressed. As further stated in the Definite Project Report, the Swan Lake HREP was undertaken to address these three primary problems. The combination of these issues lead to direct loss of fish and wildlife habitat and a decrease in fish and wildlife habitat quality. Project goals and objectives and the measures implemented to address the goals and objectives are listed in Table 2-1. The Operation and Maintenance Manual has not been finalized at this date in time.

Table 2-1. Project goals, objectives, and measures.

Goal	Objective	Measure
Restore aquatic macrophyte beds and associated invertebrate communities for benefit of migratory waterfowl	Substantially reduce future lake sedimentation	- Dredging - Riverside Dike/Levee - Water Control Structures - Hillside Sediment Control
	Maintain stable water levels during the growing season	- Riverside Dike/Levee - Water Control Structures
	Provide the ability to solidify the lake bottom	- Riverside Dike/Levee - Water Control Structures
	Enhance wave control	- Interior Closure - Islands
	Form smaller independently-managed lake units	- Interior Closure
Provide habitat for over winter survival of fish	Provide areas of deep water	- Dredging
	Allow free movement of fish between river and lake during late fall/early winter period	- Riverside Dike/Levee - Water Control Structures
	Buffer impact of cold water and ice	- Riverside Dike/Levee - Water Control Structures
Provide habitat for spawning and rearing of fish	Provide alternate structures so as to assure fish passage	- Riverside Dike/Levee - Water Control Structures
Increase overall habitat value for waterfowl and fish	Meet all of the above objectives	- All

b. Management Plan. A cyclic as well as a seasonal watering/dewatering schedule was developed in the Swan Lake Definite Project Report (Table 2-2). Timed drawdowns were designed to benefit fish and waterfowl by consolidating sediments, promoting growth and diversity of aquatic vegetation and macroinvertebrates, and improve spawning, rearing and overwintering habitat for fishes.

Table 2-2. Original management plan for Swan Lake as stated in the DPR.

Time Frame	Management Action	Purpose
Annual (Late June - mid-September)	Maximum drawdown exposing 60% of bottom surface area of Upper Swan/Fuller Lake	Promote growth of natural or seeded plants for waterfowl
Annual	Partial drawdown (~0.5 ft) of Middle Swan	Promote moist soil, emergent, and submergent vegetation for waterfowl
Every 8 - 10 years	Middle and Lower Swan drained as low as possible on a rotational basis	Consolidate sediments, enhance rooted macrophytes, and improve water clarity

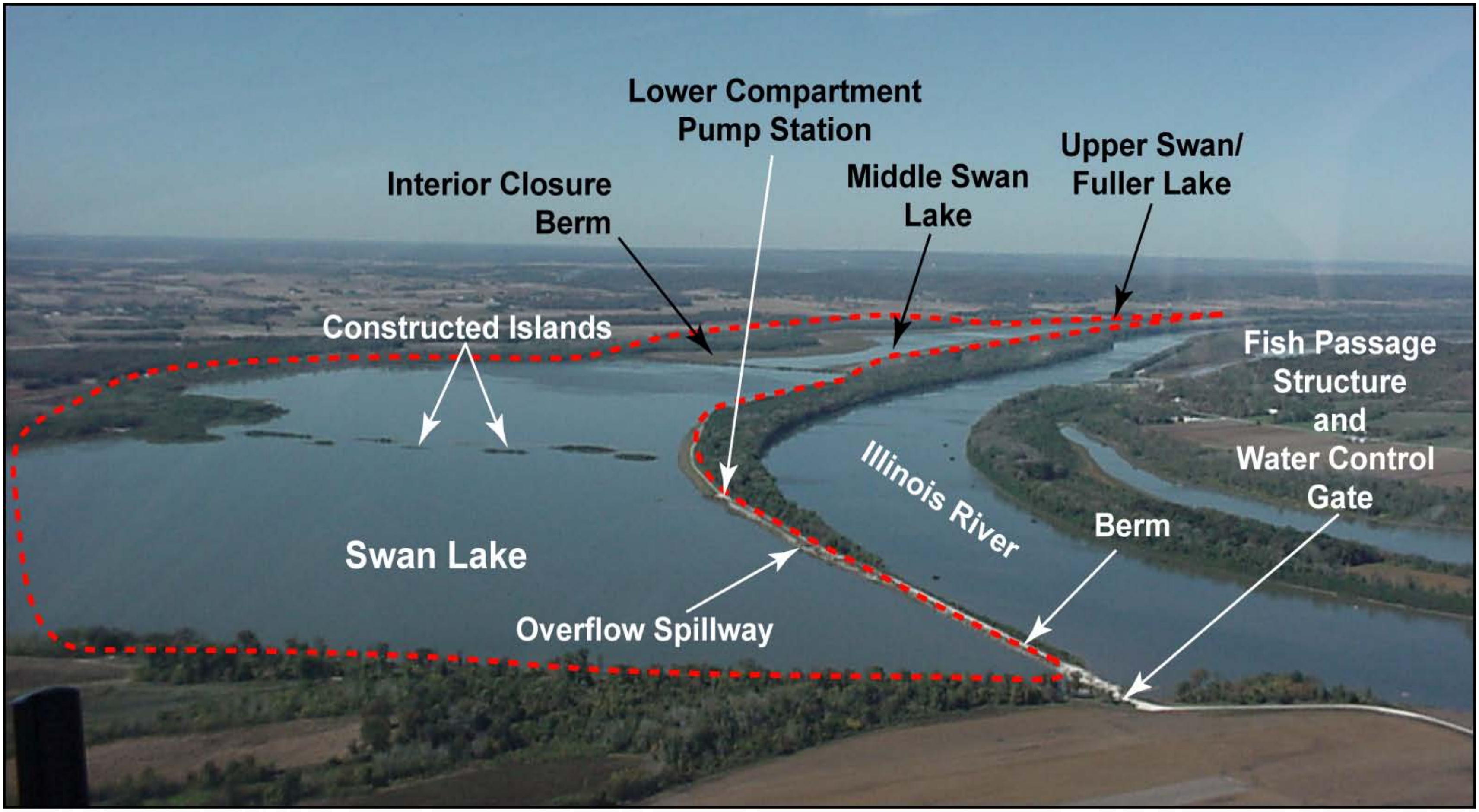
3. PROJECT DESCRIPTION

a. Project Measures. The Swan Lake project consists of a riverside levee/dike, dredging, water control/fish passage structures, pumps, an interior closure structure, islands, hillside sediment control basins, and service access (see Figure 2 for locations of features). A detailed description of each of these measures follows:

1. Riverside levee/dike. The riverside levee/dike is an 8.8-mile earthen levee that parallels the Illinois River shoreline and the perimeter of the Refuge. The levee was necessary to reduce siltation that occurs from frequent floods from the Illinois River and to improve water control capabilities. Borrow areas for levee construction run along the lake side of the levee for approximately 6 miles in Middle and Lower Swan Lakes and served to create deep water fish habitat in addition to providing fill material for levee construction. Borrow ditches were not utilized for the portion in Upper Swan. Instead fill material was obtained from off-site borrow areas in former agricultural areas.
2. Dredging. Dredging to provide deep water fish habitat was accomplished in conjunction with the construction of the riverside levee/dike. Borrow material for levee/dike construction was taken from the lake bottom immediately adjacent to the structure. This created 5.9 miles of deep water habitat.
3. Closure/fish passage structures. Closure/fish passage stop-log structures were constructed at the southern end of Lower Swan Lake (river mile 5.0) and at the upper end of Middle Swan Lake (river mile 9.8) to separate Swan Lake from the Illinois River while still allowing for fish passage.
4. Interior closure. An interior lake closure was constructed to subdivide the lower portion of Swan Lake into two independently managed, but complimentary habitat compartments, and serve as a wind barrier.

5. Water control/fish passage structures. Gravity flow sluice-gated culverts, stop-log structures, corrugated metal pipe, and pumps were installed to perform and control watering and dewatering of the Swan Lake compartments as management objectives dictate. Filling or emptying can be achieved in approximately 20 days, given proper river and weather conditions. Basic data on water control/fish passage structures follows:
    a. Upper Swan Lake/Fuller Lake to Illinois River. A 48-inch gated CMP drains this unit to the Illinois River and a 20,000 GPM reversible Couch pump facilitates watering and dewatering.
    b. Lower Swan Lake to Illinois River. At the southern end of Lower Swan Lake (RM 5.0), a control structure was installed consisting of an 20-foot wide open concrete channel containing four 52-inch wide stoplog slots. This water control structure was selected to promote fish passage. In addition, a 50,000 GPM angle pump is installed in the unit for dewatering.
    c. Middle Swan Lake to Illinois River: Middle Swan has the same style stop log structure as Lower Swan, but has a 30,000 GPM drive shaft pump with directional capability using chambered gates. It is located near the upper end of the compartment at RM 9.8.
    d. Middle Swan Lake to Lower Swan Lake. Through the interior lake closure between Lower Swan and Middle Swan Lake is a 48 inch gated CMP to release water from Middle Swan into Lower Swan.
6. Hillside Sediment Control. Erosion control practices were implemented at more than forty sites in the Swan Lake Watershed by the end of 1998. This included 25 water and sediment control basins (WASCOB) in upland watersheds to reduce sediment transported by tributaries flowing into the lake.
7. Islands. Island groups were constructed to serve as barriers to reduce turbidity from wind generated wave action.
8. Boat Ramps. Boat access areas were created/enhanced to mitigate for project impacts to existing site access areas.

Figure 2. Swan Lake HREP features.



b. Project Construction. The Swan Lake EMP HREP project was approved for construction in June 1993 at an estimated cost of $7,854,432 (equivalent to $11,953,183 in 2010). In accordance with Section 906(e) of the 1986 Water Resources Development Act (Public Law 99-662), general design and construction costs for the hillside sediment control features were shared on a 75% Federal/25% non-Federal basis. The remainder of the project features were constructed at 100% Federal cost.

c. Project Operation and Maintenance. Operation and maintenance of Swan Lake is divided between the U. S. Fish and Wildlife Service (USFWS) and the Illinois Department of Natural Resources (IDNR). IDNR manages Upper Swan/Fuller Lake and USFWS manages Lower and Middle Swan Lakes. Development of the Operation, Maintenance, Repair, Replacement and Rehabilitation Manual (OMRR&R Manual) is currently in process with completion dependent on adaptive management measures. USFWS is in possession of As-builts and operation and maintenance manuals of on-site equipment for the project. Project operation and maintenance at Swan Lake generally consists of the following:

1. Mowing and other maintenance of the perimeter and interior levees to ensure integrity during flood events. Other levee maintenance activities include grading and repairing minor erosion on dike, maintaining the gravel road on top of the riverside dike, removing flood debris, herbicide applications, burrowing animal control, reseeding, fertilizing, etc.
2. Operation, repair, and maintenance of the pump stations and water control structures to achieve desired water levels, fish passage, sediment control, etc. during all seasons.
3. Inspections conducted in conjunction with USACE personnel at least annually through adaptive management processes.
4. Emergency operations during flood conditions.

4. PROJECT PERFORMANCE MONITORING.

a. General. The monitoring and performance evaluation matrix is outlined in Appendix A. Pre- and post-project monitoring, both qualitative and quantitative, by each of the involved agencies is summarized below.

b. U.S. Army Corps of Engineers. The success of the project relative to original project objectives shall be measured utilizing data, field observations, and project inspections provided by USFWS, LTRMP/INHS, SIUC, and the Corps. The Corps of Engineers was responsible for post-project analyses of water quality, sedimentation, vegetation, aquatic macroinvertebrates, fish communities, fish movement, and waterbirds. The Corps has overall responsibility to measure and document project performance.

c. **United States Fish and Wildlife Service (USFWS).** The USFWS is responsible for operating and maintaining the Swan Lake project. In addition, the USFWS examined the age and size structure of the post-project fish population in Swan Lake, they conduct year-round ground surveys of the waterfowl on the project area, and collect anecdotal information on the project conditions and other fish and wildlife use.

d. **Southern Illinois University Carbondale (SIUC).** SIUC conducted post project monitoring of water quality, sedimentation, vegetation, aquatic invertebrates, fish communities, fish movement, and waterbirds.

e. **Long Term Resource Monitoring Program (LTRMP)/ Illinois Natural History Survey (INHS).** The LTRMP was responsible for conducting pre-project monitoring of water quality, sedimentation, vegetation, benthic invertebrates, and fishes. Post project monitoring was conducted in cooperation with Southern Illinois University at Carbondale.

f. **Illinois Department of Natural Resources (IDNR).** Each fall and winter, IDNR conducts aerial waterfowl surveys on Fuller and Swan Lakes from October to January. IDNR is also responsible for operating and maintain Fuller Lake in agreement with the USFWS.

5. EVALUATION OF AQUATIC HABITAT OBJECTIVES

1. Substantially reduce future lake sedimentation.

A. General. Sedimentation in Swan Lake has been examined from two standpoints: 1) accruing sediment inputs from outside sources (e.g. hillsides, tributaries, and the Illinois River); and, 2) re-suspension and deposition of flocculent sediment in Swan Lake by wind generated wave activity. The second issue will be covered in section 5.3.

B. Sedimentation from outside sources. Sedimentation has resulted in aggradation and disappearance of off-channel habitats throughout the Illinois River Valley, including Swan Lake. Sediment inputs from Illinois River floods and from tributaries in the local watershed have significantly affected the physiography of Swan Lake. Lee and Stall (1976) estimated that the lake had lost more than 2,000 acre-feet, or 42.2% of its total capacity between 1903 and 1975. The combined accretion from all of the Swan Lake watersheds was approximately 16 acres per year from 1968 to 1989. During the pre-impoundment era (1900-1940), the average depth of Swan Lake was estimated at 54 inches with a sedimentation rate of 0.20 inches per year. Sedimentation post-impoundment (1940-1990) increased by 2.5 times to 0.50 inches per year. This decreased the average depth of Swan Lake to an estimated 40 inches. The without-project sediment rate determined in the Swan Lake Definite Project Report (DPR) was approximately 0.33 inches per year, or 117,000 tons per year, resulting in an average water depth of 17 inches. It was estimated that one-third of the lake sedimentation would be from hillsides and two-thirds would be from the Illinois River. As chronic sedimentation is a primary objective to be addressed in the Swan Lake HREP, measures to reduce this issue included a riverside dike/levee, hillside sediment control, water control structures, and dredging (summarized in section 3a). As stated in the DPR, it is assumed that the rate of sedimentation and decrease in water depth will reach a peak. Therefore, future changes in sedimentation could be detected by changes in water depth (i.e. as sedimentation increases, water depth decreases).

Garvey et. al. (2007) examined the relationship between water depth and lake elevation to evaluate filling from sediment accumulation or deepening from scouring during three years (2004-2006) of post-project monitoring (Figure B1). They did not find any overall changes in lake depth due to sedimentation or scouring. More recent studies on the upland watershed have found that significant inputs of sediment are still occurring in Swan Lake and large deltas are forming near the mouths of the small feeder tributaries (John Mabery pers. comm.).

C. Conclusions. Sediment inputs into Swan Lake may have been retarded by the Swan Lake HREP during the three years of post-project monitoring by Garvey et al (2007). This is a short time period to evaluate long term impacts, and the authors caution using these methods to assess sedimentation in Swan Lake. Sedimentation is still significantly affecting Swan Lake, and the post-project evaluation likely failed to capture the large deltas forming near the tributary inputs in Lower and Middle Swan. Additional soil conservation practices in the upland watershed, routing the sediment inputs around Swan Lake, and/or controlling the area of sediment accumulation within Swan Lake are measures that will likely have to be considered to minimize the impacts of the persistent sedimentation in Swan Lake.

2. **Maintain stable water conditions during the growing season**.

A. General. Water control structures in Swan Lake (summarized in section 3a), include a riverside levee, pump stations for watering and dewatering, stop-log structures, and corrugated metal pipe connections. These systems were installed to maintain stable water conditions to facilitate establishment and growth of aquatic macrophytes and aquatic invertebrates, enhancing the habitat for fishes and migratory waterfowl.

B. Pre- and Post-Project Conditions. Water stages in the Illinois River at Swan Lake are controlled by the operation of Melvin Price Locks and Dam on the Mississippi River near Alton, Illinois. The pool stage maintained by Melvin Price LD is 419.5 feet NGVD under normal conditions. During the pre-project monitoring, from 1988 to 1993, the natural levee at Swan Lake was breached three of the six years. There were two drought years with no flooding, and one “typical” year with a rise in spring and fall water levels. In the three years (2004-2006) of post-project monitoring there were two flooding events, one in June 2004 and one from December 2004 to February 2005 (Garvey et. al. 2007). Drought conditions persisted from spring 2005 to the end of the project in 2006.

The 8.8-mile riverside levee/dike between Swan Lake and the Illinois River has a design elevation ranging from approximately 425.5 on the upstream end (RM 13) to 427 on the downstream end (RM 5). There is a 2,000 foot spillway on the Lower Swan levee with a with a design elevation of 426.1 NGVD. The spillway is protected by stone rip-rap and was put into place to minimize the impacts of overtopping to the remainder of the levee. With the spillway built at the design elevations stated above, the Swan Lake dike has been overtopped by Illinois River flood waters 6 of the last 9 years.

The spillway in Lower Swan Lake was overbuilt (finish height of 427.0) and portions of the levee have settled over time, which created a condition in which sections of the levee were lower than the spillway. This resulted in overtopping in areas of the levee with little or no erosion protection and subsequent damage to the levee. One of the areas where overtopping commonly occurred was just upstream of the cross-dike or closure between Middle and Lower Swan Lakes. This section of levee would be overtopped before the Lower Swan spillway releases. Damage incurred during the flood events in 2008-2009 lowered the elevation of this section of levee more than 2 feet in some areas.

The Lower Swan Lake spillway was lowered to a finish height of 425.5 feet NGVD in summer 2009 as a critical first step to reducing risk of further damage to the riverside levee. Areas where overtopping had occurred were repaired and raised a minimum of one foot over the spillway height. To further alleviate overtopping in unprotected areas, a 600 foot auxiliary spillway was constructed at an elevation of 425.7 NGVD on the riverside levee between Middle Swan Lake and the Illinois River. The auxiliary spillway was constructed just upstream of the cross-dike that separates Middle and Lower Swan Lakes in the approximate location of the previous levee wash-out.

C. Conclusions. The ability of the water control structures in Swan Lake to effectively maintain stable water conditions is most effective during years that weather and water cooperate. Flooding in either the upper Mississippi River valley or the Illinois River valley, or localized heavy rains can decrease the effectiveness of pumping. With the likelihood of periodic inundation impacting drawdown, the approach to water level management may have to be more opportunistic and maximize drawdown periods during dry years. A cyclic goal with a target number of drawdowns per unit time might be more attainable/sustainable (e.g. 6 drawdowns per 10 years).

3. Provide the ability to solidify the lake bottom.

A. General. In addition to dramatically reducing the sediment inputs and maintaining constant water levels, the water control structures of the Swan Lake HREP were designed for complete or partial dewatering of each compartment to consolidate the existing lake sediments. This would enhance the ability for rooted aquatic macrophytes to become established, decrease turbidity, and increase the diversity of aquatic macroinvertebrates.

B. In-lake sediments. Sediment re-suspension by wind generated waves was a principal aspect affecting the design of the Swan Lake HREP. The construction of the riverside levee and the installation of pumps were included in the design to enable partial or complete dewatering of the entire lake to consolidate flocculent sediments. In addition, islands were built across Middle and Lower Swan Lakes, perpendicular to the prevailing winds to reduce wind generated wave activity. Pre-project monitoring using

penetrometer measurements found average sediment depths (cm) for each unit as follows: Lower: 33.97, Middle: 35.27, Upper: 6.29 (Theiling et. al. 2000). In the post-project monitoring, penetrometer depths were not significantly different across all units from pre-project, but were within some units. Sediment depths were significantly higher in the lower unit in post-project, significantly lower in the middle unit, but did not differ significantly in the upper unit (Figures B2-3).
Pre-project monitoring of in-lake sediments re-suspended by wave activity was conducted in low water periods in an attempt to negate the inputs of river sediments. Theiling et. al. (2000), estimated a daily accretion of 104 g/m^2/day of in-lake sediments, nearly 84 pounds/m^2/year. Post-project monitoring suggested dewatering was successful in consolidating sediments (Garvey et. al. 2007), as per the Swan Lake HREP plan. They also found that frequent, intense dewatering would likely be necessary to achieve the project objectives, as the positive effects of drawdowns can quickly degrade. In Lower Swan Lake, where the drawdown schedule is much less intense, sediments were actually found to be softer in the post-project monitoring than in the pre-project. In Middle Swan, where management plans call for frequent drawdowns, sediments had hardened significantly since pre-project conditions. Upper Swan Lake/Fuller Lake showed no appreciable change as this area, likely due to this unit already being managed under an annual drawdown schedule.

C. Conclusions. The project measures were successful in providing the ability to dewater Swan Lake and to solidify the lake bottom. However, re-suspension and deposition of sediments by wind generated waves is still a major obstacle in achieving the goals of the Swan Lake HREP. The accretion rates of the flocculent sediment, especially in Lower Swan Lake, continue to impede habitat enhancement. Post-project analyses suggests that the ability to dewater the project area has the potential to substantially harden Swan Lake sediments (Garvey et. al. 2007), thereby achieving the desired results. An opportunistic approach with a more aggressive dewatering cycle on dry years is now being employed to accomplish this objective as well. The continued annual drawdown on Upper Swan/Fuller Lake has kept sediments more solidified in that unit than that of Middle and Lower. The successful draw downs in Middle Swan have had a positive impact relative to pre-project conditions in this unit as well. In Lower Swan, the lack of draw downs has left this unit the most highly impacted by accumulation and re-suspension of soft sediments.

4. Enhance wave control.

A. General. Control of wind generated wave activity to reduce the resuspension of lake sediments is a major goal in the Swan Lake HREP. Winds have a very long fetch over Swan Lake, especially Lower Swan, generating waves which keep the soft bottom sediments in suspension. For the establishment of aquatic macrophytes, damaging wave action, turbidity, and suspension/settling of lake sediments needed to be abated, so measures to reduce wave height were undertaken.

B. Island Groups. To decrease wave height and wind generated wave activity, which are persistent in resuspending Swan Lake sediments, two sets of island groups were constructed perpendicular to prevailing winds in an approximately east-west transect. The first group is located near Illinois River Mile 6.0 in Lower Swan and the second group is near R.M. 8.8 in Middle Swan. The islands were created by mechanically excavating lake bottom sediments (silt and clay) with a large 8 cubic yard clamshell bucket. The channel created from the mechanical excavation was to serve as deep over wintering fish habitat and provide conveyance for boating across the lake, which was too shallow to do so otherwise. The original plan included protecting the perimeter of each island with stone riprap. As the islands were being constructed, Swan Lake site managers decided that vegetative plantings (willow stakes) could alternatively be used to protect the islands from erosion. However, neither of the alternatives was immediately implemented leaving the island shoreline unprotected. Over time, erosion reduced the island surface area. In some cases, island mass has been reduced by more than 50 %. In addition, material eroded from the shoreline re-deposited in the exaction channel eliminating deep water habitat. Attempts to vegetate the islands was later made by project personnel, however, waterfowl usage of the islands, especially pelicans, was overwhelming and destroyed the protective vegetation.

Pre- and post-project monitoring indicated that the island groups were marginally effective at reducing wave height in Middle Swan, and not significant in reducing wave height in Lower Swan (Figure C1). Sediment deposition rates were measured upstream and downstream of island groups in Lower Swan Lake to assess the affects of the island group on sediment resuspension. Garvey et. al. (2007) found no significant differences in the deposition rates or sediment upstream or downstream of the island complex, or between pre- and post-project monitoring (Figure C2). This indicates that the resuspension of sediments has not been reduced by the creation of the island complex.

C. Lake Closure. The interior lake closure between Middle and Lower Swan Lake was constructed for water control (discussed in Section 5), and also as a barrier to wind generated wave activity to reduce resuspension of soft sediments. Lower and Middle Swan Lakes have been on different dewatering regimes, with Middle Swan having more frequent draw downs. The more aggressive dewatering schedule of Middle Swan has hardened the sediments significantly more than that of Lower Swan (Garvey et. al. 2007). It appears the interior lake closure has been effective in keeping the wind churned sediments of Lower Swan Lake confined, since Middle Swan maintains its sediment consolidation.

D. Riverside Dike/Levee. Wind generated wave activity and ice accumulation by wind is also causing persistent erosional damage to the riverside levee/dike. The levee is directly exposed to waves and ice sheets pushed by southwest and northwest winds, eroding the tow and lower slope of the berm. FWS and the corps have expended significant effort and resources to repair erosion, maintain the desired slope, and re-establish vegetation on the riverside levee each year.

E. Conclusions. The island groups had a slight impact in reducing wave height and resuspension of sediments in Middle Swan, but in Lower Swan, the island complex did not significantly alter wave height or the rate of sediment deposition from the pre-project to the post-project monitoring (Garvey et. al. 2007). The limited success may have been caused by more than one factor. The infrequent dewatering in Lower Swan had left this compartment with significantly more unconsolidated sediment. The extent of the flocculent sediment in Lower Swan may be too large for the islands to significantly impact, but their effects might be evident with more hardening of the lake bottom. In addition, if the islands of Middle and Lower Swan had been initially protected from erosion and maintained their design mass, the effects may have been more positive. The interior lake closure indicates that a barrier to wind generated wave activity can impede sediment resuspension. This closure is also protected by stone rip-rap to maintain its integrity from insults by wind, waves, and ice. Should these islands be refurbished, or additional islands built, vegetative or rock protection should be established immediately. If vegetative protection is used, frequent inspection and supplemental plantings may be necessary until the vegetation has adequately matured.

Preliminary wind/wave models were evaluated for the ability of different island configurations to impact the wind generated waves on Swan Lake (Appendix C). These models indicated that additional islands may be viable solution to the wind fetch issues on Lower and Middle Swan Lakes. Islands decreased overall wave activity and the protected areas on the lee side of islands may allow submergent aquatic vegetation to become established. However, additional island construction could be cost prohibitive, particularly if large islands or large numbers of islands need to be built to be successful. Further investigation would need to be conducted to determine if a beneficial and cost effective configuration of islands or island complexes can be created.

The area of the riverside levee/dike that has suffered persistent erosion by wind, waves, and ice has historically been mowed to allow inspection of levee conditions, prevent encroachment of woody species that would hinder the passage of construction equipment, and to prevent trees from growing roots that could pass through the levee. This strategy changed in 2009. FWS will no longer mow along the tow and lower slope of the levee to promote the establishment of vegetation and woody species. Rooted vegetation will help maintain the stability of the levee and provide protection from wind, waves, ice, and overtopping. The area that will become vegetated is far enough down the slope, and the crown of the levee is sufficiently wide, to minimize negative impacts to the integrity of the levee or operations and maintenance. Small breaks in the vegetation to allow viewing and monitoring of the project area will be created and maintained.

5. Form smaller independently-managed lake units.

A. General. An interior lake closure was constructed to subdivide the lower portion of Swan Lake into two independently managed, but complimentary habitat compartments. This closure also serves as a barrier to wind generated wave activity (see section 4.C).

B. Interior Lake Closure. A closure separating Swan Lake into two independently managed compartments was built to a uniform elevation of 423 feet NGVD, the same minimum grade as that separating Upper Swan/Fuller Lake from the lower portion of Swan Lake. The closure was then protected with stone riprap. This closure allows for management of the two compartments independently to achieve multiple objectives. The original water management plan was to continue to dewater Fuller Lake annually exposing 60% of the bottom, drawdown Middle Swan approximately 0.5 feet annually, and completely dewater Middle and Lower Swan Lakes every 8-10 years to consolidate sediments, promote growth of aquatic vegetation, and enhance water clarity (Table 2-2). The interior lake closures are two feet below the design spillway height to allow back flooding of the compartments to minimize damage to the riverside levee/dike from overtopping.

The two compartments are connected by one 48 inch corrugated metal pipe (CMP). This pipe is damaged and is insufficient for movement of water between the two compartments for complimentary management practices.

C. Conclusions. The interior lake closure has been successful in allowing for independent management objectives of Middle and Lower Swan Lakes. Lower Swan is opportunistically managed for annual dewatering with a thorough drawdown every two to three years to consolidate sediments and promote the establishment of aquatic vegetation and aquatic invertebrates. Middle Swan is managed for a complete drawdown every four years and partial dewatering on subsequent years, again, as opportunities are presented by weather and river levels.
Managing the two compartments in concert is more difficult as the 42 inch CMP is not large enough to support significant water exchange between the two units. A larger stop-log structure that allows controlled movement of a greater volume of water would be more beneficial.

6. Provide areas of deep water.

A. General. To improve the quality and diversity of habitat in Swan Lake and to provide areas for the over winter survival of fishes, one of the objectives of the HREP was to create and/or maintain areas of deep water.

B. Dredging. Dredging of the lake bottom for the construction of the riverside dike/levee created approximately 5.9 miles of deep water habitat that was approximately 30 feet wide by 10 feet deep. Additionally, the excavation of the lake bottom to create the island complexes in Middle and Lower Swan Lakes formed deep water channels to increase over wintering habitat. The dredge cuts were made in 1995, but dewatering for sediment consolidation did not occur until 2002. This resulted in the flocculent sediments being re-suspended and deposited back in the dredge cuts, especially in Lower Swan. In addition to the wind generated sedimentation rates being minimally impacted around the island complexes (see section 4.B.), the degradation of the islands themselves resulted in sloughing of the material back into the dredged areas.

C. Conclusions. Much of the deep water habitat created by dredging has been lost due to sedimentation. Original issues included Lower Swan being constructed out of sequence, with the dredge cut being made before pumps for dewatering were in place. This prohibited the consolidation of sediments in a time frame that would have kept the

flocculent material in Lower Swan from filling the newly created deep water habitat. Delayed draw downs of Middle Swan resulted in dredge cuts being filled by loose sediment as well. The lack of protection on the island complexes resulted in degradation by wind activity, and subsequent sloughing into the dredged areas.
Deep water habitat could be created again by re-dredging the same areas, dredging in areas where sediment suspension and deposition are lowest, or dredging to create more islands that would reduce wind fetch and wave activity.
Providing access to the areas of deeper water remaining in Middle Swan during winter months may still promote the over winter survival of fishes. However, the persistent sedimentation issues throughout Swan Lake will likely continue to prevent maintenance or creation of sustainable deep water habitats until abated.

7. Allow free movement of fishes between river and lake during late fall/early winter period.

A. General. Swan Lake has special significance to local fishes because it is the only major backwater available to fish in the lower Illinois River, representing approximately 40% of the total backwater habitat available for pool 26, and about 10 % of the backwater habitat on the Illinois River. Historically, the backwater habitat in Swan Lake has been important for spawning, rearing, and over winter survival of several species of riverine fishes. It is a goal of the Swan Lake HREP to provide access to overwintering habitat for fishes, while controlling water levels in the lake.

B. Fish Passage. The original backwater-river interface was a more or less constant, shallow connection between Swan Lake and the Illinois River for about 400 meters at the very downstream end of the lake. The lake was subject to back flooding through this open connection, and complete inundation from overtopping of the lake on the upper end occurred about every two years. To combat the rapid loss of the backwater lake habitat to sedimentation from the Illinois River, the lake was isolated from the river with a levee. This effectively closed off fish passage to the backwater habitat. To continue to allow movement of fishes between the river and the lake into Swan Lake, a 20-foot wide, open concrete channel containing four 52 inch wide stoplog slots was installed in both Middle and Lower Swan Lake. These structures serve to discharge minor increases in water levels, prevent an influx of river flood waters, and allow for fish passage.

C. Overwintering. The operating procedure prescribed in the DPR for the Swan Lake HREP was to manage Middle Swan Lake for waterfowl and Lower Swan for fishes. The Middle Swan stop log structure was to be closed in the winter to maintain stable water conditions for waterfowl feeding. The water control/fish passage structure in Lower Swan was left open to the river to allow access by fishes for spawning, rearing, and overwintering. In their Pre-HREP research, Sheehan et al. (1990 and 1994) determined that Swan Lake had the most volatile and least favorable temperatures for winter fish use of local backwaters previously studied. However, the pre-project fish sampling conducted by Theiling et al. (2000), concluded that abundances and frequency of riverine fishes was higher in the lake in winter, indicating that Swan Lake was an important overwintering habitat for fishes.

Post project monitoring found only intermittent increases of fish migration to Lower Swan Lake in the winter, and only temporary increases in residency time of tagged fishes in winter (Garvey et al. 2007). No pulse of directional movement with prolonged winter residency occurred in Lower Swan Lake, suggesting suitable overwintering habitat was not available.

D. Conclusions. Developing the physical conditions for fish to freely migrate between Lower Swan Lake and the Illinois River was successful. Based on the telemetry study and targeted sampling of the stop-log fish passage structure by Garvey et al. (2007), there appears to be minimal impact on the immigration and emigration of fishes common to Swan Lake. However, fishes did not utilize Lower Swan for refuge in late fall/early winter to the extent expected. Lower Swan Lake habitat conditions likely preclude this backwater as a useful overwintering area. Sedimentation has eliminated areas of deep water where thermal stratification and temperature stability can become established. Mean wintertime depths in Lower Swan Lake at regulated pool were approximately 50 cm in the post-project monitoring (Garvey et al. 2007). In addition, rapid fluctuations in temperature occur due to Lower Swan being a wind swept, shallow basin. Evidence of winter use by fishes in Lower Swan only occurred in late winter when ice cover minimized the impacts of temperature instability due to influence by wind and air (Garvey et al. 2007).

Post-project depths in Middle Swan were higher than Lower Swan, but still average well under 100 cm from November through March (Garvey et al. 2007). These depths are insufficient for complete thermal stratification, but remnant pockets of deeper water may still provide some functioning overwinter habitat in Middle Swan.

8. Buffer impact of cold water and ice.

A. General. To escape the cooler temperatures of winter and flowing conditions, river fishes often take refuge in backwater areas. Such habitats lack water currents, and if of sufficient depth, can maintain temperatures in excess of 5^{o}C (Sheehan et al. 1990, Sheehan et al. 1994). However, Sheehan (et al. 1990, Sheehan et al. 1994) suggest that a backwater must be deep enough to resist both complete freezing, as well as oxygen depletion. The configuration of backwater should also be such that they are not frequently inundated by the colder river waters during high water periods. In addition, they recommend that backwater areas provide a diversity of habitats (above 0^{o}C) in order to optimally benefit over wintering fishes, especially juveniles.

B. Protection from cold water. Winter survival of young-of-year fishes can influence future population structure of fish communities in large rivers (Sheehan et al. 1990; Sheehan et al. 1994). River water temperatures can remain near 0^{o}C for long periods of time during the winter due to mixing of moving water. The riverside dike/levee provides protection from the cold, flowing waters of the Illinois River during regulated flow. However, the lack of depth prohibits stratification and thermal refuge for overwintering fishes in Swan Lake. Pre-project monitoring found that despite the poor quality of overwintering habitat found in Swan Lake, fishes still utilized the area in winter, but this was likely due to the paucity of backwater habitat in the lower Illinois River (Sheehan et al. 1990; Sheehan et al. 1994). Post-project monitoring found that significant winter use of Lower Swan was limited to times of flooding and ice cover which promoted thermal stability in the lake, by reducing wind-induce mixing of the water column (Garvey et al. 2007).

C. Conclusions. During times of regulated flow in the winter, the project features successfully shield Swan Lake from cold flowing water and ice found in the river. However, refuge from cold flows appears to be offset by the volatile fluctuations in water temperature caused by diel fluctuations in air temperature and mixing from wind. The pervasive inputs of sediment preventing depth diversity, coupled with exposure to high wind fetch preclude Lower Swan from providing suitable over wintering habitat for fishes. This project objective does not seem attainable under the current project conditions. Consequently, future management practice in this compartment has already moved more to that of a moist soil unit with complete drawdowns two of every three years, and partial drawdowns on subsequent years. Frequent dewatering and lack of year-round connectivity to the river will increase consolidation of sediments and may reduce predation on aquatic and emergent vegetation in this unit. These actions would shift the former HREP goal of providing habitat for the over winter survival of fishes in Lower Swan, to emphasize another existing HREP goal – to restore aquatic macrophyte beds and associated invertebrate communities for benefit of migratory waterfowl.

Middle Swan appears to be better suited for overwinter survival of fishes than Lower Swan. Based on the pre- and post-project data, this unit also has limited capability as overwintering habitat for fishes, but the depth diversity and wind fetch issues are less severe in Middle Swan. Middle Swan is currently being managed for establishment of submergent and emergent aquatic vegetation for waterfowl, with a complete drawdown every four years and partial dewatering on subsequent years. The current drawdown regime in Middle Swan is likely the most practical management plan for this unit to continue to enhance macrophyte establishment and macroinvertebrte abundance. Access to overwintering habitat in Middle Swan can be provided to Illinois River fishes while maintaining this dewatering schedule.

9. Provide alternate structures so as to assure fish passage.

A. General. Prior to the Swan Lake HREP, an opening over a shallow sand bar approximately 400 m wide allowed fishes to migrate in and out of Swan Lake. The construction of the riverside dike, to decrease sedimentation and allow for water control, closed off this connection to the Illinois River. One of the primary design criteria for the water control structures in the Swan Lake HREP is that they allow fish passage into and out of Middle and Lower Swan Lakes for spawning, rearing, foraging, and overwintering. Immigration and emigration of the Swan Lake fish community was monitored to determine the success of these structures.

B. Structures for fish passage. A 20-foot wide, open concrete channel containing four 52 inch wide stoplog slots was installed in both Middle and Lower Swan Lakes to allow fish passage from the Illinois River. After the project became operational, trap nets and telemetry were utilized to determine directional movement between the Illinois River and Lower Swan Lake, as well as residency time of selected species (Garvey et. al. 2007). Trap nets found that Freshwater Drum, White Bass, and Gizzard Shad were the most common species passing through the stop log structure in Lower Swan Lake in 2003 - 2005. Larger adults of several species entering Lower Swan Lake was highest in the spring and summer during these years, indicating that this area is still important for spawning and recruitment dynamics in the lower Illinois River (Garvey et. al. 2007). However, overall numbers of native sport fishes moving into Lower Swan Lake is lower than was observed in the pre-HREP monitoring. Post project monitoring showed that the exotic Silver and Bighead Carps, introduced from Asia, frequently move in and out of Swan Lake, using this area for spawning, rearing, and foraging. Bighead and Silver Carp were both present in great numbers in Swan Lake in summer 2009 (John Mabery pers. comm.).

C. Conclusions. The installation of the two fish passage/water control stop log structures was successful in allowing for passage of riverine fishes into Swan Lake during times the structures are open to the river. However, numbers of native fishes moving from the Illinois River into Swan Lake have decreased since the project was constructed. Several factors may have influenced this shift, including the decreased size of the passage structures as compared to the 400 meter opening that was available pre-construction; the fact that the stop log structures are not open to the river year round; the highly variable flow rates through the stop log structure as the river stage increases or decreases; and the lack of a natural rise and fall regime of the lake with the normal river stage. Another obvious shift is the difference in the fish assemblage in the lower Illinois River due to the explosion of the Asian carp species. These two species attributed for more than 90% of the fish biomass observed in a fish kill in Swan Lake in 2009.

6. EVALUATION OF PROJECT GOALS

1. Restore aquatic macrophyte beds and associated invertebrate communities for benefit of migratory waterfowl

A. General. Restoration of aquatic plant communities and aquatic macroinvertebrate communities for the benefit of migratory waterfowl was a primary focus of the project measures. Decreasing sedimentation and turbidity, solidifying the lake bottom, implementing seasonal water control, and reducing wave action were identified as key steps in achieving this goal.

B. Aquatic Macrophytes. According to Theiling et. al. (2000), immediately following its creation in 1938, Swan Lake supported abundant submersed aquatic plants. However, due to more or less permanent inundation of Swan Lake after the construction of Lock and Dam 26 in 1938, and increased sedimentation, aquatic vegetation all but disappeared in the Middle and Lower Swan Lakes. During the pre-HREP monitoring a small area of submersed aquatic vegetation remained near the connection between Swan Lake and the Illinois River. In Upper Swan, or Fuller Lake, submersed aquatic vegetation persisted when it was not drawn down during the growing season. Emergent vegetation occurred only in a narrow band along the periphery of Lower and Middle Swan, but was more prevalent in the annually dewatered areas of Fuller Lake.

In Upper Swan/Fuller Lake, submersed and rooted floating vegetation remained established with similar species composition when comparing pre- and post-project monitoring (Table E2). In Middle Swan, establishment of aquatic vegetation was minimal in post-project, in contrast to the presence of several species in pre-project surveys. Lower Swan also had seven species established in pre-project surveys, but virtually no submersed aquatic nor rooted floating vegetation in post-project monitoring. Draw downs in Middle Swan were successful in promoting growth of emergent vegetation for the two of three years draw downs occurred (2004 and 2005), but the lack of drawdown in 2006 prevented establishment of emergent vegetation (Table E1). In addition, experiments with cages placed in Middle Swan to exclude common carp, grass carp, and aquatic turtles (e.g. red-eared sliders) indicated that aquatic vegetation may become established in this unit if protected from herbivorous species (unpublished data). Repeated and prolonged flooding from 2008 to 2010, coupled with on-going silt resuspension throughout the lake, eliminated the few submersed aquatic plant becoming established in Swan Lake.

C. Invertebrate Communities. Secondary production of macroinvertebates is one of the most important functions of backwaters, as energy from primary production and detritus is made available to higher trophic levels including birds and fish. The promotion of moist soil vegetation in Swan Lake was anticipated to increase the associated aquatic macroinvertebrate communities to provide a protein rich food source for migrating waterfowl. According to Garvey et al (2007), the post-HREP measures that supported moist soil vegetation increased macrophyte diversity and abundance as well as overall macroinvertebrate abundance and biomass. Changes in invertebrate abundance between pre- and post-HREP were variable between habitat types and seasons, but there was an increase in invertebrate abundance during late spring, when some species appear to increase their dependence on invertebrates, having a positive influence on both dabbling and diving ducks (Appendix F).

D. Conclusions. The establishment of emergent and submersed aquatic vegetation may be achieved in Lower and Middle Swan Lake with the current, more frequent draw down schedule that will help reduce turbidity and consolidate sediments. The maintenance of stable water conditions during draw down years is important for the establishment of emergent vegetation as shoreline areas with gradual slopes can be affected by minor influences in water levels. Introduction of seeds and tubers, along with control of herbivores may assist reestablishment of submersed vegetation, but may be difficult to conduct on a large enough scale. Intense draw downs during dry years will exclude aquatic herbivores during the growing season and enhance the ability of rooted emergent vegetation to get started. Furthermore, continued water level management that may eventually provide conditions to restore vegetative communities and water quality conditions will continue to promote macroinvertebrate abundance and biomass.

2. Provide habitat for over winter survival of fish

A. General. The lack of over wintering habitat in the lower Illinois River gives Swan Lake potential significance to the fish community in this area. As water temperatures drop in late fall and winter, fishes migrate, often in great numbers, to backwater areas to seek stable temperatures and protection from main channel flows. To provide valuable overwintering habitat, these backwaters need to be of sufficient depth and seldom inundated by flood waters in winter months.

B. Over Winter Habitat. A primary goal of the Swan Lake HREP was to create/enhance over wintering habitat for fishes by providing access to deep water that was protected from main channel flows during late fall and winter. The measures implemented to achieve this included the riverside levee, fish passage structures in Middle and Lower Swan, and dredging to create deep water habitat. Post-project monitoring indicated that the riverside levee is effective at shielding Swan Lake from the cold water and ice in the Illinois River during normal flow conditions. Sampling and telemetry in the areas of the stop log structures confirmed the ability of fishes to access the Swan Lake backwater habitats. The dredge cuts around the islands and along the riverside levee have filled back in with the flocculent sediments resuspended by wind and wave action, as well as the sediment inputs from the hillside areas.

During the post-HREP monitoring, Garvey et al (2007) observed no seasonal increases in abundance of any fish species during fall that would indicate individuals were seeking overwintering habitat in Swan Lake. The shallow windswept Lower Swan Lake is unsuitable for overwintering habitat due to the extreme temperature volatility making physiological acclimation and preferred temperature selection difficult. The slightly deeper habitat found in Middle Swan Lake is likely more suitable for maintaining overwintering habitat, and telemetered fishes accessed this area during the post-HREP study.

C. Conclusions. The lack of available overwintering habitat in Lower Swan and the slightly deeper water remaining in Middle Swan lend to revising this project goal and subsequent management strategy. A preliminary management revision would be to treat both Lower Swan and Middle Swan as moist soil units and allow Middle Swan to remain open in fall for overwintering habitat for fishes. This objective to provide overwintering habitat to fishes in Middle Swan can be achieved while maintaining the current drawdown schedule in this compartment (complete dewatering every four years and partial drawdowns on subsequent years). It is important to maintain the drawdown schedule in Middle Swan so as to continue the consolidation of sediments to decrease turbidity and establish aquatic macrophytes for improved water quality and aquatic invertebrate abundance.

3. Provide habitat for spawning and rearing of fish

A. General. Floodplain areas and backwaters are important for many riverine species for spawning and nursery habitat. Backwater areas often provide the lentic conditions necessary for development of young-of-year fishes. The ability to maintain stable water conditions in Swan Lake while affording fish passage is critical to achieving the goal of providing habitat for spawning and rearing of fishes.

B. Spawning and Rearing Habitat. Both pre- and post-HREP monitoring found Swan Lake to be important to recruitment dynamics of Illinois River fishes (Garvey et al 2007, Sheehan et al. 1990, Sheehan et al 1994). The size and diversity of fishes utilizing Swan Lake increased in spring and summer in the post-HREP monitoring, indicating that adult fish were likely moving into the area to spawn. However, a shift in the species assemblage was observed to be increasing numbers of non-sport fishes, such as Asian carps, and decreasing numbers of sport fishes, such as black and white crappie and largemouth bass. The species that appear to be decreasing in Swan Lake are typically those that prefer firmer substrates, improved water clarity, and abundant aquatic plant growth for spawning, rearing, and foraging habitats.

C. Conclusions. The enhanced ability to provide stable water conditions for spawning and rearing of fishes, while allowing for fish passage, was achieved with the riverside dike and stop log structures. However, turbidity and sedimentation continue to impact the available spawning and nursery habitat for several species, including some sport fishes. The more aggressive drawdown schedule now being employed in Middle and Lower Swan Lakes will likely improve consolidation of sediments. This should further decrease turbidity and continue to promote the establishment of aquatic macrophytes, all of which will improve the spawning and rearing habitat in Swan Lake.

The tradeoff to improving and maintaining quality spawning and nursery habitat in Swan Lake requires the more frequent drawdown schedule. During dewatered years, the length of time fishes can spawn and larval and juvenile fishes can forage in the lake can be significantly shortened (dewatering can begin as early as June). But with a less frequent dewatering schedule, turbidity and sedimentation will continue to degrade the available spawning and nursery habitat, and reduce recruitment potential during years the lake is not dewatered. This wet-dry cycle in Swan Lake more closely approximates what would be expected under a normal hydrograph, thus benefiting fishes, plants, and wildlife.

The recent increase in bighead and silver carp in Swan Lake is also a probable impact to successful recruitment of native fishes. Young-of-year individuals of many native species feed primarily on zooplankton, which is also the primary food source of Asian carp, especially bighead carp. Numbers of Asian carp utilizing Swan Lake has dramatically increased over recent years. During the 2009 summer drawdown, USFWS personnel at Swan Lake noted that over 90% of the thousands of fishes trapped and killed in the lake were Asian carp (John Mabery, USFWS, pers comm.). Asian carp are likely foraging in Swan Lake and increasing their reproductive capabilities; this was supported by the increased residency observed within the lake during spring (Garvey et al 2007). The increased use in Swan Lake by Asian carp for foraging during the spring months would coincide with larval and juvenile native fishes hatching and foraging as well. Furthermore, most Asian carps captured in trap nets were young-of-year fishes as they moved between the lake and the river during the summer and fall suggests this system enhances reproduction via improved hatching success and nursery habitat (Garvey et al 2007).

4. Increase overall habitat value for waterfowl and fish

A. General. The overarching goal of the Swan Lake HREP was to provide the physical conditions necessary for creating a wide spectrum of strategies for waterfowl and fisheries management.

B. Waterfowl. The density of diving and dabbling ducks increased in Swan Lake when comparing pre- and post-HREP numbers (Table X). This may have been in part due to an increase in the continent-wide waterfowl populations, however, ducks were foraging successfully in Middle Swan Lake and likely gaining energy for reproduction in spring and migration in fall (Garvey et al 2007). Although aquatic macrophyte density and diversity was lower in the post-HREP, aquatic invertebrate abundance and biomass increased, providing a protein rich food source for migratory waterfowl at Swan Lake (Appendix G).

Table 6.1. Duck use-days (DUDs), peak abundance, and an index of individual residence time (R/T) in days by lake unit at Swan Lake, Illinois during the pre-HREP (1993) and post-HREP (2004 and 2005) evaluation periods. Residence time is estimated as the ratio of DUDs to peak abundance.

Lake Unit	1993			2004			2005		
	DUDs	Peak	R/T	DUDs	Peak	R/T	DUDs	Peak	R/T
Lower	65,617.00	3,158.00		98,126.00	4,291.00		272,141.00	7,793.00	
Middle	19,818.00	953.00		183,052.00	8,005.00		293,798.00	8,412.00	
Moist-soil	24,427.00	1,175.00		31,777.00	1,390.00		59,165.00	1,994.00	
Upper/Fuller	21,156.00	1,017.00		45,030.00	1,969.00		261,727.00	7,495.00	
Total	131,018.00	6,303.00	20.8	357,985.00	15,655.00	22.9	891,710.00	25,694.00	34.3

C. Fish. The ability to maintain and manipulate water levels in Middle and Lower Swan Lake while allowing for fish passage was successful. Both native and exotic species were observed passing through the stop log structures in the post-HREP sampling. The habitat in Lower Swan Lake is largely unsuitable for overwinter survival of fishes. The winter use of this area by Illinois River fishes appears to occur only during high water and when the lake becomes ice covered. This is due to Lower Swan lacking sufficient depth to buffer the impacts of wind and fluctuations in air temperature. Swan Lake continues to provide important spawning and rearing habitat for fishes based on post-construction sampling efforts. However, due to lack of vegetation and firm substrates, low water clarity, and increasing numbers of exotic species, desirable, native species are likely being displaced.

D. Conclusions. The increase in aquatic macroinvertebrate biomass and the presence of emergent vegetation during years with effective dewatering provide valuable resources for migratory waterfowl, as is evidenced by increase waterfowl use on Swan Lake. The increased frequency of drawdowns will continue to enhance the habitat and resources in Swan Lake for future waterfowl populations.

Due to the shallow nature of Lower Swan, management for overwintering habitat for fishes is not a practical use of this area. Increased project benefits for migratory waterfowl can be realized by managing this area similar to a moist soil unit, as is currently being done. Management for overwintering habitat may have to be conducted in Middle Swan, even though the availability of suitable habitat is only slightly greater.

Although Swan Lake is still utilized for spawning and rearing by native fishes, additional habitat improvements such as decreased sedimentation and turbidity are much needed to increase successful recruitment. In addition, the explosion of the Asian carp population has further impacted the use of Swan Lake by native fishes. Bighead and silver carps composed the overwhelming majority of fishes in Swan Lake, in both numbers and biomass, immediately following the 2009 drawdown. The large number of carp that died during the drawdown raised some public concern regarding odor, water quality, and water level management at Swan Lake. Because some fish and fish bodies were pulled through the pumps and into the river during dewatering, a barrier had to be built in front of the Lower Swan pump station. A metal frame with vertical metal bars spaced two inches apart was placed around the sump area of the Lower Swan pump to keep fishes from being entrained. Garvey et al (2007) found that both bighead and silver carp tend to avoid backwater habitats during summer, especially in times of low flow. And for most years, water temperature in Swan Lake increases during summer months and subsequently dissolved oxygen decreases. However, weather conditions in summer 2009 were cooler and wetter than average, which may have maintained higher water quality conditions later into the year, thus keeping the large number of carp in Swan Lake. In years with a more typical summer pattern, most Asian carp may leave Swan Lake before the drawdown, avoiding pump entrainment.

In smaller, more confined bodies of water, as opposed to the open river, the ravenous feeding behavior of Asian carp has been observed to have detrimental effects on the native fishes competing for the same food resources (Nate Caswell, USFWS, pers. comm.). Many of the native fishes that spawn in Swan Lake also utilize the zooplankton on which the Asian carps feed. The larger, more efficient feeding Asian carps likely out compete the young of year fishes that need zooplankton for successful recruitment. Developing a viable solution to reducing the number of Asian carp in Swan Lake would be difficult. For example, physical barriers that prevent the passage of Asian carp into Swan Lake would also prevent the passage of native fishes for spawning, rearing, and overwintering.

7. CONCLUSIONS AND RECOMMENDATIONS

Sedimentation continues to be one of the largest obstacles to meeting the goals of the Swan Lake HREP. The annual sediment inputs from the watershed as well as resuspension of the flocculent material by wind generated wave activity continue to contribute to loose substrates and increased turbidity. As river levels and climactic conditions allow, Lower Swan is now managed for annual dewatering with a thorough drawdown every two to three years, and Middle Swan is managed for a complete drawdown every four years and partial dewatering on subsequent years. This opportunistic dewatering schedule should continue to consolidate sediments, decrease turbidity, and promote the establishment of aquatic vegetation (primarily emergent) and aquatic invertebrates. In addition, the experimental plantings of aquatic macrophytes and exclusion of herbivorous species in Middle Swan may further facilitate these processes. The advancement of aquatic vegetation, the decreased turbidity, and hardening of the lake bottom will provide much improved spawning and rearing habitat for native fishes.

In addition to addressing existing sediment in Swan Lake, future efforts at Swan Lake will need to focus on the ongoing sediment inputs. The watersheds draining into Swan Lake from the hillside areas are producing enough sediment to form deltas in the areas where they enter Middle and Lower Swan Lake. Channeling the hillside watersheds and their sediment load away from Swan Lake may be one option to effectively reducing a significant portion of the future sediment accumulation in Swan Lake. Restricting the area within Swam Lake that sediment from the tributaries can accumulate may be another option. Small berms that reduce flow and cause suspended sediment to "fall out" as it enters the lake could contain the sediment inputs to the delta areas. The elevation of these delta areas would continue to increase as sediment accumulated. Over time, these deltas would become vegetated and could eventually support bottomland hardwood species. These wooded areas could then filter future sediment inputs and restore natural processes to the lake.

As water control in the Swan Lake HREP is critical to meeting the diverse objectives for waterfowl and fishes, it is imperative that each of the water control structures is able to serve the intended function. The corrugated metal pipe that connects Middle and Lower Swan is insufficient in allowing for water control between the two units. This CMP should ideally be replaced with a larger, more effective structure that can be more readily operated, such as a stop log structure.

The shallow basin in Lower Swan Lake is much more suited for management as a moist soil unit, as opposed to a backwater for overwintering fishes. On years with successful drawdowns, abundant emergent vegetation grows, providing significant forage for waterfowl as well as for the aquatic invertebrates that colonize these areas by spring. Continuing these management practices in Lower Swan is proving more beneficial to meeting other project goals. To better achieve the goal of providing habitat for the overwinter survival of fishes, consideration could be given to providing fishes access to Middle Swan Lake in late fall and winter. Though not exceedingly deeper than Lower

Swan, Middle Swan does have some areas of deeper water as well as slightly more protection from winds that dramatically reduce water temperatures. The current drawdown schedule can be maintained to continue to consolidate sediments and establish aquatic plants, and still provide fall and winter access for Illinois River fishes.

The explosion of the Asian carp populations has impacted design, operation, adaptive management, resource management, and some environmental benefits of the Swan Lake HREP. Future management objectives for native fish populations in Swan Lake will also have to include impacts by the Asian carps. They are likely to persist as one of the dominant fishes in Swan Lake until science or innovative measures are developed to exclude or remove them.

As the Swan Lake HREP continues to progress and evolve, so should the project goals and measures to attain those goals. For example, limitations from flooding and climactic conditions have revised the management procedures to an opportunistic approach. Instead of employing a multi-year, pre-set management plan, USFWS is capitalizing on the conditions each season and year bring. Sedimentation, exotic species, unforeseen results of the HREP measures, etc., will all continue to require adaptive management processes, revision of project goals, and innovative procedures to meet those goals.

At this time, the O & M manual is still under preparation. Operation and maintenance has been conducted in accordance with the evolving project goals and objectives. Adaptive management strategies have been developed, coordinated, and deployed in an ongoing effort to improve project design and function. The water control structures are being operated and maintained correctly, and regular site inspections by the Refuge Manager have resulted in proper coordination and corrective maintenance actions. As project goals are developed and met through adaptive management processes, the operations and maintenance manual will be finalized for USFWS site managers.

Table 7.1. Status of Swan Lake HREP objectives.

Goal	Objective	Measure	Objective Status
Restore aquatic macrophyte beds and associated invertebrate communities for benefit of migratory waterfowl	Substantially reduce future lake sedimentation	- Dredging - Riverside Dike/Levee - Water Control Structures - Hillside Sediment Control	Partially Met
	Maintain stable water levels during the growing season	- Riverside Dike/Levee - Water Control Structures	Met (as water and river levels allow)
	Provide the ability to solidify the lake bottom	- Riverside Dike/Levee - Water Control Structures	Met
	Enhance wave control	- Interior Closure - Islands	Not Met
	Form smaller independently-managed lake units	- Interior Closure	Met
Provide habitat for over winter survival of fish	Provide areas of deep water	- Dredging	Not Met
	Allow free movement of fish between river and lake during late fall/early winter period	- Riverside Dike/Levee - Water Control Structures	Met
	Buffer impact of cold water and ice	- Riverside Dike/Levee - Water Control Structures	Met
Provide habitat for spawning and rearing of fish	Provide alternate structures so as to assure fish passage	- Riverside Dike/Levee - Water Control Structures	Met
Increase overall habitat value for waterfowl and fish	Meet all of the above objectives	- All	Improved

APPENDIX A.

MONITORING AND PERFORMACE EVALUTION MATRIX

Monitoring and Performance Evaluation Matrix

Type of Activity	Purpose	Responsible Agency	Implementing Agency	Funding Source	Remarks
Sedimentation Problem Analysis	System-wide problem definition. Evaluates planning assumptions.	USFWS	USFWS (EMTC)	LTRM	Leads into pre-project monitoring; defines desired condtions for plan formulation.
Pre-Project Monitoring	Identifies and defines problems at HREP site. Established need for proposed project features	Sponsor	Sponsor	Sponsor	Attempts to begin defining baseline. See DPR Sections 2 and 3.
Baseline Monitoring	Establishes baselines for performance evalualtion.	Corps	Field station or sponsor thru Cooperative Agreements or Corps	LTRM	Appendix DPR-L shows the locations of and sites for physical/chemical data collection. Actual data collection will be accomplished during P&S phase. For biological baseline information, see Appendix DPR-J.
Data Collection for Design	Includes identification of project objectives, design of project, and development of performance evaluation plan.	Corps	Corps	HREP	Comes after the fact sheet. This data aids in defining the baseline. See DPR sections 4-7 and 13.
Construction Monitoring	Assesses construction impacts; assures permit conditions are met.	Corps	Corps	HREP	Environmental protection specifications to be included in construction contract documents. Inter-agency field inspections will be accomplished during project construction phase.
Performance Evaluation Monitoring	Determine success of project as related to objectives.	Corps (quantitative field observations)	Field station or sponsor thru Cooperative Agreements or Corps	LTRM	Comes after construction phase of project. See DPR Section 13.
Analysis of Biological Response to Projects	Determine critical impact levels, cause-effect relationships, and effect on long-term losses of significant habitat.	USFWS	USFWS (EMTC)	LTRM	Problem Analysis and Trend Analysis studies of habitat projects.
	Demonstrate success or failure of habitat.	Corps	Corps/USFWS/(EMTC)/Others	LTRM	Biological Response Study tasks beyond Scope of Performance Evaluation, Problem Analysis, and Trend Analysis.

APPENDIX B.

SEDIMENTATION

Figure B1. Relationships of water depth to lake elevation in the lower, middle and upper units of Swan Lake during the three years of post-project monitoring.

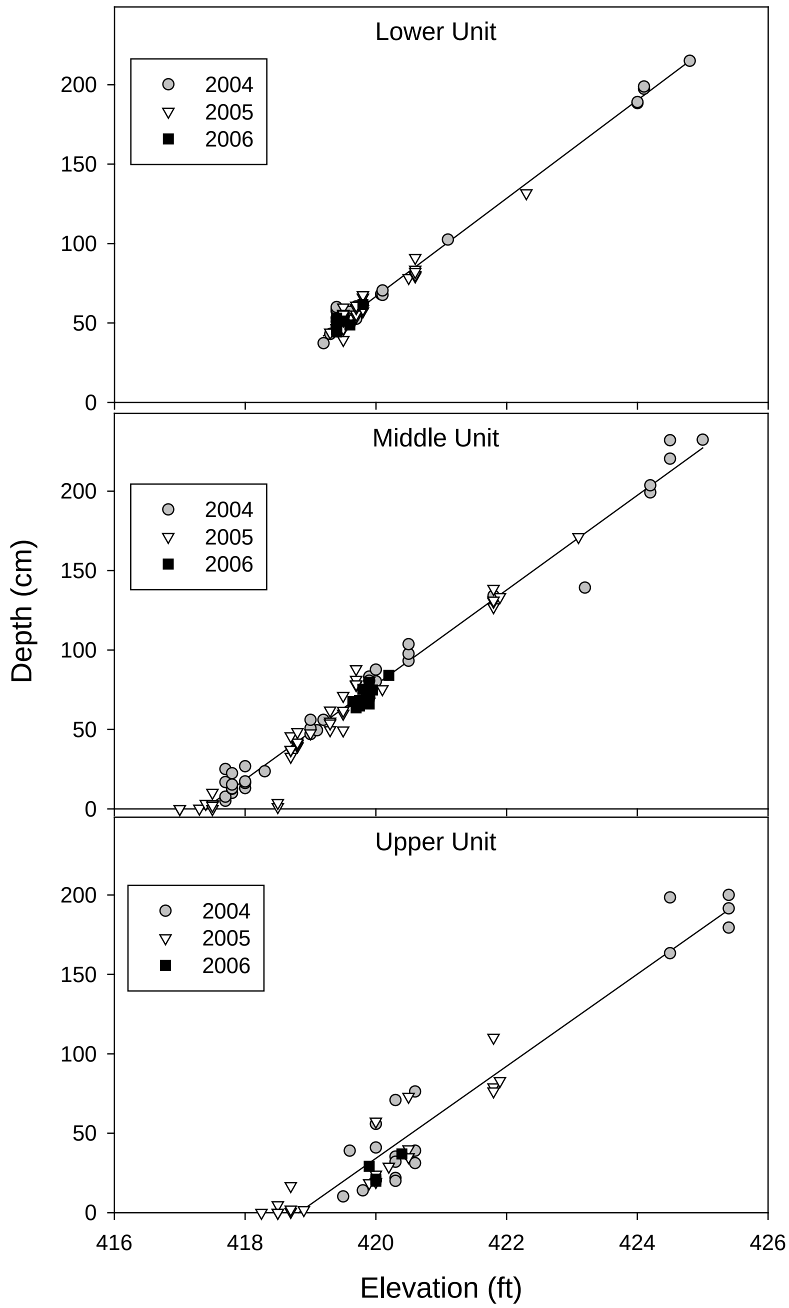


Figure B2. Mean (± standard error) penetrometer depth from pre- and post-project monitoring in the lower, middle and upper units of Swan Lake.

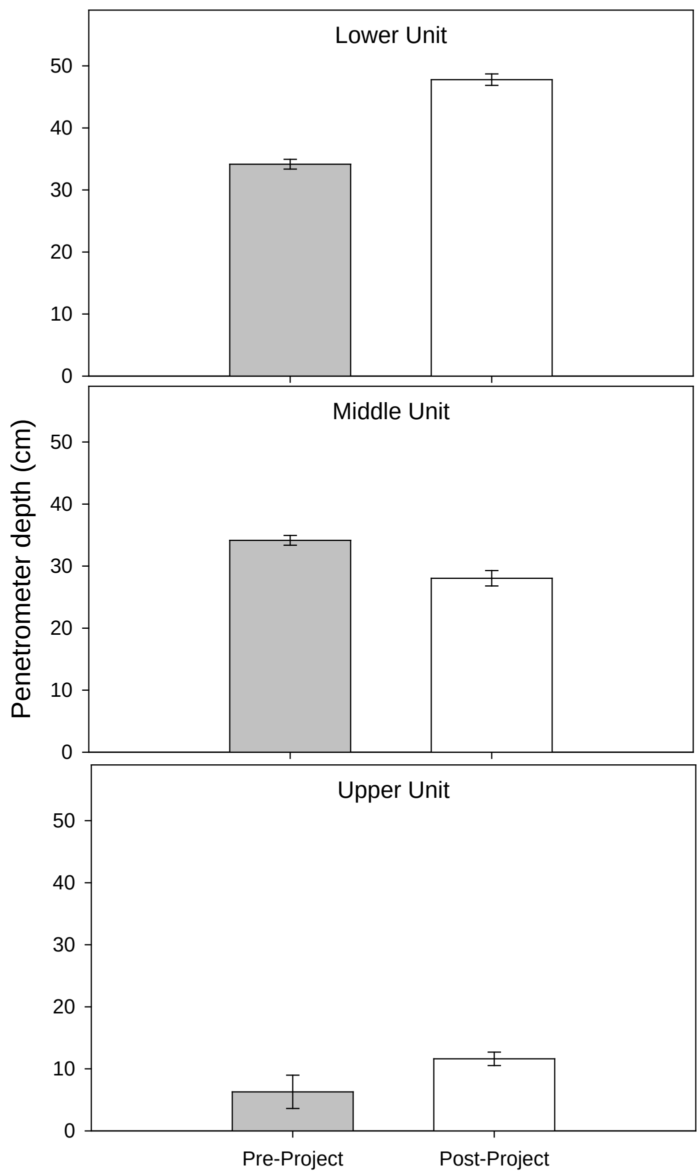


Figure B3. Frequency of occurrence of sites among 10 cm groupings of penetrometer depth measured during pre- and post-project monitoring in the lower, middle and upper units of Swan Lake.

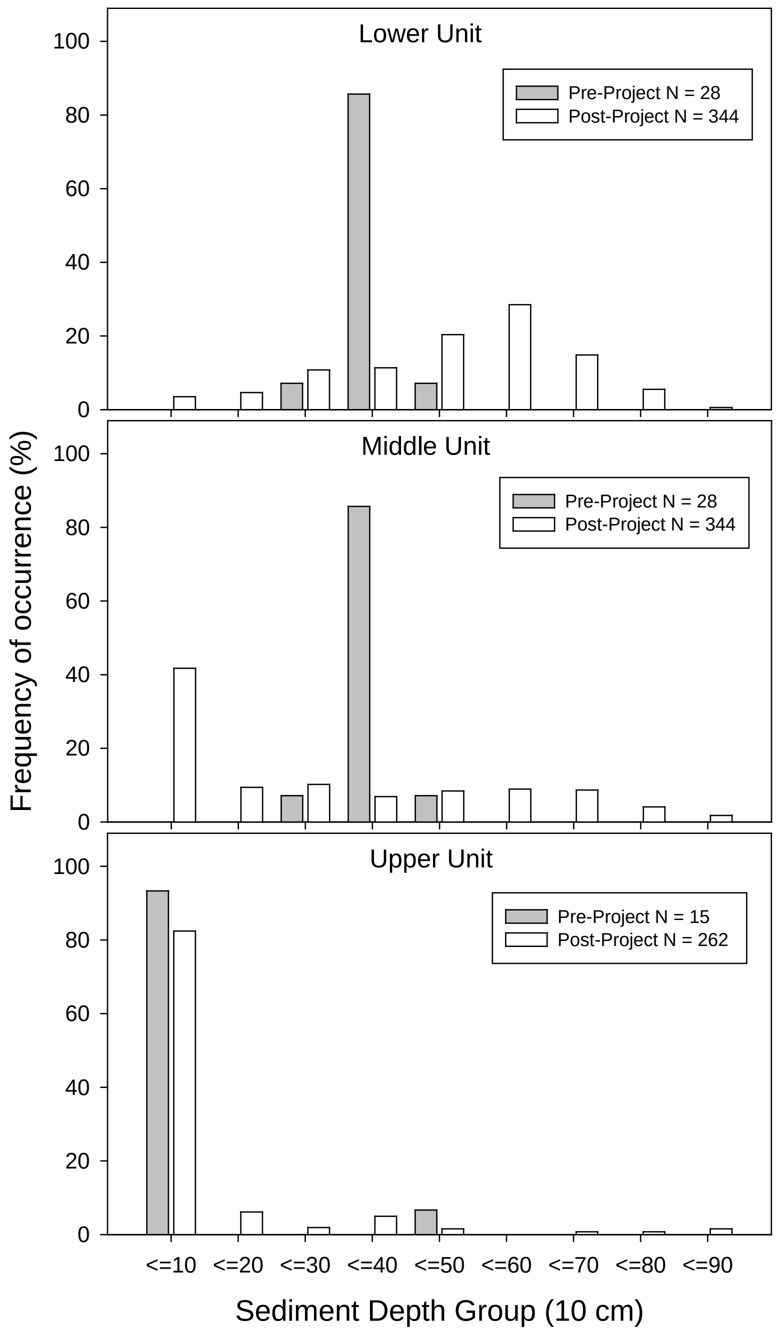
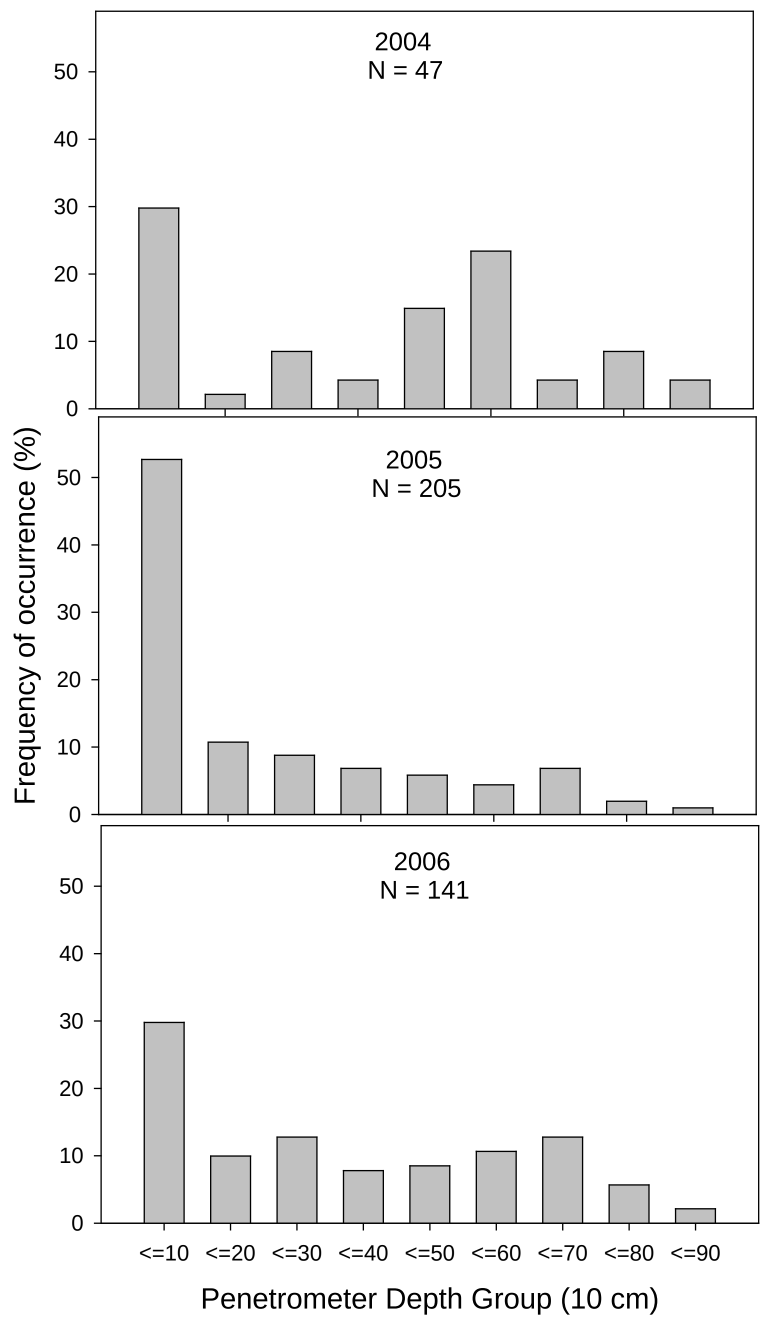


Figure B4. Frequency of occurrence of sites among 10 cm groupings of penetrometer depth measured during post-project monitoring (2004, 2005, 2006) in the middle unit of Swan Lake.



APPENDIX C.

WAVE CONTROL AND WEIGHTED WIND FETCH MAPS AND SUMMARY CHARTS

Figure C1. The relationship between wave height and wind speed between pre- and post-project monitoring of the lower, middle, and upper units of Swan Lake.

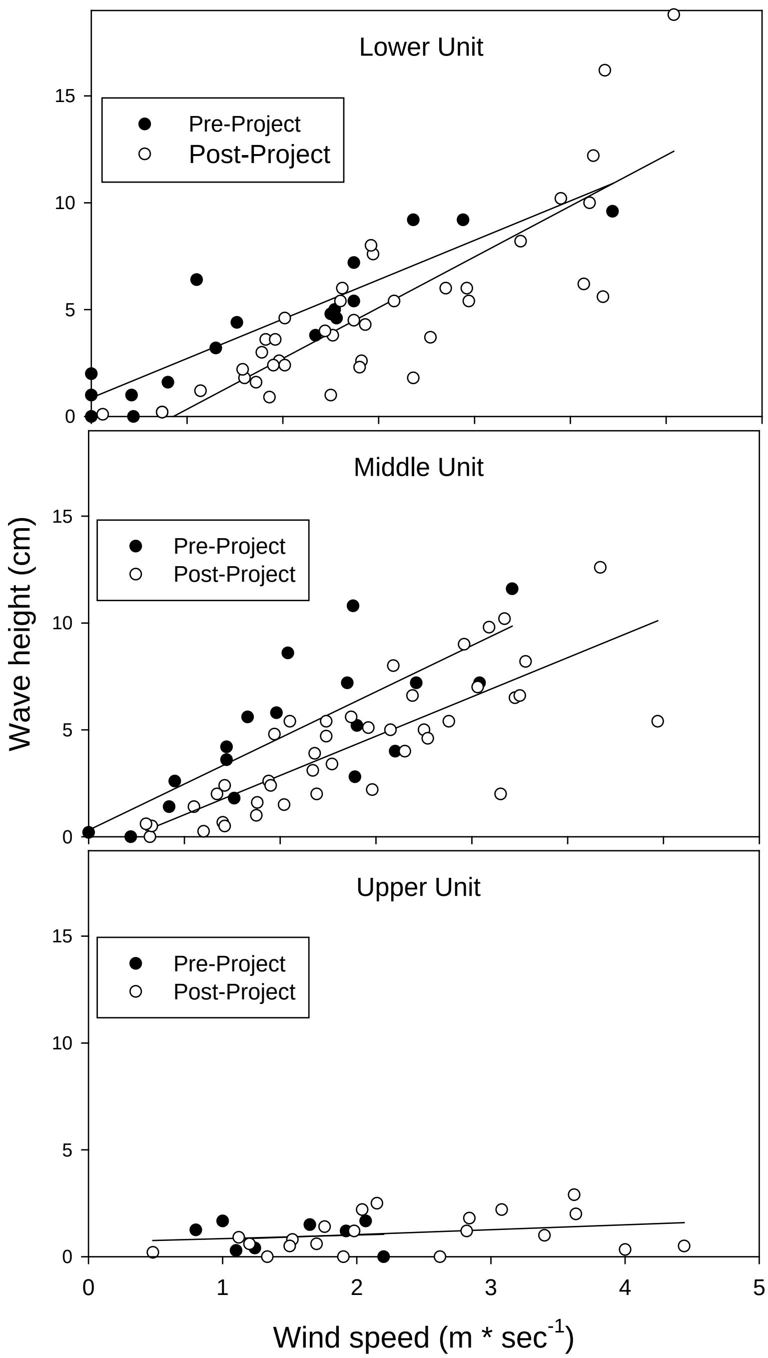
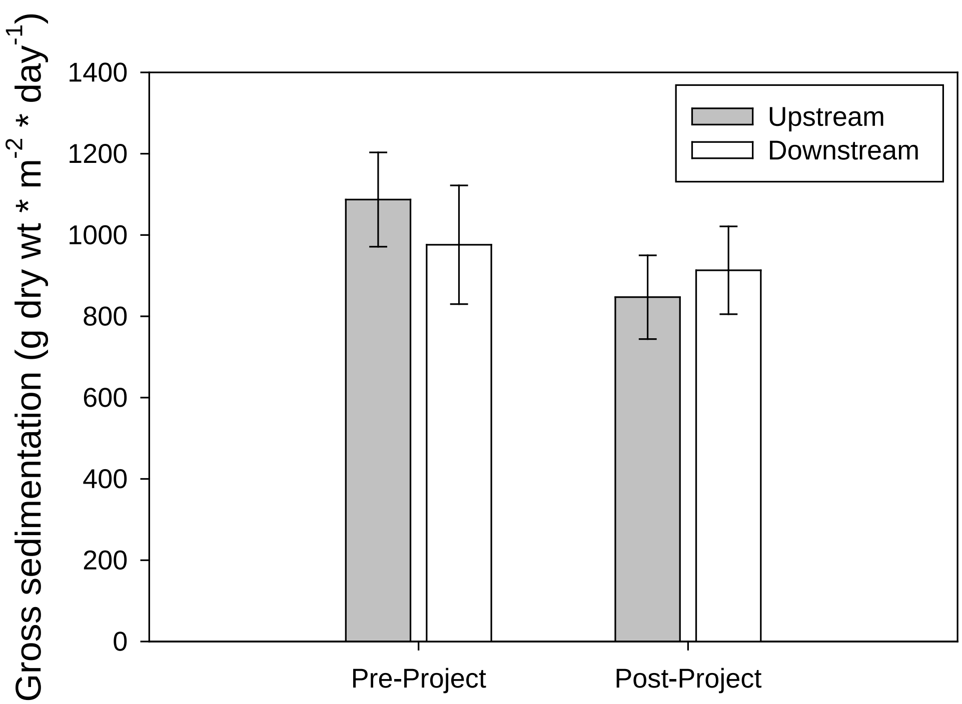


Figure C2. Mean (± standard error) gross sedimentation rate sampled at one location upstream and one location downstream of the island groups in the lower unit of Swan Lake during pre- and post-project monitoring.



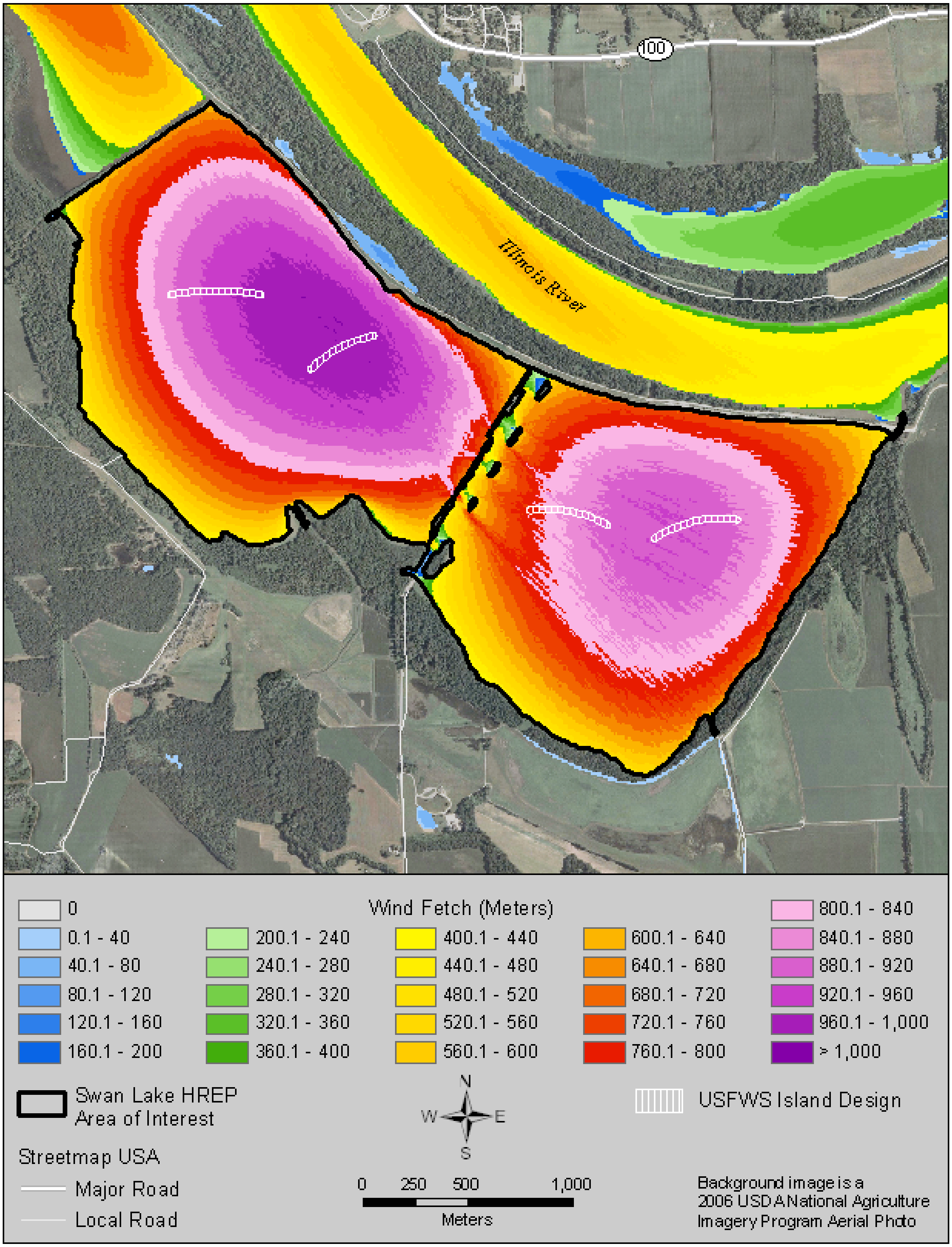


Figure C3. Weighted fetch results for existing conditions for Swan Lake HREP overlaid with proposed USFWS island design

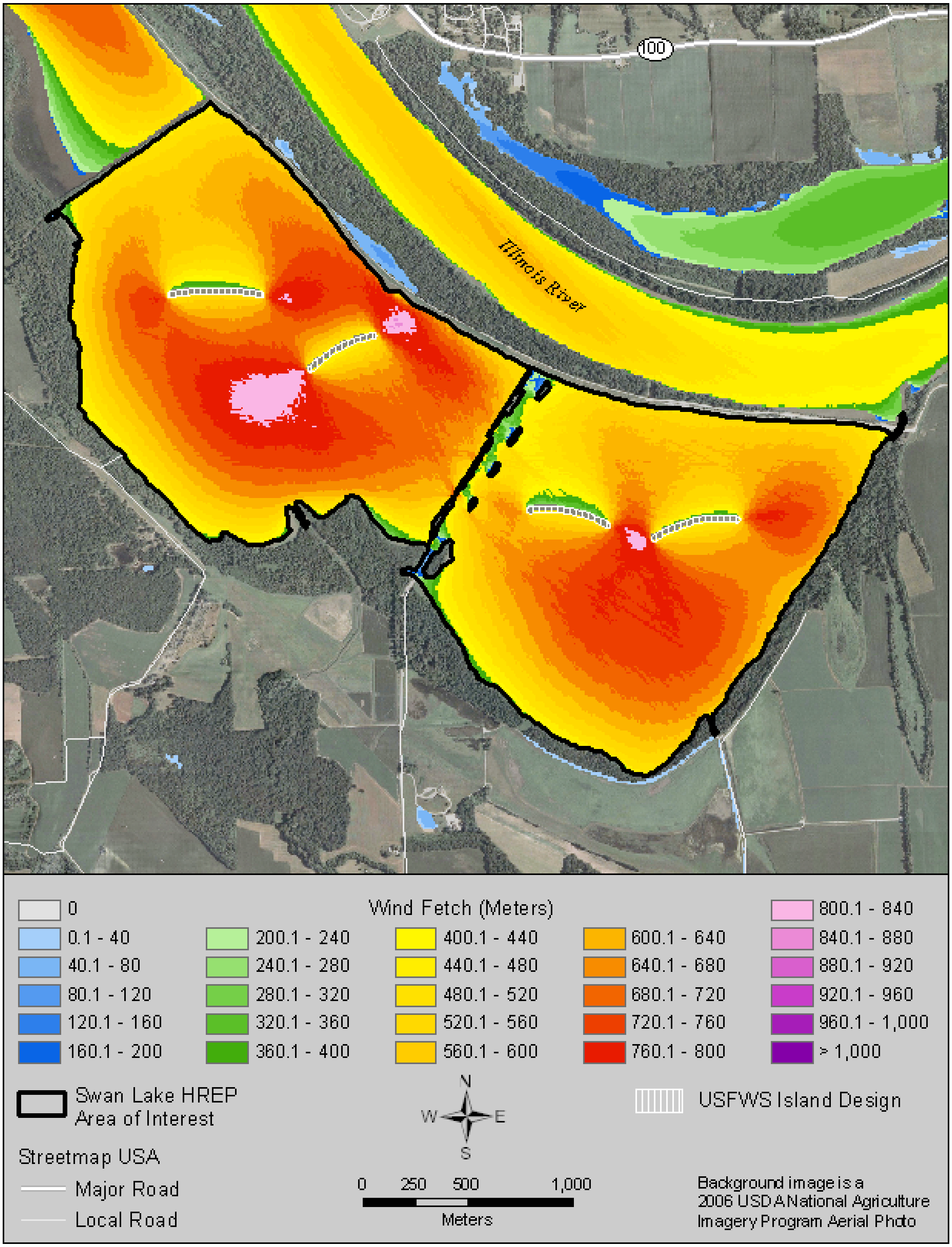


Figure C4. Weighted fetch results for Swan Lake HREP applying USFWS proposed island design

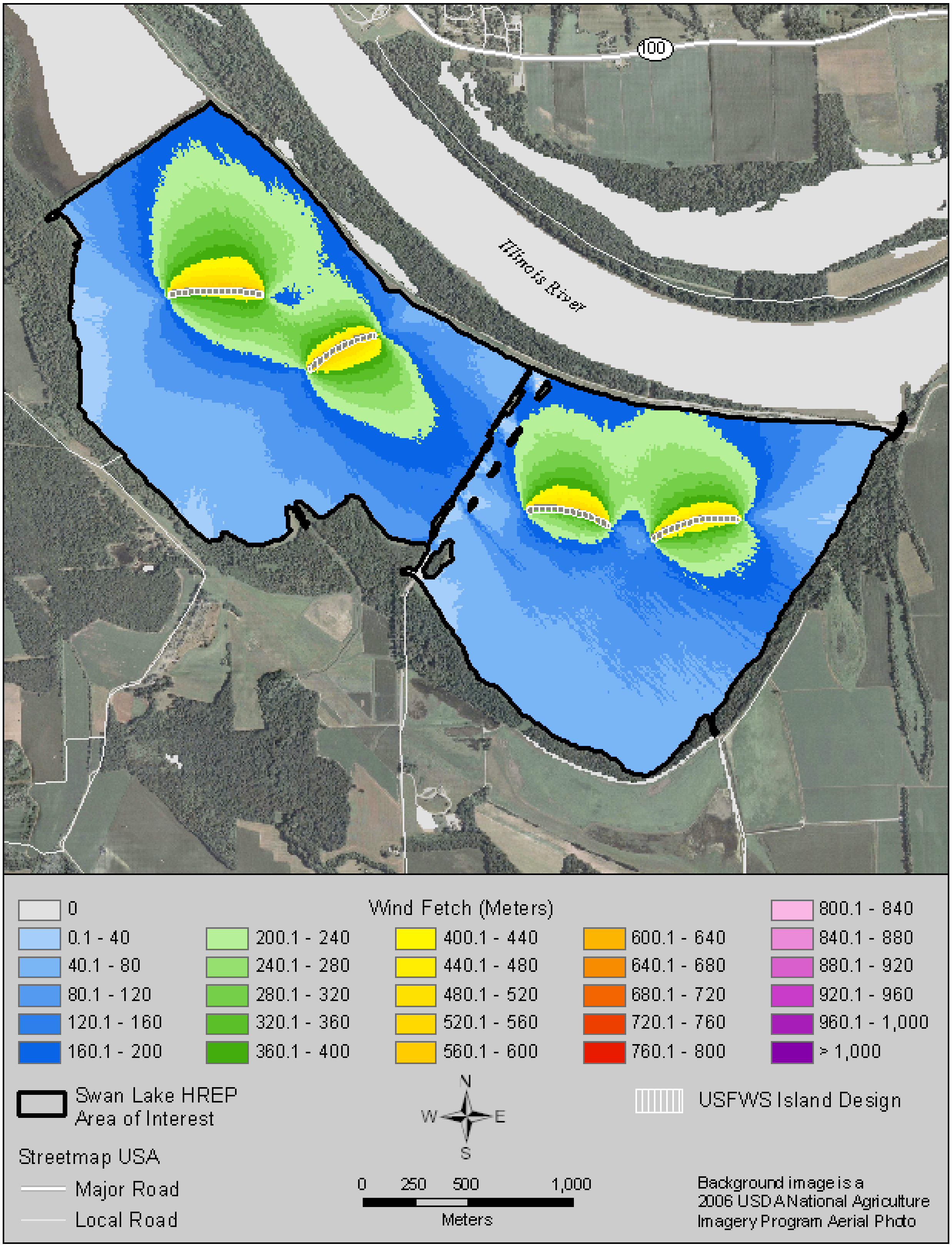


Figure C5. Difference in weighted fetch between existing conditions and USFWS proposed island design for Swan Lake HREP

The following chart displays the percent decrease in total weighted fetch between existing conditions and the USFWS proposed island design for Swan Lake HREP (Figure 83).

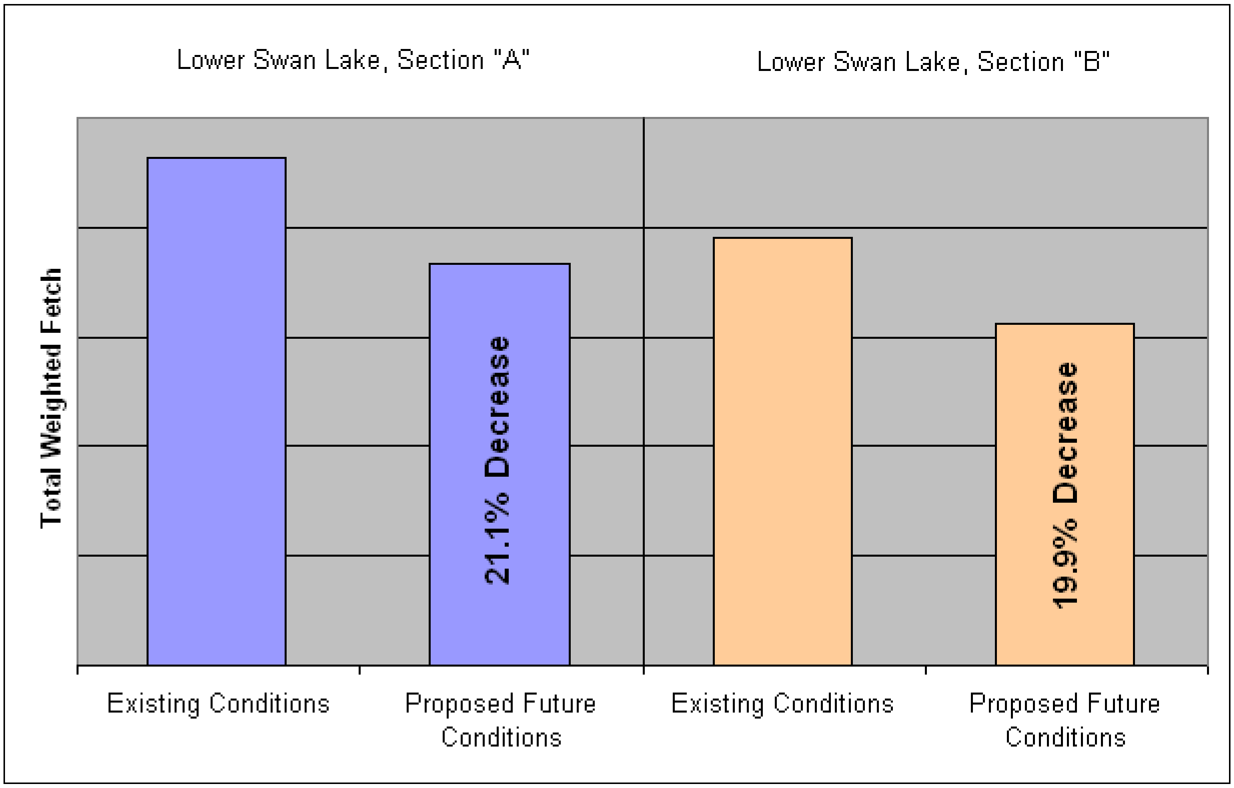


Figure C6. Chart displaying the percent decrease in total weighted fetch between existing conditions and USFWS proposed island design for Swan Lake HREP

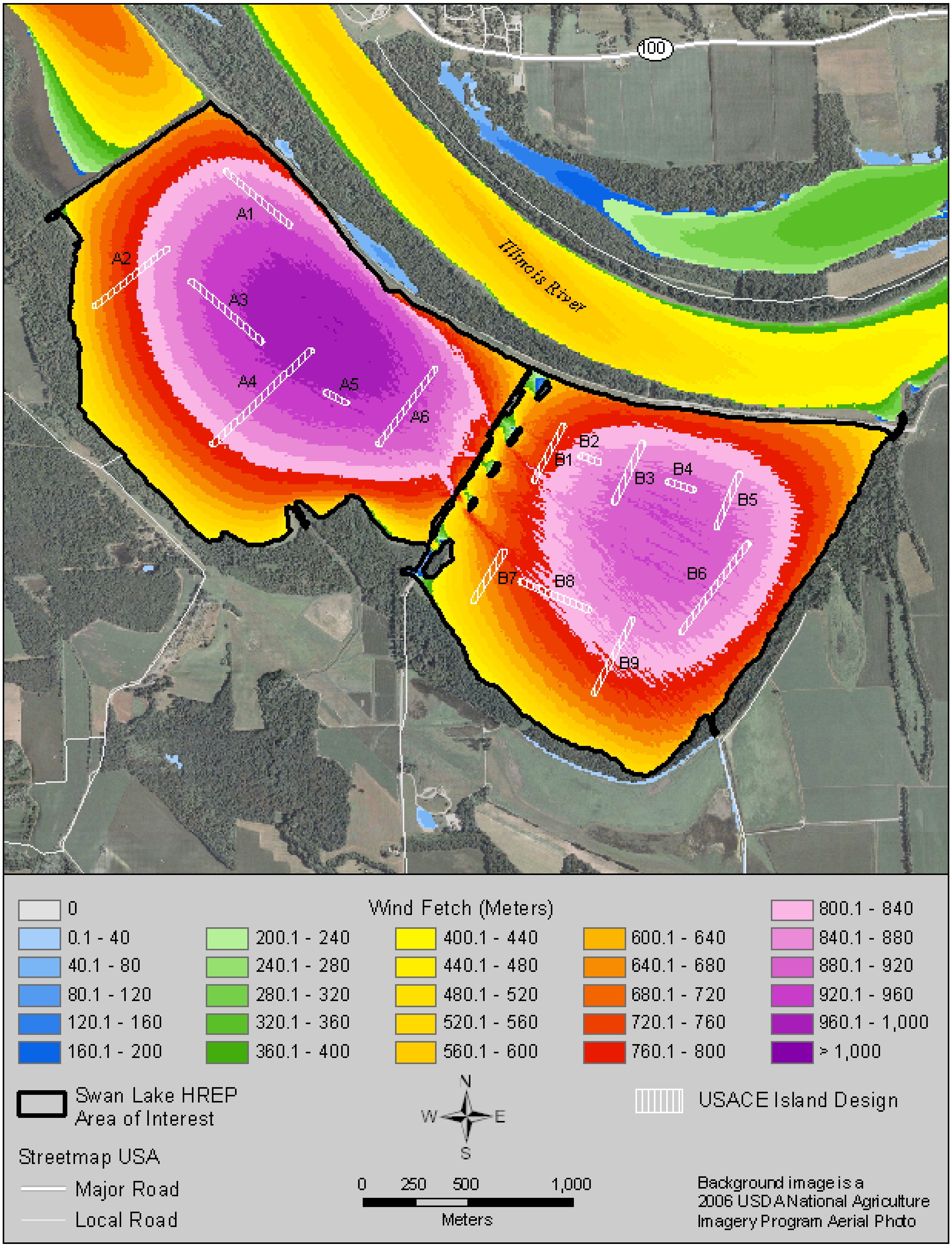


Figure C7. Weighted fetch results for existing conditions for Swan Lake HREP overlaid with proposed USACE island design

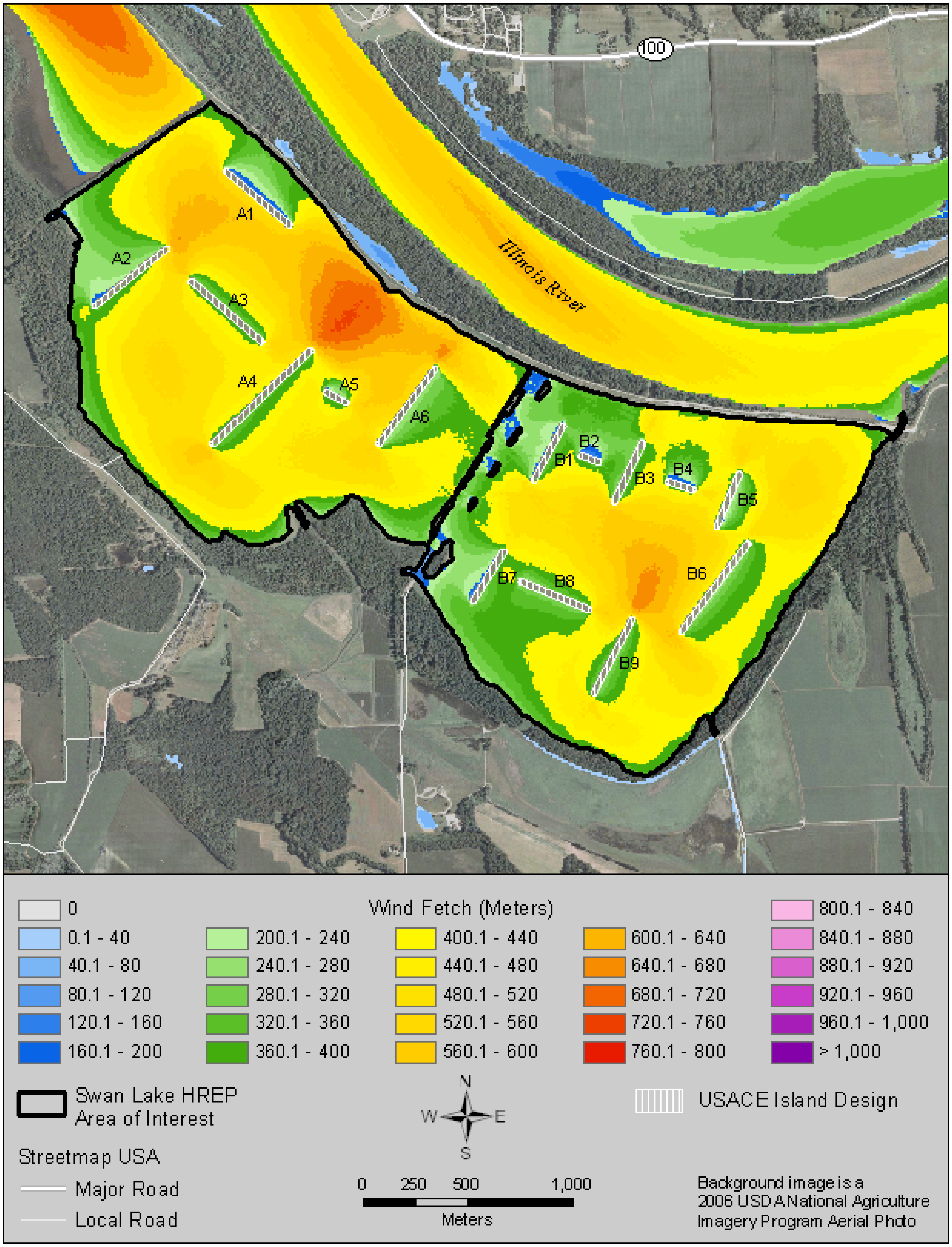


Figure C8. Weighted fetch results for Swan Lake HREP applying USACE proposed island design

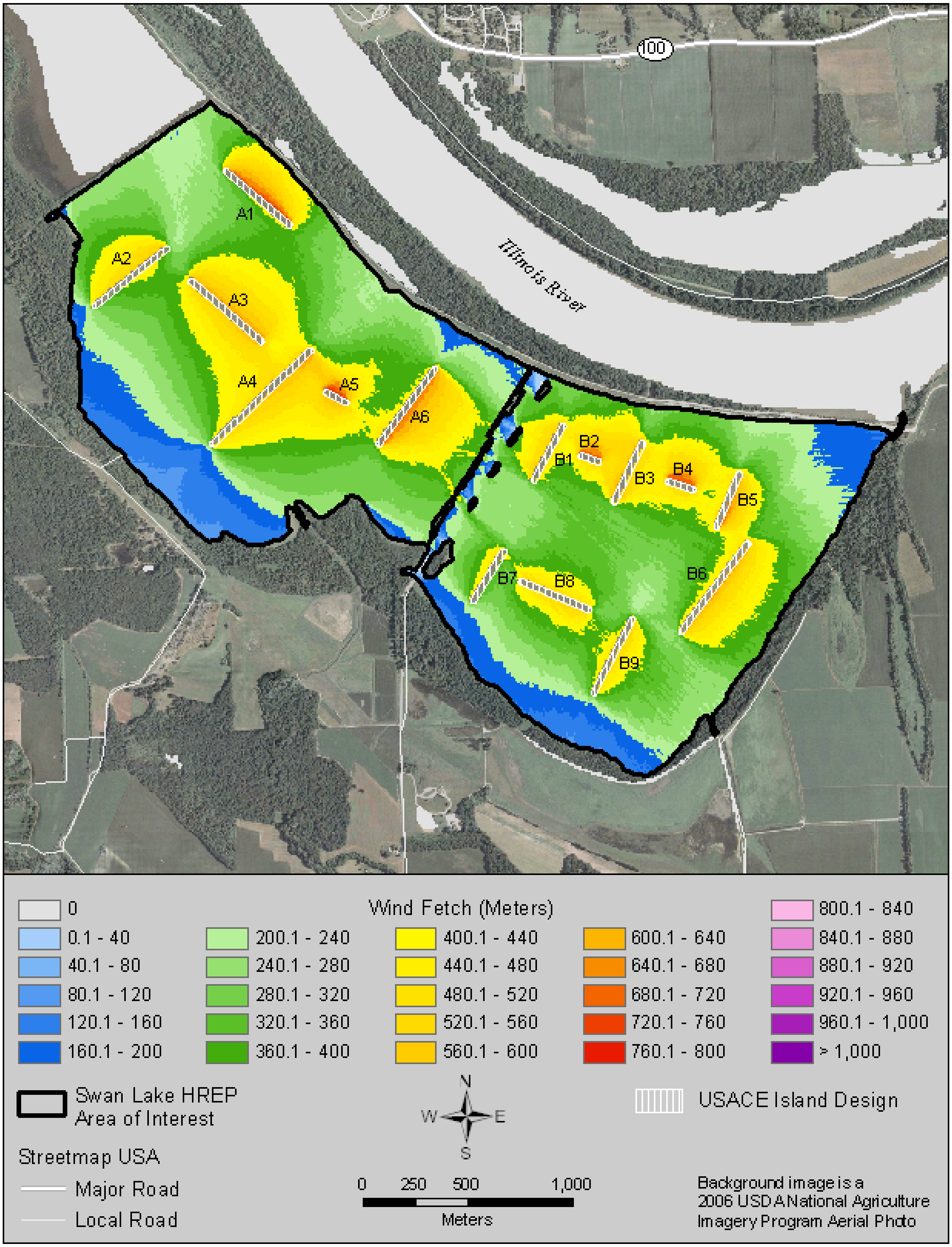


Figure C9. Difference in weighted fetch between existing conditions and USACE proposed island design for Swan Lake HREP

The following chart displays the percent decrease in total weighted fetch between existing conditions and the USACE proposed island design for Swan Lake HREP (Figure 87).

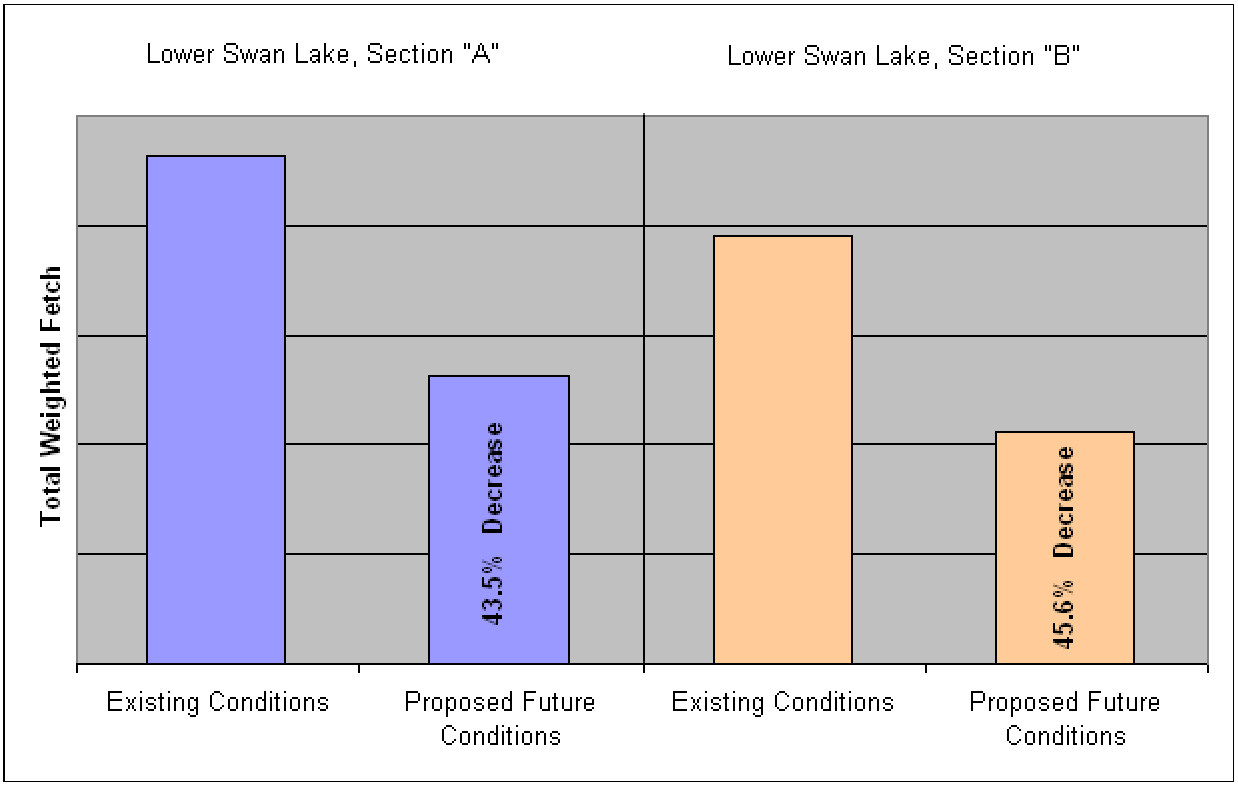


Figure C10. Chart displaying the percent decrease in total weighted fetch between existing conditions and USACE proposed island design for Swan Lake HREP

APPENDIX D.

RESPONSE, HABITAT, AND MOVEMENT OF FISHES

Table D1. Total number of fishes captured in the lower and middle units of Swan Lake during pre- and post-project monitoring.

			Summer				Winter			
			Lower		Middle		Lower		Middle	
Scientific Name	Common Name	Code	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Lepisosteidae										
Lepisosteus platostomus	shortnose gar	SNGR	112	222	47	214	18	24	84	28
Lepisosteus oculatus	spotted gar	STGR	3	0	0	5	0	0	2	1
Amiidae										
Amia calva	bowfin	BWFN	2	9	15	29	0	1	11	31
Clupeidae										
Alosa chrysochloris	skipjack herring	SJHR	16	8	10	8	0	0	0	0
Dorosoma cepedianum	gizzard shad	GZSD	2431	12439	10110	29523	113	803	103	1778
Dorosoma petenense	threadfin shad	TFSD	2	4	12	0	0	0	0	3
Hiodontidae										
Hiodon tergisus	mooneye	MNEY	0	0	0	0	3	0	0	0
Cyprinidae										
Hypophthalmichthys nobilis	bighead carp	BHCP	1	40	0	92	0	24	0	47
Hypophthalmichthys molitrix	silver carp	SVCP	0	22	0	4	0	4	0	28
Ctenopharyngodon idella	grass carp	GSCP	0	0	0	1	0	2	0	26
Carassius auratus	goldfish	GDFH	5	2	1	2	2	1	3	3
Cyprinus carpio	common carp	CARP	713	124	303	670	371	326	231	254
Notemigonus crysoleucas	golden shiner	GDSN	0	1	0	1	0	0	0	0
Macrhybopsis storeriana	silver chub	SVCB	1	0	2	0	0	0	0	0
Cyprinella spiloptera	spotfin shiner	SFSN	0	0	0	1	0	0	0	0
Pimephales promelas	fathead minnow	FHMW	0	0	6	0	0	0	0	0
Pimephales notatus	bluntnose minnow	BNMW	0	1	0	2	0	0	0	0
Pimephales vigilax	bullhead minnow	BHMW	0	2	1	1	0	0	0	0
Notropis atherinoides	emerald shiner	ERSN	454	12357	396	10132	0	0	0	0
Notropis shumardi	silverband shiner	SBSN	0	1	0	1762	0	0	0	0
Notropis stramineus	sand shiner	SNSN	0	0	0	1	0	0	0	0
Notropis buchanani	ghost shiner	GTSN	1	0	0	0	0	0	0	0
Catostomidae										
Ictiobus cyprinellus	bigmouth buffalo	BMBF	87	9	32	20	93	2	145	40
Ictiobus bubalus	smallmouth buffalo	SMBF	2	0	3	1	6	1	3	2
Ictiobus niger	black buffalo	BKBF	19	9	30	9	58	2	65	7

Table D1 Continued.

			Summer				Winter			
			Lower		Middle		Lower		Middle	
Scientific Name	Common Name	Code	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Ictiobus spp.	YOY buffalo	YOYbuff	40	9	146	504	0	2	0	1
Carpiodes carpio	river carpsucker	RVCS	4	0	5	1	9	1	6	2
Catostomus commersonii	white sucker	WTSK	0	0	0	1	0	0	0	0
Ictaluridae										
Ictalurus punctatus	channel catfish	CNCF	28	75	13	54	3	1	30	3
Ameiurus natalis	yellow bullhead	YLBH	11	2	1	28	5	4	16	6
Ameiurus melas	black bullhead	BKBH	1	2	16	53	0	5	6	3
Ameiurus nebulosus	brown bullhead	BNBH	0	0	0	16	0	0	0	1
Noturus gyrinus	tadpole madtom	TPMT	1	0	0	0	0	0	0	0
Poeciliidae										
Gambusia affinis	western mosquitofish	MQTF	23	41	5	975	0	0	0	0
Atherinidae										
Labidesthes sicculus	brook silverside	BKSS	2	2	0	7	0	0	0	0
Percichthyidae										
Morone chrysops	white bass	WTBS	48	196	35	162	35	168	27	39
Morone mississippiensis	yellow bass	YWBS	3	2	1	9	3	13	9	9
Centrarchidae										
Pomoxis nigromaculatus	black crappie	BKCP	43	61	288	458	29	31	328	109
Pomoxis annularis	white crappie	WTCP	39	31	54	96	36	25	292	23
Micropterus salmoides	largemouth bass	LMBS	1	2	0	1	1	1	2	0
Lepomis gulosus	warmouth	WRMH	0	2	0	89	0	0	0	0
Lepomis cyanellus	green sunfish	GNSF	1	14	2	21	0	6	2	1
Lepomis macrochirus	bluegill	BLGL	448	61	1953	596	36	23	231	19
Lepomis humilis	orangespotted sunfish	OSSF	1	1224	45	10921	1	14	0	2
Percidae										
Stizostedion canadense	sauger	SGER	0	0	0	1	0	0	0	0
Etheostoma asprigene	mud darter	MDDR	1	1	0	3	0	0	0	0
Sciaenidae										
Aplodinotus grunniens	freshwater drum	FWDM	792	269	1000	1930	51	26	142	27

Table D2. Proportions of ultrasonically tagged fishes located either actively or passively within various water bodies during November 2003 – August 2005, and proportion of fish captured and released in either the Illinois River or lower Swan Lake that did not pass through the lower Swan Lake water control structure during the minimum transmitter life. Fishes not passing through the structure were excluded from analyses.

		Located manually or passively (%)**					Did not pass thorugh structure (%)**	
Species*	N	ILR	LSL	MSL	MSR	UK	ILR	LSL
BHC	50	78	34	2	2	2	32	12
CCF	31	77	65	10	3	10	23	23
CMC	31	68	71	13	0	6	10	10
SLC	50	80	22	8	2	2	62	0

* BHC = bighead carp, CCF = channel catfish, CMC = common carp, SLC = silver carp

** ILR = Illinois River, LSL = Lower Swan Lake, MSL = Middle Swan Lake, MSR = Mississippi River, UK = Unknown

Figure D1. Sample sizes (lines) and differences in mean + 1 SE movement (bars) through the lower Swan Lake water control structure for ultrasonically tagged fishes monitored with stationary receivers. All data were standardized by the daily number of tagged fish that passed through the structure (dashed line) and were restricted to the minimum transmitter life specified by the manufacturer. Letters indicate Tukey-Kramer adjusted differences among seasons.

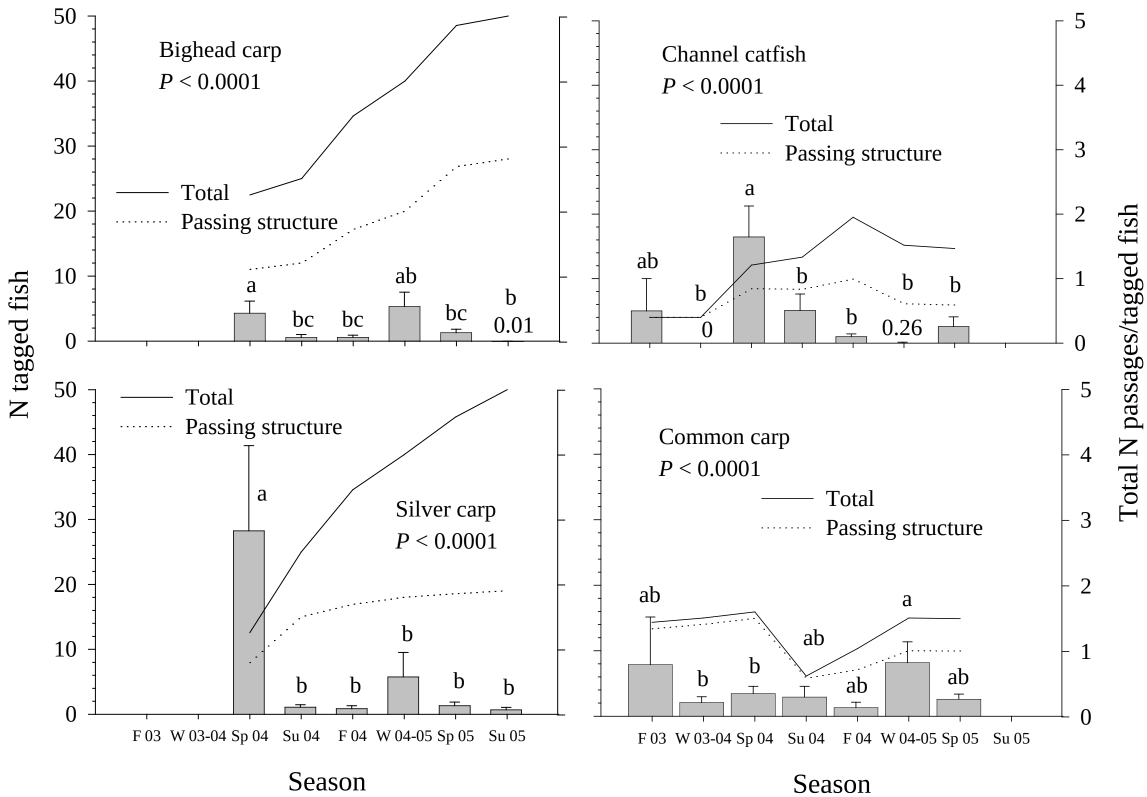


Table D3. Results of seasonal paired t-tests comparing mean daily temperatures within lower Swan Lake against mean daily temperatures within the Illinois River from October 2003 through August 2005. Lower Swan Lake was warmer than the Illinois River during most seasons.

Year	Season	df	*t*	*P*
2003	Fall*	42	2.41	0.02
	Winter	90	6.63	<0.0001
2004	Spring	91	6.48	<0.0001
	Summer	91	2.36	0.02
	Fall*	90	2.23	0.03
	Winter	89	6.14	<0.0001
2005	Spring	91	5.91	<0.0001
	Summer*	34	1.85	0.07

*Indicates the Illinois River was warmer than lower Swan Lake.

Figure D2. Mean daily differential temperatures (lower Swan Lake °C minus Illinois River °C) observed between lower Swan Lake and the Illinois River. Squares indicate approximate periods of ice cover; circles indicated approximate periods of flooding.

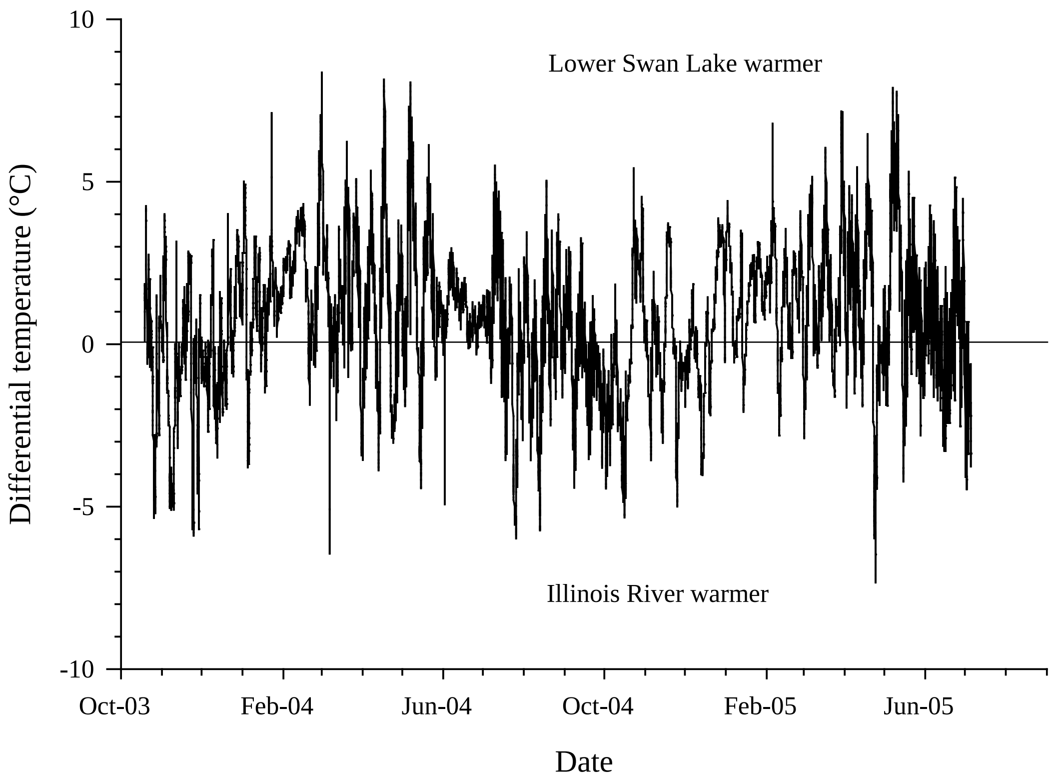


Figure D3. Mean + 1 SE monthly Asian carp residency time (bars) within lower Swan Lake and mean monthly depth (lines) at the lower Swan Lake water control structure (left column). Mean + 1 SE monthly common carp and channel catfish residency time (bars) within lower Swan Lake and mean monthly differential temperature between lower Swan Lake and the Illinois River (lake minus river; lines; right column). Only those abiotic factors found to be associated with residency time are plotted on graphs.

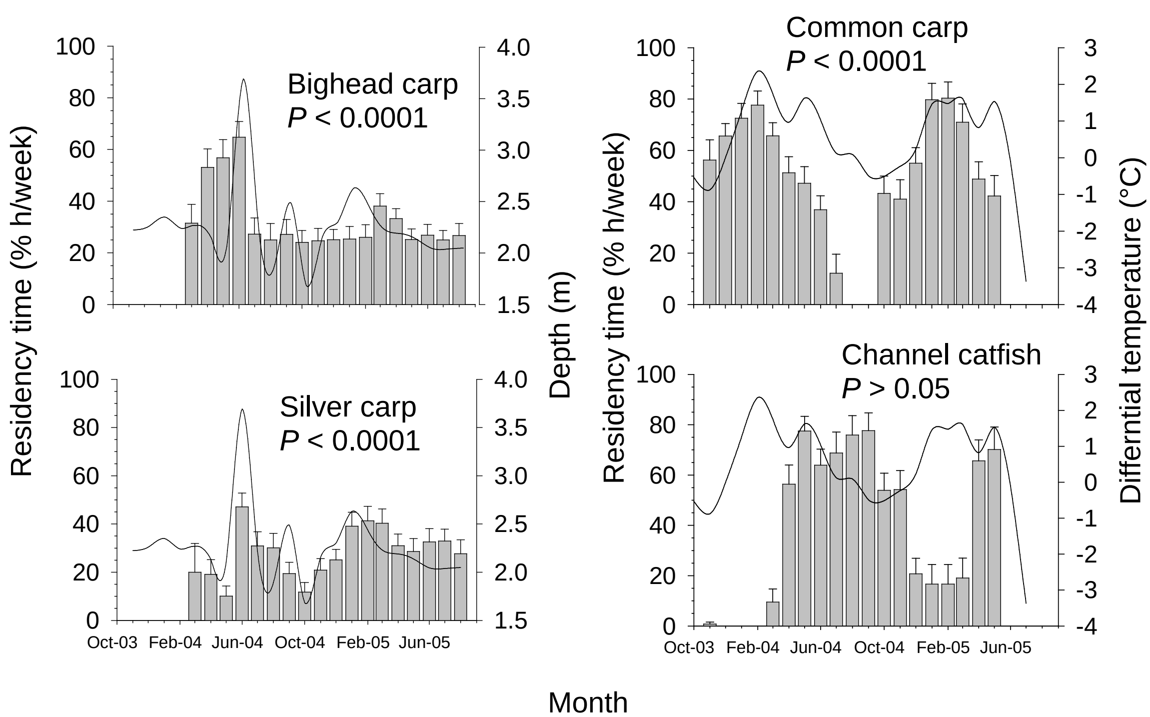


Figure D4. Mean species richness and Shannon diversity index from tandem fyke samples in the lower unit of Swan Lake for pre-project (1992 – 1993) and post-project (2004-2006) monitoring periods. Error bars are one standard error.

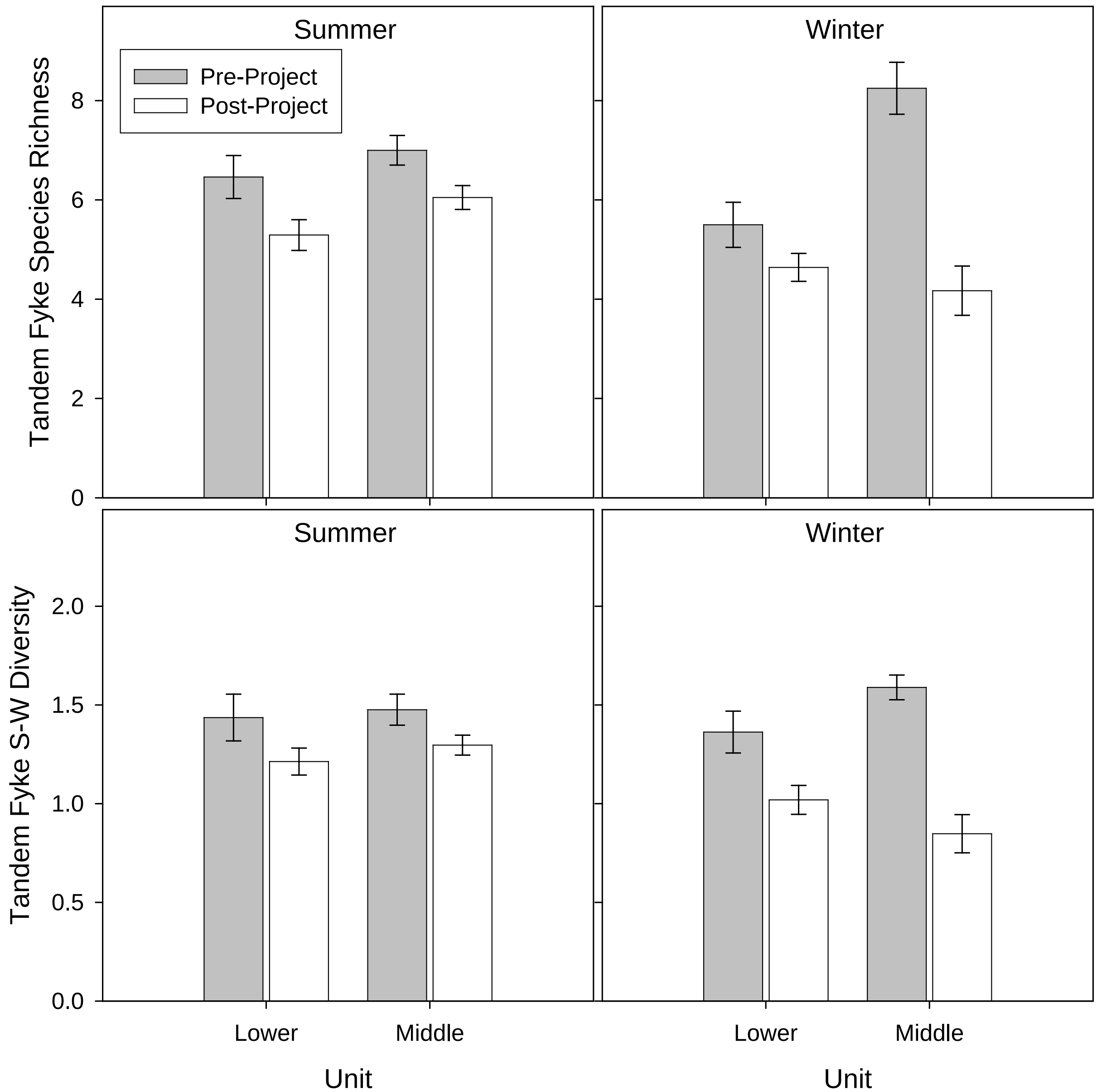


Figure D5. Mean catch-per-unit-effort (CPUE) from tandem fyke nets sets in the lower unit of Swan Lake for pre-project (1992 – 1993) and post-project (2004-2006) monitoring periods. See Table F1 for species codes. Error bars are one standard error.

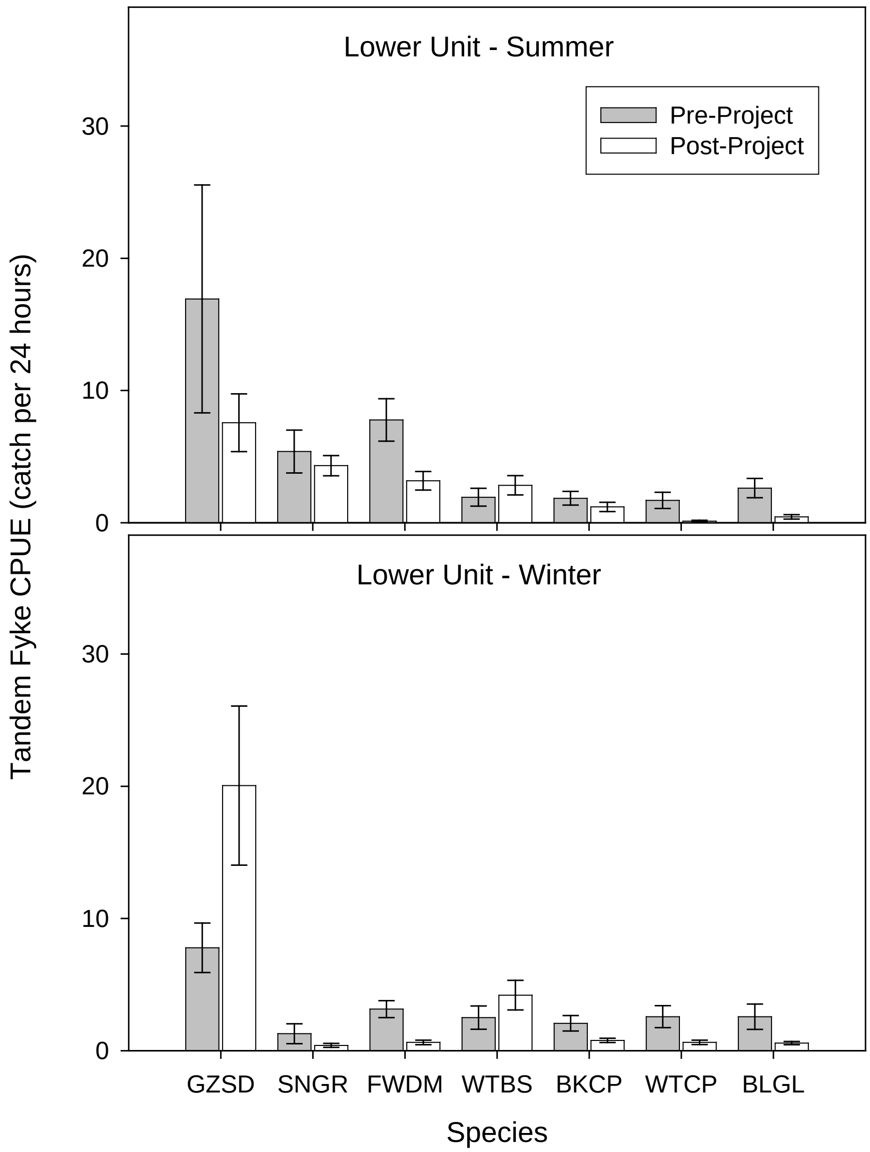


Figure D6. Mean catch-per-unit-effort (CPUE) from tandem fyke nets sets in the middle unit of Swan Lake for pre-project (1992 – 1993) and post-project (2004-2006) monitoring periods. See Table F1 for species codes. Error bars are one standard error.

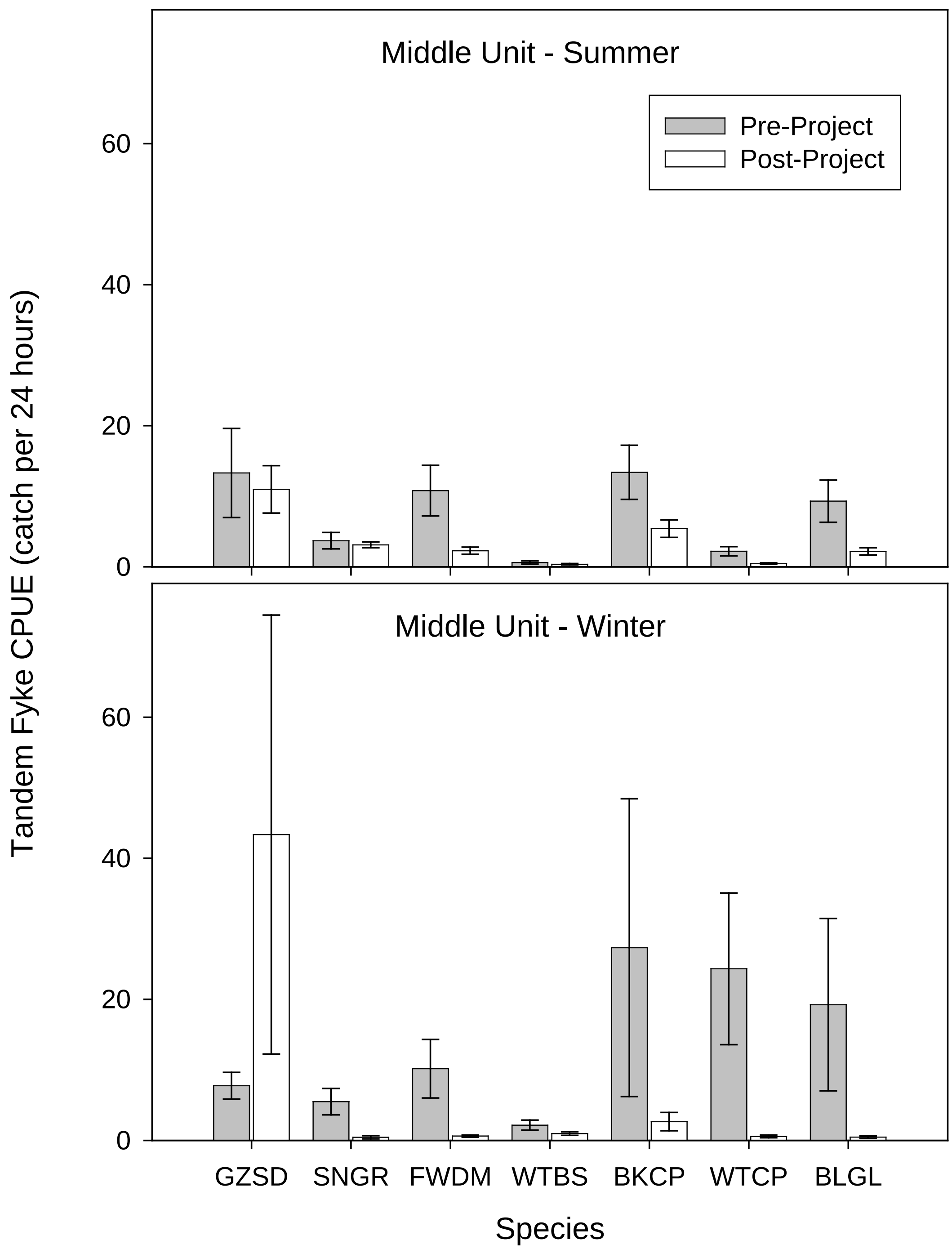


Figure D7. Mean relative abundance from trammel nets sets in the lower unit of Swan Lake for pre-project (1992 – 1993) and post-project (2004-2006) monitoring periods. See Table F1 for species codes. Error bars are one standard error.

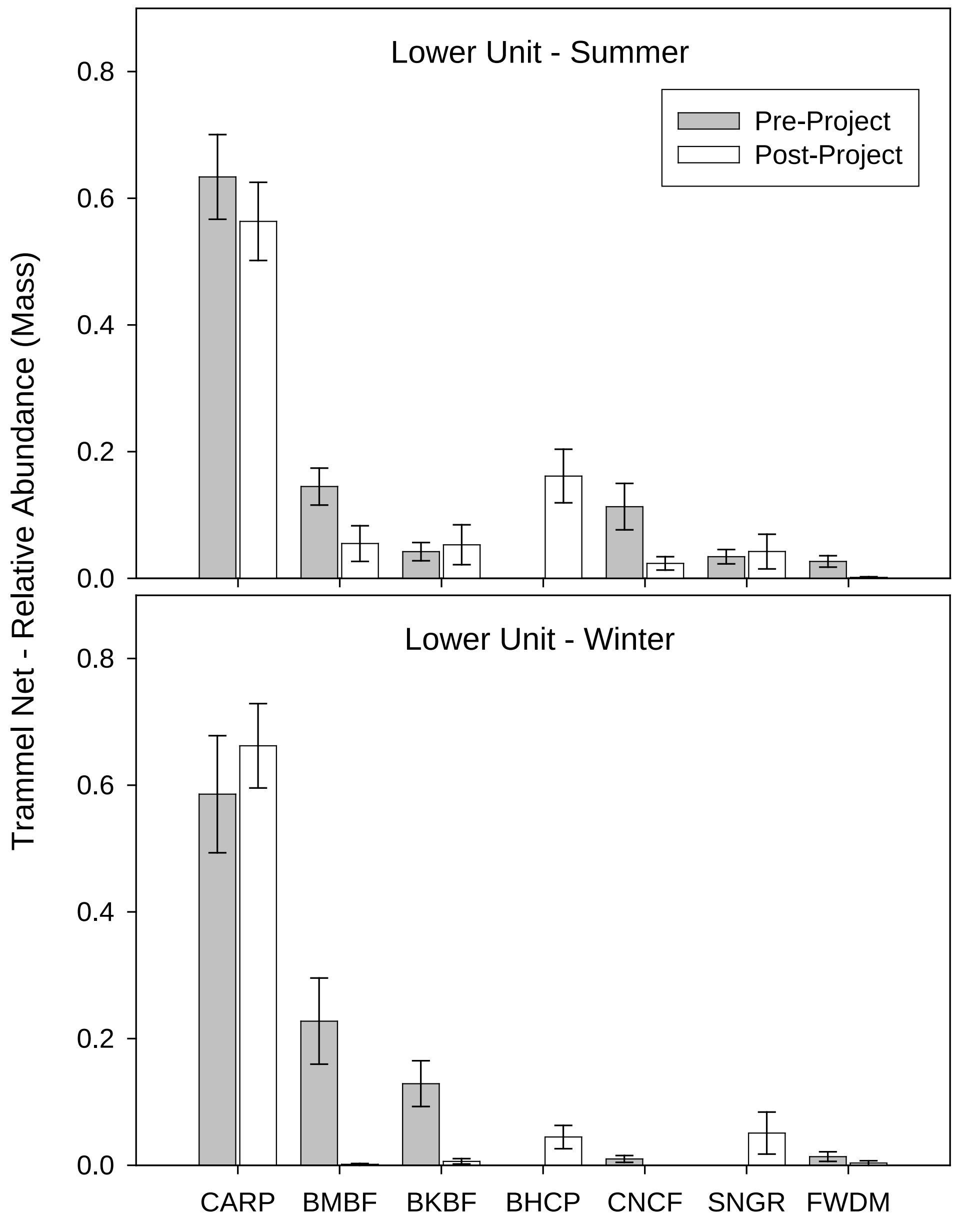


Figure D8. Mean relative abundance from trammel nets sets in the middle unit of Swan Lake for pre-project (1992 – 1993) and post-project (2004-2006) monitoring periods. See Table F1 for species codes. Error bars are one standard error.

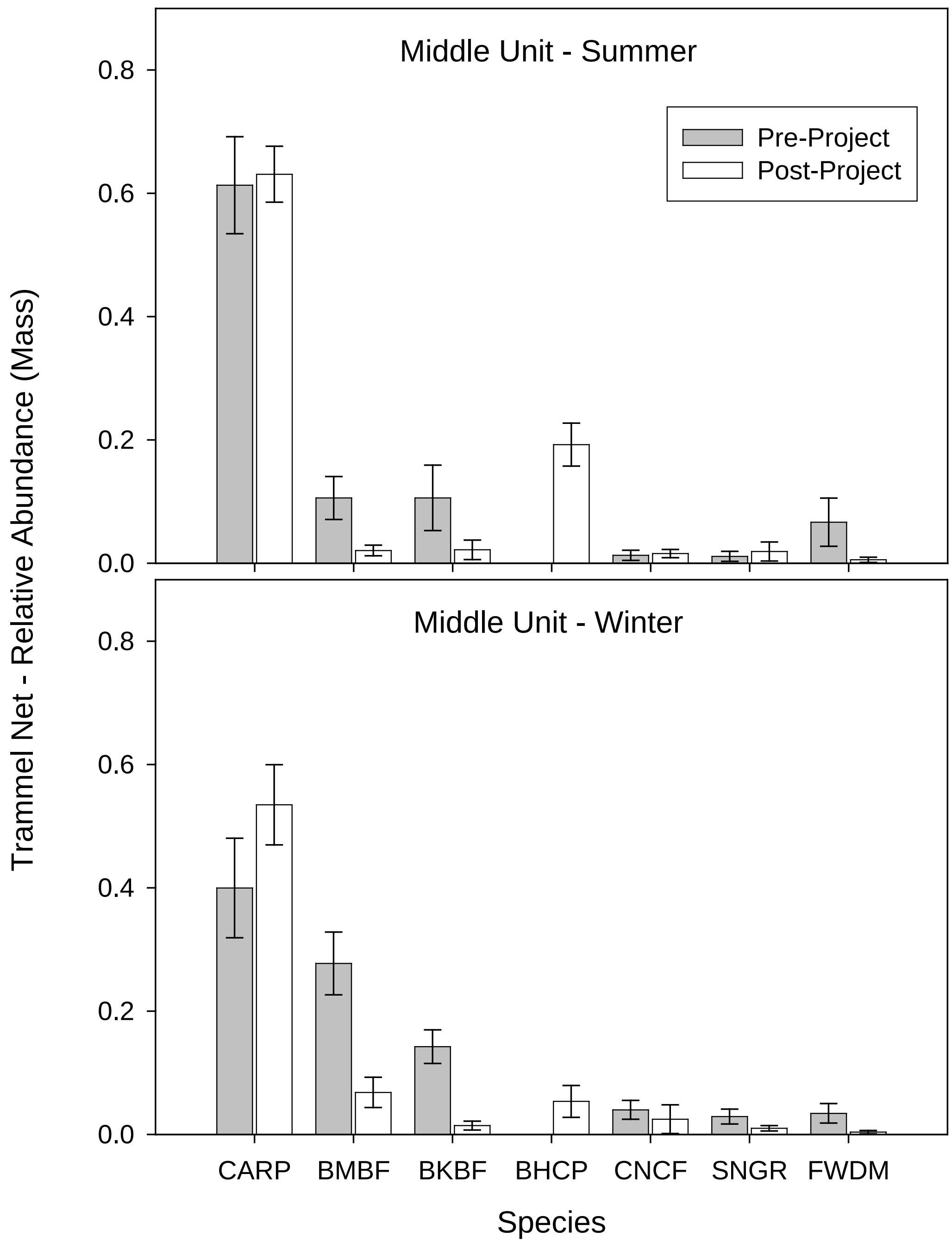


Figure D9. Mean catch-per-unit-effort (CPUE) for young-of-the-year fishes captured in tandem mini-fyke nets sets in Swan Lake for pre-project (1992 – 1993) and post-project (2004-2006) monitoring periods. See Table F1 for species codes. Error bars are one standard error.

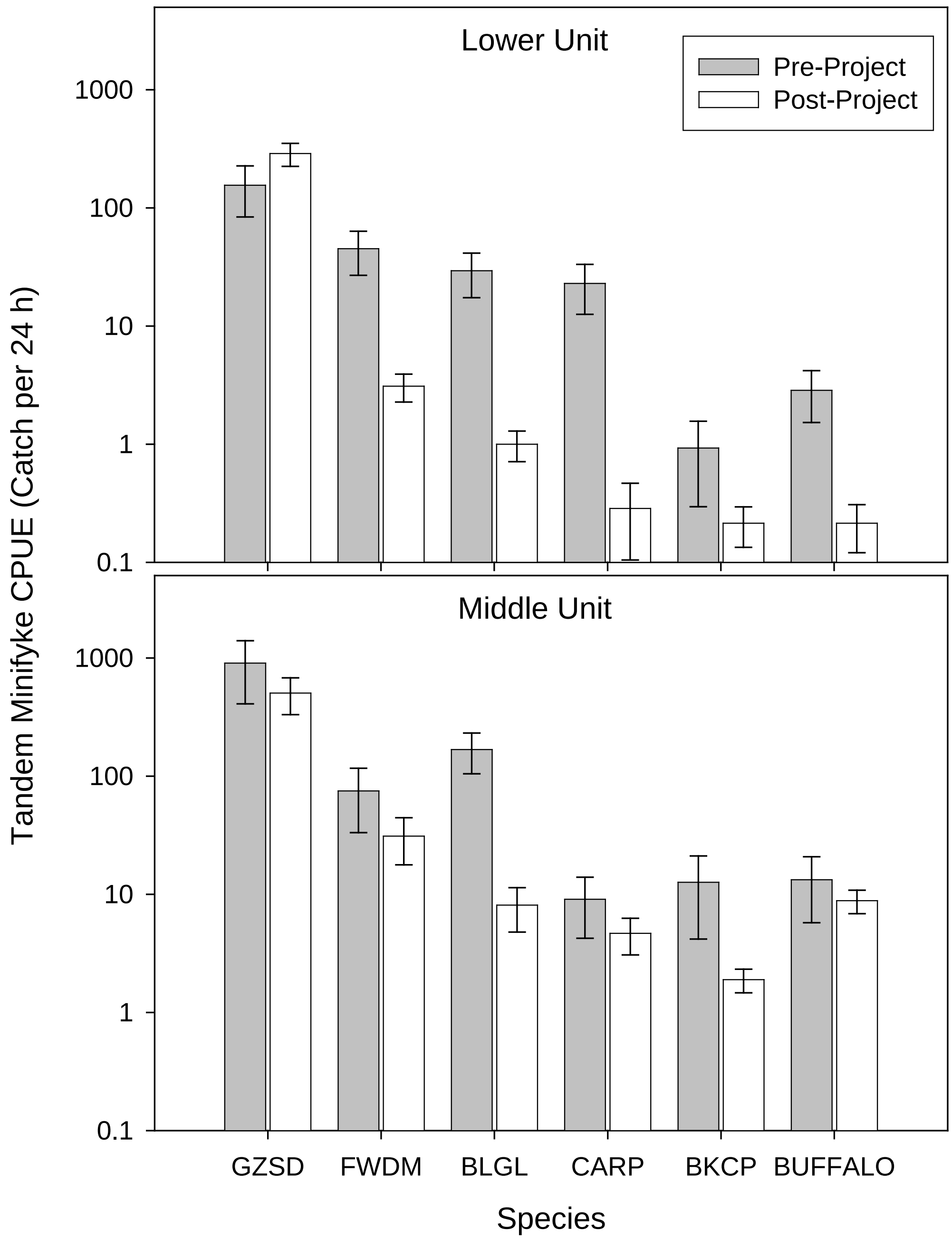
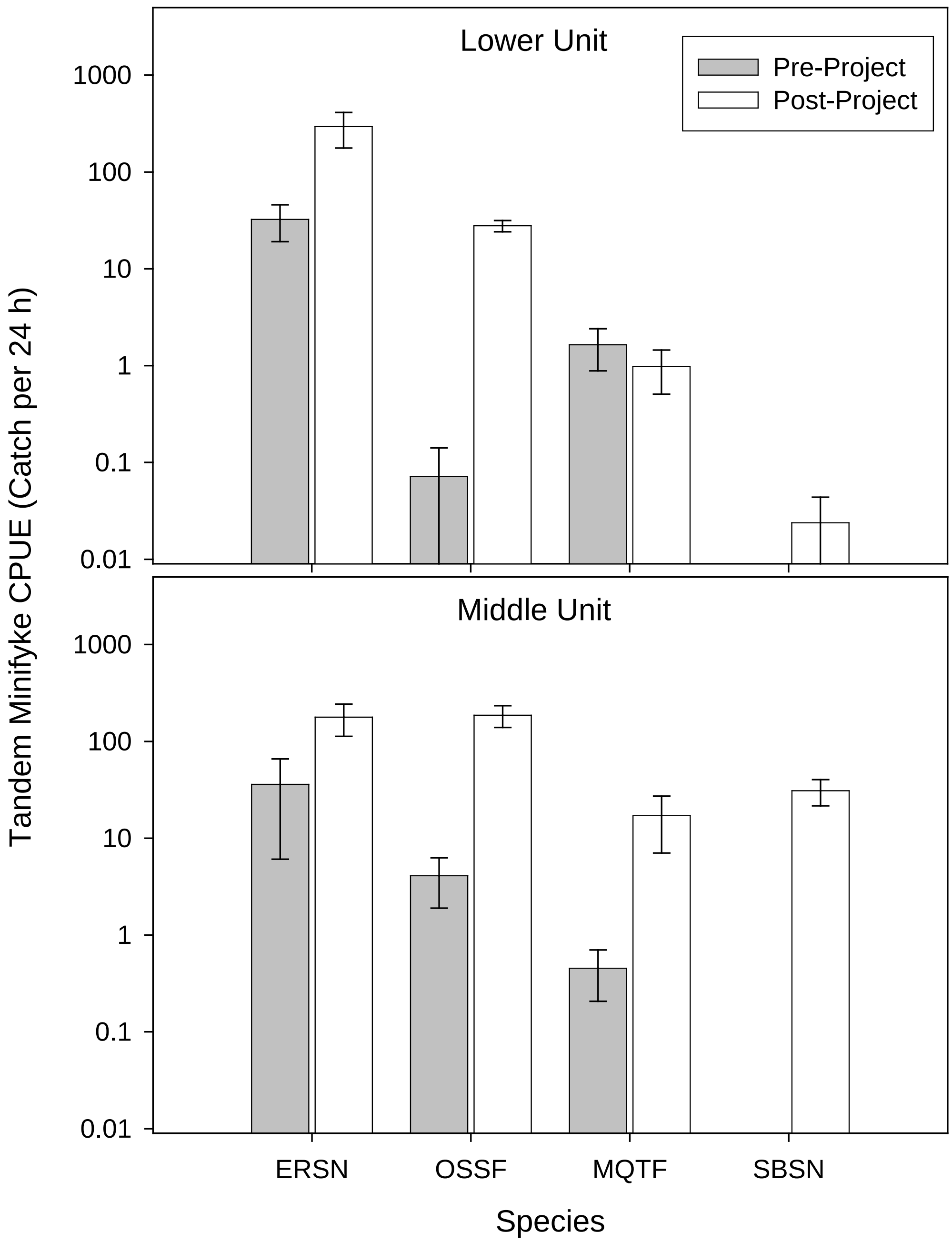


Figure D10. Mean catch-per-unit-effort (CPUE) for species of small adult size captured in tandem mini-fyke nets sets in Swan Lake for pre-project (1992 – 1993) and post-project (2004-2006) monitoring periods. See Table F1 for species codes. Error bars are one standard error.



APPENDIX E.

AQUATIC MACROPHYTES

Table E1. Frequency of occurrence (%) and mean surface coverage (%) for aquatic vegetation species found during post-project monitoring (2004-2006) of the middle unit of Swan Lake.

Common Name	Scientific Name	Frequency of Occurrence	Mean Coverage	Coverage Standard Error
	Non-rooted Floating Vegetation			
Common duckweed	*Lemna minor*	11.73	0.019	0.008
Greater duckweed	*Spirodela polyrrhiza*	4.47	0.007	0.005
	Rooted Floating Vegetation			
American lotus	*Nelumbo lutea*	1.12	0.00	0.00
	Emergent Vegetation			
Redroot flatsedge	*Cyperus erythrorhizos*	15.64	3.359	0.884
Amazon sprangletop	*Leptochloa panicoides*	11.73	1.421	0.576
Millet	*Echinochloa spp.**	11.73	0.205	0.123
Rough cocklebur	*Xanthium strumarium*	7.82	0.618	0.281
Curlytop knotweed	*Polygonum lapathifolium*	6.70	0.054	0.035
Nodding beggartick	*Bidens cernua*	6.70	0.417	0.267
Valley redstem	*Ammannia coccinea*	5.59	0.205	0.092
Rice cutgrass	*Leersia oryzoides*	5.59	0.050	0.033
Indian lovegrass	*Eragrostis pilosa*	5.03	1.719	0.694
Roundfruit hedgehyssop	*Gratiola virginiana*	2.79	0.106	0.054
Black willow	*Salix nigra*	2.23	0.00	0.00
Coast cockspur grass	*Echinochloa walteri*	1.68	0.00	0.00
Arumleaf arrowhead	*Sagittaria cuneata*	1.68	0.073	0.060
Disk waterhyssop	*Bacopa rotundifolia*	1.12	0.024	0.019
Whitestar	*Ipomoea lacunosa*	1.12	0.006	0.004
Broadleaf arrowhead	*Sagittaria latifolia*	1.12	0.108	0.108
Yellow nutsedge	*Cyperus esculentus*	1.12	0.004	0.004
Tall amaranth	*Amaranthus rudis*	0.56	0.002	0.002
Eastern cottonwood	*Populus deltoides*	0.56	0.002	0.002
Prickly fanpetals	*Sida spinosa*	0.56	0.002	0.002
Fall panicgrass	*Panicum dichotomiflorum*	0.56	0.00	0.00
Witchgrass	*Panicum capillare*	0.56	0.00	0.00
Pennsylvania smartweed	*Polygonum pensylvanicum*	0.56	0.00	0.00
Filamentous algae		2.23	0.112	0.112

**Echinochloa* spp. Includes three varieties of native millet that are very difficult to differentiate: *E. crus-galli, E. muricata microstachya, and E. muricata muricata*.

Table E2. Frequency of occurrence (%) and mean surface coverage (%) for aquatic vegetation species found during post-project monitoring (2004-2006) of the upper unit of Swan Lake.

Common Name	Scientific Name	Frequency of Occurrence	Mean Coverage	Coverage Standard Error
	Non-rooted Floating Vegetation			
Common duckweed	*Lemna minor*	58.75	1.031	0.450
Greater duckweed	*Spirodela polyrrhiza*	37.50	0.444	0.223
Columbian watermeal	*Wolffia columbiana*	2.50	0.042	0.042
	Rooted Floating Vegetating			
Floating primrose	*Ludwigia peploides*	30.00	2.296	0.908
	Submersed Aquatic Vegetation			
Sago pondweed	*Stuckenia pectinata*	31.25	0.471	0.471
Southern waternymph	*Najas guadalupensis*	15.00	0.021	0.021
Coontail	*Ceratophyllum demersum*	10.00	0.00	0.00
Horned pondweed	*Zannichellia palustris*	8.75	0.642	0.604
Leafy pondweed	*Potamogeton foliosus*	2.50	0.00	0.00
	Emergent Vegetation			
Millet	*Echinochloa spp.*	26.25	1.733	0.784
Japanese millet	*Echinochloa esculenta*	13.75	3.429	1.778
Curlytop knotweed	*Polygonum lapathifolium*	8.75	0.021	0.021
Amazon sprangletop	*Leptochloa panicoides*	8.75	0.392	0.255
Common buttonbush	*Cephalanthus occidentalis*	7.50	0.00	0.00
Redroot flatsedge	*Cyperus erythrorhizos*	6.25	1.846	1.177
Rice cutgrass	*Leersia oryzoides*	5.00	0.317	0.258
Tall amaranth	*Amaranthus rudis*	5.00	0.050	0.050
Pennsylvania smartweed	*Polygonum pensylvanicum*	3.75	0.00	0.00
Coast cockspur grass	*Echinochloa walteri*	3.75	0.004	0.004
Halberdleaf rosemallow	*Hibiscus laevis*	3.75	0.008	0.008
Eastern swamprivet	*Forestiera acuminata*	3.75	0.00	0.00
Unidentified smartweed	*Polygonum* spp.	3.75	0.00	0.00
Black willow	*Salix nigra*	1.25	0.021	0.021
Whitestar	*Ipomoea lacunosa*	1.25	0.00	0.00
Horsetail paspalum	*Paspalum fluitans*	1.25	0.00	0.00
Filamentous algae		35.00	5.404	1.989

Figure E1. Frequency of occurrence for the five most common taxa of emergent vegetation from post-project monitoring, late-season sampling, in the middle unit of Swan Lake. *Cyperus* is redroot flatsedge, *Leptochloa* is Amazon sprangletop, *Xanthium* is rough cocklebur, *Polygonum* is curlytop knotweed, and *Echinochloa* includes several species of native millet.

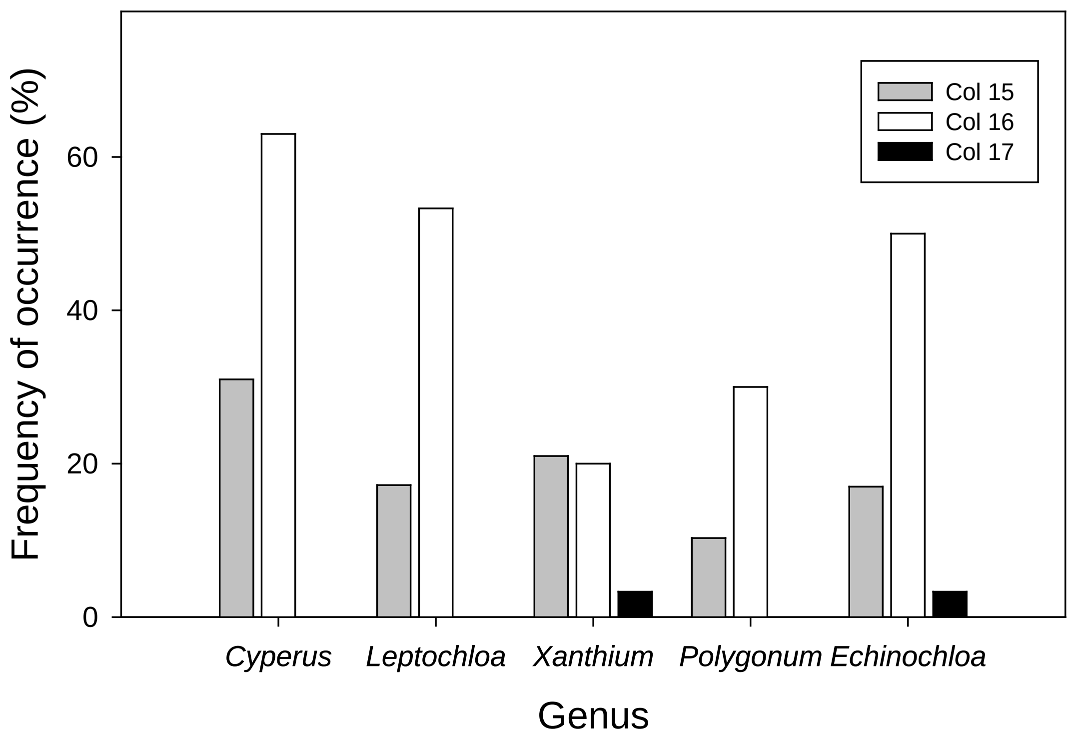
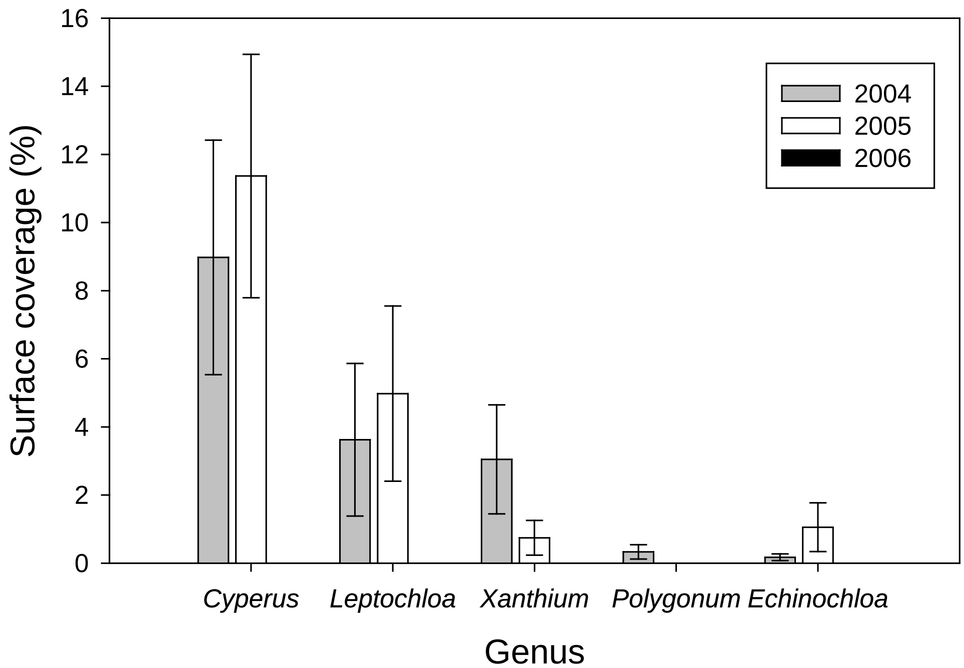


Figure E2. Mean surface coverage (± standard error) for the five most common taxa of emergent vegetation from post-project monitoring, late-season sampling, in the middle unit of Swan Lake. *Cyperus* is redroot flatsedge, *Leptochloa* is Amazon sprangletop, *Xanthium* is rough cocklebur, *Polygonum* is curlytop knotweed, and *Echinochloa* includes several species of native millet.



APPENDIX F.

AQUATIC MACROINVERTEBRATES

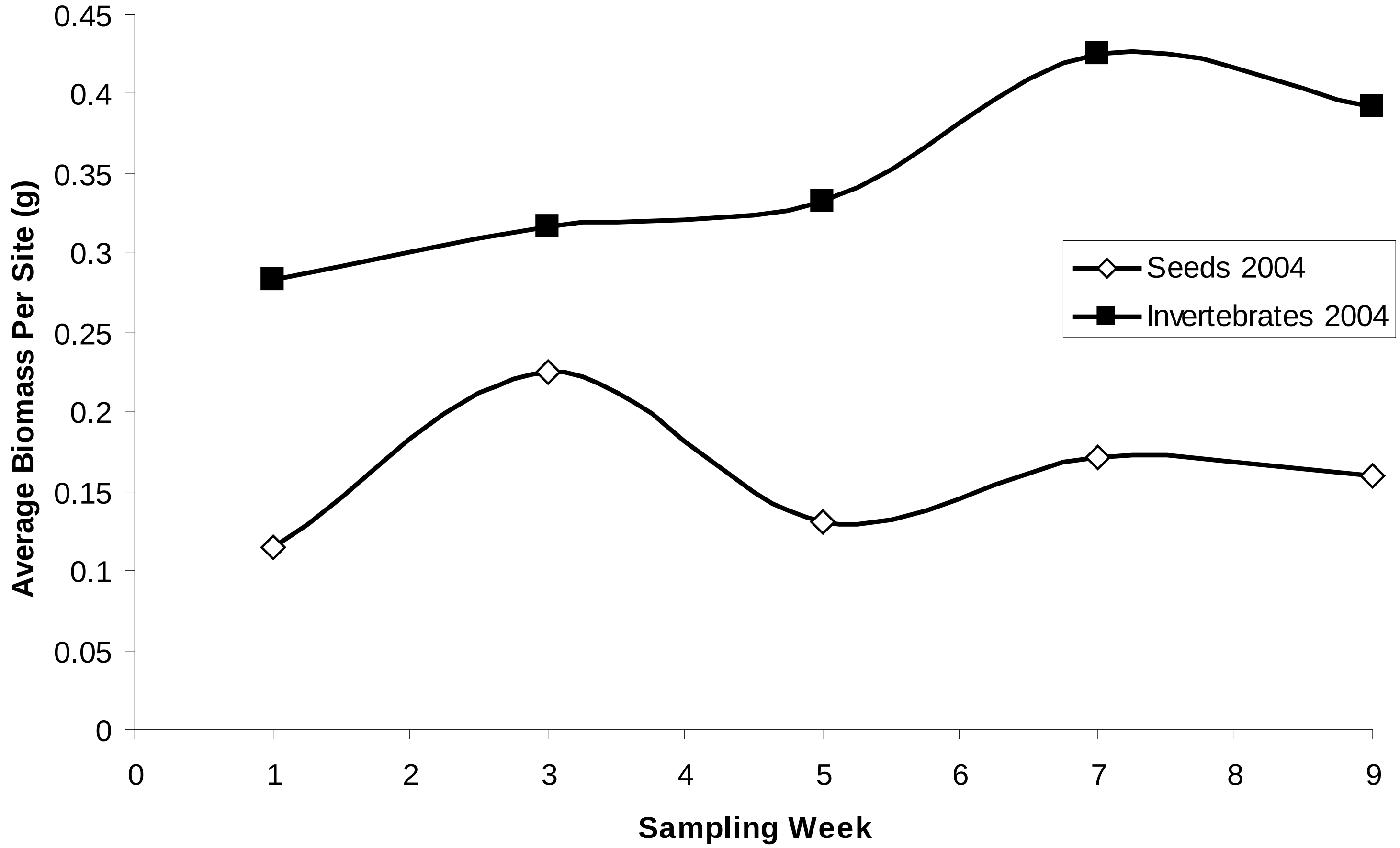


Figure F1. Average biomass of seeds and invertebrates available at random sampling locations on Swan Lake during spring 2004. Sampling began 2 March (week 1), and concluded 28 April (week 9).

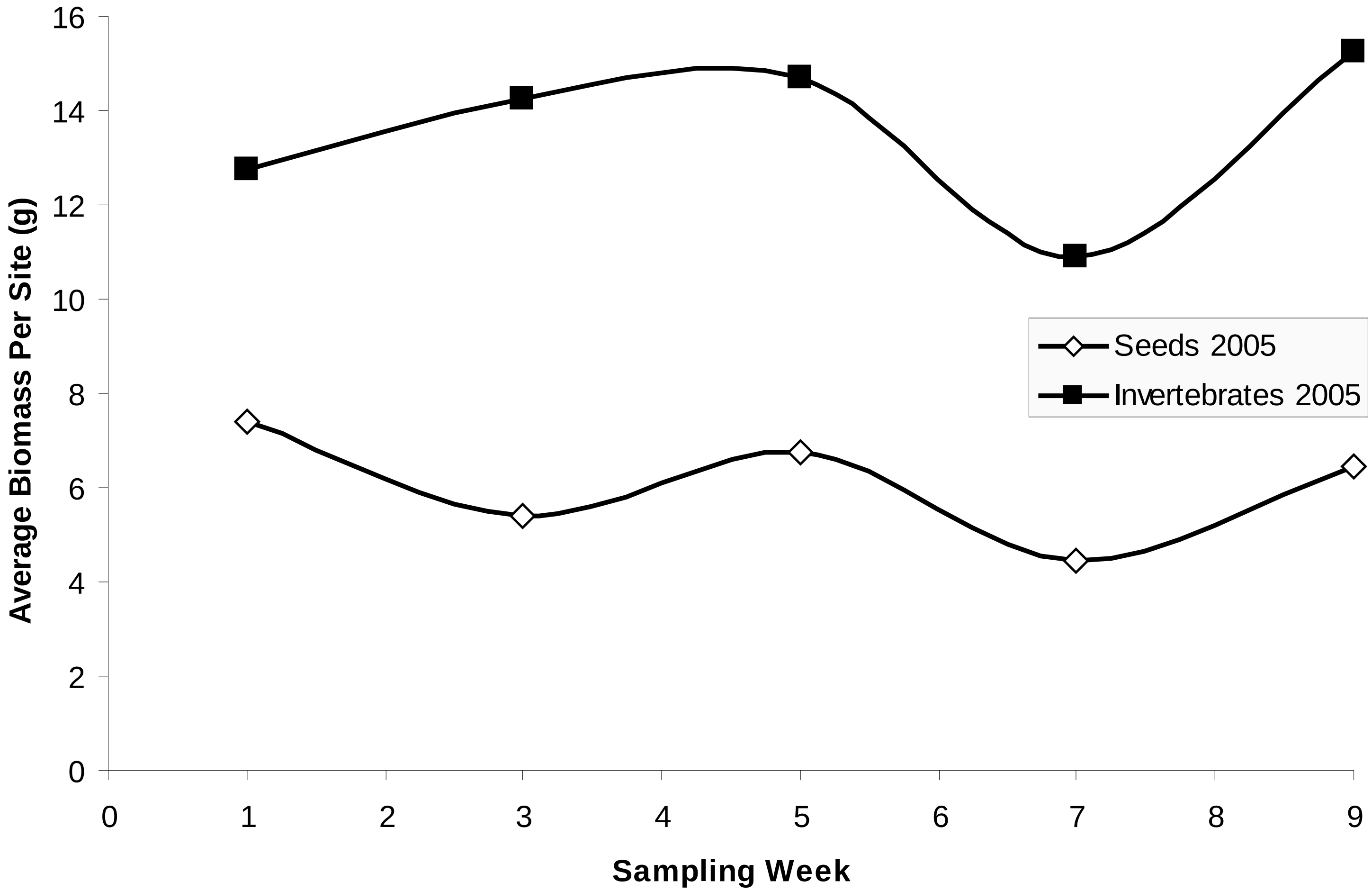


Figure F2. Average biomass of seeds and invertebrates available at random sampling locations on Swan Lake during spring 2005. Sampling began 5 March (week 1), and concluded 30 April (week 9).

APPENDIX G.

MIGRATORY WATERFOWL

Table G1. Foods consumed by mallards (n = 15) during spring migration 2004 on Swan Lake, Illinois. Foods making up less than 0.1% aggregate mass of diet are listed as trace (tr.).

Food Item	Aggregate %	% Occurrence
Animal Material (High Protein)	12.5	67
Isopoda (aquatic sow bugs)	7.3	40
Culicidae (mosquito)	3.6	13
Unknown Invertebrate Material	0.6	7
Other Diptera Larvae	0.3	7
Gastropoda (snails)	0.3	20
Amphipoda (scuds)	0.3	33
Hydrophilidae (beetle)	0.1	7
Curculionidae (beetle)	tr.	7
Oligochaeta (worms)	tr.	7
Sphaeridae (fingernail clams)	tr.	7
Plant Material (High Carbohydrate)	87.5	100
Leersia oryzoides (rice cut-grass)	31.3	67
Polygonum spp.(smartweed)	22.9	60
Root Parts	19.0	20
Echinochloa spp. (millet)	6.8	27
Unknown Seeds	3.0	47
Bidens spp. (beggars ticks)	2.9	67
Amaranthus spp.(pigweed)	1.1	27
Polygonum spp. (tearthumb)	0.5	7
Cuscuta spp. (dodder)	tr.	7

Table G2. Foods consumed by mallards (n = 37) during spring migration 2005 on Swan Lake, Illinois. Food items making up less than 0.1% aggregate mass of diet are listed as trace (tr.).

Food Item	Aggregate %	% Occurrence
Animal Material (High Protein)	24.5	62
Gastropoda (snails)	8.4	38
Isopoda (aquatic sow bugs)	6.1	35
Sphaeridae (fingernail clams)	5.1	11
Chironomidae (midges)	3.1	19
Hirudinea (leeches)	0.4	14
Odonata (Coenagionidae/Aeshnidae)	0.3	8
Trichoptera (caddisflies)	0.3	5
Amphipoda (scuds)	0.2	16
Corixidae (water boatmen)	0.2	19
Oligochaeta (worms)	0.1	11
Coleoptera (Dytiscidae/Hydrophilidae beetles)	0.1	14
Platyhelminthes (flatworms)	0.1	3
Belostomatidae (giant water bugs)	0.1	5
Unknown Invertebrate Material	tr.	5
Cladocera (water fleas)	tr.	5
Culicidae (mosquito)	tr.	5
Nematoda (roundworms)	tr.	5
Diptera - Tabanidae (house flies)	tr.	3
Ephemerpotera (mayflies)	tr.	3
Acariformes (aquatic mites)	tr.	5
Ostracoda (seed shrimp)	tr.	5
Hymenoptera - Formicidae (ants)	tr.	3
Copepoda	tr.	3
Collembola (springtails)	tr.	3
Unknown Invertebrates	tr.	8
Plant Material (High Carbohydrate)	75.5	100
Echinochloa spp. (millet)	22.6	57
Polygonum spp. (smartweed)	13.6	68
Leersia oryzoides (rice cut-grass)	11.4	43
Tubers	7.2	14

Table G2 continued.

Food Item	Aggregate %	% Occurrence
Unknown Seeds	6.1	41
Cuscuta spp. (dodder)	4.0	19
Cephalanthus occidentalis (buttonbush)	3.8	22
Cyperus spp. (nut sedges)	3.6	49
Bidens spp. (beggars ticks)	2.2	11
Polygonum spp. (tearthumb)	1.0	8
Potamogeton spp. (pondweed)	tr.	3
Amaranthus spp. (pigweed)	tr.	14
Sagittaria lattifolia (arrowhead)	tr.	3

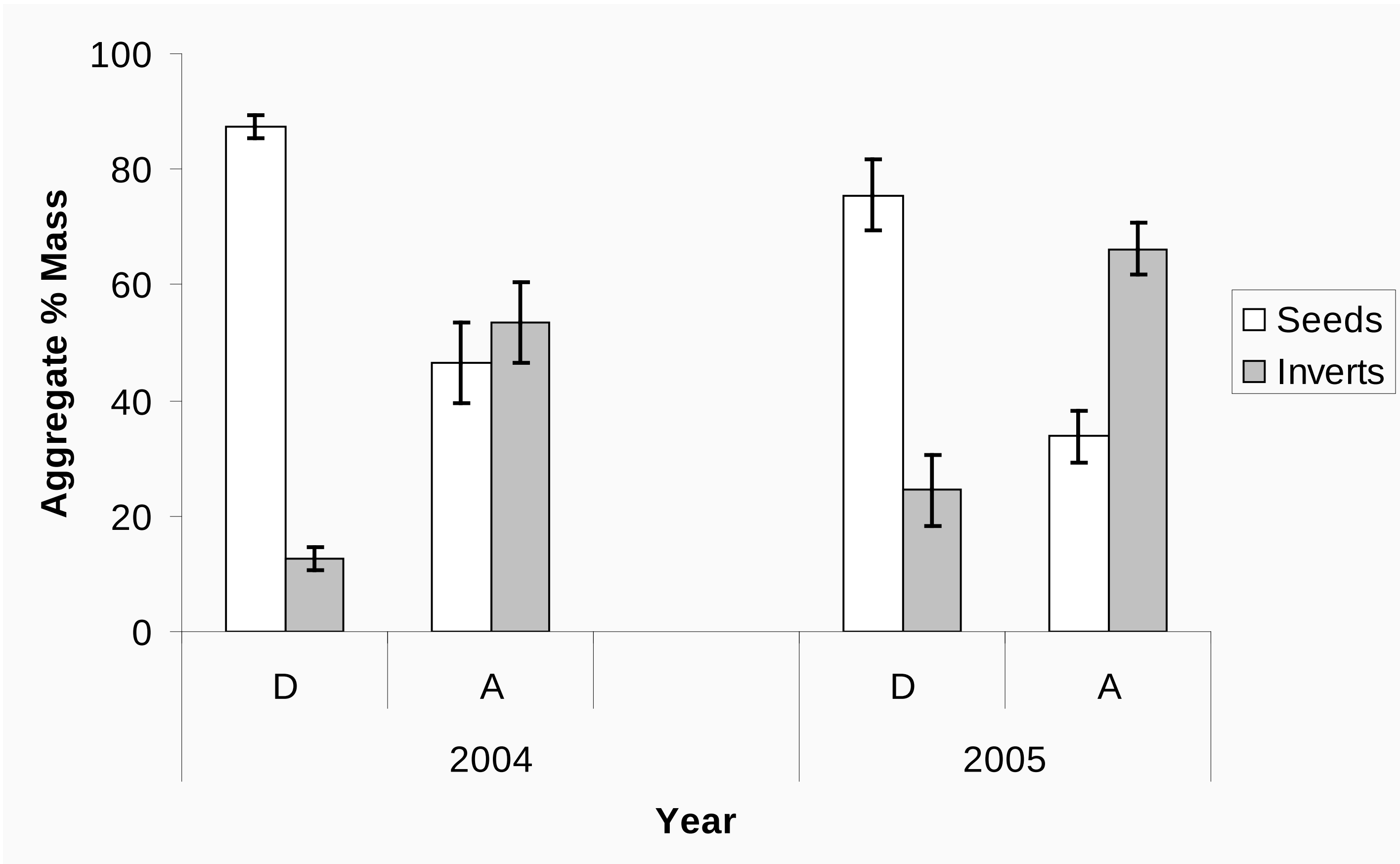


Figure G1. Diet (D) and food available (A) at mallard collection sites, with standard errors, during springs 2004 and 2005 at Swan Lake, IL.

Table G3. Foods consumed by lesser scaup (n = 26) during spring migration 2004 on Swan Lake, Illinois. Food items making up less than 0.1% aggregate mass of diet are listed as trace (tr.).

Food Item	Aggregate %	% Occurrence
Animal Material (High Protein)	62.8	96
Gastropoda (snails)	23.4	42
Chironomidae (midges)	8.7	27
Isopoda (aquatic sow bugs)	8.5	38
Nematoda (roundworms)	6.6	65
Cladocera (water fleas)	4.9	42
Hirudinea (leeches)	3.3	15
Coleoptera (Dytiscidae/Hydrophilidae beetles)	2.0	8
Unknown Invertebrate Material	1.6	27
Copepoda	1.2	42
Oligochaeta (worms)	1.0	4
Ostracoda (seed shrimp)	0.7	27
Corixidae (water boatmen)	0.5	8
Acariformes (aquatic mites)	0.3	27
Coenagrionidae (damselflies)	0.1	4
Amphipoda (scuds)	0.1	12
Plant Material (High Carbohydrate)	37.2	85
Polygonum spp. (smartweed)	20.0	62
Cuscuta spp. (dodder)	7.2	12
Leersia oryzoides (rice cut-grass)	2.3	8
Echinochloa spp. (millet)	2.3	15
Cyperus spp. (nut sedge)	2.1	58
Tubers	1.4	4
Bidens spp. (beggars ticks)	1.0	8
Unknown Seeds	0.8	31
Sagittaria lattifolia (arrowhead)	0.1	8
Cephalanthus occidentalis (buttonbush)	tr.	4
Amaranthus spp. (pigweed)	tr.	8

Table G4. Foods consumed by lesser scaup (n = 35) during spring migration 2005 on Swan Lake, Illinois. Food items making up less than 0.1% aggregate mass of diet are listed as trace (tr.).

Food Item	Aggregate %	% Occurrence
Animal Material (High Protein)	25.3	80
Gastropoda (snails)	13.0	46
Nematoda (roundworms)	2.9	17
Sphaeridae (fingernail clams)	2.8	9
Isopoda (aquatic sow bugs)	2.5	23
Chironomidae (midges)	1.2	20
Oligochaeta (worms)	0.7	6
Unknown Invertebrate Material	0.6	6
Acariformes (aquatic mites)	0.5	20
Hirudinea (leeches)	0.4	6
Unknown Invertebrates	0.3	17
Corixidae (water boatmen)	0.2	14
Amphipoda (scuds)	0.1	14
Trichoptera (caddisflies)	tr.	6
Ostracoda (seed shrimp)	tr.	14
Coleoptera - Dytiscidae (beetles)	tr.	6
Cladocera (water fleas)	tr.	11
Copepoda	tr.	6
Culicidae (mosquito)	tr.	3
Plant Material (High Carbohydrate)	74.7	100
Leersia oryzoides (rice cut-grass)	29.6	51
Polygonum spp. (smartweed)	14.9	54
Echinochloa spp. (millet)	12.4	37
Cyperus spp. (nut sedges)	5.9	69
Cuscuta spp. (dodder)	4.6	14
Unknown Seeds	3.1	23
Cephalanthus occidentalis (buttonbush)	2.7	9
Potamogeton spp. seeds (pondweeds)	0.8	14
Bidens spp. (beggars ticks)	0.5	20
Amaranthus spp. (pigweed)	tr.	9
Sagittaria lattifolia (arrowhead)	tr.	20

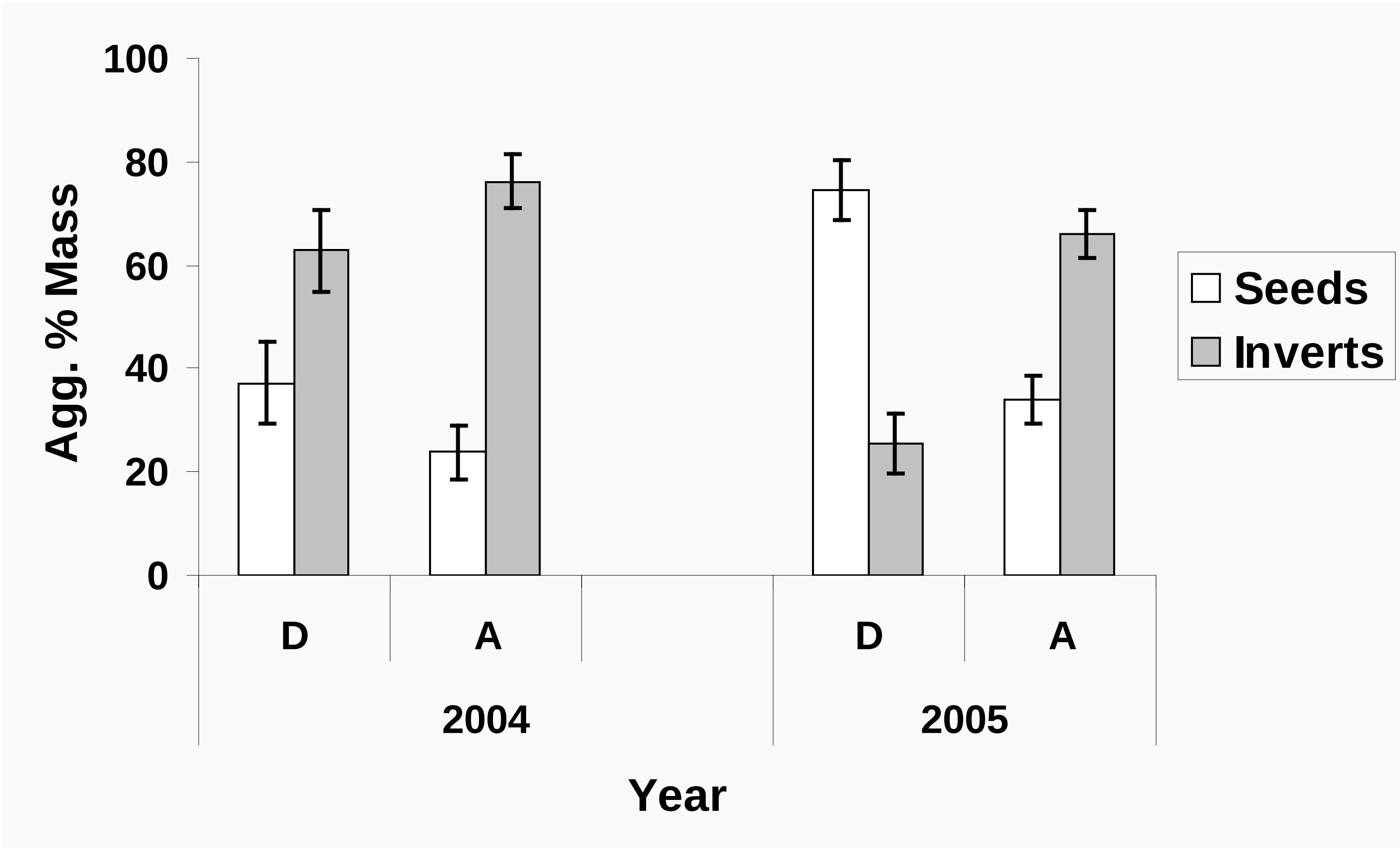


Figure G2. Diet (D) and food available (A) at lesser scaup collection sites, with standard errors, during springs 2004 and 2005 at Swan Lake, IL.