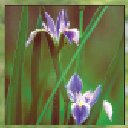
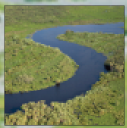
SOUTH FLORIDA WATER MANAGEMENT DISTRICT

# VOLUME II
# KISSIMMEE RIVER RESTORATION STUDIES

# Defining Success: *Expectations for Restoration of the Kissimmee River*

*November 2005*

Technical Publication ERA 433


*Edited by:*

David H. Anderson

Stephen G. Bousquin

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KISSIMMEE RIVER RESTORATION STUDIES

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*Edited by David H. Anderson, Stephen G. Bousquin,
Gary E. Williams, and David J. Colangelo*

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# FOREWORD

A recent survey of restoration projects concluded that more than $1 billion has been spent each year since 1990 on river restoration projects within the continental United States and that only 10% of the projects indicated any kind of evaluation to determine if project goals were being met (Bernhardt et al. 2005). The Kissimmee River Restoration Project is recognized nationally as one of the best examples of a well-documented evaluation program. Evaluation played a critical role in selecting among alternative restoration plans during the Kissimmee River Demonstration Project, and it will continue to play a critical role in determining if the project is successful and in providing feedback for adaptive management. This volume contains a summary of the success criteria that have been developed for this project.

The Kissimmee River Restoration Project was authorized by the Water Resources Development Act of 1992 and is intended to reestablish ecological integrity to the central region of this floodplain river ecosystem by undoing the impacts of channelization that occurred during the 1960s as part of the Central and Southern Flood Control Project. The flood control project channelized the Kissimmee River along the entire length from Lake Kissimmee to Lake Okeechobee. Channelization involved the excavation of a canal (C-38) that was much deeper and wider than the natural river channel and the installation of six water control structures along the length of the canal to regulate the movement of water. Before channelization, the Kissimmee River meandered across a floodplain that was up to two miles in width. Long periods of floodplain inundation in most years allowed the development of a mosaic of floodplain wetlands that supported a variety of fish, wading birds, waterfowl, and other wildlife. After channelization, the canal became the main conduit for the flow of water, and remnants of the natural river channel were stagnant. Most of the floodplain was drained, but the areas immediately upstream of the water control structures were permanently impounded. These hydrologic changes altered habitat conditions resulting in reductions of wetland plant communities.

Major features of the restoration project include removing two water control structures, filling approximately 22 miles (35 kilometers) of canal, and carving new sections of river channel to connect channel remnants, which will create approximately 44 miles (70 kilometers) of continuous river channel and associated floodplain. The remaining water control structures will be operated to provide more natural hydrologic conditions. The reestablishment of natural hydrologic conditions is expected to result in the recovery of ecological integrity. Ecological integrity is defined as an ecosystem with "the capability of supporting and maintaining a balanced, integrated, adaptive community having species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Karr and Dudley 1981).

The plan for the Kissimmee River Restoration Project recognized monitoring as an essential component of the project to gage project success and to guide adaptive management during and following the project (U. S. Army Corps of Engineers 1991). However, monitoring changes over time is not sufficient to determine if the project is successful or to trigger adaptive management (Anderson and Dugger 1998). To guide decision-making, criteria are needed that can be used to interpret changes as being desirable or not. Such criteria were developed for the evaluation program of the Kissimmee River Restoration Project. These criteria, called restoration expectations, are presented in this volume. A recent companion volume (Bousquin et al. 2005) presents the data on which these restoration expectations were based.

### The Expectations

A restoration expectation is a statement of an expected response to the restoration project based on the difference between the channelized river (baseline condition) and a reference condition representative of the pre-channelization condition, or the best attainable estimate of the pre-channelization condition. An original set of sixty-one expectations was completed by July 1999 when the first phase of construction was beginning. Based on several rounds of external and internal peer-review, this list was shortened primarily by combining related expectations and by eliminating those that lacked reference data. The review process resulted in a final set of twenty-five expectations.

Of the twenty-five expectations, nine describe abiotic responses for hydrology, geomorphology, and water quality. These abiotic responses are important because they will drive responses by biotic components. Five are especially important because they describe the reestablishment of the hydrologic attributes (stage, velocity, and discharge) that are expected to drive the recovery by other components of the ecosystem.

The remaining expectations are biological and focus on communities or functional groups (e.g., guilds) of organisms rather than on single species. Five expectations describe changes in plant communities in the river channel and floodplain. These plant expectations have inherent value as indicators of success, but plants are also an important habitat component for many animals. Thus, achieving expectations for plant communities is an indication that important habitat characteristics are being reestablished for other groups of organisms.

Six expectations describe invertebrate and amphibian and reptile communities. Like plant communities, changes in guilds or communities of invertebrates or amphibians and reptiles can serve as indicators of ecological integrity. Recovery by these groups is also an indication that the linkages in the food web are being reestablished that are needed to support higher trophic levels. Five expectations describe anticipated changes in fish and bird communities.

**Standardized format**

The development of the expectations followed a process that specified certain pieces of information that were required for each expectation (Toth and Anderson 1998). Most of this information is presented in the companion baseline studies volume (Bousquin et al. 2005). This compendium volume is a collection of summary documents for the expectations. These documents present the information required for each format in a standardized format. The value of this compendium is to ensure adequate documentation of each expectation and to provide a ready reference to the expectations over the remainder of the restoration project. Each expectation document contains the following twelve pieces of information:

- **Title:** identifies the expectation.
- **Expectation:** states the success criterion that will be evaluated to determine restoration success and concisely describes the anticipated change including values for quantitative metrics.
- **Author:** identifies the person(s) responsible for creating the expectation and who should be contacted to answer any questions.
- **Date:** identifies when an expectation was developed.
- **Relevant Endpoints**: identifies characteristics of concern that reflect the restoration goal.
- **Metric:** identifies the attributes that will be measured to evaluate the expected change.
- **Baseline Condition:** characterizes the state of the metric for the disturbed (pre-restoration) system.
- **Reference Condition:** describes the state or value of the metric if the system had not been disturbed (i.e., an ecosystem with ecological integrity).
- **Mechanism for Achieving Expectation:** explains how the restoration will cause the system to change, so that the metric achieves the expected value.
- **Adjustment for External Constraints:** explains any adjustments to the reference condition because of constraints external to the restoration project.
- **Means of Evaluation:** describes how the expectation will be evaluated including the sampling design (sampling sites, control sites, sampling methods, replication, and frequency), the calculation of metrics, and the evaluation of the expectation (statistical test, comparison to a threshold).
- **Time Course:** estimates the time required to achieve an expectation.

**Integration, restoration success, and adaptive management**

Collectively, the restoration expectations describe a view of the Kissimmee River ecosystem with ecological integrity. Any effort to evaluate project success should integrate the responses for all of the expectations as well as any other information about the recovering ecosystem. Judgments about restoration success should treat the expectations as guidelines and recognize the limited amount of reference condition information (e.g., the number of years of pre-channelization data or number of reference sites) that was available for each. One goal of the restoration evaluation program has been to provide feedback for adaptive management during the during the restoration project and afterwards. The evaluation of the restoration expectations allows for that feedback by defining an anticipated response and time course during which the response should be observed. A slower response than expected should trigger consideration of the need for adaptive management.

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# EXPECTATION 1

# CONTINUOUS RIVER CHANNEL FLOW

**Expectation**

The number of days that discharge is equal to 0 cfs in a water year will be zero for restored channels of the Kissimmee River.

**Author**

David H. Anderson, South Florida Water Management District
Joanne Chamberlain, South Florida Water Management District (*Current affiliation:* BEM Systems Inc.)

**Date**

April 1, 1999; revised March 22, 2002; revised June 9, 2005

**Relevant Endpoints**

Restoration - Physical Integrity - Hydrology
Restoration - System Functional Integrity - Habitat Quality
Restoration - System Functional Integrity - Persistence

**Metrics**

Number of days per water year with zero discharge

**Baseline Condition**

The number of days per water year with zero discharge was calculated as the total number of days in a water year (May 1–April 30), when mean daily discharge was greater than 0 cfs. Baseline conditions were derived for long-term monitoring stations at S-65 (Water Years 1972–1999) and S-65E (Water Years 1972–1999). These stations are located in the Kissimmee River at the outflow of Lake Kissimmee and near Lake Okeechobee. An additional flow station (PC33) was established in a remnant channel and had only a single year of baseline data (Water Year 1999). Additional details are provided in Anderson and Chamberlain (2005).

At S-65, the number of days with zero discharge ranged from 0 d to 312 d and averaged 111 d (standard error = 20.60). At S-656E, the range was 1 d to 312 d and averaged 28.07 d (SE = 7.01). For the single water year at PC33, the number of days of zero discharge was 346 d. During the baseline period, the number of days of zero discharge increased in the early 1980s at both S-65 and S-65 E (Figure 1-1).

The seasonal distribution of zero flow days (Table 1-1) reflects the existing flood control operational schedule at S-65. Frequencies of zero flow conditions are lowest between February and May when discharges are made to lower lake stages in preparation for wet season rainfall. No flow periods are most common during June to December when lakes are allowed to fill to their maximum flood control elevation.

Data from PC33 indicate that zero flows occurred through the remnant river channel 75% of the time from November 1997 to May 1999. Instantaneous discharges measured in other remnant river channels verified that frequent no flow conditions occurred in all remnant river channels in Pool C.

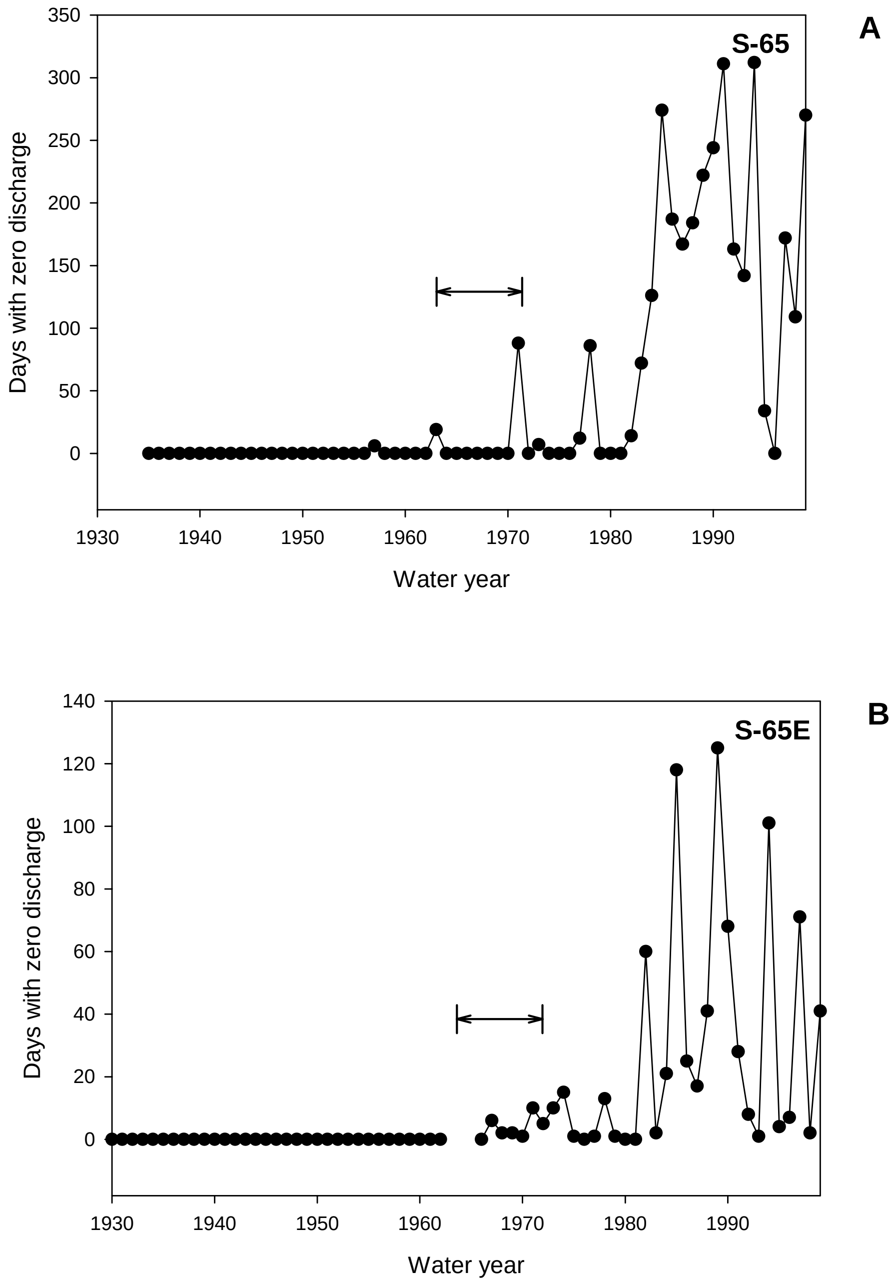


Figure 1-1. Number of days each water year that mean daily discharge was 0 cfs at S-65 (A) and S-65E (B). Double-headed arrows indicate the time interval when channelization occurred.

### Reference Condition

Pre-channelization reference conditions were based on mean daily discharge at S-65 (Water Years 1935–1962) and for S-65E (Water Years 1930–1962). At S-65, the number of days of zero discharge was 0 d in every water year except one (Figure 1-1). At S-65E, the number of days with zero discharge was 0 d for each reference period. During October 1956, six days of reverse flow into Lake Kissimmee followed 16 in. of rainfall in two days. Severe drought conditions existed prior to this storm, and constructed levees along the river reduced the floodplain width to 400 ft in some downstream areas. The heavy rainfall and constricted floodplain caused reverse flow from the river to Lake Kissimmee. Low flows typically occurred during April and May (Toth et al. 1995; 1997). Headwater inflows contributed approximately 60% of the flows through the Kissimmee River, while tributary contributions represented about 40% of historical discharges.

Table 1-1. Mean number of days that zero discharge occurred at S-65 during 1971 to 1998.

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 4 | 5 | 2 | 2 | 13 | 14 | 10 | 9 | 14 | 15 | 12 |

### Adjustment for External Constraints

The expectation of continuous flow does not account for flood control and navigation constraints on the new regulation schedule or operation rules for the upper basin. Modeling conducted to develop this new regulation schedule indicates that zero flow could occur occasionally. However, during the simulation period (1970–1987), the basin received approximately 10% less rainfall than during the pre-channelization period (Obeysekera and Loftin 1990) and the model underestimated discharges by approximately 20%. More normal (average) rainfall conditions will decrease the likelihood of zero flow conditions.

### Mechanism for Achieving Expectation

A new regulation schedule and operation rules were developed to provide continuous headwater inflows that reflect climatic inputs to the upper basin and a more natural, seasonally variable flow regime. Implementation of the new schedule is anticipated in 2010 after acquisition of all real estate interests along Lakes Kissimmee, Hatchineha, and Cypress and Phase II/III of construction for the river river restoration have been completed. However, an interim regulation schedule, which allows partial reestablishment of historic headwater inflows, was implemented in January 2001.

Restoration of the physical form of the river, through backfilling C-38 and carving new river segments, will force flows through the Kissimmee River channel.

### Means of Evaluation

Daily discharge data at S-65 and PC33 will be used to calculate the number of days per year that zero flow occurs in the river. Data from PC33 will be the primary focus because it is located in a restored river channel. The ecological significance of brief no-flow periods will be evaluated with related restoration studies. Initial evaluation will begin after implementation of the interim regulation schedule and continue annually for a minimum of five years after the new regulation schedule is implemented.

### Time Course

Restoration of flow regimes will be initiated following implementation of the interim regulation schedule. However, due to constraints of the interim schedule, continuous flows may not occur until the new regulation schedule is implemented.

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# EXPECTATION 2

# ANNUAL DISTRIBUTION AND YEAR-TO-YEAR VARIABILITY OF MONTHLY MEAN FLOWS

### Expectation

Intraannual monthly mean flows will reflect historic seasonal patterns and have interannual variability (coefficient of variation) <1.0.

### Author

Joanne Chamberlain, South Florida Water Management District (*Current affiliation:* BEM Systems Inc.)

### Date

April 1, 1999; revised May 21, 2002

### Relevant Endpoints

Restoration - Physical Integrity - Hydrology
Restoration - Physical Integrity - Hydrogeomorphic Processes
Restoration - Physical Integrity - Disturbance
Restoration - System Functional Integrity - Habitat Quality
Restoration - System Functional Integrity - Persistence

### Metrics

Annual pattern of monthly mean discharge
Interannual coefficient of variation for monthly mean discharge

### Baseline Condition

Baseline conditions were derived from daily discharge at S-65, S-65C, and S-65E from 1971 to 1998, and daily discharge at PC33 on Micco Bluff Run, a remnant river channel in Pool C. S-65 is located at the outlet of the Upper Kissimmee Basin and contributes approximately 60% of the flows through the channelized Kissimmee River. S-65C is located near the middle of the area to be restored. The S-65E structure is located at the outlet of the Kissimmee River basin, approximately seven miles downstream from the restoration project limits. Data collected from November 1997 to May 1999 at PC33 are representative of baseline conditions in sections of river channel that will be affected by the first phase of restoration.

The monthly mean of daily discharge describes average flow for a given month. Data at S-65, S-65C, and S-65E show that highest flows occurred from January through April and in August and September; while low flows occurred in June, November, and December (Figure 2-1A). During wet season months (June through October), flows increased along the channelized river due to lower basin tributary inflows. During the dry season, flows were primarily a function of headwater discharges with little difference between upstream and downstream locations.

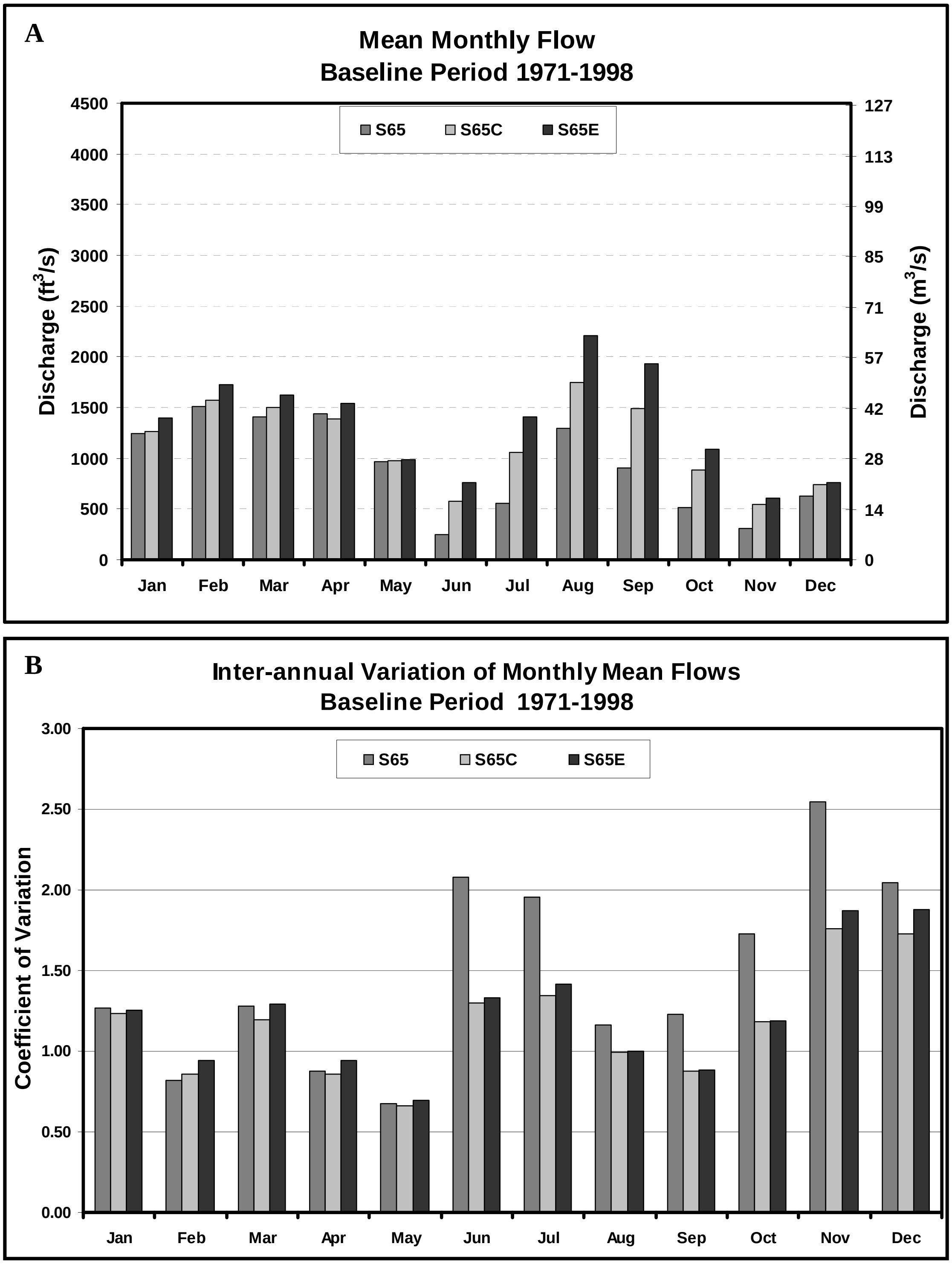


Figure 2-1. (A) Baseline mean monthly flows along the channelized Kissimmee River. (B) Baseline year-to-year variation of monthly mean flows along the channelized Kissimmee River.

Discharges at the S-65 structures represent flows in the C-38 canal and are different from flow conditions in remnant river channels. Monthly mean discharges at PC33 did not exhibit a seasonal pattern. Discharges were zero 75% of the time from November 1997 to May 1999. Daily river flows (PC33) were less than 5% of C-38 discharge 83% of the period when PC33 flows were >0 $ft^3/s$.

Interannual variation of monthly mean flows (Figure 2-1B), as described by the coefficient of variation (standard deviation/mean), was high (relative to the historic system) during most months. S-65 had the highest variability, which occurred during months with high frequencies of zero flow (June, July, October, November, and December). Baseline intraannual and interannual distributions of monthly mean flows are the result of the current operation schedule at S-65, which is designed to lower stages in the headwater lakes between February and June in preparation for wet season rainfall. Lakes are allowed to fill to their maximum flood control elevation between June and November and may remain at that elevation through February. Flood control operations have resulted in a seasonal shift of high and low flows and extended periods of no flow.

**Reference Condition**

Reference conditions were derived from daily discharge data at historic river channel gages at the outlet of Lake Kissimmee (near existing location of S-65) and near Lake Okeechobee (near existing location of S-65E) from 1933 to 1960.

Historic mean monthly flows (Figure 2-2A) were highest during September through November and lower from January through June. Interannual variation of historic monthly flows (Figure 2-2B) indicates minimal differences between months, with the largest variation occurring in June at the downstream gage near Lake Okeechobee.

Figures 2-2A and 2-2B include estimated historic data at the existing location of S-65C [S-65C (est.)], which represents reference conditions for the lower portion of the first phase of restoration. These data were estimated using historic daily discharge at the outlet of the Kissimmee River basin (S-65E) and the ratio of drainage basin areas associated with these locations.

**Adjustment for External Constraints**

The expectation does not account for flood control and navigation constraints on the new regulation schedule or operation rules for the upper basin. Modeling conducted to develop this regulation schedule indicates that low to no flow could occur occasionally.

Land use changes (i.e., loss of uplands to pasture and construction of numerous farm ditches) in tributary watersheds have altered the timing of inflows to the river. However, monthly mean discharge data will mask brief periods of rapid runoff during storm events.

**Mechanism for Achieving Expectation**

A new regulation schedule and operation rules were developed to provide headwater inflows that reflect climatic inputs to the upper basin and a more natural, seasonally variable flow regime. Restoration of the physical form of the river, through backfilling C-38 and carving new river segments, will direct flows through the Kissimmee River channel.

**Means of Evaluation**

Reestablishment of the annual distribution and year-to-year variability of monthly mean flows will be evaluated by comparing post-restoration data with historic data (Figures 2-2A and 2-2B). Monthly mean flows, calculated from daily discharge data at S-65 and PC33, will be graphed to qualitatively assess restoration of the seasonal pattern of flows (i.e., annual low flows between April and June, annual high flows in October, and an increase in mean monthly flows from June to October, followed by a decrease in mean monthly flows from October to June). Statistical analyses will evaluate differences in the coefficient of variation of monthly discharges between post-restoration and historical data using a significance level of 0.05. Hypotheses testing will begin with a minimum of ten years of data. The data set should include the historic range (0–9,000 $ft^3/s$) of flow conditions at S-65.

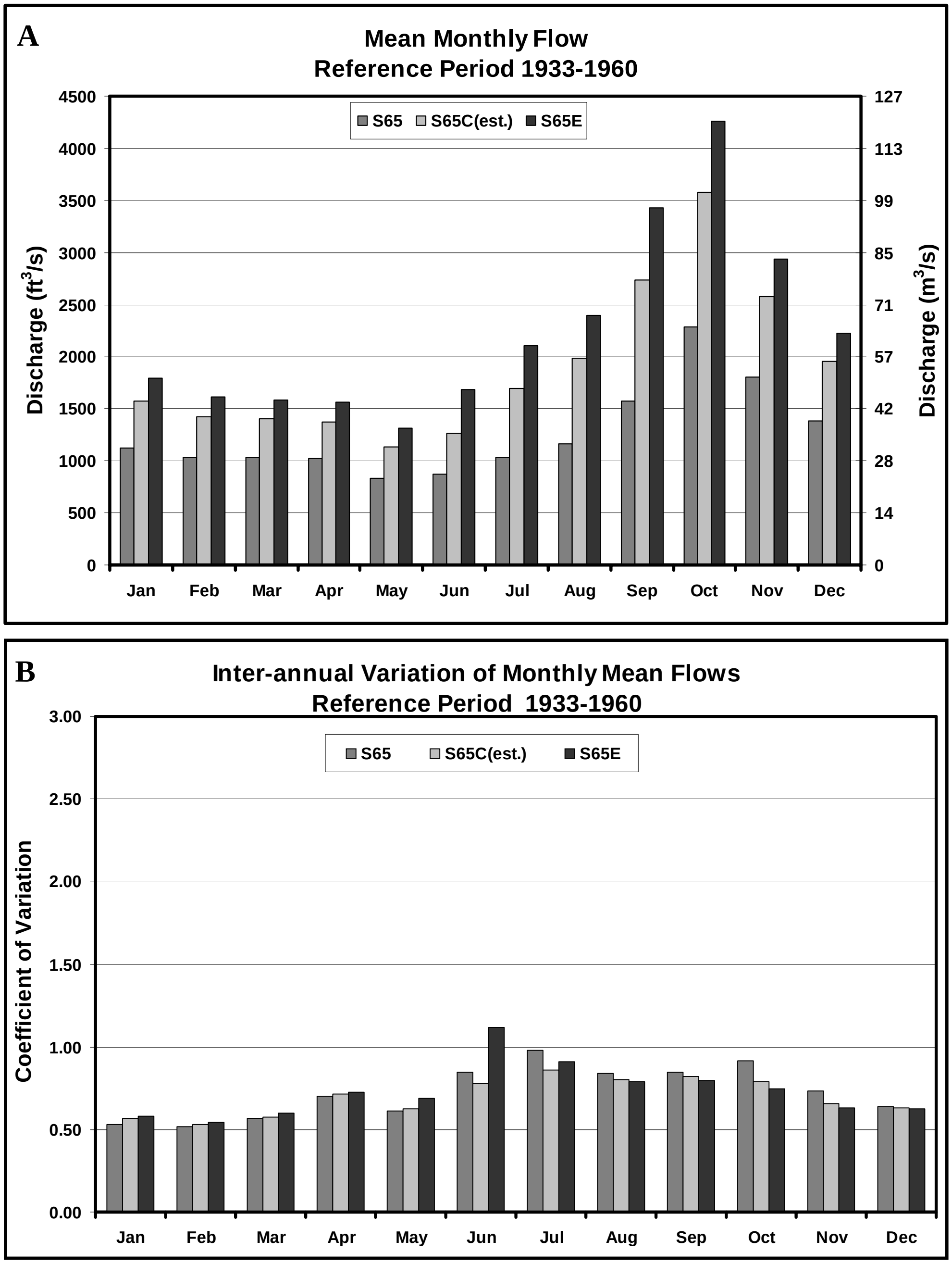


Figure 2-2. (A) Historic mean monthly flows along the Kissimmee River. S-65 represents flows at the outlet of Lake Kissimmee. S-65E represents flows near Lake Okeechobee. S-65C (est.) represents estimated flow conditions for the lower portion of the first phase of restoration. (B) Historic year-to-year variation of monthly mean flows along the Kissimmee River. S-65 represents flows at the outlet of Lake Kissimmee. S-65E represents flows near Lake Okeechobee. S-65C (est.) represents estimated flow conditions for the lower portion of the first phase of restoration.

**Time Course**

Implementation of the new regulation schedule, which is scheduled for 2010, cannot begin until all real estate interests have been acquired along Lakes Kissimmee, Hatchineha, and Cypress. However, an interim regulation schedule, which provides partial reestablishment of historic headwater inflows, was implemented in January 2001. Redistribution of monthly flow regimes will be initiated with implementation of the interim regulation schedule, backfilling of C38, and recarving of new river sections. However, due to the constraints of the interim schedule, monthly flow regimes may not reflect historic patterns and variability until the new regulation schedule is implemented.

# EXPECTATION 3

## STAGE HYDROGRAPH CHARACTERISTICS

### Expectation

River channel stage will exceed the average ground elevation for 180 d per water year and stages will fluctuate by 3.75 feet.

### Author

David H. Anderson, South Florida Water Management District
Joanne Chamberlain, South Florida Water Management District (*Current affiliation:* BEM Systems Inc.)

### Date

April 1999; revised December 2002; revised June 2005

### Relevant Endpoints

Impact Assessment - Flood Control
Restoration - Physical Integrity - Hydrology
Restoration - System Functional Integrity - Habitat Quality
Restoration - System Functional Integrity - Persistence
Restoration - System Functional Integrity - River/Floodplain Interactions

### Metrics

Inundation (number of days that river channel stage exceeds the average ground elevation in a water year)
Range of fluctuation in a water year

### Baseline Conditions

Baseline conditions were based on mean daily stage for river channel stations at Fort Kissimmee (Water Year 1985–1999), Fort Basinger (Water Year 1999), and S-65E (Water Year 1972–1999). Fort Kissimmee had been deactivated during channelization and was reactivated just after a fluctuating stage regulation schedule was implemented for Pool B as part of the Kissimmee River Demonstration Project. Fort Basinger was also deactivated during channelization and was reactivated only one water year before construction began for Phase I of the restoration project. Stage data were used to calculate two metrics: change in stage per water year and inundation (the number of days that stage exceeded the average ground elevation). Average ground elevations were 43 feet at Fort Kissimmee, 28.5 feet at Fort Basinger, and 21 feet at S-65E (Obeysekera and Loftin 1990). Additional details on methods can be found in Anderson and Chamberlain (2005).

During the baseline period, the values for the inundation metric were much lower for stage monitoring sites at Fort Kissimmee and Fort Basinger, which are located near the upper end of Pool B and D, respectively (Figure 3-1). At S-65E, stage is measured at the lower end of the pool where stages are influenced by water pooled upstream of the water control structure.

For the baseline period, the change in stage at Fort Kissimmee reflects the fluctuating stage regulation schedule for Pool B. The change in stage at S-65E was more typical of the period with a narrow range of fluctuation that was much smaller than the reference condition.

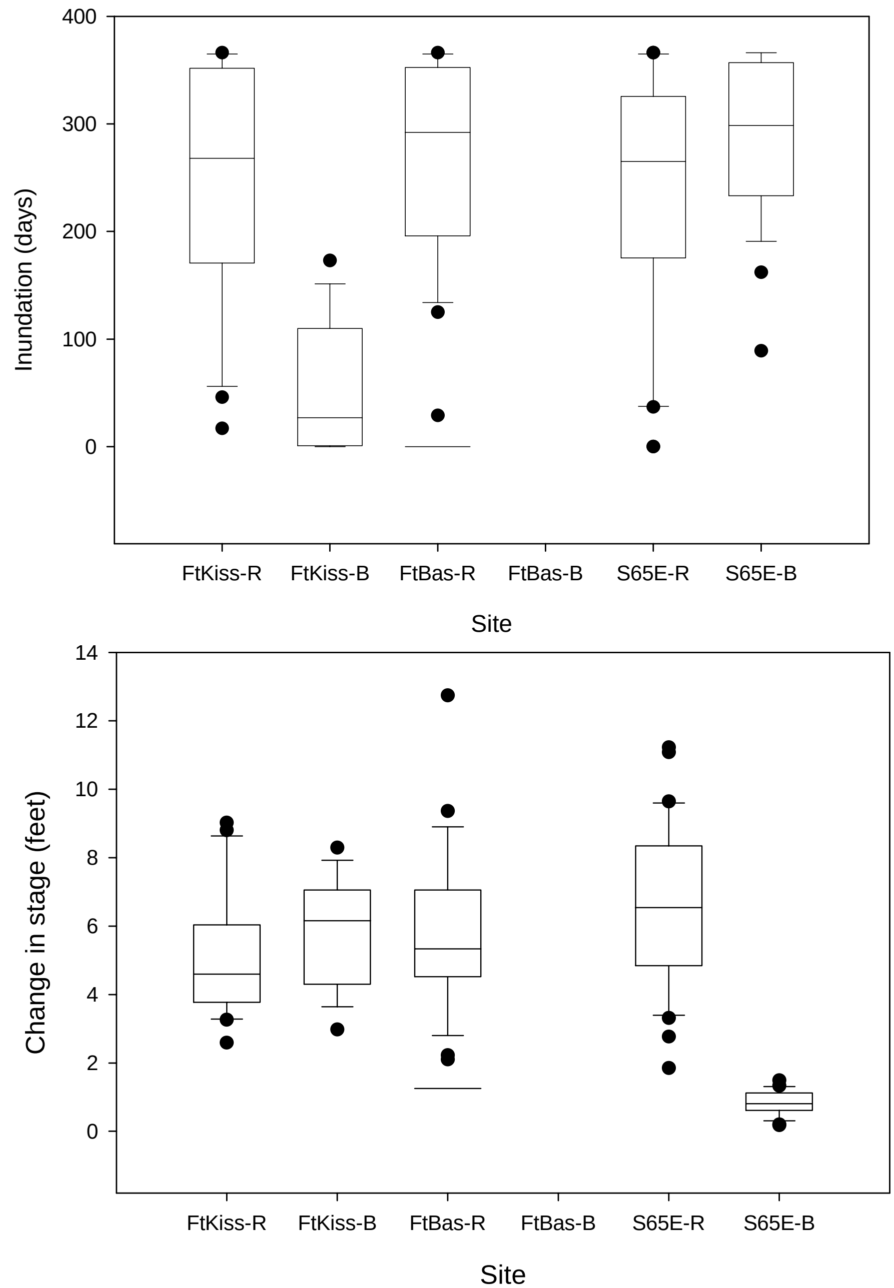


Figure 3-1. Box plots for inundation (number of days that stage exceeds the average ground elevation in a water year) and the change in stage per water year. Sites were Fort Kissimmee during the reference period (FtKiss-R) and baseline (FtKiss-B) periods, Fort Basinger during reference (FtBas-R) and baseline (FtBas-B) periods, and S-65E during reference (S65E-R) and baseline (S65E-B) periods. A box plot was not constructed for Fort Basinger during the baseline period because the single water year of data during the baseline period was insufficient.

**Reference Conditions**

Reference conditions were based on mean daily stage at Fort Kissimmee (Water Year 1943 – 1962), Fort Basinger (Water Year 1933–1959), and S-65E (Water Year 1931–1962).

During the reference period, boxplots for the inundation metric overlapped broadly for Fort Kissimmee, Fort Basinger, and S-65E (Figure 3-1). This overlap suggested that a threshold could be established for any station. For inundation, the 25$^{th}$ percentile was at least 180 d, so a reasonable expectation would be for inundation to be 180 d in most years.

Boxplots for the change in stage metric for the reference period also broadly overlapped, which suggested that a threshold could be established for a desirable minimum fluctuation in stage for most years. The 25$^{th}$ percentile for change in stage during the reference period was 3.75 feet, so that a fluctuation in stage of 3.75 feet might be expected in most years.

**Adjustments for External Constraints**

Achievement of this expectation depends on completion of the restoration project and the implementation of the headwaters revitalization stage regulation schedule for S-65. It is also highly dependent on rainfall conditions, and it may be necessary to develop a relationship between rainfall and stage using pre-channelization data to modify the expected duration of inundation and the range of stage fluctuation described in this expectation.

**Mechanism for Achieving Expectation**

Restoration of the physical form of the river through backfilling C-38 and carving new river segments will redirect flows through the Kissimmee River and lead to overflow onto the floodplain. A new regulation schedule and operation rules were developed to provide headwater inflows that reflect climatic inputs to the upper basin and a continuous, seasonally variable flow regime in the restored Kissimmee River. Regulation schedules and operation rules at S-65C and S-65D will be modified to reestablish historic stage-discharge relationships. Slow drainage of water off the floodplain (stage recession rates) also will facilitate reestablishment of floodplain inundation characteristics.

**Means of Evaluation**

Both the change in water level per water year and inundation are independent of the location so that they can be evaluated at any river channel stage monitoring station along the river. The inundation metric does require that the average ground level at the station be estimated. This expectation will be evaluated for Phase I using data collected at PC33. When Phase II/III is completed, it can be evaluated at Fort Basinger. Evaluation will consist of comparing measured values to the thresholds established in the expectation. If the thresholds are exceeded, the expectation will be achieved.

**Time Course**

Pre-channelization stage characteristics should be reestablished following the implementation of interim regulation schedules at S-65 and S-65C, backfilling of C-38, and recarving of new river sections. Interim regulation schedules at S-65 and S-65C were implemented in January 2001, and provide for partial reestablishment of historic flows and floodplain hydroperiods. Implementation of the new headwater regulation schedule should begin in late 2010.

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# EXPECTATION 4

# STAGE RECESSION RATES

**Expectation**

An annual prolonged recession event will be reestablished with an average duration ≥173 days and with peak stages in the wet season receding to a low stage in the dry season at a rate that will not exceed 1.0 ft (30 cm) per 30 days.

**Author**

Joanne Chamberlain, South Florida Water Management District (*Current affiliation:* BEM Systems Inc.)

**Date**

April 1, 1999; revised November 2002

**Relevant Endpoints**

Restoration - Physical Integrity - Hydrology
Restoration - Physical Integrity - Disturbance
Restoration - System Functional Integrity - Habitat Quality
Restoration - System Functional Integrity - River/Floodplain Interactions

**Metrics**

Thirty-day stage recession rate
Duration of recession events

**Baseline Conditions**

Baseline conditions were derived from daily average headwater stage at S-65C and S-65D from 1971 to 1998. During the baseline period, stages in Pools C and D were a function of operational schedules for water control structures S-65C and S-65D. Stage fluctuations typically did not vary more than 0.5 ft (15 cm) from control elevations (Figure 4-1). Due to the lack of fluctuation of water levels, there were no significant stage recession events during the baseline period.

**Reference Conditions**

Reference conditions were derived from daily stage data at Fort Kissimmee (Figure 4-2) and Fort Basinger (Figure 4-3) from 1942 to 1959. Based on these data, peak stages typically occurred in September or October and slowly receded until May or June. Slow stage recession rates provided connectivity between the river and floodplain, which contributed to habitat diversity and functionality, and allowed for the transfer of food resources.

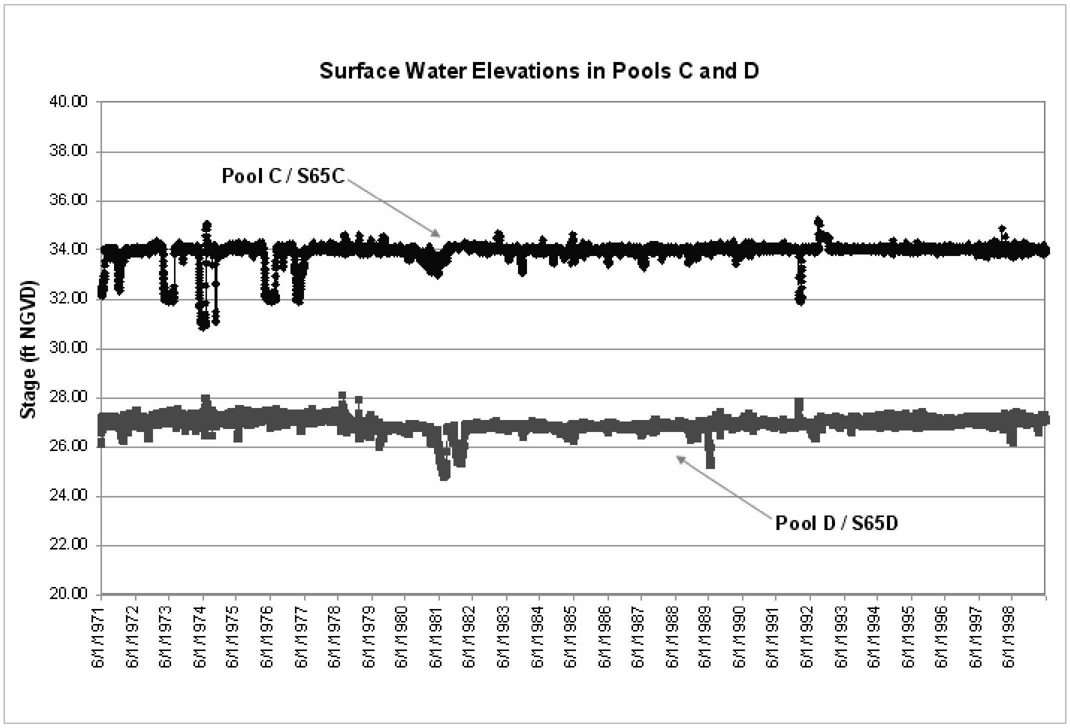


Figure 4-1. Daily surface water levels at S-65C and S-65D along C-38.

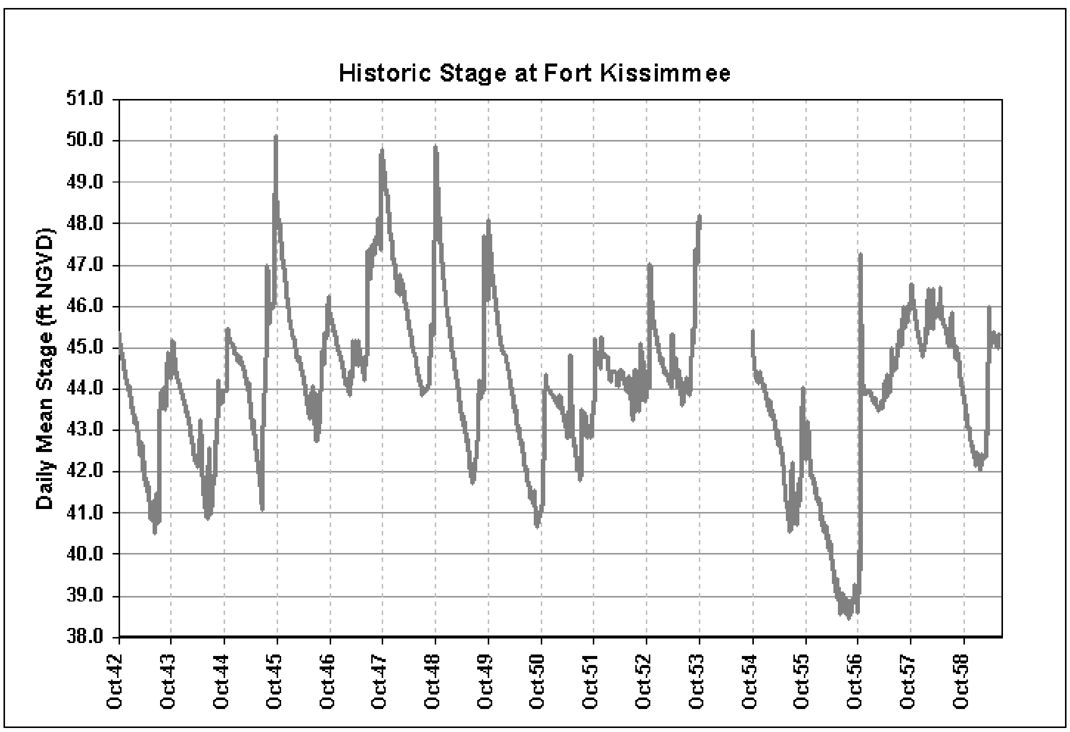


Figure 4-2. Historic daily surface water levels at Fort Kissimmee.

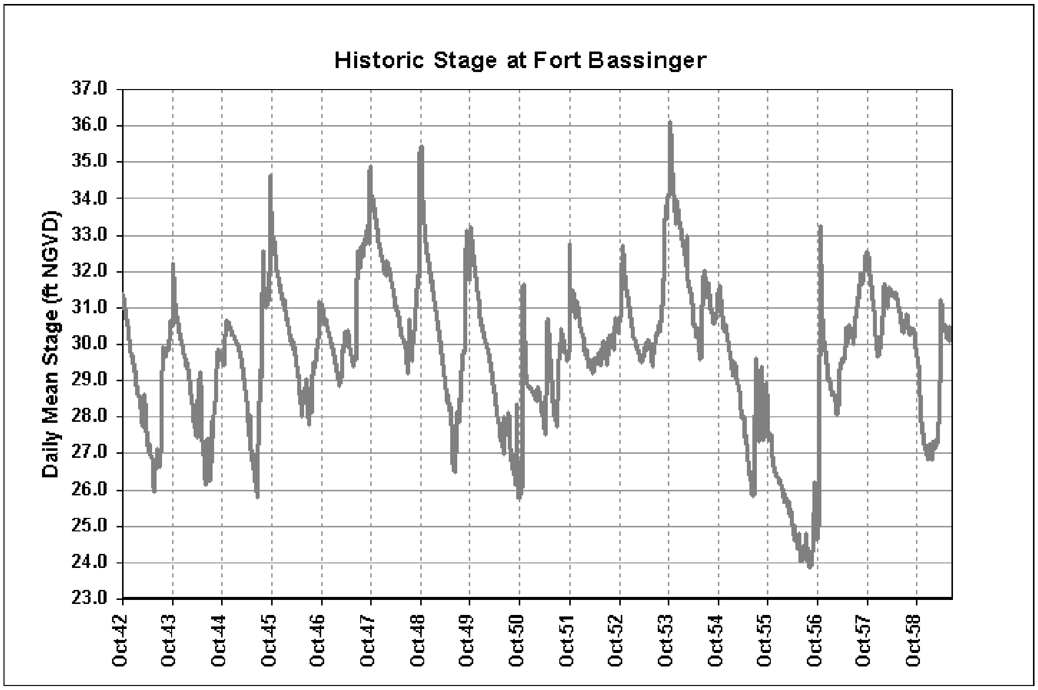


Figure 4-3. Historic daily surface water levels at Fort Basinger.

Thirty-day recession rates were calculated by the difference in maximum and minimum stages for each recession event divided by the total number of days water levels receded, and multiplied by 30 days (Tables 4-1 and 4-2). Small increases in stage were ignored during prolonged recession events. However, if stage increased >1.5 ft (45 cm), the recession event ended and another event began.

The duration of recession events at Fort Kissimmee (Table 4-1) ranged from 66 to 359 days and averaged 218 days. Stage recession rates ranged from 0.26 to 1.39 ft (8 to 42 cm) per 30 days. Only 1 of the 17 recession events exceeded 1.0 ft (30 cm) per 30 days. In April 1951, a dry season rainfall event caused stages to rise briefly before receding to a seasonal low in June. This recession event lasted 66 days, with water levels receding at a rate of 1.39 ft (42 cm) per 30 days.

The duration of recession events at Fort Basinger (Table 4-2) ranged from 16 to 355 days and averaged 173 days. Stages receded at a rate that ranged from 0.27 to 1.93 ft (8 to 59 cm) per 30 days. Rates of 7 of the 22 recession events exceeded 1.0 ft (30 cm) per 30 days and were associated with unusual weather conditions. Three events (April 1944, April 1951 and October 1957) resulted from aberrant dry season rainfall, which caused stages to rise briefly before receding to a seasonal low in June. During the recession event of 1948–1949, stage decreased by 8.9 ft (271 cm) and followed two extremely wet years that were due to hurricanes in the Kissimmee valley. In 1955–1956, two of three recession events had short durations (<20 days) and occurred early in the wet season prior to the normal seasonal stage recession period from September to May. The October 1956 to February 1957 event lasted 121 days and occurred during a severe drought, which was followed by rainfall that caused stages to increase until October 1957.

### Adjustments for External Constraints

Aberrant weather conditions (e.g., El Nino, winter fronts) may cause multiple recession events within a year and result in shorter average durations and recession rates that may exceed 1.0 ft (30 cm) per 30 days.

Table 4-1. Historic stage recession rates at Fort Kissimmee. Events exceeding the 1.00 ft/30 d recession rate are in bold.

| Year | Start Date | End Date | Start Stage (ft) | End Stage (ft) | Change in Stage (ft) | Duration (days) | Rate (ft/day) | Rate (ft/30days) | # of Events per Year |
|---|---|---|---|---|---|---|---|---|---|
| 1942-43 | 3-Sep-42 | 12-May-43 | 45.7 | 40.9 | 4.8 | 251 | 0.02 | 0.58 | 1 |
| 1943-44 | 11-Oct-43 | 5-Jun-44 | 45.2 | 40.9 | 4.3 | 238 | 0.02 | 0.55 | 1 |
| 1944-45 | 26-Oct-44 | 20-Jun-45 | 45.5 | 41.1 | 4.4 | 237 | 0.02 | 0.55 | 1 |
| 1945-46 | 18-Sep-45 | 13-May-46 | 50.1 | 43.3 | 6.8 | 237 | 0.03 | 0.87 | 1 |
| 1946-47 | 22-Sep-46 | 12-Feb-47 | 46.3 | 43.9 | 2.4 | 143 | 0.02 | 0.5 | 1 |
| 1947-48 | 23-Sep-47 | 1-Jul-48 | 49.8 | 43.9 | 6 | 282 | 0.02 | 0.63 | 1 |
| 1948-49 | 4-Oct-48 | 31-May-49 | 49.7 | 41.9 | 7.9 | 239 | 0.03 | 0.99 | 1 |
| 1949-50 | 1-Oct-49 | 28-Aug-50 | 48.1 | 40.7 | 7.4 | 331 | 0.02 | 0.67 | 1 |
| 1950-51 | 31-Oct-50 | 30-Mar-51 | 44.4 | 42.8 | 1.5 | 150 | 0.01 | 0.31 | 2 |
| | **22-Apr-51** | **27-Jun-51** | **44.8** | **41.8** | **3.1** | **66** | **0.05** | **1.39** | |
| 1951-52 | 20-Nov-51 | 30-Jun-52 | 45.2 | 43.3 | 2 | 223 | 0.01 | 0.26 | 1 |
| 1952-53 | 23-Oct-52 | 3-Jun-53 | 47 | 43.6 | 3.4 | 223 | 0.02 | 0.46 | 1 |
| 1953-54 | No Data | --- | --- | --- | --- | --- | --- | --- | --- |
| 1954-55 | 1-Oct-54 | 19-Jun-55 | 45.4 | 40.6 | 4.9 | 261 | 0.02 | 0.56 | 1 |
| 1955-56 | 13-Sep-55 | 27-May-56 | 44.1 | 38.6 | 5.5 | 257 | 0.02 | 0.64 | 1 |
| 1956-57 | 17-Oct-56 | 20-Feb-57 | 47.3 | 43.5 | 3.8 | 126 | 0.03 | 0.9 | 1 |
| 1957-58 | 5-Oct-57 | 22-Dec-57 | 46.5 | 44.8 | 1.7 | 78 | 0.02 | 0.66 | 1 |
| 1958-59 | 28-Jan-58 | 22-Jan-59 | 46.4 | 42.1 | 4.4 | 359 | 0.01 | 0.36 | 1 |

Table 4-2. Historic stage recession rates at Fort Basinger. Events exceeding the 1.00 ft/30 d recession rate are in bold.

| Year | Start Date | End Date | Start Stage (ft) | End Stage (ft) | Change in Stage (ft) | Duration (days) | Rate (ft/day) | Rate (ft/30days) | # of Events per Year |
|---|---|---|---|---|---|---|---|---|---|
| 1942-43 | 3-Oct-42 | 21-May-43 | 31.4 | 26 | 5.4 | 230 | 0.02 | 0.71 | 1 |
| 1943-44 | 5-Oct-43 | 29-Mar-44 | 32.2 | 27.4 | 4.8 | 176 | 0.03 | 0.82 | 2 |
| | **19-Apr-44** | **6-Jun-44** | **29.2** | **26.2** | **3.1** | **48** | **0.06** | **1.93** | |
| 1944-45 | 5-Nov-44 | 21-Jun-45 | 30.7 | 25.8 | 4.9 | 228 | 0.02 | 0.64 | 1 |
| 1945-46 | 22-Sep-45 | 14-May-46 | 34.6 | 28 | 6.6 | 234 | 0.03 | 0.85 | 1 |
| 1946-47 | 17-Sep-46 | 11-Feb-47 | 31.2 | 28.8 | 2.3 | 147 | 0.02 | 0.48 | 1 |
| 1947-48 | 24-Sep-47 | 3-Jul-48 | 34.9 | 29.2 | 5.7 | 283 | 0.02 | 0.6 | 1 |
| 1948-49 | **6-Oct-48** | **1-Jun-49** | **35.5** | **26.6** | **8.9** | **238** | **0.04** | **1.12** | 1 |
| 1949-50 | 5-Oct-49 | 4-Jun-50 | 33.2 | 27 | 6.2 | 242 | 0.03 | 0.77 | 1 |
| 1950-51 | 26-Oct-50 | 6-Apr-51 | 31.6 | 27.5 | 4.1 | 162 | 0.03 | 0.76 | 2 |
| | **24-Apr-51** | **27-Jun-51** | **30.7** | **27.8** | **2.9** | **64** | **0.05** | **1.37** | |
| 1951-52 | 3-Oct-51 | 25-Mar-52 | 32.8 | 29.2 | 3.6 | 174 | 0.02 | 0.62 | 1 |
| 1952-53 | 28-Oct-52 | 4-Jun-53 | 32.7 | 29.4 | 3.3 | 219 | 0.02 | 0.46 | 1 |
| 1953-54 | 13-Oct-53 | 25-May-54 | 36.1 | 29.5 | 6.6 | 224 | 0.03 | 0.88 | 1 |
| 1954-55 | 20-Jun-54 | 10-Jun-55 | 32 | 25.9 | 6.1 | 355 | 0.02 | 0.52 | 1 |
| 1955-56 | **4-Jul-55** | **20-Jul-55** | **29.5** | **27.4** | **2.1** | **16** | **0.13** | **---** | 3 |
| | **11-Aug-55** | **30-Aug-55** | **29.4** | **27.4** | **2** | **19** | **0.11** | **---** | |
| | 19-Sep-55 | 29-May-56 | 28.9 | 24 | 4.9 | 253 | 0.02 | 0.58 | |
| 1956-57 | **21-Oct-56** | **19-Feb-57** | **33.2** | **28.1** | **5.2** | **121** | **0.04** | **1.28** | 1 |
| 1957-58 | **7-Oct-57** | **22-Dec-57** | **32.5** | **29.6** | **2.9** | **76** | **0.04** | **1.13** | 2 |
| | 3-Feb-58 | 20-Jun-58 | 31.6 | 30.4 | 1.2 | 137 | 0.01 | 0.27 | |
| 1958-59 | 20-Jul-58 | 25-Dec-58 | 30.8 | 26.8 | 4 | 158 | 0.03 | 0.76 | 1 |

**Mechanism for Achieving Expectation**

Reestablishment of slow stage recession rates will be achieved by restoring the physical form of the Kissimmee River, implementing new regulation schedules, and reestablishing wetland vegetation on the floodplain. Backfilling C-38 and carving new river segments will direct flows through the river and floodplain. A new headwater regulation schedule and operation rules will provide continuous inflows to the Kissimmee River. Regulation schedules and operation rules based on historic stage-discharge relationships at downstream structures (S-65C and S-65D) and the limited conveyance of the restored river and floodplain will control recession rates in the restored system.

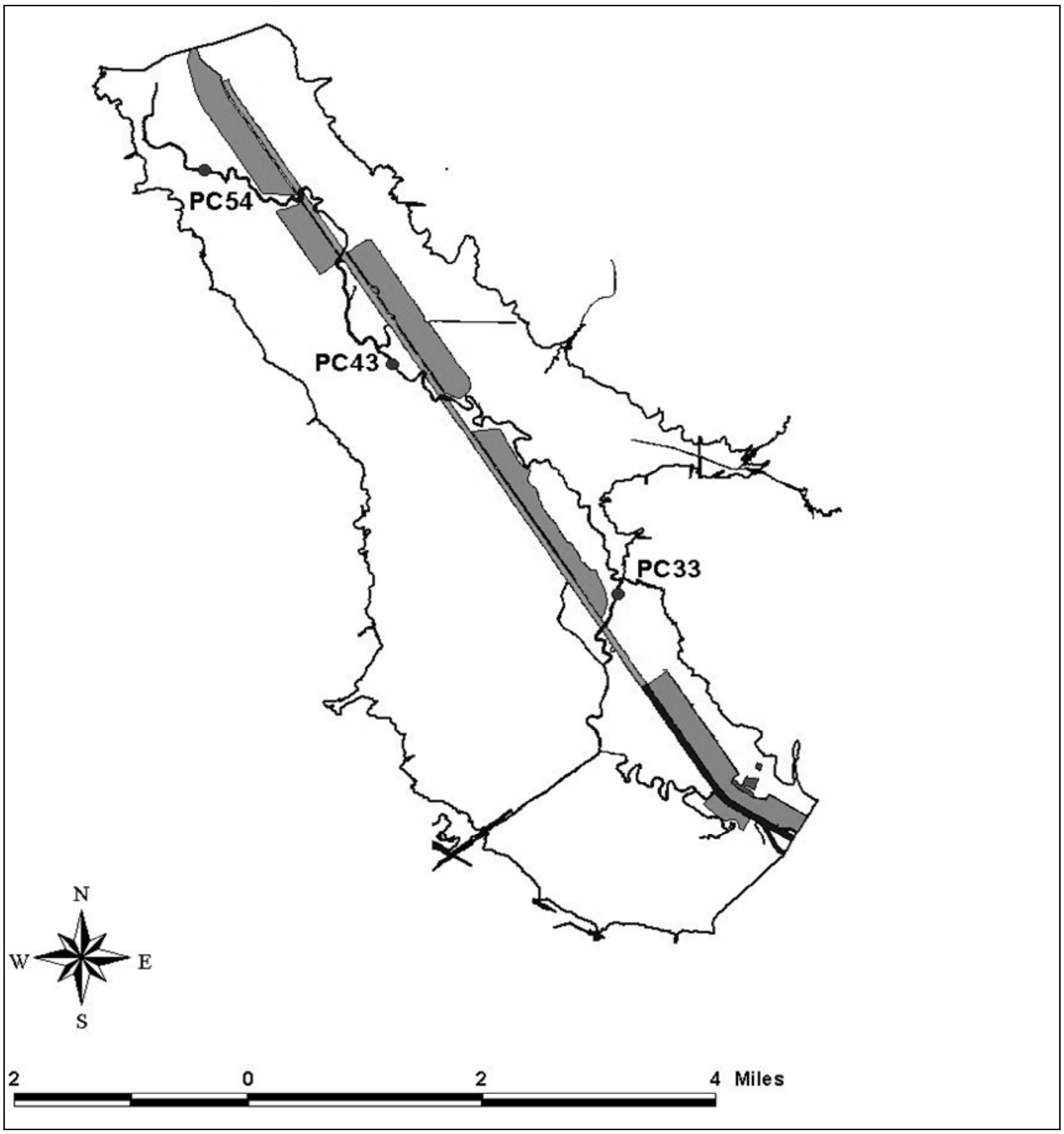


Figure 4-4. Locations of stations that will be used to evaluate stage recession rates along the restored river for Phase I of the restoration project.

**Means of Evaluation**

Recession rates will be calculated annually using daily stage data collected at PC33, PC43, and PC54 in Pool C (Figure 4-4). A recession event will begin with the peak wet season stage and continue to a dry season low. Small increases in stage will be ignored. However, if the stage increase exceeds 1.5 ft (45 cm), the recession event will end and another event will begin. Thirty-day recession rates will be calculated by the difference in maximum and minimum stages for each recession event divided by the total number of days water levels receded, and multiplied by 30 days. The expectation will be achieved if the average duration of recession events is ≥173 days and recession rates are ≤1.0 ft (30 cm) per 30 days.

**Time Course**

Natural stage recession rates will be reestablished following implementation of the new headwater regulation schedule, which is scheduled for 2010. Interim regulation schedules at S-65 and S-65C were implemented in June 2001 and provide for partial reestablishment of historic inflows, stage fluctuations, and stage recession rates. Evaluation of the average duration and rate of recession events will require a minimum of ten years of data. This data set should include the average annual historic stage fluctuations [~4 to 6 ft (122 to 183 cm)].

# EXPECTATION 5

# RIVER CHANNEL VELOCITIES

### Expectation

Mean velocities within the main river channel will range from 0.8 to 1.8 ft/s (0.2 to 0.6 m/s) a minimum of 85% of the year.

### Author

Joanne Chamberlain, South Florida Water Management District (*Current affiliation:* BEM Systems Inc.)

### Date

June 1, 1999; revised November 16, 2002

### Relevant Endpoints

Restoration - Physical Integrity - Hydrology
Restoration - Physical Integrity - Hydrogeomorphic Processes
Restoration - System Functional Integrity - Habitat Quality

### Metrics

Frequency of mean channel velocity

### Baseline Conditions

Baseline conditions were derived from daily discharge at site PC33 on Micco Bluff Run, a remnant river channel in Pool C. Data from this site is representative of baseline conditions (November 1997-May 1999) within remnant river channels that will be affected by the first phase of restoration.

Daily discharge at PC33 ranged from 0 to 1170 $ft^3/s$ (33 $m^3/s$), but flows greater than 100 $ft^3/s$ (2.8 $m^3/s$) occurred only 5% of the time. Mean channel velocities were calculated by dividing discharge by the cross sectional area of the river channel and ranged from 0.0 to 1.61 ft/s (0.49 m/s). However, because remnant river channels rarely conveyed discharge, mean channel velocities were less than 0.8 ft/s (0.2 m/s) 99% of the baseline period.

### Reference Conditions

Reference conditions were derived from the U. S. Geological Survey (USGS) historic stream gauging data at the Kissimmee River below Lake Kissimmee (USGS site 2269000) and at the Kissimmee River near Cornwell/Bassinger (USGS site 2272500). A total of 342 measurements were collected between 1931 and 1959 (309 below Lake Kissimmee and 33 near Cornwell/Bassinger). Of these measurements, 179 were rated fair to excellent by the USGS and were used to derive mean velocities in the main river channel, which ranged between 0.8 to 1.8 ft/s (0.2 to 0.6 m/s) during 93% of these sampling events (Figure 5-1). Main channel discharges associated with velocities between 0.8 to 1.8 ft/s (0.2 to 0.6 m/s) ranged from approximately 100 to 2100 $ft^3/s$ (3 to 59 $m^3/s$), with flows exceeding 500 $ft^3/s$ (15 $m^3/s$) during 88% of the sampling events.

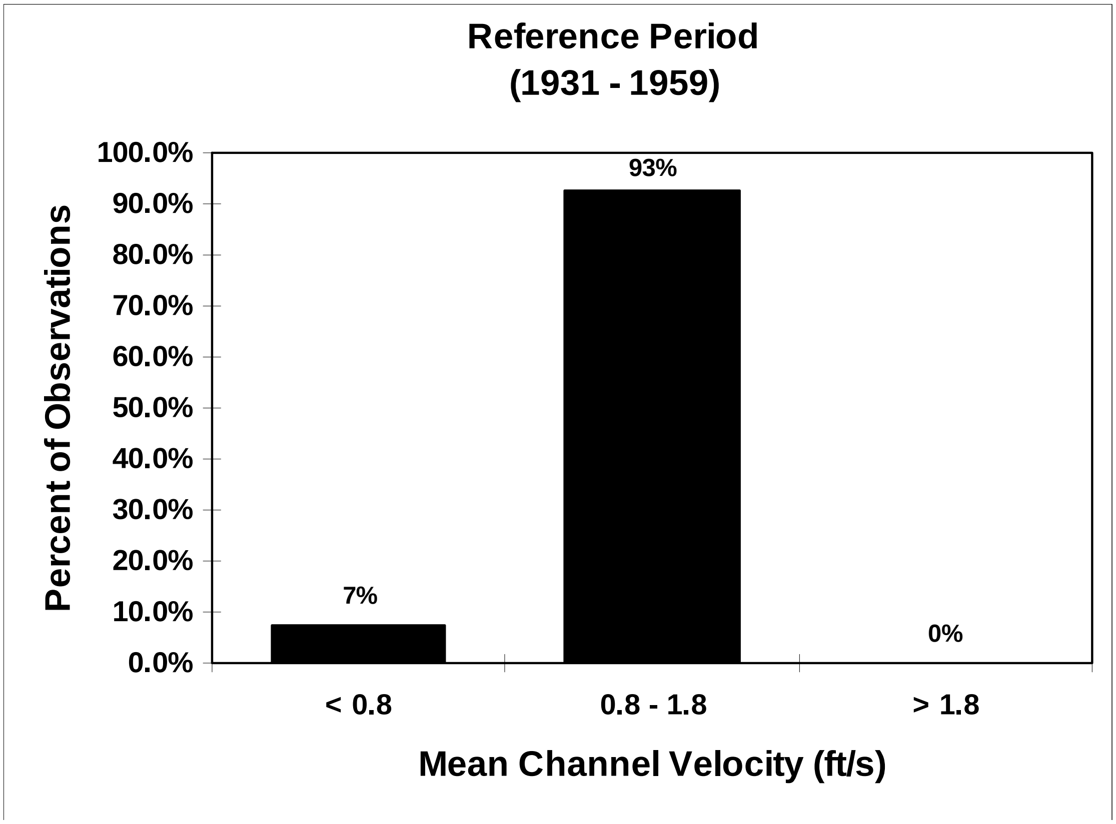


Figure 5-1. Frequency distribution of mean channel velocities near Fort Bassinger (n=24) and downstream of Lake Kissimmee (n=155). Data were collected during stream gauging events and are not from continuous monitoring.

**Adjustments for External Constraints**

None

**Mechanism for Achieving Expectation**

Backfilling C-38 and carving new river segments to connect remnants of the historic river channel will restore the physical form of the Kissimmee River, which will then convey flows.

Implementation of a new headwater regulation schedule and operation rules will provide continuous headwater inflows that reflect climatic inputs to the upper basin and a more natural, seasonally variable flow regime. Water regulation schedules and operation rules for downstream control structures (S-65C and S-65D) will be modified to maintain historic surface water gradients and associated velocities along the restored river. Downstream control of water levels is needed to ensure that unnaturally high and potentially erosive velocities do not occur within the river channel. New regulation schedules and operation rules for S-65C and S-65D will be based on estimated historic stage-discharge relationships at these locations. S-65C is the downstream control for Phase I of restoration. S-65D will serve as the downstream control for the entire restoration project and will be established at the completion of Phase II/III.

**Means of Evaluation**

The historic range and frequency of mean velocities within the main river channel will be compared to post-restoration conditions. Daily stage and discharge data will be used to calculate mean channel velocities in the restored river by dividing discharge by cross sectional area. Bathymetric surveys of channel cross sectional area will be collected at least twice a year to monitor changes to hydraulic geometry.

Post-restoration evaluations will begin at the completion of Phase I and Phase II/III construction. Mean channel velocities at PC33 will be used to evaluate post-restoration velocities for Phase I. Data from a new discharge/velocity station established within a section of river restored during Phase II/III will be compared to historic conditions after the completion of Phase II/III backfilling. A minimum of three years of data will be used for evaluation of each phase of the project and should include the historic distribution of flows. The expectation will be achieved if a minimum of 85% (annually) of mean daily velocities within the main river channel range between 0.8 and 1.8 ft/s (0.2 to 0.6 m/s) for a minimum of three years after each phase of restoration.

**Time Course**

Reestablishment of the frequency of historic mean channel velocities will occur following backfilling of C-38, recarving of new river sections, and implementation of new regulation schedules. Implementation of the new headwater regulation schedule cannot begin until all real estate interests have been acquired along Lakes Kissimmee, Hatchineha and Cypress, which is tentatively scheduled for 2010. However, interim regulation schedules at S-65 and S-65C were implemented in January 2001 and provide for partial reestablishment of historic headwater inflows.

# EXPECTATION 6

# RIVER CHANNEL BED DEPOSITS

### Expectation

In remnant river channels, mean thickness of substrate-overlying river bed deposits will decrease by $\geq$65%, percent of samples without substrate-overlying river bed deposits will increase by $\geq$165%, and the thickness of substrate-overlying river bed deposits at the thalweg will decrease by $\geq$70%.

### Author

David H. Anderson, South Florida Water Management District
Pat Davis, South Florida Water Management District
Don Frei, South Florida Water Management District (*Current affiliation*: National Marine Fisheries Service)

### Date

June 29, 1999; revised June 26, 2002

### Relevant Endpoints

Physical Integrity - River Channel Substrate Characteristics
Physical Integrity - Hydrogeomorphic Processes
System Functional Integrity - Habitat Quality
System Functional Integrity - Habitat Diversity

### Metrics

Mean thickness of substrate-overlying deposits
Percent of samples without substrate-overlying deposits
Thickness of substrate-overlying deposits at the thalweg

### Baseline Condition

Organic deposits and, to a lesser extent, marl deposits have accumulated on the natural channel bed in all remnant river channels since channelization (Toth 1991; 1993). Much of this organic matter is derived from floating aquatic plants and rooted macrophytes, which in the absence of flow have expanded their coverage in mid-channel and littoral areas, respectively. As these plants die, they are a source of organic deposition. The thickness and distribution of these deposits were quantified by taking core samples on 86 transects across remnant river channels in the Impact area (Pools B and C) and 21 transects in the Control area (Pool A) during 1997–1999 (Anderson et al. 2005). Deposits on the pre-channelization channel bed substrate were quantified for each transect with three metrics: (1) mean thickness of substrate-overlying deposits, (2) percent of samples without substrate-overlying deposits, (3) and the thickness of substrate-overlying deposits at the thalweg. Mean thickness of substrate-overlying deposits estimates the amount of deposition on a transect by averaging the thickness of substrate-overlying deposits for all cores from that transect. Percent of samples without substrate-overlying deposits is the percent of samples on a transect without such deposits above the substrate layer. Thalweg deposition thickness is the thickness of the substrate-overlying deposits at the deepest part of the channel and estimates the amount of deposition above the substrate layer in the portion of the channel cross-section that should have the least deposition because it experiences the highest water velocities and thus the greatest tractive forces. Each of these metrics was estimated for each transect, and the values were averaged across transects to obtain a mean and a standard error for transects in the Impact and Control areas. Mean ± standard error thickness of the substrate-overlying deposits was 14 ± 0.7 cm in the Impact area and 22 ± 1.9 cm in the Control area. Percent of samples without substrate-overlying deposits was 3 ± 0.65% in the Impact area and 1 ± 0.4% in the Control. The thickness of substrate-overlying deposits at the thalweg averaged 21 ± 2.2 cm in the Impact area and 38 ± 5.1 cm in the Control area.

### Reference Condition

Prior to channelization, the river bed substrate was composed primarily of deposits of fine and medium-grained sands intermixed with shells, silt, and clay that were laid down during the late Miocene/Pleistocene epochs (Warne et al. 2000). In baseline core samples from Control and Impact areas, the substrate beneath the accumulated organic/marls deposits was primarily sand (Anderson et al. 2005).

Because pre-channelization data were not available, data collected during the Kissimmee River Demonstration Project (1985–1988) (Toth 1991; 1993) were used as the reference condition for expected changes in substrate-overlying deposits. During the Demonstration Project, weirs were used to divert up to 60% of the flow through the C-38 canal to each of three remnant river channels (R1, R2, and R3) in Pool B (Toth 1993). Between April 1985 and December 1988, each remnant channel had flow ≥26 $m^3/s$, which approaches bankfull discharge, for 233–307 days (Toth 1991). River channel sediments were characterized by collecting core samples using similar methods to those used for the baseline study on 24 transects across these remnant river channels. Transects were sampled one time before reestablishing flow, and up to six times after flow was reestablished, which allowed the tracking of changes in the three metrics used for the baseline study. Mean thickness of the substrate-overlying deposits declined from 15 cm to 5 cm, a 67% reduction (Figure 6-1). Percent of samples without substrate-overlying deposits increased from an average of 21% to 56%, an increase of 167%. The thickness of substrate-overlying deposits at the thalweg decreased by 70% from an average of 30 cm to 9 cm. These reference values are likely to be conservative estimates of the condition of the river bed substrate before channelization because these metrics continued to change (Figure 6-1) and because the magnitude and duration of flow was less than what was observed prior to channelization. Achieving these values within three years of reestablishing flow indicates the reestablishment of processes that determine river bed substrate characteristics. These processes will likely continue until the channel adjusts to the restored flow conditions.

### Mechanism for Achieving Expectation

Backfilling of the C-38 canal and carving new river channels to connect the remnant channels should restore flow to the river channel. Reestablishing the pre-channelization flow regime to reconnected river channels should flush the accumulated layer of organic and marl deposits or bury it beneath sand that is transported by flow. Maintaining continuous flow will reduce the loading of organic matter deposited on the channel substrate by reducing the mid-channel cover of floating aquatic vegetation, and restricting rooted macrophytes, such as *Nuphar lutea* and *Polygonum densiflorum*, to the channel littoral zone. Reducing the area of rooted macrophytes bed should also reduce the capability of the river channel to retain organic matter, because the roots of these plants can help trap organic particles.

### Adjustments for External Constraints

None

### Means of Evaluation

Post-construction core sampling will be conducted at the same permanent transects in the Impact and Control areas established for the baseline study. Interim evaluation of the three metrics will be conducted annually by sampling 24 randomly selected transects from the Impact area during the dry season. When all expectation metrics have been achieved for the interim transects, all transects in the Control and Impact areas will be sampled during the following dry season. The expectation will be evaluated by comparing the observed values to those stated in the expectation. The expectation will be considered achieved if mean thickness of the substrate-overlying deposits decreases by $\geq$65%, if the percent of samples without substrate-overlying deposits increases by $\geq$165%, and if the thickness of substrate-overlying deposits at the thalweg decreases by $\geq$70%.

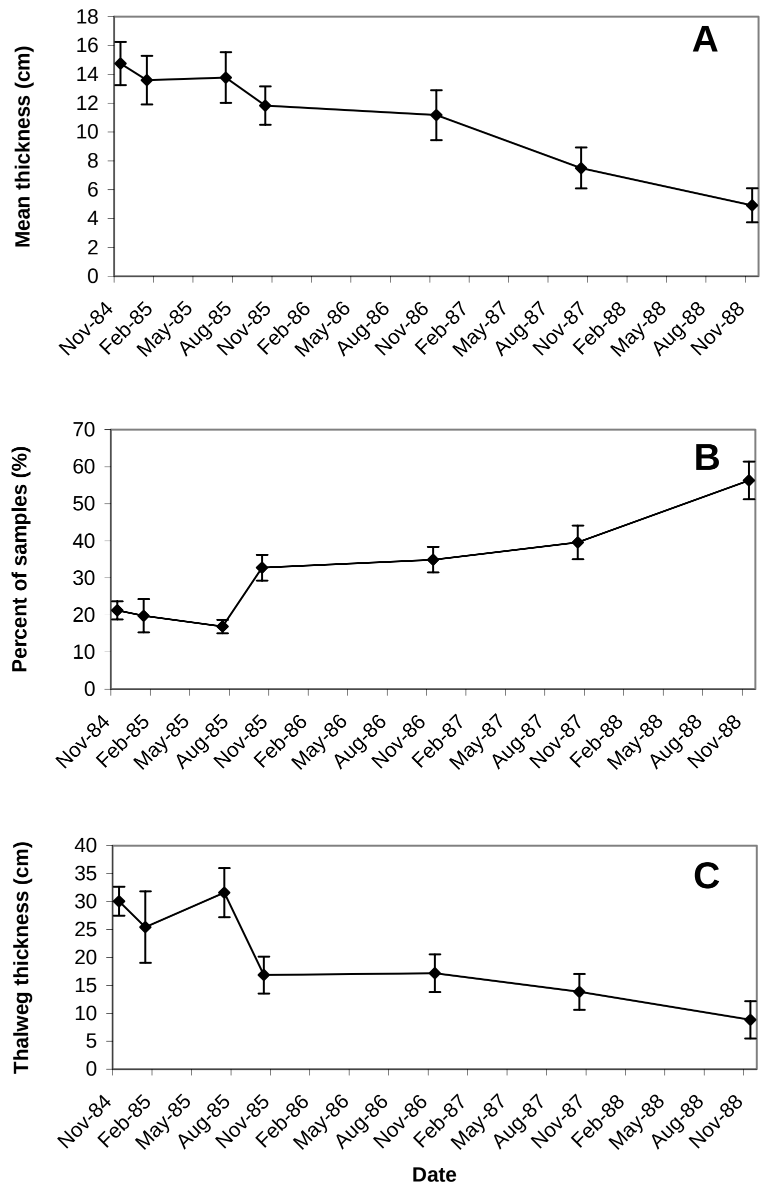


Figure 6-1. Mean values ($\pm$ standard error) for (A) mean thickness of substrate-overlying deposits, (B) percent of samples without substrate-overlying deposits, and (C) the thickness of substrate-overlying deposits at the thalweg during the Kissimmee River Demonstration Project. The first sample date is prior to the weirs being installed and combines data from November 1984 for R3, March 1985 for R2, and July 1985 for R1.

### Time Course

Based on results of the Pool B Demonstration Project, flushing of the depositional layer overlying the substrate, and changes in the river bed should occur within three years of reestablishing the pre-channelization flow regime.

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# EXPECTATION 7

## SAND DEPOSITION AND POINT BAR FORMATION INSIDE RIVER CHANNEL BENDS

### Expectation

Point bars will form on the inside bends of river channel meanders with an arc angle >70°.

### Author

Don Frei, South Florida Water Management District (*Current affiliation*: National Marine Fisheries Service)
Pat Davis, South Florida Water Management District
David H. Anderson, South Florida Water Management District

### Date

June 29, 1999; revised April 3, 2001

### Relevant Endpoints

Ecological Integrity/Restoration/Physical Integrity - River Channel Substrate Characteristics
Ecological Integrity/Restoration/Physical Integrity - Hydrogeomorphic Processes
Ecological Integrity/Restoration /System Functional Integrity - Habitat Quality
Ecological Integrity/Restoration /System Functional Integrity - Habitat Diversity

### Metrics

Number of meanders with point bars

### Baseline Conditions

Aerial photographs taken since channelization indicate that active point bars (i.e., sand deposition found on the inside bend of meanders) are not visible in remnant river channels (Anderson et al. 2005). Point bars that were present in the pre-channelized system have been colonized by vegetation, and elimination of flow has precluded development of new bars. Cross sectional profiles show a remnant sloping riverbed along inner portions of meanders remains, but submerged portions of these relic point bars are covered with organic deposits or aquatic vegetation.

### Reference Conditions

Point bars were likely an important habitat feature in the historic Kissimmee River. Point bars provided topographic diversity and a range of flow velocities useful to many species (Bain et al. 1988, Lobb and Orth 1991, Sheldon and Meffe 1995), and likely provided spawning habitat for pit nesters (e.g., centrarchids) (L. Glenn, personal communication), refuge and foraging habitat for small fish, and habitat for shore birds and foraging wading birds. Point bars are typical of rivers with sinuous, low-gradient, meandering channels, sandy substrates, and well-developed floodplains in broad drainage basins (Leopold 1994, Rosgen 1994, 1996).

We quantified the occurrence of point bars using historical aerial photographs during extreme low water levels (38.64 NGVD at Fort Kissimmee) in June 1956. Point bars occurred on the inside of 329 of 330 river meanders with an arc angle >70°. We used an arc angle of 70° (Rosgen 1996) to distinguish meander bends from minor curvature of the channel. Largest point bars occurred on curves downstream of long, straight river runs.

Point bars formed on inside curves of meanders after flow was partially restored to remnant river channels in Pool B (Toth 1993). After the Test Fill Plug was constructed in 1994 (Koebel et al. 1999), point bars in the adjacent remnant river channel increased in area and height, particularly after high flows in winter 1998.

### Mechanism for Achieving Expectation

Point bar formation is a result of sediment transport and deposition and has a well-documented relationship to river suspended sediment size and flow velocities (Knighton 1998). Restoration of point bars will be dependent on the discharge volume and duration of flow. Reestablishment of historical flow regimes (e.g., bankfull discharge of 40–50 $m^3/s$) is expected to reestablish active point bar formation on inside curves of meanders in remnant river channels.

### Adjustments for External Constraints

None

### Means of Evaluation

Point bar formation will be monitored annually for five years after reestablishment of flow through the river channel. The formation or reappearance of point bars will be tracked and georeferenced with GPS along 80 meanders with an arc angle >70º within Pool C and lower Pool B. This area will be affected by restored flow from the first phase of the restoration project.

### Time Course

Based on sediment transport and deposition in Pool B during the Kissimmee River Demonstration Project of 1985–1988 and after the Test Fill Plug construction in 1994, point bar formation will occur following bankfull discharge events. Reestablishment of pre-channelization point bar distribution will occur within three to five years, depending on the magnitude and duration of bankfull discharge.

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# EXPECTATION 8

# DISSOLVED OXYGEN CONCENTRATIONS IN THE RIVER CHANNEL

## Expectation

Mean daytime concentration of dissolved oxygen in the Kissimmee River channel at 0.5–1.0 m depth will increase from <1–2 mg/L to 3–6 mg/L during the wet season (June–November) and from 2–4 mg/L to 5–7 mg/L during the dry season (December–May). Mean daily concentrations will be greater than 2 mg/L more than 90% of the time. Dissolved oxygen concentrations within 1 m of the channel bottom will exceed 1 mg/L more than 50% of the time.

## Author

David J. Colangelo , South Florida Water Management District
Brad Jones, South Florida Water Management District

## Date

June 10, 1999; revised March 4, 2002

## Relevant Endpoints

Restoration - Chemical Integrity - Surface Water Quality
Restoration - Chemical Integrity - Dissolved Oxygen Dynamics
Restoration - System Functional Integrity - Habitat Quality

## Metrics

Mean wet season daytime concentration of dissolved oxygen at 0.5 m
Mean dry season daytime concentration of dissolved oxygen at 0.5 m
Annual percentage of samples with dissolved oxygen concentrations >2 mg/L
Percent of time with dissolved oxygen concentrations near the bottom >1 mg/L

## Baseline Condition

Concentrations of dissolved oxygen (DO) in stagnant river runs are frequently below 1 mg/L, even near the water surface at midday. During 1996 through 1999, mean concentrations (0.5 m depth) in monthly sampling in seven river runs in Pools A and C (Table 8-1) ranged from 0.7 to 1.9 mg/L during the wet season and from 2.5 to 3.8 mg/L during the dry season (Figure 8-1). Dissolved oxygen exceeded 2 mg/L in <60% of the measurements and exceeded 5 mg/L in <20% of the measurements (Figure 8-2). At two stations (Oxbow 13 and Montsdeoca Run) with continuous (one reading every 15 minutes at 1.0 m) monitoring, DO concentrations exceeded 2 mg/L for 22% of the baseline period of record (July 1997–June 1999) and exceeded 5 mg/L for 6% of this period (Figure 8-3).

Depth profile data from May–June 1999 in Pool C (D. Colangelo, unpublished data), and from earlier years in Pool B, show DO values typically ranging from 2–3 mg/L at the water surface, and declining to <1 mg/L below a 1.0 m depth during summer months (Rutter et al. 1986, Toth 1991).

Table 8-1. Dissolved oxygen concentrations in the channelized Kissimmee River and other Florida streams (reference sites).

| Water Body | SFWMD Reference ID | County | Period of Record (month/yr) | Frequency[1] | # Samples |
|---|---|---|---|---|---|
| Reference Sites | | | | | |
| Fisheating Creek | FECSR78 | Glades | 4/73–2/99 | W-M | 447 |
| Arbuckle Creek | ARBKSR98 | Highlands | 2/88–2/99 | BiM | 86 |
| Lake Marian Creek | DLMARNCR | Polk | 4/82–9/85 | M | 37 |
| Tiger Creek | ETIGERCR | Polk | 4/82–6/85 | M | 33 |
| Josephine Creek | JOSNCR17 | Highlands | 2/88–2/99 | M-BiM | 85 |
| Boggy Creek | ABOGG | Osceola | 8/81–3/99 | M | 202 |
| Catfish Creek | ROSALIEC | Polk | 11/84–9/85 | M | 11 |
| Kissimmee River | | | | | |
| Ice Cream Slough Run (Pool A) | KREA 97 | Polk | 11/96–3/99 | M | 27 |
| Rattlesnake Hammock Run (Pool A) | KREA 91 | Polk | 3/96–3/99 | M | 29 |
| Schoolhouse Run (Pool A) | KREA 92 | Polk | 3/96–3/99 | M | 31 |
| Montsdeoca Run (Pool C) | KREA 98 | Highlands | 3/96–3/99 | M | 14 |
| Oxbow 13 (Pool C) | KREA 93 | Highlands | 3/96–3/99 | M | 29 |
| Micco Bluff Run (Pool C) | KREA 94 | Okeechobee | 3/96–3/99 | M | 28 |
| MacArthur Run (Pool C) | KREA 95 | Highlands | 12/97–3/99 | M | 31 |

[1]W = Weekly; M = Monthly; BiM = Bi-Monthly

**Reference Condition**

No DO data were collected before channelization, so the reference condition has been derived from data on seven free-flowing, blackwater, south Florida streams. Multiple metrics were used to describe DO regimes. Mean DO concentrations change seasonally due to differences in water temperature and community metabolism. Anoxic benthic conditions can severely limit available habitat for aerobic organisms, and DO concentrations less than 2 mg/L are considered uninhabitable by many aquatic species. Each stream had at least 11 samples collected over a minimum of one year, and some streams were sampled for more than ten years (Table 8-1). Measurements were taken with a DO probe at 0.5 m depth, at intervals ranging from weekly to bimonthly. Mean DO concentrations ranged from 2.4 to 6.0 mg/L during the wet season and from 3.7 to 7.4 mg/L during the dry season (Figure 8-1). In five of the seven streams, DO was >5 mg/L in more than 50% of the samples. More than 90% of the samples had concentrations greater than 2 mg/L in all streams. All streams had DO concentrations >1 mg/L over 90% of the time (Figure 8-2). Although no water column profile data have been examined for these streams (and in most cases do not exist), it is assumed that oxygen values near the bottom are usually higher when streamflow is present. This was observed during the Pool B Kissimmee River Demonstration Project when weirs across C-38 diverted flow to adjacent remnant river runs. Although oxygen concentrations remained low, more uniform DO profiles were observed during the summer (Rutter et al. 1989).

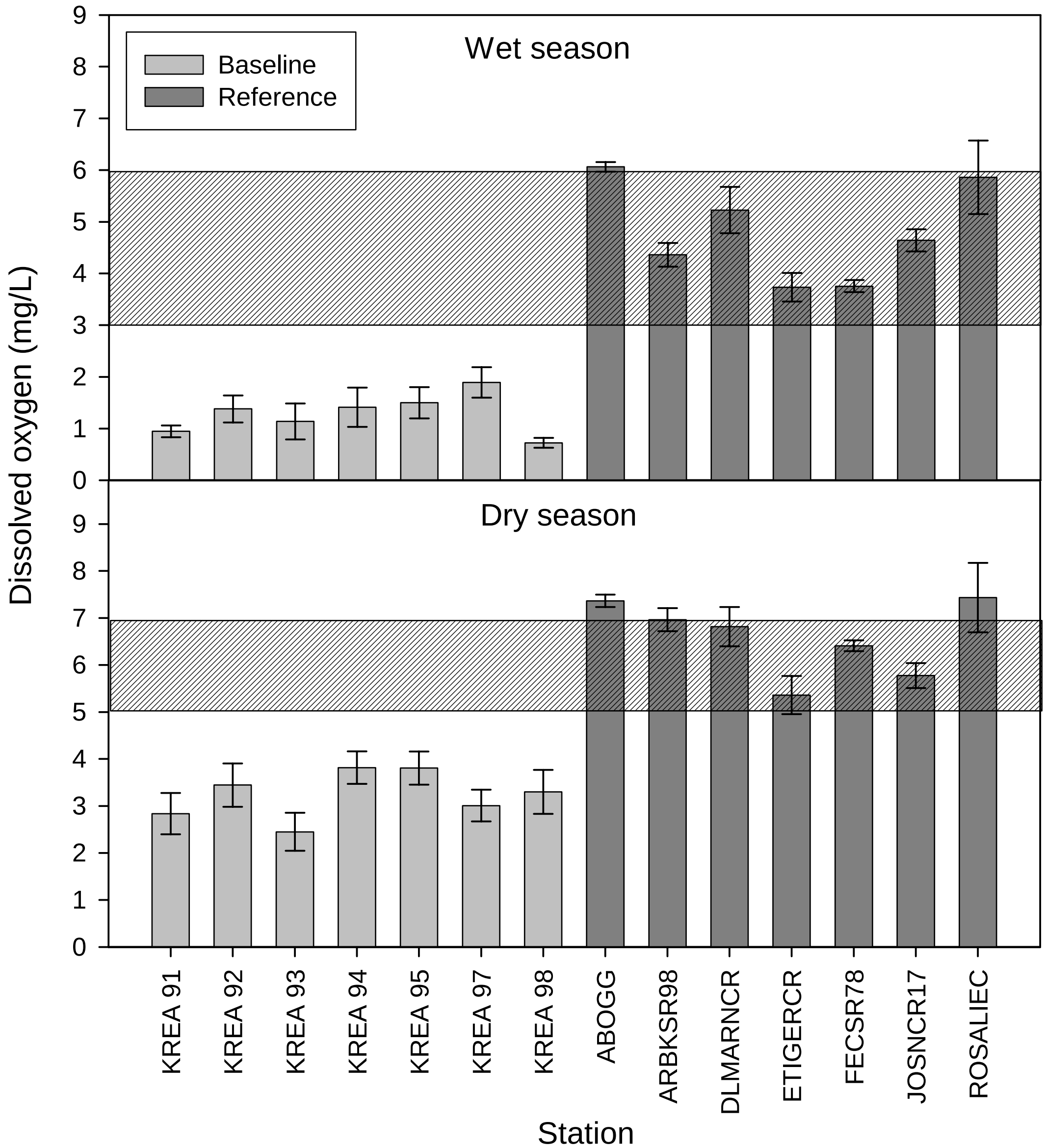


Figure 8-1. Mean (± standard error of the mean) dissolved oxygen (DO) concentrations in free-flowing, blackwater, south Florida streams and remnant runs of the channelized Kissimmee River during the wet (June–November) and dry (December–May) season. Cross-hatched area represents expected range of DO concentrations in the Kissimmee River after restoration.

These reference streams may not completely represent conditions that existed in the pre-channelized river. Artificial drainage, nonpoint-source runoff and point source effluent may increase oxygen demand in these streams and other factors such as headwater characteristics, flow velocities, and water depth may differ from the pre-channelized Kissimmee River. However, due to similarities in flow, watershed characteristics, and water quality, these streams exemplify oxygen regimes in the former river.

Using these streams as a reference, the mean concentration of DO in the Kissimmee River (center of channel, near water surface, at midday) was estimated to be between 3–6 mg/L during the wet season and between 5–7 mg/L during the dry season.

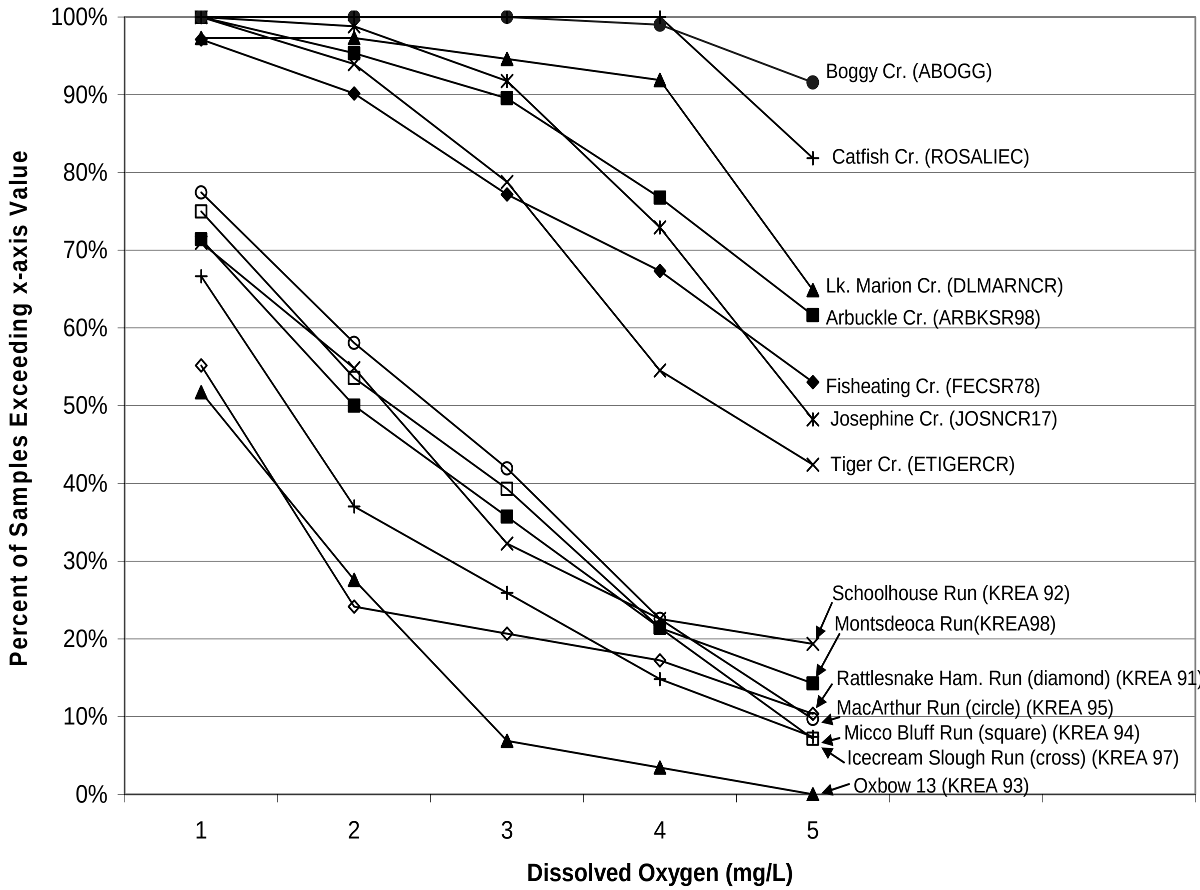


Figure 8-2. Dissolved Oxygen concentrations at 0.5 m depth in south Florida reference streams and remnant runs of the channelized Kissimmee River.

### Adjustments for External Constraints

Dissolved oxygen concentrations in the upper reach of the restored segment will continue to reflect oxygen-depleted inputs from C-38.

### Mechanism for Achieving Expectation

Restoration of continuous, variable flow through the historic river channel is expected to flush flocculent organic matter, and increase DO concentrations by reducing biochemical and sediment oxygen demand and by increasing atmospheric aeration. Continuous channel flow should inhibit encroachment by aquatic macrophytes, so the need for herbicide treatments should be reduced, Continuous flow should limit accumulation of organic matter. Higher water levels and more natural hydropatterns will lead to less input of oxygen-depleted groundwater.

**Means of Evaluation**

Monthly data collection will continue at the seven remnant run stations that were sampled during the baseline period (Table 8-1) (see Time Course section below). This data will be used to evaluate changes in mean daytime wet and dry season DO concentrations. Mean DO values are useful measures of changes in the DO regime because mean values limit the influence of short-term extremes. Aquatic biota inhabiting south Florida streams are tolerant of short-term (10–24 hours) low DO conditions. Other monitoring stations in the canal and remnant runs, including up to eight stations with 24-hour (96 samples/day) automated monitoring, will be used to evaluate if mean daily DO concentrations exceed 2 mg/L 90% of the time. At some of these stations, weekly water quality profiles are collected throughout the water column. Data from these stations will be used to evaluate changes in DO gradient. Pre- and post-restoration data will be compared, and post-restoration data will be compared to the reference data and data from Pool A. Increased DO within the Pool C runs will be evaluated by statistical tests, frequency analysis (e.g., Figure 8-2), and time series analysis.

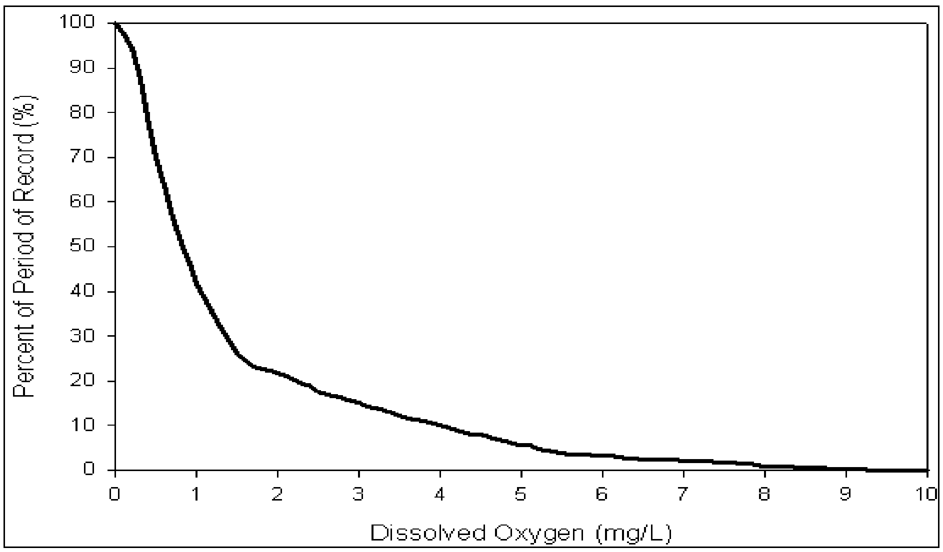


Figure 8-3. Percent of period of record (July 1997–June 1999) that Dissolved oxygen (DO) within remnant river channels exceeded x-axis values. Data are based on mean (average of 96 values per day) daily DO concentrations at two remnant river run stations in Pool C (Oxbow 13 and Montsdeoca Run). Dissolved Oxygen readings were taken at a depth of 1.0 m at each station.

To evaluate how DO responds to diversion of flows to the remnant runs, four other sample stations were established during April 1999 in remnant river runs near the canal C-38 backfilling. At each of these stations, DO profiles are sampled weekly with a water quality probe. Monitoring stations will be moved or added as the construction activity moves upstream. This sampling network will include three automated stations for 24-hour monitoring in the river runs. Automated stations can monitor DO during the lowest portion of the diel cycle and during periods of severe hypoxia, while daytime monitoring will gather measurements from a wider network of stations and allow comparisons with data from reference streams. All sampling will continue for three to five years after construction is complete to ensure that changes in DO regimes are not transitory.

**Time Course**

All metrics for DO concentrations in the river channel are expected to be met within two years after all phases of construction are complete and continuous flow is restored to the river channel. An interim water level operation plan was implemented in January 2001 and will at least partially reestablish hydrological characteristics required for restoration. Daytime concentrations of DO will begin to improve when construction has recreated enough of the historic river channel to allow continuous flow, reaeration, and restored channel characteristics to significantly affect the oxygen balance. Because little improvement in DO was observed during the Pool B Demonstration Project (Rutter et al. 1989), it is likely that flow must be restored to more than one remnant river segment to significantly affect DO concentrations in the restored reach of the river. Therefore, improvement in the diel oxygen cycle may not be observed until backfilling extends upstream of Micco Bluff Run, and flow is restored to the reconnected Micco Bluff and MacArthur Runs. Improvement in DO conditions will be most evident during the wet season because wet season baseline DO concentrations are very low.

During backfilling, DO may be affected by mobilization of organic sediments and decayed vegetation in the channel and floodplain. However, these events should not have a persistent ecological impact.

**Literature Cited**

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# EXPECTATION 9

# TURBIDITY AND SUSPENDED SOLIDS CONCENTRATIONS IN THE RIVER CHANNEL

### Expectation

Mean turbidity in the restored river channel will not differ significantly from mean turbidity in similar south Florida streams (3.9 NTU), and the median total suspended solids concentration will not exceed 3 mg/L.

### Author

Brad Jones, South Florida Water Management District

### Date

June 8, 1999; revised June 18, 2003

### Relevant Endpoints

Impact Assessment - Water Quality

### Metrics

Mean turbidity
Median total suspended solids

### Baseline Condition

Turbidity and total suspended solids (TSS) were very low in all remnant river runs sampled during 1996–1999 (Table 9-1). Mean turbidity ranged from 1.3 to 3.5 NTU. Total suspended solids concentrations were ≤ 25 mg/L, and were usually lower than the detection limit (i.e., <3 mg/L). Slightly higher turbidity values were measured in summer, and appear to reflect greater densities of phytoplankton, as indicated by chlorophyll *a* concentrations (Figures 9-1 and 9-2).

### Reference Condition

No turbidity or TSS data were collected before the river was channelized, so the reference condition was derived from general knowledge of pre-channelized conditions and data on other south Florida streams. Turbidity in the former river is assumed to have been very low due to: (1) the river's location in a watershed with nearly flat topography, sandy soils, and low-intensity land use; (2) headwater inflow from Lake Kissimmee; (3) low channel velocities; and (4) filtering effects of marsh and littoral vegetation. Turbidity caused by eroded particles from the watershed should have been negligible, and any turbidity present would have been due to plankton, suspended detritus, or sediment erosion during extreme flows. In a flowing blackwater river surrounded by dense vegetation, phytoplankton blooms would have been rare, so turbidity and TSS would have remained low. Average values probably did not differ significantly from baseline values (turbidity <5 NTU and TSS <3 mg/L), but maximum values may have been less.

Historical descriptions and data appear to support these assumptions about low turbidity and suspended solids. In addition to headwater flow from Lake Kissimmee, which supplied 58% of total river discharge (Bogart and Ferguson 1955), river flow was maintained by groundwater seepage from aquifers underlying upland areas (Parker 1955). Daily monitoring of Kissimmee River water quality from the SR 70 bridge west of Okeechobee showed little annual variation in concentrations of dissolved constituents (Love 1955), indicating no or limited impact from surface runoff, although flow during this period (1940–1941) was only moderate (~1000–3000 cfs). Floods were characterized by slow changes in stage, low flow velocities, and long periods of recession. Floodwaters were relatively clear and little silt was left after floods passed (Bogart and Ferguson 1955). This suggests that suspended material associated with surface runoff did not have a significant influence on water quality in the pre-channelized river.

Due to the lack of reference data from the pre-channelized river, eight free-flowing, blackwater streams (Table 9-2) in south Florida were selected as reference sites. These streams and their watersheds share some features of the former Kissimmee River (e.g., low topographic relief, sandy substrate, presence of swamps or marshes, low velocity), although other characteristics may differ (e.g., watershed size, discharge, watershed development and artificial drainage). Turbidity and TSS values (Table 9-3) in these streams are low (mean turbidity = 2.0–6.5 NTU), and are probably typical of the former Kissimmee River. Values have ranged up to two orders of magnitude higher in these streams, but such events are rare and were sometimes caused by surface runoff and local disturbances. The pre-channelized Kissimmee River probably did not exhibit these extremes due to the characteristics of the river and its watershed.

Table 9-1. Turbidity and total suspended solids (TSS) in remnant river runs of Pools A and C (March 19, 1996 to June 8, 1999).

| | Turbidity (NTU) | | | | TSS (mg/L)[1] | | |
|---|---|---|---|---|---|---|---|
| Water Body and SFWMD Station ID | N | Median | Mean ± Std. Error | Max. | N | Median | Max. |
| Ice Cream Slough Run--Pool A (KREA 97)[2] | 31 | 2.5 | 2.5 ± 0.2 | 6.5 | 31 | <3.0 | 11.0 |
| Rattlesnake Ham. Run--Pool A (KREA 91) | 31 | 2.2 | 2.3 ± 0.2 | 4.5 | 31 | <3.0 | 7.0 |
| Schoolhouse Run--Pool A (KREA 92) | 35 | 2.4 | 3.5 ± 0.5 | 17.3 | 35 | <3.0 | 25.0 |
| Montsdeoca Run--Pool C (KREA 98)[3] | 17 | 1.2 | 1.3 ± 0.2 | 3.6 | 18 | <3.0 | 3.0 |
| Oxbow 13--Pool C (KREA 93) | 32 | 1.9 | 2.1 ± 0.1 | 3.7 | 33 | <3.0 | 13.0 |
| Micco Bluff Run--Pool C (KREA 94) | 31 | 1.6 | 1.9 ± 0.2 | 5.5 | 32 | <3.0 | 18.0 |
| MacArthur Run--Pool C (KREA 95) | 34 | 1.6 | 1.8 ± 0.2 | 6.3 | 35 | <3.0 | 5.0 |

1 - Most total suspended solids values were below detection limit (usually <3.0 mg/L). Consequently, means and standard errors for TSS are not shown.

2 - Ice Cream Slough Run data begins in November 1996.

3 - Montsdeoca Run data begins in December 1997.

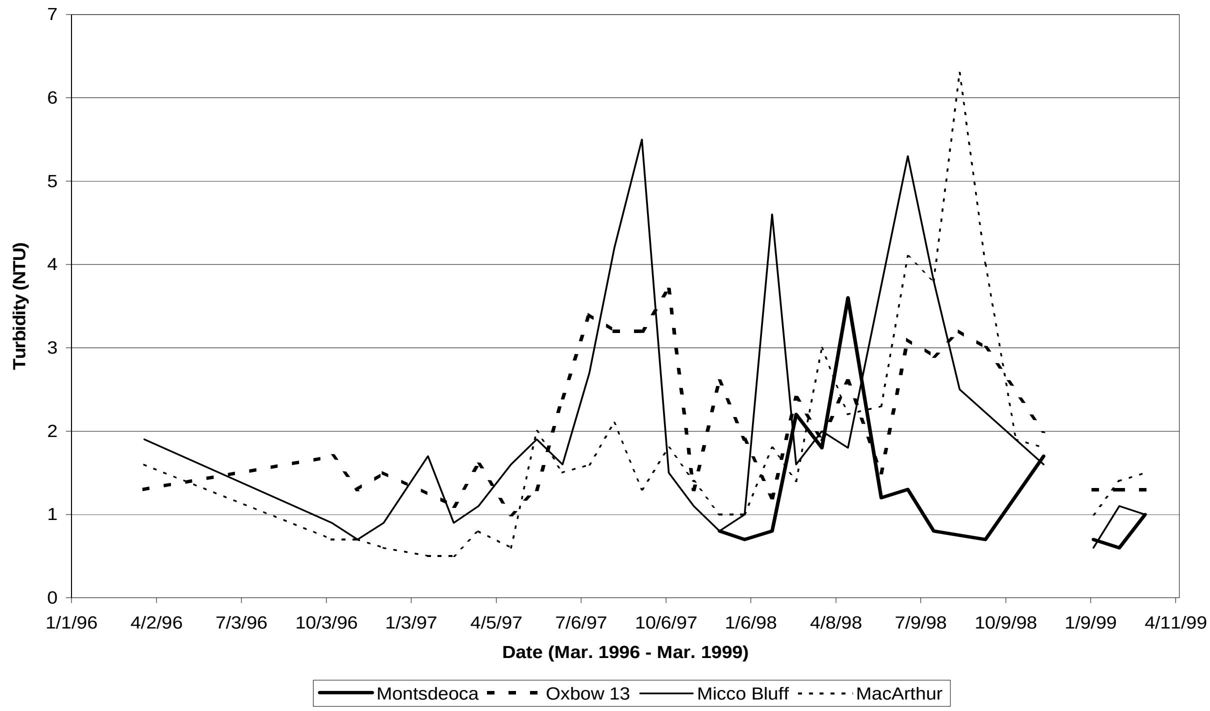


Figure 9-1. Turbidity in remnant river runs of Pool C.

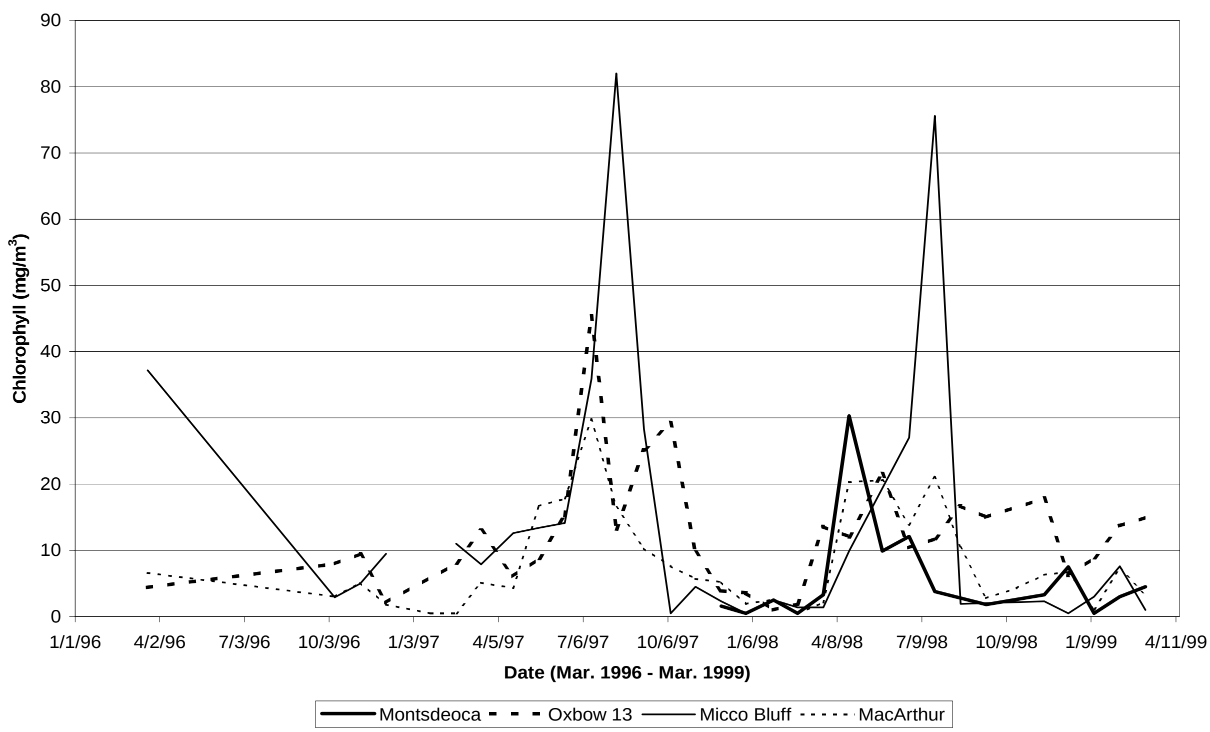


Figure 9-2. Chlorophyll *a* in remnant river runs of Pool C.

Table 9-2. South Florida Water Management District data sets for Florida streams used as reference sites for turbidity and total suspended solids.

| Water Body | SFWMD Station ID | County | Period of Record (month/year) | Frequency |
|---|---|---|---|---|
| Fisheating Creek | FECSR78 | Glades | 4/73–2/99 | Weekly - Monthly |
| Arbuckle Creek | ARBKSR98 | Highlands | 2/88–2/99 | Bi-Monthly |
| Lake Marian Creek | DLMARNCR | Polk | 4/82–9/85 | Monthly |
| Reedy Creek | CREEDYBR | Osceola | 4/85–3/99 | Monthly |
| Tiger Creek | ETIGERCR | Polk | 4/82–6/85 | Monthly |
| Josephine Creek | JOSNCR17 | Highlands | 2/88–2/99 | Monthly - Bi-Monthly |
| Boggy Creek | ABOGG | Osceola | 8/81–3/99 | Monthly |
| Catfish Cr.-S. Branch | ROSALIEC | Polk | 11/84–9/85 | Monthly |

Table 9-3. Turbidity and total suspended solids (TSS) data for Florida stream reference sites.

| | Turbidity (NTU) | | | | TSS (mg/L)[1] | | |
|---|---|---|---|---|---|---|---|
| Water Body | N | Median | Mean ± Std. Error | Max. | N | Median | Max. |
| Fisheating Creek | 393 | 1.6 | 3.8 ± 0.9 | 290.0 | 365 | <3.0 | 986.7 |
| Arbuckle Creek | 85 | 2.9 | 3.4 ± 0.2 | 14.4 | 39 | <3.0 | 24.0 |
| Lake Marian Creek | 37 | 2.0 | 4.5 ± 1.9 | 70.0 | 13 | 4.0 | 15.0 |
| Reedy Creek | 150 | 1.3 | 2.0 ± 0.2 | 18.9 | 99 | <3.0 | 58.0 |
| Tiger Creek | 33 | 3.9 | 3.9 ± 0.3 | 8.7 | 12 | 3.0 | 8.0 |
| Josephine Creek | 85 | 2.2 | 2.4 ± 0.2 | 10.5 | 39 | <3.0 | 14.0 |
| Boggy Creek | 204 | 2.0 | 6.5 ± 2.8 | 570.0 | 116 | <3.0 | 416.0 |
| Catfish Cr.-S. Branch | 11 | 3.8 | 4.8 ± 0.8 | 11.1 | 4 | 4.5 | 11.0 |

1 - Most TSS values were below detection limit (usually <3.0 mg/L). Consequently, means and standard errors for TSS are not shown.

**Adjustments for External Constraints**

Future turbidity levels in the northern portion of the restored river channel might be influenced by water flowing from C-38. If algal blooms form in Lake Kissimmee or Pool A, turbidity will increase in at least the upper portion of the restored river. Disturbances related to construction, maintenance, or land use changes in tributary watersheds also might affect turbidity and suspended solids concentrations.

**Mechanism for Achieving Expectation**

After initial flows have flushed accumulated organic deposits from the river channel, turbidity and TSS values will return to reference levels. Flow velocities in the restored river will not be great enough to cause elevated turbidity and TSS. Possible inputs of suspended solids from channelized tributary flows will be alleviated by backfilling of these floodplain drainage ditches. Continuous flow through the historic river channel will prevent dense phytoplankton blooms that are the main cause of higher turbidity in the channelized system.

**Means of Evaluation**

Turbidity and TSS are monitored every two to four weeks in river runs of Pools A and C and at C-38 structures. In addition, turbidity probes mounted on floating platforms have been placed in Micco Bluff and MacArthur Runs to log turbidity data at 15 minute intervals. A t-test will determine if the restored river channel has mean turbidity similar to reference streams. The Wilcoxon rank test will be used to test similarity of TSS concentrations. Monitoring will continue for at least two years after Phase I construction is completed and flushing of the river bed has stabilized. Post-restoration data will be compared to the reference condition annually.

**Time Course**

Pool C river runs may be affected by mobilization of accumulated vegetation and organic deposits as discharge is diverted to these channels. Turbidity and TSS are expected to return to reference levels after one full year of moderate flow (20 to 40 $m^3$ per second) through the restored river channel.

**Literature Cited**

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Love, S. K. 1955. Quality of ground and surface water. Pages 727-833 in G. G. Parker, G. E. Ferguson, and S. K. Love. Water resources of southeastern Florida. Supply Paper 1255. U. S. Geological Survey, Tallahassee, Florida, USA.

Parker, G. G. 1955. Geomorphology. Pages 127-155 in G. G. Parker, G. E. Ferguson, and S. K. Love. Water resources of southeastern Florida. Supply Paper 1255. U. S. Geological Survey, Tallahassee, Florida, USA.

# EXPECTATION 10

## WIDTH OF LITTORAL VEGETATION BEDS RELATIVE TO CHANNEL PATTERN

### Expectation

Littoral vegetation beds will persist in restored river channels, but their mean widths will decrease to:
(1) Five meters or less from the bank on inner channel bends.
(2) Four meters or less from the bank on straight channel reaches.

### Author

Stephen G. Bousquin, South Florida Water Management District
Caroline Hovey, South Florida Water Management District (*Current affiliation*: Hovey Environmental)

### Date

May 10, 1999 (Hovey); revised March 2002 (Bousquin); revised December 2004 (Bousquin)

### Relevant Endpoints

Sociopolitical - Navigation
Sociopolitical - Aesthetic Values
Restoration - System Functional Integrity - Habitat Diversity
Restoration - System Functional Integrity - Habitat Quality

### Metrics

Mean width of littoral vegetation beds on inner channel bends
Mean width of littoral vegetation beds on straight channel reaches

### Baseline Conditions

Baseline sampling was conducted twice annually from 1998 to 1999 during the winter dry season (usually February–March) and the summer wet season (August–September). Sampling was conducted at fixed transects distributed in non-flowing (remnant) channels of Pools A (Control area), and B and C (Impact area) at permanent transects marked on opposite banks with galvanized steel poles. Transects are located both at channel bends and straight reaches in order to capture variation associated with channel pattern. One-meter wide belt transects were established during sampling by sighting between the poles and placing 1 m by 2 m quadrats on the upstream side of the sightline, with the long dimension of the quadrat on the transect. Baseline surveys were initiated at the left bank facing downstream and were continued across the channel by adding consecutive quadrats. Vegetation bed widths were estimated (to the nearest 1 m) along the transects from the bank to the waterward edge of the bed by counting quadrats that contained >5% cover. Beds were measured on both sides of the channel at each transect. For calculations, each transect was subdivided into two transect sections, one for the vegetation bed on either side of the channel. Widths and vegetated percentage of channel were averaged over all sampled transect sections in each pattern category for each of the four sample periods. An average of 130 transect sections were measured per sample period in the Impact area; 42 transect sections were measured per sample period in the Control area.

Grand means for the baseline period are the averages of the four baseline sample period means for each pattern category (*n*=4). Reference-baseline comparisons presented below use Impact area data to represent baseline conditions. Data from the Control area will be used in future restoration evaluation to assess the effects of background variation in measured variables using a before-after-control-impact (BACI) approach (e.g., Stuart-Oaten et al. 1992). For more details on this project, see Bousquin 2005.

During the baseline period, mean vegetated percentage of river channels was 56.7% ± 5.0%. Inner bend widths averaged 12.4 m ± 0.7 m, outer bends 6.0 m ± 1.0 m, and straight sections 9.3 m ± 0.6 m (Table 10-1).

Table 10-1. Mean widths and vegetated percentage of channel in the baseline (channelized) Control and Impact area and reference (restored flow) data, 1998–1999. Impact area data were used to represent baseline conditions for comparisons with the reference data; Control area data will be used in future before-after-control-impact comparisons. Tests conducted with two-way ANOVA. Asterisk denotes nonsignificant test results.

| Metric | Category | Area | Mean | Standard error | *n* | *P* |
|---|---|---|---|---|---|---|
| Width | Inner | Control | 12.5 | 0.6 | 4 | N/A |
| | | Impact | 12.4 | 0.7 | 4 | < 0.001 |
| | | Reference | 5.0 | 0.4 | 12 | |
| | Outer | Control | 7.9 | 0.7 | 4 | N/A |
| | | Impact | 6.0 | 1.0 | 4 | 0.081* |
| | | Reference | 3.8 | 0.5 | 20 | |
| | Straight | Control | 13.8 | 0.4 | 4 | N/A |
| | | Impact | 9.3 | 0.6 | 4 | < 0.001 |
| | | Reference | 3.6 | 0.6 | 13 | |
| Vegetated percentage of channel | | Control | 75.9 | 3.9 | 4 | N/A |
| | | Impact | 56.7 | 5.0 | 4 | |

### Reference Conditions

Reference surveys conducted in 1998 to estimate pre-channelization conditions used methods similar to those presented above for baseline data. These data were from a June 1998 field survey of littoral vegetation (C. Hovey, unpublished data) in a semi-restored river channel in Pool B (Toth 1991), which had received intermittent flow diverted from C-38 since 1988, and continuous flow for nine months prior to sampling. Reference data were collected at 42 beds at inner channel bends (*n*=11), outer bends (*n*=19), and straight reaches (*n*=12) of river channel. Beds in each of these categories were averaged to derive reference means.

Mean bed widths in the reference survey were 5.0 m ± 0.4 m on inner bends, 3.8 m ± 0.5 m on outer bends, and 3.6 m ± 0.6 m on straight reaches. Reference means for inner bends and straight reaches were significantly different from baseline means ($P$ <0.001, two-way analysis of variance on ranks, Table 10-1). Outer bends were not significantly different from means in the baseline data ($P$ = 0.081, Table 10-1). Baseline mean widths are graphed with reference means and expected post-restoration widths, which were based on the reference data (Figure 10-1).

Because no difference was detected between baseline and reference widths on inner bends, an expectation was not developed for outer bends.

### Adjustments for External Constraints

The magnitude and effect of herbicide applications will be assumed to be similar in the Control and Impact areas, and during the baseline and post-restoration periods. Bed widths showed no detectable reductions four months after application of herbicide (Bousquin, unpublished data).

### Mechanism for Achieving Expectation

Restoration of continuous flow through river channels will reduce the width of littoral vegetation beds by mechanical removal of plants, substrate, and floating mats. Widths will be determined by flow regimes that will vary with channel pattern. Initial high flows through the channels will remove much of the floating vegetation.

### Means of Evaluation

Following completion of Phase I construction, two years of semiannual sampling will be used to evaluate initial responses to flow restoration. Following this period, post-restoration sampling will continue for at least two years. This schedule assumes normal flow regimes. If needed, sampling will be continued until mat widths have stabilized. Post-restoration sampling methodology will be identical to baseline sampling.

The baseline data were evaluated to estimate statistical power and the sample sizes (numbers of sample periods) needed in the post-restoration period to conduct reliable before-after comparisons. Power was estimated for standard t-tests (one-tailed) using only the Impact area data. Assuming equal or lower variability in the post-restoration data, the changes predicted for bed widths at inner bends and straight reaches will be detectable (if they occur) at $\alpha \leq 0.05$ and $\beta \leq 0.1$ (power $\geq 0.9$) with data from three post-restoration sampling periods.

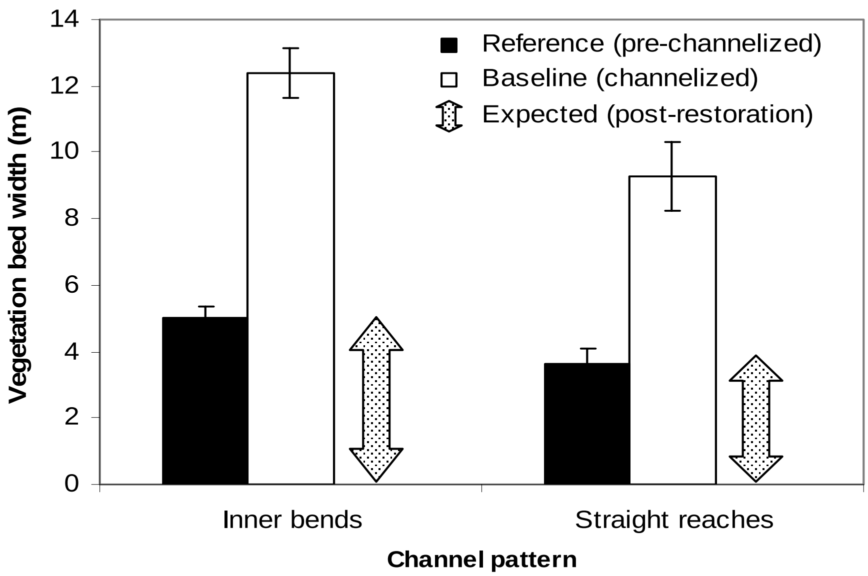


Figure 10-1. Mean relative cover of littoral bed widths on inner bends and straight reaches of river channel in the baseline and reference littoral vegetation surveys, showing values expected following restoration of flow based on reference data. Error bars indicate ± one standard error of the mean.

### Time Course

Initially, sufficiently high flows will be needed to remove mid-channel vegetation and alter mat widths; subsequently, flow must be sustained to maintain these new conditions (Toth et al. 1995). Stabilization of widths is expected to occur within one to three years of backfilling and restored flow, but monitoring will be continued until bed widths stabilize.

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# EXPECTATION 11

## PLANT COMMUNITY STRUCTURE IN RIVER CHANNELS

### Expectation

Littoral plant community structure will undergo the following changes in restored river channels:

(1) Combined mean relative cover of emergent species will increase to >80%.

(2) Combined mean relative cover of floating and mat-forming species will decrease to <10%.

### Author

Stephen G. Bousquin, South Florida Water Management District
Caroline Hovey, South Florida Water Management District (*Current affiliation*: Hovey Environmental)

### Date

May 11, 1999 (Hovey); revised April 2002 (Bousquin); revised December 2004 (Bousquin)

### Relevant Endpoints

Sociopolitical-Nuisance (Non-Native) Species
Restoration-Biological Integrity-Community Structure
Restoration-System Functional Integrity-Habitat Quality

### Metrics

Relative cover of emergent species
Relative cover of floating and mat-forming species

### Baseline Conditions

Baseline sampling was conducted twice annually from 1998 to 1999 during the winter dry season (usually February–March) and the summer wet season (August–September) at fixed transects distributed in non-flowing (remnant) channels of Pools A (Control area), and B and C (Impact area). Each transect is permanently marked on opposite banks with galvanized steel poles. Vegetation sampling was conducted in one-meter wide belt transects established by sighting between the transect poles and placing 1 m by 2 m quadrats on the upstream side of the sightline, with the long dimension of the quadrat on the transect. Surveys were initiated at the left bank facing downstream and were continued across the channel by adding consecutive quadrats. For each quadrat, we recorded the overall percentage cover of living and dead vegetation to the nearest 5%, and cover of all plant species using a six-level system developed by Daubenmire (1959). The midpoints of cover classes were used for calculations involving species cover classes (Table 11-1) (Daubenmire 1959). Relative cover was averaged over all sampled vegetated transect sections for each species or growth-form for each of the four baseline sample periods. Grand means for the baseline period are the averages of the four sample period means for each species or growth-form ($n$=4). For calculcations, each transect was subdivided into two transect sections, one for the vegetation bed on either side of the channel. An average of 125 vegetated transect sections occurred per sample period in the Impact area; 42 vegetated transect sections occurred per sample period in the Control area.

Reference-baseline comparisons presented below use Impact area data to represent baseline conditions. Data from the Control area will be used in future restoration evaluation to assess the effects of background variation in measured variables using a before-after-control-impact (BACI) approach (e.g., Stuart-Oaten et al. 1992). For more detail on this project, see Bousquin 2005.

Emergent species and floating/mat-forming species had similar mean relative cover in the baseline period. Of living plant cover, 49.6% ± 4.0% was floating and mat-forming species, 43.3% ± 3.4% was emergent species, and the remainder was submergent and other species (e.g., terrestrial species and taxa identified only to family or genus) (Figure 11-1).

Table 11-1. Reference and baseline mean relative cover for emergents, floating and mat-forming species, and overall living plant cover in the baseline Control and Impact areas and in the reference data. Only Impact area data were used to represent the baseline in comparisons with reference data.

| Metric | Category | Area | Mean | Standard error | *n* | *P* |
|---|---|---|---|---|---|---|
| Relative cover (by growth form) | Emergent | Control | 62.2 | 4.0 | 4 | N/A |
| | | Impact | 43.3 | 3.4 | 4 | < 0.01 |
| | | Reference | 95.5 | 2.0 | 13 | |
| | Floating & Mat-forming | Control | 34.1 | 3.9 | 4 | |
| | | Impact | 49.6 | 4.0 | 4 | < 0.01 |
| | | Reference | 4.5 | 2.0 | 13 | |
| Average percentage live plant cover | | Control | 59.6 | 4.4 | 4 | N/A |
| | | Impact | 43.6 | 6.0 | 4 | |

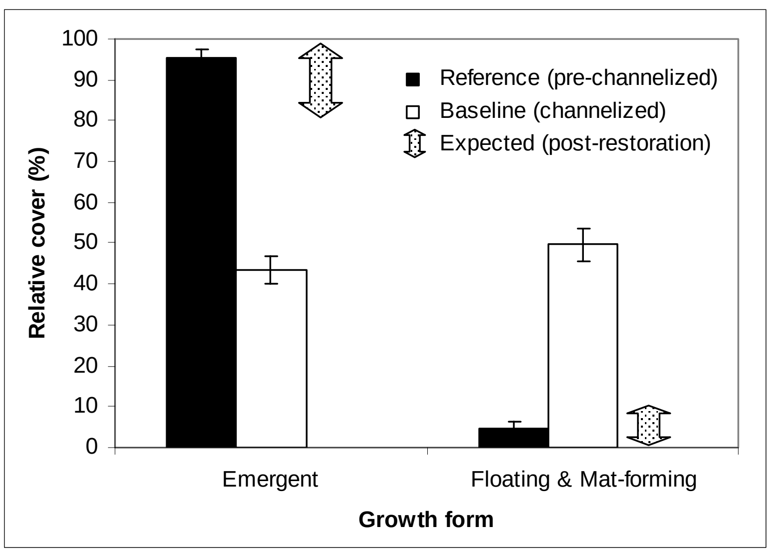



Figure 11-1. Mean relative cover of emergent species and floating and mat-forming species in the Pool B reference data and in the baseline Impact area data. Error bars represent one standard error of the mean.

Relative cover, relative frequency, and importance values (IV, the sum of relative frequency and relative cover) for species with values >5% in any of these three metrics in either or both the baseline and reference data are shown in Table 11-1. Six of the species on this list were floating/mat-forming species, including the tiny floating aquatic fern, *Salvinia minima* (water spangles), which had the highest IV in the baseline period data. Two other small-leaved floating plants, *Wolffiella gladiata* (watersprite), and *Lemna* sp. (duckweed) occurred with lower IV. Also on this list, and present in both data sets, were *Eichhornia crassipes* (water hyacinth) and *Pistia stratiotes* (water lettuce); both are floating, invasive exotics, and the only floating species recorded in the reference data. Several floating and mat-forming species were present in the baseline data but not in the reference data, including: *Scirpus cubensis*, a mat-forming sedge; *S. minima*; *Lemna* sp.; and *W. gladiata.*

Common emergent species in the baseline and reference data were *Nuphar lutea* (spatterdock), *Polygonum densiflorum* (smartweed), the native grass *Panicum hemitomon* (maidencane), *Alternanthera philoxeroides* (alligatorweed), *Hydrocotyle umbellata* (pennywort), and the shrub *Ludwigia peruviana* (Peruvian primrosewillow).

### Reference Conditions

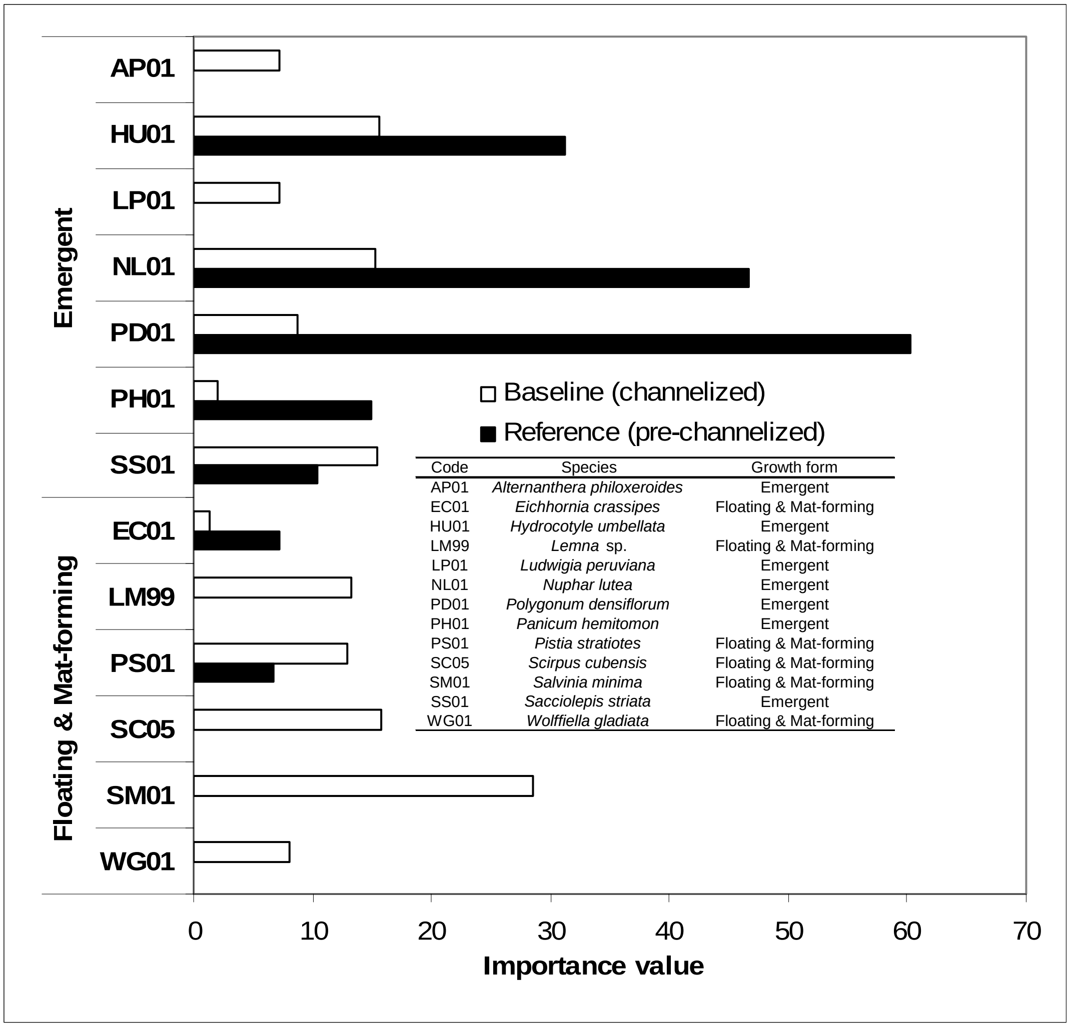
Reference surveys to estimate pre-channelization conditions used methods similar to those for baseline data. Data to estimate pre-channelization littoral plant community structure were obtained from the Kissimmee River Demonstration Project semi-restored run. Cover class (Daubenmire 1959) data from a field survey of 13 transects in the semi-restored channel (C. Hovey, unpublished data) were used to estimate mean relative cover of plant species under flowing conditions. Relative cover means for the reference field survey are the averages of sampled vegetation beds (two transect sections per transect, *n*=26) that occurred at the 13 transects.

Emergent species clearly dominated littoral zones in the semi-restored flowing channel. Based on the field survey data, mean combined relative cover of emergents was 95.5% ± 2.0%, and the estimate based on photointerpretation was 97%. Mean combined relative cover of floating and mat-forming species in the field survey was 4.5% ± 1.9%, and 3% in the photointerpretation estimate. Mean relative cover of emergent species and floating and mat-forming species was significantly different between the baseline and reference survey data (P <0.01, Kruskal-Wallis one-way analysis of variance on ranks) (Table 11-2).

Baseline means are graphed with reference means and expected post-restoration cover of emergents and floating and mat-forming species, which were based on the reference data (Figure 11-2).

Table 11-2. Mean relative cover, mean relative frequency, and importance values for all species that occurred with values of ≥ 5% in any of these metrics in the baseline Impact or reference data. Importance is the sum of relative cover and relative frequency.

| Form | Code | Species | Relative cover (%) | | Relative frequency (%) | | Importance | |
|---|---|---|---|---|---|---|---|---|
| | | | Reference (pre-channelized) | Baseline (channelized) | Reference (pre-channelized) | Baseline (channelized) | Reference (pre-channelized) | Baseline (channelized) |
| Emergent | AP01 | *Alternanthera philoxeroides* | 0.0 | 2.1 | 0.0 | 5.2 | 0.0 | 7.3 |
| | HU01 | *Hydrocotyle umbellata* | 12.5 | 8.8 | 18.8 | 6.8 | 31.3 | 15.6 |
| | LP01 | *Ludwigia peruviana* | 0.0 | 3.2 | 0.0 | 4.1 | 0.0 | 7.3 |
| | NL01 | *Nuphar lutea* | 26.4 | 11.0 | 20.3 | 4.2 | 46.7 | 15.2 |
| | PD01 | *Polygonum densiflorum* | 35.2 | 4.7 | 25.0 | 4.1 | 60.2 | 8.8 |
| | PH01 | *Panicum hemitomon* | 5.5 | 0.6 | 9.4 | 1.4 | 14.9 | 2.0 |
| | SS01 | *Sacciolepis striata* | 4.1 | 8.5 | 6.3 | 6.9 | 10.4 | 15.4 |
| Floating & Mat-forming | EC01 | *Eichhornia crassipes* | 2.5 | 0.5 | 4.7 | 0.8 | 7.2 | 1.3 |
| | LM99 | *Lemna* sp. | 0.0 | 5.5 | 0.0 | 7.7 | 0.0 | 13.2 |
| | PS01 | *Pistia stratiotes* | 2.0 | 7.6 | 4.7 | 5.3 | 6.7 | 12.9 |
| | SC05 | *Scirpus cubensis* | 0.0 | 10.3 | 0.0 | 5.5 | 0.0 | 15.8 |
| | SM01 | *Salvinia minima* | 0.0 | 20.8 | 0.0 | 7.7 | 0.0 | 28.5 |
| | WG01 | *Wolffiella gladiata* | 0.0 | 2.9 | 0.0 | 5.2 | 0.0 | 8.1 |




| Code | Species | Growth form |
|---|---|---|
| AP01 | *Alternanthera philoxeroides* | Emergent |
| EC01 | *Eichhornia crassipes* | Floating & Mat-forming |
| HU01 | *Hydrocotyle umbellata* | Emergent |
| LM99 | *Lemna* sp. | Floating & Mat-forming |
| LP01 | *Ludwigia peruviana* | Emergent |
| NL01 | *Nuphar lutea* | Emergent |
| PD01 | *Polygonum densiflorum* | Emergent |
| PH01 | *Panicum hemitomon* | Emergent |
| PS01 | *Pistia stratiotes* | Floating & Mat-forming |
| SC05 | *Scirpus cubensis* | Floating & Mat-forming |
| SM01 | *Salvinia minima* | Floating & Mat-forming |
| SS01 | *Sacciolepis striata* | Emergent |
| WG01 | *Wolffiella gladiata* | Floating & Mat-forming |

Figure 11-2. Common species in baseline (channelized) and reference (flowing) area remnant channels.

### Adjustments for External Constraints

The magnitude and effect of herbicide applications will be assumed to be similar in the Control and Impact areas, and during the baseline and post-restoration periods. Bed widths showed no detectable reductions by four months after herbicide application (Bousquin, unpublished data).

### Mechanism for Achieving Expectation

Post-restoration changes in plant community structure of littoral zones will be dependent on the return of flow to remnant river channels. Initial high flows will remove much of the mid-channel vegetation. Because most mid-channel species are floating non-native species, this initial flow will cause reductions in cover of both floating/mat-forming species and non-native species. Subsequently, flow must be sustained so that species better suited to continuous flow and varying water levels can become dominant.

The predicted shift to dominance by emergents is not dependent on colonization, because most sampled vegetation mats (>98%) were composed of mixtures of emergents and floating and mat-forming species. The expectation of higher relative cover and dominance of emergent species following restoration also does not suggest that absolute cover of emergent species will increase. Because relative cover is calculated relative to total vegetation cover, a decrease in the absolute cover of floating and mat-forming species could result in higher relative cover of emergents, even if absolute cover of emergents remains unchanged. Moderate expansion of emergents may take place as channel substrate and cross-sections change; however, the expectation is not dependent on such expansion.

### Means of Evaluation

Following completion of Phase I construction, two years of semiannual sampling will be used to evaluate initial responses to flow restoration. Following this period, post-restoration sampling will continue for at least two years, assuming normal flow regimes. If needed, sampling will be continued until bed community structure has stabilized. Post-restoration sampling methodology will be identical to baseline sampling.

The baseline data were evaluated to estimate statistical power and the sample sizes (numbers of sample periods) needed in the post-restoration period to conduct reliable before-after comparisons. Power was estimated for standard t-tests (one-tailed) using only the Impact area data. Assuming equal or lower variability in the post-restoration data, the predicted amounts of change for both emergents and floating and mat-forming species will be detectable (if they occur) at $\alpha \leq 0.05$ and $\beta \leq 0.1$ (power $\geq 0.9$) with two sample periods of restored-condition data.

### Time Course

Changes in plant community structure are expected one to three years after backfilling and restored flow (Toth et al. 1995), but monitoring will continue until community structure stabilizes.

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# EXPECTATION 12

## AREAL COVERAGE OF FLOODPLAIN WETLANDS

### Expectation

Wetland plant communities will cover >80% of the area of the floodplain restored in Phases I–IV.

### Author

Laura Carnal, South Florida Water Management District

### Date

March 3, 1999; revised October 8, 2002; revised March 2003, February 2005, July 2005

### Relevant Endpoints

Sociopolitical - Total Wetland Area
Sociopolitical - Nuisance (Exotic) Species
Restoration - System Functional Integrity - Habitat Quality

### Metrics

Percent of restored area of floodplain covered by wetlands

### Baseline Conditions

Early post-channelization vegetation data based on 1973 and 1974 aerial photography (adjusted from Milleson et al. 1980) indicate that wetland vegetation covered approximately 29% of Pools A–D three years after channelization of the Kissimmee River. More recent vegetation mapping of Pool C (Carnal and Bousquin 2005) during the channelized period indicate that the area of wetland plant communities in Pool C was similar in 1996, with coverage of 32%. Most wetlands during the channelized period occurred in the lower, impounded portions of pools and in depressions and sloughs (Carnal and Bousquin 2005).

### Reference Conditions

Pre-channelization aerial photography (1952–1954) data (adjusted from Pierce et al. 1982) indicate that, prior to channelization, wetland plant communities covered approximately 81% of the floodplain in the restoration and control areas of Pools A–D, 83% of Pool C alone, and 80% of the area slated for restoration in construction Phases I–IV (Table 12-1). The restoration-area pre-channelization data were used to predict the expected minimum of 80% wetland coverage following restoration of flow and inundation.

**Adjustments for External Constraints**

The River Acres residential community in southeastern Pool D will not be included in the restoration project. This site has an area of approximately 153 ha and was dominated by marsh wetland communities prior to channelization. This area was subtracted from reference condition data to arrive at the 80% wetlands expectation (Figure 12-1).

Table 12-1. Areal coverage of wetlands and other general vegetation categories by restoration phase. The 1952 pre-channelization data (Pierce et al. 1982) were used to predict the expected effect of restoration on wetland area. The 1974 data (Milleson et al. 1980) were used for whole-system channelized-condition (baseline) estimates.

| | | Area (ha) | | Percent of restoration area | |
|---|---|---|---|---|---|
| Phase | Status | 1952 | 1974 | 1952 | 1974 |
| Phase I | Aquatic | 61 | 36 | 0.6 | 0.3 |
| | Non-vegetated | 210 | 561 | 2.0 | 5.4 |
| | Unknown | 20 | 0 | 0.2 | 0.0 |
| | Upland | 402 | 2414 | 3.8 | 23.1 |
| | Wetland | 3154 | 836 | 30.1 | 8.0 |
| Phase II/III | Aquatic | 115 | 68 | 1.1 | 0.7 |
| | Non-vegetated | 461 | 961 | 4.4 | 9.2 |
| | Unknown | 17 | 1 | 0.2 | 0.0 |
| | Upland | 389 | 2019 | 3.7 | 19.3 |
| | Wetland | 3405 | 1337 | 32.5 | 12.8 |
| Phase IV | Aquatic | 25 | 50 | 0.2 | 0.5 |
| | Non-vegetated | 120 | 219 | 1.1 | 2.1 |
| | Unknown | 6 | 0 | 0.1 | 0.0 |
| | Upland | 186 | 661 | 1.8 | 6.3 |
| | Wetland | 1354 | 761 | 12.9 | 7.3 |
| Phase IVA | Aquatic | 8 | 12 | 0.1 | 0.1 |
| | Non-vegetated | 65 | 122 | 0.6 | 1.2 |
| | Unknown | 2 | 0 | 0.0 | 0.0 |
| | Upland | 33 | 185 | 0.3 | 1.8 |
| | Wetland | 439 | 228 | 4.2 | 2.2 |
| Grand Total | | 10472 | 10472 | 100 | 100 |

**Mechanism for Achieving Expectation**

Backfilling of the C-38 canal and implementation of the new headwaters regulation schedule (Bousquin et al. 2005) will reestablish depth, extent, duration, and frequency of floodplain inundation. Historic floodplain inundation regimes will create conditions favorable for wetland vegetation. Wetland vegetation will colonize flooded habitat through seed dispersal and vegetative reproduction of remnant communities, and from germination of viable remnant seed banks. Increased inundation of the floodplain will rapidly eliminate upland species that are intolerant of flooding. Evidence that such a shift will take place was observed in Rattlesnake Hammock Marsh, a 228 ha impoundment in the Pool A floodplain that was created in 1990 and subjected to increased hydroperiods in the early 1990s (Toth et al. 1998). The coverage of wetland communities in the impoundment increased from virtually zero following channelization (Milleson et al. 1980) to >40% by 1996, including 80 ha of broadleaf marsh and 14 ha of wet prairie (L. Carnal, SFWMD, unpublished data).

### Means of Evaluation

Total floodplain wetland area will be tracked for each phase of the project at three-5 year intervals after reestablishment of historic floodplain hydroperiod characteristics. After Phase I of restoration (most of Pool C and lower Pool B), wetland communities should eventually cover approximately 3154 ha (30%) of the 10,472 ha area encompassed by all phases of restoration. Phase II/III (most of Pool D and lower Pool C) will restore an additional 3405 ha (33%) in the restoration area. Following Phase IV (two additional sections of lower Pool B), an additional 1793 ha of wetlands or 17% of the total restored area will be added, for a cumulative total restored wetland area of 8352 ha or approximately 80% of the restoration area.

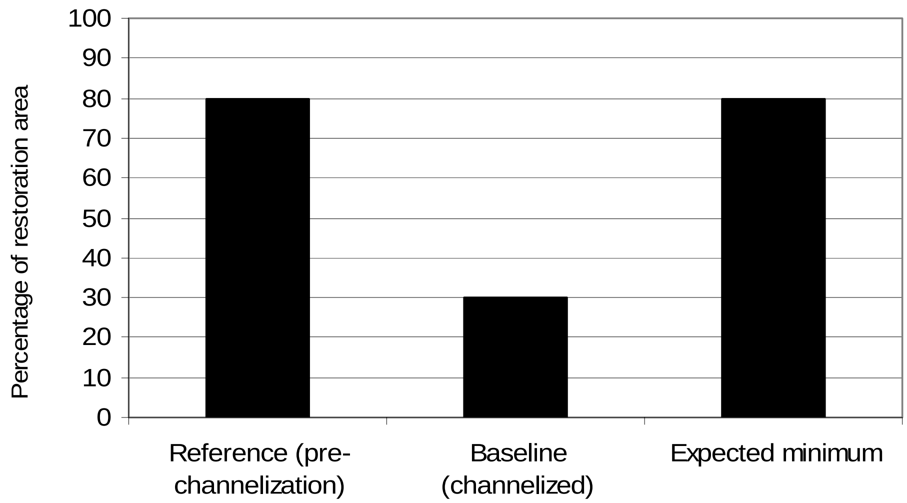


Figure 12-1. Pre-channelized, channelized, and expected percentages of wetland vegetation in the restoration project area.

Aerial photography will be acquired, interpreted, converted to digital map data, and georeferenced to produce a seamless vegetation map. Ground truth data will be collected simultaneously for use in signature calibration and accuracy assessment. The mapped vegetation data will be used to calculate the areal coverage of each classified community and to detect changes in area. Total wetland area will be compared to the adjusted reference values, which were derived from the pre-channelization (1952–1954) vegetation map of Pierce et al. (1982). The expectation will be achieved when the percentage of wetland area on the restored portion of Pools B, C, and D meet or exceed the predicted values. Satellite image data may be acquired and interpreted to assess intermediate change with lower resolution than aerial photography. Aerial photography acquired for each phase of the restoration project will include Pool A (north of the restoration area), which will serve as a channelized-condition control site. While plant communities on small portions of the Pool A floodplain may change in response to restoration project activities (e.g., backfilling of local agricultural ditches, breaching the tie-back levee between Pools A and B to allow sheet flow on the floodplain), such changes will be taken into account during evaluations.

### Time Course

Reestablishment of >80% coverage of floodplain wetland plant communities in the restored areas of Pools B, C, and D will take four to five years after the following two requirements have been met. First, the backfilling of the C-38 canal must be completed for all restoration phases, and second, the headwaters revitalization stage regulation schedule, which will mimic historic hydroperiods (Bousquin et al. 2005, Williams et al. 2005), must be implemented.

The rate of change in plant communities will be linked closely to hydrologic conditions in the years following backfilling (Toth et al. 1995). If the floodplain experiences extended drought conditions in the early years of recovery, or the new regulation schedule does not restore historic hydrology, it is likely that upland herbaceous and shrub species will persist in areas where wetland species are expected to reestablish. These upland species will decline when normal climatic conditions return and historic hydrology is restored.

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# EXPECTATION 13

# AREAL COVERAGE OF BROADLEAF MARSH

### Expectation

Broadleaf Marsh will cover at least 50% of the restored floodplain in Pools B, C, and D.

### Author

Laura Carnal, South Florida Water Management District

### Date

June 6, 1998; revised October 8, 2002; revised March 2003; revised February 2005

### Relevant Endpoints

Ecological Integrity/Sociopolitical - Total Wetland Area
Restoration - System Functional Integrity - Habitat Quality - Habitat Diversity

### Metrics

Percent of restored floodplain area covered by Broadleaf Marsh

### Baseline Conditions

Early post-channelization data (adjusted from Milleson et al. 1980) based on 1973 and 1974 aerial photography indicate that Broadleaf Marsh (BLM) communities (defined in Bousquin and Carnal 2005) covered 10% of the 10,472 ha area that will be affected by Phases I–IV of restoration.

### Reference Conditions

Pre-channelization (1952–1954) data (adjusted from Pierce et al. 1982) indicate that BLM covered approximately 49% of the area that will be affected by all phases of the restoration project (Table 13-1). The pre-channelization restoration-area data, adjusted as described below, were used as reference conditions to obtain the value of 50% BLM coverage predicted by this expectation.

### Adjustments for External Constraints

MacArthur Impoundment was constructed prior to the historical photography used by Pierce et al. (1982) to map pre-channelization vegetation. This 600 ha system of levees and ditches was created to drain wetlands for use as cattle pasture. The impoundment likely shortened hydroperiods, creating favorable conditions for wet prairie communities in the southern end of the impoundment and upland species in the northern end. Because the surrounding area was historically dominated by broadleaf, it is likely that BLM associations will reestablish in the area after the ditches and levees are removed and hydrology is restored. The area of the impoundment occupied by maidencane (*Panicum hemitomon*) Wet Prairie (425 ha) prior to channelization was added to the reference condition value to adjust the expected value. The River Acres residential community in southeastern Pool D will not be included in the restoration project. This site has an area of approximately 153 ha and was historically dominated by BLM and Wet Prairie communities. This area was subtracted from the adjusted reference condition value.

Based on these adjustments, BLM communities are expected to increase incrementally with each phase of restoration. Following Phase I, BLM is expected to occur on approximately: 20% of the area affected by the restoration in Pools B, C, and D (adjusted for MacArthur Impoundment); an additional 22% following Phase II/III (adjusted for River Acres); and an additional 9% following Phase IV, for a cumulative total of approximately 51% of the area affected by the project. This expectation will be achieved when the total areal coverage of BLM in restored portions of Pools B, C, and D is at least 50% (Figure 13-1).

Table 13-1. Areal coverage and percentages of Broadleaf Marsh prior to channelization (1952) and three years after channelization (1974) in the areas to be restored in restoration Phases I–IV.

| | Area (ha) by year | | Percent of restoration area (10,472 ha) by year | |
|---|---|---|---|---|
| Restoration phase | 1952 | 1974 | 1952 | 1974 |
| Phase I | 1672 | 175 | 16.0 | 1.7 |
| Phase II/III | 2504 | 565 | 23.9 | 5.4 |
| Phase IV | 674 | 124 | 6.4 | 1.2 |
| Phase IVA | 256 | 190 | 2.4 | 1.8 |
| Totals | 5106 | 1054 | 49 | 10 |

**Mechanism for Achieving Expectation**

Backfilling of the C-38 canal and implementation of the interim and new headwaters stage regulation schedule will reestablish historic floodplain inundation characteristics of depth, extent, duration, and frequency (Bousquin et al. 2005). Prolonged floodplain inundation regimes will create conditions favorable for BLM vegetation (Toth et al. 1995). Broadleaf marsh species will colonize flooded habitat through seed dispersal, vegetative growth from remnant communities, and from germination of remnant seed banks. A similar shift from pasture to BLM was observed in Rattlesnake Hammock Marsh, a 228 ha impoundment in Pool A, which was created in 1990 and subjected to increased hydroperiods in the early 1990s (Toth et al. 1998). Broadleaf Marsh communities increased from virtually zero coverage following channelization (Milleson et al. 1980) to approximately 80 ha by 1996 (L. Carnal, SFWMD, unpublished data). Following restoration, most areas that are currently pasture are expected to revert to BLM. However, the established pasture grasses are adapted to periodic wet conditions, so consistently long hydroperiods are needed to displace bahia grass (*Paspalum notatum*) and bermuda grass (*Cynodon dactylon*). C-38 and areas that are currently occupied by spoil will experience successional phases and eventually will be colonized by BLM species.

**Means of Evaluation**

The areal coverage of BLM will be tracked in three-5 year intervals after reestablishment of historic floodplain hydroperiod characteristics for each phase of the project. Aerial photography will be acquired, interpreted, converted to digital map data, and georeferenced to produce a seamless vegetation map. Ground truth data will be collected simultaneously for use in signature calibration and accuracy assessment. The mapped vegetation data will be used to calculate the areal coverage of each classified community and to detect changes in areal extent of communities. Total BLM area will be compared with the adjusted reference values for each restoration phase. Satellite image data may be acquired and interpreted to provide additional vegetation data to assess intermediate change.

Aerial photography will include Pool A, which will not be backfilled and serves as a control site. While Pool A vegetation floodplain may experience some change in response to restoration-related activities (e.g., backfilling of local agricultural ditches, breaching the tie-back levee between Pools A and B to allow sheet flow on the floodplain), these changes will be taken into account in evaluations. Changes in each phase of the project will be evaluated by comparing vegetation map data for the baseline period with post restoration data, relative to the Pool A control.

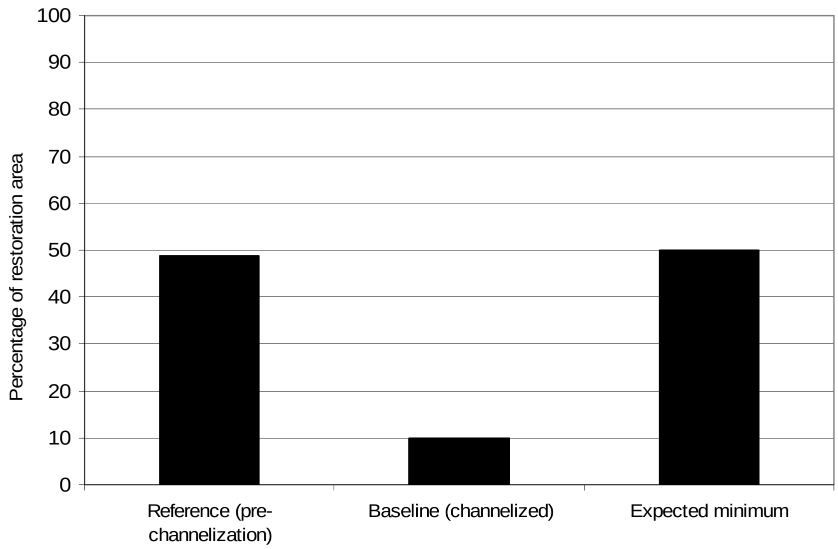


Figure 13-1. Pre-channelization, channelized, and expected percentages of Broadleaf Marsh in the restoration project area.

## Time Course

Two requirements are necessary to achieve this expectation. First, backfilling of the C-38 canal must be completed for all restoration phases, and second, implementation of the headwaters revitalization stage regulation schedule, which will mimic historic hydroperiods (Bousquin et al. 2005) must take place. However, the rate of transition in vegetation communities will be linked closely to the hydrologic conditions in the years following backfilling (Toth et al. 1995). If the floodplain experiences extended drought conditions in the early years of recovery, or the interim regulation schedule does not reestablish historic inundation regimes, it is likely that upland weeds, shrubs, and pasture grasses will persist on the floodplain and impede reestablishment of BLM species. These upland species will decline when normal climatic conditions return and historic hydrology is restored.

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# EXPECTATION 14

## AREAL COVERAGE OF WET PRAIRIE

### Expectation

Wet Prairie communities will cover at least 17% of the floodplain restored by Phases I–IV of the restoration project.

### Author

Laura Carnal, South Florida Water Management District

### Date

May 25, 1999; revised October 28, 2002; revised March 2003; revised February 2005

### Relevant Endpoints

Sociopolitical - Total Wetland Area
Restoration - System Functional Integrity - Habitat Quality - Habitat Diversity

### Metrics

Percent of restored floodplain area covered by Wet Prairie

### Baseline Conditions

Early post-channelization data (adjusted from Milleson et al. 1982) indicate that in 1973 and 1974, three years after channelization was completed, Wet Prairie communities (defined in Bousquin and Carnal 2005) covered approximately 11% of the area to be restored in Phases I–IV (10,472 ha ) of the Kissimmee River Restoration Project (Table 14-1).

### Reference Conditions

Pre-channelization data based on mapping of 1952 to 1954 aerial photography (adjusted from Pierce et al. 1982), indicate that Wet Prairie communities comprised approximately 22% of the areas of Pools B–D slated for restoration in construction Phases I–IV (Table 14-1). These pre-channelization restoration-area data, adjusted as described below, were used as reference conditions for predicting post-restoration recovery of Wet Prairie to 17% of the restored system.

### Adjustments for External Constraints

Historical reference condition data are based on aerial photography taken after MacArthur Impoundment was constructed. This system of levees and ditches was created to drain wetlands for pasture use, and likely shortened hydroperiods. This created favorable conditions for Wet Prairie species in the southern end of the impoundment and upland pasture species in the northern end. Historic vegetation data (Pierce et al. 1982) show expanses (425 ha) of *Panicum hemitomon* (maidencane) that occurred in MacArthur Impoundment. Because the surrounding area was historically dominated by Broadleaf Marsh species, maidencane is not expected to remain in this area after the ditches and levees have been degraded. Therefore, the 425 ha of maidencane within the impoundment was subtracted from reference condition data. The River Acres residential community in southeastern Pool D will not be included in the restoration project. This site has an area of approximately 153 ha and was historically dominated by Broadleaf Marsh and Wet Prairie communities. This area has also been subtracted from reference condition data.

Based on these adjustments, Wet Prairie is expected to cover: 7% of the floodplain affected by Phase I; 3% of that affected by Phase II/III; and 6% of that affected by Phase IV, for a cumulative total of 17% expected cover in the restoration area. This expectation will be achieved when Wet Prairie communities cover at least 17% of the total floodplain area in the Phase I–IV restoration area (Figure 14-1).

Table 14-1. Areal coverage and percentages of Wet Prairie prior to channelization (1954) and three years after channelization (1974) in the areas to be restored during restoration Phases I–IV.

| | Area (ha) | | Percent of restoration area (10,472 ha) | |
|---|---|---|---|---|
| | 1952 | 1974 | 1952 | 1974 |
| Phase I | 1185 | 525 | 11.3 | 5.0 |
| Phase II/III | 515 | 182 | 4.9 | 1.7 |
| Phase IV | 471 | 402 | 4.5 | 3.8 |
| Phase IVA | 179 | 17 | 1.7 | 0.2 |
| Totals | 2350 | 1125 | 22 | 11 |

**Mechanism for Achieving Expectation**

Backfilling of the C-38 canal, and implementation of the interim and new headwaters stage regulation schedules (Bousquin et al. 2005), will reestablish floodplain inundation characteristics (depth, extent, duration, and frequency). Historic floodplain inundation regimes will create conditions favorable for growth and reproduction of Wet Prairie species. Wet Prairie species will colonize through seed dispersal and vegetative reproduction of remnant communities, and from germination of remnant seed banks. Wet Prairie associations will reestablish along the periphery of the floodplain and on the higher elevations within Broadleaf Marsh communities where annual hydroperiods range from three to eight months with depths <25 cm. Reestablishing longer hydroperiods will eventually eliminate upland species that are less tolerant of fluctuating water depths and periods of inundation. A shift from pasture to Wet Prairie communities was measured in Rattlesnake Hammock Marsh, a 228 ha impoundment in the Pool A floodplain that was created in 1990 and subjected to fluctuating water levels (Toth et al. 1998). Wet Prairie communities were virtually absent following channelization (Milleson et al. 1980) and increased to 14 ha by 1996 (L. Carnal, SFWMD, unpublished data).

**Means of Evaluation**

The areal coverage of Wet Prairie will be tracked in three-5 year intervals after reestablishment of historic floodplain hydroperiod characteristics for each phase of the project. Aerial photography will be acquired, interpreted, converted to digital map data, and georeferenced to produce a seamless vegetation map. Ground truth data will be collected simultaneously for use in signature calibration and accuracy assessment. The mapped vegetation data will be used to calculate the areal coverage of each classified community and to detect changes in area. Wet Prairie communities will be determined by dominance of diagnostic species (Bousquin and Carnal 2005). Wet Prairie includes 14 community types (Bousquin and Carnal 2005) with vegetation cover that is dominated by: diagnostic wetland grasses, such as *Panicum hemitomon* and *Luziola fluitans*; forbs, such as *Polygonum punctatum* and *Iris virginica*; or sedges such as *Juncus effusus* and *Cyperus* spp.). Polygons that contain transitional plant mixtures will be field-verified to ascertain the correct community association. Total Wet Prairie area will be compared with the adjusted reference values. Post-restoration Wet Prairie floodplain coverage will be overlaid on the historic Wet Prairie coverage to determine differences in distribution, and to calculate percent overlap of cover.

For each phase of the project, changes in the area of Wet Prairie communities in the restored reach will be evaluated by comparing the changes from the baseline period to the post restoration period relative to those in the Pool A control. While vegetation communities on a portion of the Pool A floodplain may change in response to altered hydrology caused by the restoration project (e.g., backfilling of local agricultural ditches, breaching the tie-back levee between Pools A and B to allow sheet flow on the floodplain), these changes will be taken into account during the analysis.

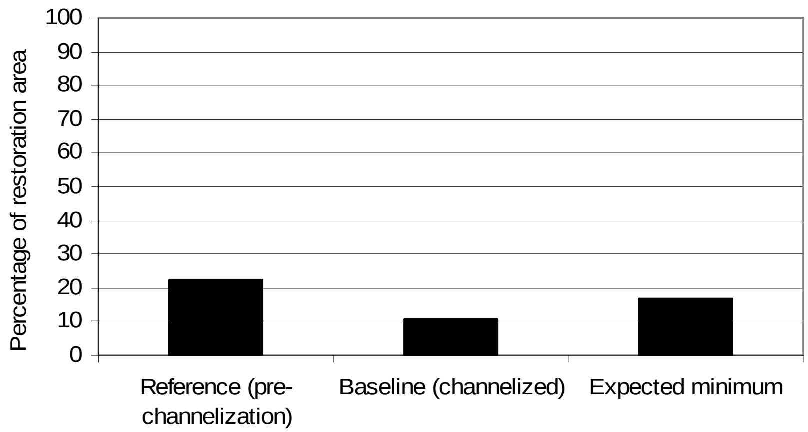


Figure 14-1. Pre-channelization, channelized, and expected percentages of Wet Prairie in the restoration project area. Reference conditions were adjusted downward in deriving the expectation because two former areas of Wet Prairie are not expected to succeed to Wet Prairie in the restored system (see text).

**Time Course**

Two requirements are necessary to achieve this expectation. First, completion of C-38 backfilling for each restoration phase must occur, and second, the implementation of the headwaters revitalization stage regulation schedule, which will mimic historic hydroperiods (Williams et al. 2005), must take place. Within three growing seasons after historic hydroperiods are restored, some areas of the floodplain should reflect dominance by Wet Prairie species. However, these species cannot tolerate prolonged hydroperiods where water levels exceed 25 cm. As the floodplain experiences consistent inundation, there may be a short period when the areal coverage of Wet Prairie declines until it reestablishes at higher elevations and more favorable water levels. This expectation should be achieved within four years, once historic hydroperiods are reestablished for each phase of the project.

The rate of transition of the vegetation communities will be linked closely to the hydrologic conditions in the years following backfilling (Toth et al. 1995). If the floodplain experiences extended drought conditions in the early years of recovery, or the interim regulation schedule does not reestablish suitable inundation regimes (three to eight month hydroperiod), it is likely that upland weeds, shrubs, and pasture grasses will persist in areas where Wet Prairie species are expected to reestablish. These upland species will decline when normal climatic conditions return and historic hydrology is restored.

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# EXPECTATION 15

# RIVER CHANNEL MACROINVERTEBRATE DRIFT COMPOSITION

### Expectation

Macroinvertebrate drift composition will be dominated by Coleoptera, Diptera, Ephemeroptera, and Trichoptera.

### Author

Joseph W. Koebel Jr., South Florida Water Management District

### Date

August 4, 1998; Revised October 20, 2005

### Relevant Endpoints

Restoration - System Functional Integrity - Habitat Quality

### Metrics

Percent of drift accounted for by Coleoptera
Percent of drift accounted for by Diptera
Percent of drift accounted for by Ephemeroptera
Percent of drift accounted for by Trichoptera

### Baseline Condition

Aquatic invertebrate drift samples were collected quarterly from remnant channels of Pool A and C beginning in January 1998. Two drift nets (0.1 $m^2$ equipped with 125 µm mesh netting) were placed 15 cm below the water surface and 0.5 m above the substrate at three locations within each of three remnant river channels in Pool A and C. Samples were collected at 8-hour intervals (+ 1 hour) over a 24-hour period. Current velocity at each surface and bottom net opening, wind direction, and wind velocity were measured whenever a net was set or removed. All samples were preserved in the field with 10% buffered formalin stained with rose bengal.

Macroinvertebrate taxa, including, Coleoptera, Diptera, Ephemeroptera, and Odonata, comprise <1% of total drift density and 23–29% of total drift biomass in Pools A and C. Macro- and microcrustaceans accounted for approximately 97–99% of total drift density and 54–56% of total drift biomass in Pools A and C. Miscellaneous taxa (Hemiptera, Trichoptera, Lepidoptera, Collembola, Gastropoda, Nematoda, and Oligochaeta), comprised <1% and <3% of remaining drift numbers in Pool A and C, respectively. Miscellaneous taxa accounted for approximately 16% and 22% of total drift biomass in Pool A and C, respectively. This is very different from free-flowing southeastern Coastal Plain blackwater rivers, where larval Coleoptera, Diptera, Ephemeroptera, and Trichoptera are the major contributors to drift numbers and biomass.

**Reference Condition**

Historical data on aquatic invertebrate drift composition within the Kissimmee River are unavailable. Reference conditions have been developed based on invertebrate drift data from two unregulated, sixth-order southeastern Coastal Plain rivers, the Satilla and Ogeechee Rivers, Georgia (Benke et al. 1986, 1991). These studies indicate larval Coleoptera, Diptera, Ephemeroptera, and Trichoptera are the major contributors to drift numbers and biomass (Table 15-1). Because these groups of organisms likely were abundant in the pre-channelized Kissimmee River, it is likely that they accounted for the greatest proportion of aquatic invertebrate drift density and biomass. Therefore, aquatic invertebrate drift composition should provide a reliable indicator of restored hydrology and aquatic invertebrate community structure within the river channel. Following restoration of flow, invertebrate drift density and biomass should be dominated by macroinvertebrates (primarily Coleoptera, Diptera, Ephemeroptera, and Trichoptera).

**Adjustments For External Constraints**

None.

**Mechanism for Achieving Restoration**

Reestablishment of an aquatic macroinvertebrate community typical of unmodified southeastern Coastal Plain river/floodplain ecosystems is a prerequisite for reestablishing invertebrate drift composition typical of southeastern, blackwater river systems. Restoration of continuous flow and in-channel habitat structure will be the impetus for macroinvertebrate colonization of restored habitats. Colonization by most river channel macroinvertebrate taxa likely to be found in the drift will occur through adult oviposition.

Restored seasonal, variable flow patterns are expected to reestablish macroinvertebrate drift composition typical of unmodified southeastern Coastal Plain rivers, primarily through behavioral (i.e., periodic, for example, to escape from a predator) and constant (i.e., continuous background drift due to accidental dislodgement) drift mechanisms.

Table 15-1. Major invertebrate groups found in the drift of the Satilla and Ogeechee Rivers, Georgia (Benke et al. 1986, 1991) and Pool C of the channelized Kissimmee River. There was no significant difference between invertebrate drift numbers or biomass between Pools A and C; therefore, only Pool C data is presented. Numbers indicate frequency of occurrence.

| | Satilla River | | Ogeechee River | | Kissimmee River (Pool C) | |
|---|---|---|---|---|---|---|
| Taxonomic Group | Density | Biomass | Density | Biomass | Density | Biomass |
| Diptera | 52.9 | 53.8 | 27.3 | 10.6 | < 1 | 11.2 |
| Coleoptera | 11.3 | 21.5 | 6.2 | 27.4 | < 1 | 2.5 |
| Ephemeroptera | 5.8 | 6.2 | 15.4 | 34.6 | < 1 | 7.4 |
| Trichoptera | 18.6 | 13.8 | 11.5 | 20.2 | -- | -- |
| Odonata | 1.4 | 4.6 | 1 | 5.3 | <1 | 2.4 |
| Crustacea* | 10 | < 1 | 31.9 | 1.9 | 96.8 | 54.6 |
| Miscellaneous | -- | -- | 6.7 | -- | 2.7** | 21.9** |

* Includes macro- and microcrustaceans.

** Includes Hemiptera, Trichoptera, Megaloptera, Lepidoptera, Collembola, Gastropoda, Oligochaeta, and Nematoda.

**Means of Evaluation**

Invertebrate drift will be sampled monthly beginning two years after implementation of the revised headwaters regulation schedule. A modified baseline sampling procedure will be used for post-construction restoration evaluation. Three samples will be collected for four hours beginning at dusk using 31 cm X 31 cm drift nets equipped with 125 µm netting facing into the direction of flow, at depths 15 cm below the water surface and 0.5 m above the channel substrate. Because of potential differences in current velocity at the surface and bottom of the water column, nets at each of these locations will provide a better estimate of total water column drift rates. Surface and bottom nets will be placed at three randomly selected locations within reconnected river channels in Pool C, and one randomly selected location in each of three remnant channels in Pool A. Current velocity (m/s) will be measured at each net opening when nets are deployed and retrieved to determine mean current velocity and volume of water sampled. Samples will be analyzed for invertebrate taxonomic composition. Macroinvertebrate drift will be measured for at least two consecutive years. Macroinvertebrate drift composition will be compared to the baseline condition and stated expectation.

**Time Course**

Colonization of river channel habitats by macroinvertebrates typical of unmodified southern Coastal Plain rivers likely will occur within 6 to 12 months following implementation of the interim upper basin regulation schedule. However, the interim regulation schedule does not provide the consistent and predictable inflow characteristics of the revised headwaters schedule. The unpredictable nature of the interim regulation schedule may have impacts on aquatic invertebrate community structure within reconnected river channels due to periods of no flow, extreme flow, and low levels of dissolved oxygen. Therefore, macroinvertebrate drift composition will be determined after implementation of the revised schedule. This should allow macroinvertebrate composition within the river channel to stabilize, resulting in less variable drift composition.

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# EXPECTATION 16

## INCREASED RELATIVE DENSITY, BIOMASS, AND PRODUCTION OF PASSIVE FILTERING-COLLECTORS ON RIVER CHANNEL SNAGS

### Expectation

The passive filtering-collector guild will account for the greatest proportion of mean annual density, mean annual biomass, and mean annual snag-dwelling macroinvertebrate production.

### Author

Joseph W. Koebel Jr., South Florida Water Management District

### Date

March 10, 1999; Revised May 2, 2005

### Relevant Endpoints

Restoration - Biological Integrity - Community Structure
Restoration - Biological Integrity - Food Web Structure
Restoration - Biological Integrity - Productivity
Restoration - System Functional Integrity - Habitat Quality
Restoration - System Functional Integrity - Habitat Use
Restoration - System Functional Integrity - Energy Flow Dynamics

### Metrics

Percent of annual density accounted for by passive filtering-collectors
Percent of annual biomass accounted for by passive filtering-collectors
Percent of annual production accounted for by passive filtering-collectors

### Baseline Conditions

Snag samples were collected from remnant river channels quarterly between August 1995 and May 1997. Passive filtering-collectors accounted for only 2–3% of mean annual density, 1% of mean annual biomass, and 2–3% of mean annual production in Pools A and C (Figure 16-1).

### Reference Conditions

Historical data on the composition, mean annual density, mean annual biomass, and mean annual production of the snag-dwelling, passive filtering-collector macroinvertebrate guild are not available for the Kissimmee River. The primary source of information on aquatic invertebrate community structure and production on snags within the pre-channelized Kissimmee River have been derived from published data on functional feeding group composition, density, biomass, and annual production of snag-dwelling invertebrates in the Satilla River

(Georgia). The Satilla is a sixth-order, southeastern Coastal Plain blackwater river with similar physical, chemical, and hydrologic patterns as the historic Kissimmee River (Benke et al. 1984). Although species composition on snags may differ between systems, similar physical and chemical characteristics should result in similar patterns of invertebrate abundance, standing stock biomass, production, and functional feeding group composition. Filtering-collectors were selected as an indicator guild because they often account for the largest proportion of mean annual density, biomass, and production on snags in southeastern river systems. Additionally, intolerant taxa (e.g., filtering-collector caddisflies) often respond predictably (decrease) to increased perturbation (e.g., no flow, low dissolved oxygen) (Lenat 1988, Lamberti and Berg 1995, Barbour et al. 1996).

Within the Satilla River, passive filtering-collectors accounted for 75–80% of total numbers, 65–75% of total biomass, and 72–79% of total production at two sample locations (Benke et al. 1984) (Figure 16-1). Based on the low baseline estimates for these metrics in the Kissimmee River (Figure 16-1), it is likely that an increase in abundance, biomass, and production of passive filtering-collectors will be an excellent indicator of improved habitat quality and restoration of biotic integrity.

## Adjustment for External Constraints

None

## Mechanism for Achieving Restoration

Continuous, variable flow within reconnected river channels will be the impetus for colonization, persistence, and increased productivity of snag-dwelling passive filtering-collectors. Because most passive filtering-collectors are sedentary and utilize various sieving mechanisms for removing particulate matter from suspension, continuous flows are necessary to transport fine particulate organic matter that can be captured and used as a food source. The potential for high standing stock biomass of several filtering-collector taxa (primarily Trichoptera) and rapid biomass turnover rates for others (e.g., Simuliidae and filtering chironomids) likely will result in the greatest proportion of mean annual density, biomass, and production being attributed to filtering-collectors.

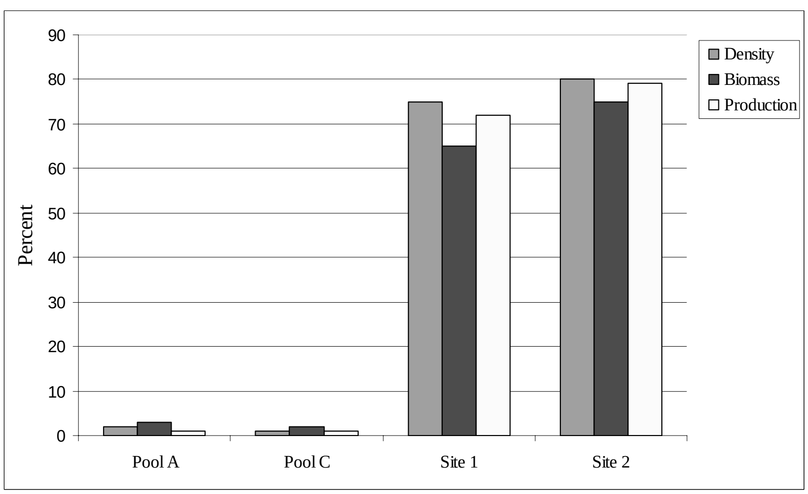


Figure 16-1. Mean annual density, biomass, and production of passive filtering-collectors on snags in the Kissimmee River (Pools A and C), and Satilla River, Georgia (Sites 1 and 2) (Benke et al. 1984).

## Means of Evaluation

Sampling of existing snag habitat will commence approximately six months following initiation of the interim upper basin regulation schedule (January 2001) and reestablishment of continuous flow through reconnected river channels. Snag-dwelling macroinvertebrate density, biomass, and production will be analyzed for a minimum of three years following reestablished flow. Post-construction sampling methods will be similar to those outlined in Anderson et al. (1998), and include collection of monthly, replicate (five) snag samples from randomly selected locations within reconnected channels of Pool C and remnant channels of Pool A. Samples will be analyzed for invertebrate species identity, functional feeding group composition, density, and standing stock biomass. Passive filtering-collectors will be identified according to Merritt and Cummins (1996). Production will be calculated using the instantaneous growth rate method. Growth equations for major taxa will be determined experimentally or obtained from the literature (e.g., Stites and Benke 1989). Monthly means will be averaged annually to determine mean monthly density and biomass for the filtering-collector guild. The three annual estimates of mean monthly density and biomass will be averaged to obtain a mean annual value. The three estimates of annual production also will be averaged to determine mean annual production. Results will be compared to baseline data and the stated expectation. Additional sampling may follow periodically (year five–six after reestablishment of continuous flow) to validate that the expectation has been achieved.

Although values for these metrics may vary from year to year, a multi-year, multi-metric evaluation of changes in macroinvertebrate community composition and production on snags will provide an objective measure of restoration-related changes that integrate potential intra- and inter-annual variability. Use of annual metrics for evaluating changes in functional group composition, density, biomass, and production on snags does not preclude evaluation of other metrics (e.g., total taxa richness, dominance, seasonal patterns of density, biomass, and production) that may contribute to further understanding of the biological significance of any observed change.

**Time Course**

Because macroinvertebrate filtering-collectors are uncommon within the channelized system, the time frame for redistribution of density, biomass, and production among functional feeding groups is primarily dependent on colonization by filtering-collectors and displacement of existing dominant functional feeding groups, which will depend on the distance colonists must travel. Small and large-bodied filtering-collectors, primarily chironomids, simuliids, and caddisflies will immigrate from lotic systems within the Kissimmee basin (e.g., Fisheating Creek, Tiger Creek, Cypress Creek, Weohykapka Creek), and will likely colonize within six to nine months. The expected increase in density, biomass, and production of passive filtering-collectors on existing woody debris is expected to occur within three years following reestablishment of continuous flow.

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## EXPECTATION 17

## AQUATIC INVERTEBRATE COMMUNITY STRUCTURE IN BROADLEAF MARSHES

### Expectation

Aquatic macroinvertebrate species richness and species diversity will be $\geq$65 and $\geq$2.37 respectively, in restored Broadleaf Marsh (currently pasture in the channelized system).

### Author

Joseph W. Koebel Jr., South Florida Water Management District

### Date

August 26, 1998; Revised May 2, 2005

### Relevant Endpoint

Restoration - Biological Integrity - Community Structure
Restoration - Biological Integrity - Biodiversity
Restoration - System Functional Integrity - Habitat Quality
Restoration - System Functional Integrity - Habitat Use

### Metrics

Mean annual macroinvertebrate species richness
Mean annual macroinvertebrate species diversity

### Baseline Conditions

Quarterly, replicate (three) aquatic invertebrate samples were collected from remnant Broadleaf Marsh habitats in Pools A and C from August 1995–May 1997. Broadleaf Marsh habitat in Pool A was dry during most of this period, and was sampled only once during the two-year study. Species richness (22) and diversity (0.81) were very low, reflecting poor quality (dry) habitat during most of the period. Broadleaf Marsh habitat in Pool C was sampled three times between August 1995 and May 1997. Species richness (65) and diversity (2.37) were greater than in Pool A, although low compared to natural wetland systems of central Florida.

Pasture habitat in Pools A and C (drained portions of the floodplain expected to convert to Broadleaf Marsh following restoration) was dry throughout most of the two-year study, and was not sampled. Theoretically, macroinvertebrate species richness and diversity are 0 and 0.0, respectively, in dry upland pasture.

**Reference Conditions**

Although historic data on aquatic invertebrate community structure of Broadleaf Marsh habitats within the Kissimmee River ecosystem are not available. Documented studies on aquatic invertebrate community structure of subtropical wetland systems are limited (Rader 1994, 1999, Evans et al. 1999), and have focused on systems that are structurally different from pre-channelization Broadleaf Marshes of the Kissimmee River (i.e., Water Conservation Areas and flatwoods marshes). Although these studies do provide insight into the potential for high species richness and diversity within restored or natural marshes of Florida, the primary source of information on aquatic invertebrate species richness and diversity within pre-channelization Broadleaf Marsh is derived from existing baseline data from Pool C.

**Adjustments for External Constraints**

None

**Mechanism for Achieving Expectation**

Reestablishing long-term hydroperiods and associated development of a diverse, heterogeneous wetland plant community likely will allow for colonization and persistence of a diverse macroinvertebrate community. The expectation for species richness and diversity in restored Broadleaf Marsh is based on the occurrence of aquatic invertebrates in remnant, but altered, Broadleaf Marsh habitat during the baseline period. Assuming that a restored marsh will support an aquatic invertebrate community with at least the same species richness and diversity as remnant marsh, a conservative estimate of species richness and diversity are 65 and 2.37, respectively, in restored marshes in Pool C (currently pasture in the channelized system).

**Means of Evaluation**

Sampling of remnant Broadleaf Marsh and restored Broadleaf Marsh will commence two years after initiating the revised upper basin headwaters schedule, and coincide with sampling of fishes, amphibians, reptiles, and wading birds within floodplain habitats. Methods will be similar to those outlined in Anderson et al. (1998), and include monthly, replicate (five) throwtrap (area = 0.25 $m^2$) samples from randomly selected locations within Pool A and C Broadleaf Marsh and Pasture habitats undergoing transition to Broadleaf Marsh.

Expectations for species richness and diversity will be evaluated only after reestablishment of historic marsh vegetation characteristics (i.e., cover dominated by *Pontederia cordata*, *Sagittaria lancifolia*, *Leersia hexandra*, and *Panicum hemitomon*). These metrics were selected based on best available reference conditions for characterizing aquatic invertebrate community structure. A sample mean will be calculated for each month and averaged annually to determine mean monthly species richness and diversity. Sampling will continue for a minimum of three years following reestablished floodplain hydroperiods and historic Broadleaf Marsh vegetation characteristics. The three annual estimates of mean monthly species richness and diversity will be averaged to determine a mean annual value. Use of these metrics for comparing restoration-related change does not preclude use of other metrics (e.g., cumulative species richness across months, seasonal patterns of abundance and diversity, taxa dominance, functional feeding group composition, and functional habitat composition) to further understand the biological significance of observed changes. Results will be compared to baseline data and the stated expectation. Additional sampling may follow periodically (e.g., year six) to validate that the expectation has been achieved.

**Time Course**

The time frame for reestablishing a diverse aquatic invertebrate community within newly created wetlands is primarily dependent on the rate at which floodplain habitats are re-inundated, the duration of inundation, depth of inundation, and how fast the mosaic of wetland plant species become reestablished.

Implementation of the revised headwaters regulation schedule is expected to seasonally inundate floodplain habitats in Pool C. Invertebrate response likely will be rapid, with mobile taxa, primarily coleopterans, dipterans, ephemeropterans, hemipterns, and odonates, colonizing within one month. During the first hydrologic cycle, it is expected that a wetland plant community will become reestablished and crustaceans (amphipods, isopods, crayfish, and freshwater shrimp), gastropods, and mollusks likely will colonize. It is likely that the stated expectation will be achieved within three years following reestablishment of pre-channelization hydroperiods.

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# EXPECTATION 18

## AQUATIC INVERTEBRATE COMMUNITY STRUCTURE IN RIVER CHANNEL BENTHIC HABITATS

### Expectation

The macroinvertebrate fauna of river channel benthic habitats will primarily consist of taxa that are common and characteristic of sandy substrates (Table 18-1).

### Author

Joseph W. Koebel Jr., South Florida Water Management District

### Date

May 8, 1998; Revised May 2, 2005

### Relevant Endpoints

Restoration - Biological Integrity - Biodiversity
Restoration - Biological Integrity - Population Abundance
Restoration - System Functional Integrity - Habitat Quality
Restoration - System Functional Integrity - Habitat Use

### Metrics

Number of invertebrate taxa characteristic of sand habitats

### Baseline Conditions

Because channelization of the Kissimmee River greatly altered geomorphic characteristics of the historic system, marginal river channel sand bars no longer exist along most of the channelized river. Most of the historic sand substrate within mid-channel habitats of remnant river channels is covered with a thick layer of flocculent organic matter.

Mid-channel benthic habitats were sampled quarterly between August 1995 and May 1997 in Pools A and C using a standard benthic coring device. Samples were processed using a 125 µm mesh sieve that likely retained early instars of most taxa. Mean annual density of macroinvertebrates within mid-channel benthic habitats of Pool A was 1005 individuals $m^{-2}$. Core taxa (those accounting for greater than 5% of total numbers, all dates combined) included Nematoda (23.0%), Acarina (9.7%), *Chironomus* sp. (12.5%), *Parachironomus* sp. (5.8%), *Polypedilum* sp. (5.8%), and *Ablabesmyia* sp. (5.8%). Of the core taxa, only *Polypedilum* sp. is considered a taxon characteristic of sand substrates. Members of the Tanytarsini group (including *Tanytarsus* sp., another taxa considered characteristic of sand substrates) also were present, but in very low numbers. Total macroinvertebrate mean annual density within mid-channel benthic habitats of Pool C was 1172 individuals $m^{-2}$. Core taxa included *Caenis diminuta* (18.4%), *Hyallela azteca* (8.8%), *Chaoborus* sp. (9.2%), *Microtendipes* sp. (12.2%), *Chironomus* sp. (9.2%), Tanytarsini group (7.6%), and *Labrundinia* sp. (6.1%). *Polypedilum* sp. also was present, but in very low numbers.

**Reference Conditions**

Historical data on invertebrate community structure in river channel sand habitats are not available for the Kissimmee River. The primary source of information on sand-dwelling macroinvertebrates within the pre-channelized Kissimmee River was derived from published data on community composition of sand-dwelling macroinvertebrates in the Ogeechee and Satilla Rivers, Georgia (Benke et al. 1984, Stites 1986). The Ogeechee River, a sixth-order, blackwater river in the lower Coastal Plain of Georgia, is characterized by low gradient, mean annual discharge of 66.8 $m^3\ s^{-1}$ (44 year period of record), mean annual temperature ranging from 3-32$^{\circ}$C (Stites 1986), and a river channel bottom consisting of 80-90% sand (Stites and Benke 1989). The Satilla River is a sixth-order, blackwater southeastern Coastal Plain river characterized by a very low gradient, low pH, high organic carbon, and high color (Benke et al. 1986). Additional information was derived from published reports and personal observations on the geographic distribution of sand-dwelling fauna occurring within or near the Kissimmee basin (Berner and Pescador 1988; Dunkle 1989; Epler 1992; Heard 1979; Merritt et al. 1996; Pescador et al. 1995; Toth 1991).

Within the Ogeechee and Satilla rivers, dominant sand-dwelling macroinvertebrates include: the dipterans *Corynoneura taris*, *Cladotanytarsus* sp., *Cryptochironomus* sp., *Lopescladius* sp., *Parakiefferiella* sp., *Rheosmittia* sp., *Robackia* sp.; the group Orthocladinae; Ceratopogonidae; Corbicula fluminea (Mollusca); and oligochaetes (Table 18-1). Based on habitat preferences and geographic distributions throughout Florida, other taxa likely to be present in sand habitats of the restored Kissimmee River include: the dipterans *Cricotopus* sp., *Polypedilum* sp., *Tanytarsus* sp., and *Thienemanniella* sp. (Epler 1992, Merritt et al. 1996); Ephemeroptera, including *Stenonema* sp. and *Cercobrachys* sp. (Berner and Pescador 1988); mollusks, including *Musculium/Pisidium* complex (Toth 1991); and Trichoptera, including *Oecetis* sp. and *Setodes* sp. (Merritt et al. 1996).

**Adjustments for External Constraints**

None

**Mechanism for Achieving Restoration**

Stites and Benke (1989) indicate that mid-channel habitats of the Ogeechee River are composed of sand generally void of organic deposits. Restoration of continuous, variable flow through remnant river channels of the Kissimmee River is expected to flush organic deposits, or redistribute existing sand to cover deposits. This response has been observed in revitalized channels of Pool B following the Kissimmee River Demonstration Project (Toth 1991, J.W. Koebel, SFWMD, personal observation).

Time to restoration of benthic macroinvertebrate communities will be a function of colonization rates, once habitat has been reestablished. Most taxa that make up the sandy benthic community of the Ogeechee River occur within the lower Kissimmee basin or adjacent watersheds, and many are likely to quickly colonize restored substrates. Colonization is likely to occur through adult oviposition and downstream transport (drift) of larvae. Because densities of aquatic invertebrates are highly variable within and between habitats and systems, it is not reasonable to predict specific densities of benthic invertebrates within restored sand habitats in the Kissimmee River. However, reference conditions do allow for the prediction of taxa that are characteristic of sandy habitats and likely to colonize restored substrates (Table 18-1). It is unlikely that all taxa will be present in restored habitats; however, the presence of representative taxa (Table 18-1) likely will show substantive change relative to the baseline condition, and therefore, be reasonable indicators of habitat restoration and biotic integrity.

**Means of Evaluation**

Sampling of river channel sand habitats will commence approximately six months following habitat restoration. Post-construction sampling methods will be identical to those outlined in Anderson et al. (1998), and include the collection of monthly, replicate (five), mid-channel benthic cores from randomly selected locations within remnant river channels in Pools A and reconnected channels in Pool C. Five samples also will be collected from permanently submerged portions of reestablished marginal channel sand bars in reconnected channels in Pool C. Replicate samples will be analyzed for macroinvertebrate species composition and habitat preference. Sampling of mid- and marginal channel benthic sand habitats will continue for three years following restoration of habitat structure. Community composition will be compared to the baseline condition and stated expectation.

**Time Course**

Habitat restoration will follow a successional pattern driven by the magnitude and duration of flow. It is likely that continuous, variable flows will result in restoration of mid- and marginal sand habitats within 24 to 36 months of reestablishing continuous flow. Results of the Pool B demonstration project (Toth 1993) indicate that organic deposits along 23 of 25 cross-sections in river channels were swept away or covered with a layer of clean sand following three years of restored flow. Periods of unusually high discharge will decrease the time frame associated with habitat restoration.

Once habitat has been restored, colonization by some taxa will be rapid. Chironomids are likely to colonize within 90 days, followed by early instar mayflies, caddisflies, and dragonflies within six to 12 months. Larger taxa, including clams and mussels, likely will colonize within one to two years.

Table 18-1. Sand-dwelling taxa in reference sites and the channelized Kissimmee River, and taxa likely to colonize restored sand habitats of the Kissimmee River.

| Taxon | Satilla River[1] | Ogeechee River[2] | Kissimmee-Pool A | Kissimmee-Pool C | Restored Kissimmee | Reference |
|---|---|---|---|---|---|---|
| Diptera | | | | | | |
| *Corynoneura* | X*** | X | | | X | Merritt et al. 1996 |
| *Cladotanytarsus* | X** | X | | | | |
| *Cryptochironomus* | X** | X | | | X | Merritt et al. 1996 |
| *Lopescalidius* | | X | | | X | Epler 1992 |
| *Parakiefferiella* | X*** | X | | | X | Epler 1992 |
| *Paracladoplelma* | | | | | X | Epler 1992 |
| *Polypedilum* | X** | X | X# | X# | X | Merritt et al. 1996 |
| *Rheosmittia* | | X | | | X? | Epler 1992 |
| *Robackia* | X*** | X | | | X | Epler 1992 |
| *Tanytarsus* | X** | | | | X | Merritt et al. 1996 |
| *Tanytarsini group* | | | X# | X# | X | Merritt et al. 1996 |
| *Thienemaniella* | X** | | | | X | Epler 1992 |
| Orthocladinae | | X | | | X | Epler 1992 |
| Ceratopogonidae | X*** | X | | | X | Merritt et al. 1996 |
| Ephemeroptera | | | | | | |
| *Stenonema* | | | | | X | Berner&Pescador 1988 |
| *Cercobrachys* | | | | | X | Berner&Pescador 1988 |
| Mollusca | | | | | | |
| *Musculium* | | | | | X | Toth 1991 |
| *Pisidium* | | | | | X | Toth 1991 |
| *Corbicula fluminea* | | X | | | X | Toth 1991 |
| Trichoptera | | | | | | |
| *Nectopsyche* | | | | | X | Pescador et al. 1995 |
| *Oecetis* | | | | | X | Merritt et al. 1996 |
| *Setodes* | | | | | X | Merritt et al. 1996 |

** = frequent
*** = abundant
# = rare
1 = Benke et al. 1984, 2 = Stites 1986

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## EXPECTATION 19

## NUMBER OF AMPHIBIANS AND REPTILES USING THE FLOODPLAIN

### Expectation

At least 24 wetland amphibian and reptile taxa will be found in restored Broadleaf Marsh habitats (i.e., those that currently exist as pasture).

### Author

Joseph W. Koebel Jr., South Florida Water Management District

### Date

July 20, 1998; Revised May 2, 2005

### Relevant Endpoints

Restoration - Biological Integrity - Community Structure
Restoration - Biological Integrity - Biodiversity
Restoration - System Functional Integrity - Habitat Quality
Restoration - System Functional Integrity - Habitat Use

### Metrics

Cumulative number of amphibian and reptile taxa

### Baseline Conditions

Visual encounter surveys (VES) and casual observations (visual and aural) were used to describe herpetofaunal species richness in pasture habitats of Pool A and C of the channelized Kissimmee River ecosystem. Visual encounter surveys were conducted monthly, along nine 50-meter long fixed transects, over a 12 month period in pasture habitats beginning in March 1998. Opportunistic observations of amphibians and reptiles were recorded from pasture habitats during this study and other non-herpetological studies from August 1995 through March 1999. Data indicate the occasional occurrence of wetland amphibians and reptiles in pasture habitats. Numbers in parentheses indicate total number of individuals observed (visually or aurally) or captured. Five wetland species including *Hyla cinerea* (nine), *Gastrophryne carolinensis* (seven), *Rana sphenocephala* (one), *Pseudacris ocularis* (one), and *Anolis carolinensis* (two) were identified along VES transects or casually observed in Pool A pasture. Three wetland species including *H. cinerea* (two), *G. carolinensis* (one), and *R. sphenocephala* (one), were identified along pasture VES transects or casually observed in Pool C pasture.

### Reference Conditions

Historical data on amphibian and reptile abundance and distribution in the Kissimmee River ecosystem are limited. However, some insight into herpetofaunal species richness of historic Kissimmee River marshes may be gained from herpetofaunal surveys of permanent wetlands of the Avon Park Bombing Range (APBR). The APBR borders the Kissimmee River in Pool A and B (Highlands and Polk Counties) and contains over 54,000 acres of natural wetlands, of which less than 5% have been directly disturbed or impacted. Franz et al. (2000) surveyed the APBR for sensitive herpetofaunal species between October 1996 and May 1998. Data from these surveys indicates that 24 wetland amphibian and reptile taxa are characteristic or frequently occur in permanent wetlands of the APBR (Table 19-1).

Additionally, Carr (1940) presents a comprehensive review of amphibian and reptile habitat distributions throughout Florida, and lists species that are characteristic, frequently occur, or are occasional within each habitat. Twenty-six taxa were identified by Carr (1940) as characteristic or frequently occurring in freshwater marshes of Florida (Table 19-1).

Samples from remnant broadleaf marsh in Pool C also provide reference conditions for taxa richness in marsh habitat. Visual encounter surveys were conducted monthly, along nine 50-meter long fixed transects, over a 31 month period from August 1995 through March 1998 in broadleaf marsh habitats in Pool C. Ten throwtrap samples also were collected monthly from March 1997 through February 1999 in remnant broadleaf marsh in Pool C. Nineteen amphibian and reptile taxa were captured or observed in remnant marsh during this period, of which 14 are considered characteristic or frequent inhabitants of permanent wetlands of central Florida (Carr 1940) (Table 19-1).

The expectation of at least 24 taxa in restored broadleaf marsh is based on limited reference conditions, which are not sufficient to predict the exact number of species expected to be found at a standard sample site. However, reference conditions are sufficient to estimate the number of taxa likely to occur in restored broadleaf marshes of the Kissimmee River. This estimate is primarily based on the presence of 24 wetland amphibian and reptile taxa described as characteristic or frequently occurring in undisturbed freshwater marshes of the APBR (Franz et al. 2000). These taxa are fairly consistent with those of Carr (1940). Although the species listed as characteristic or frequent in Table 19-1 represent those that are most common and ubiquitously distributed throughout undisturbed wetlands of central Florida, the expectation will be evaluated using all taxa listed in Table 19-1.

**Adjustments for External Constraints**

It is unlikely that any species of amphibian or reptile was extirpated following channelization. However, in the event of prolonged drought or other habitat-altering event (e.g., fire), amphibians and reptiles are likely to emigrate to more suitable habitat. The absence of herpetofauna from broadleaf marsh habitats during these periods should be viewed as temporal variability within the system, and not an indication that the expectation has not been achieved.

**Mechanism for Achieving Expectation**

Reestablishing a full range of hydrologic variation within floodplain pasture habitats including floodplain hydroperiod and variable depth patterns will be the impetus for reestablishment of broadleaf marsh vegetation and an aquatic invertebrate community necessary for colonization and persistence of amphibians and reptiles. Adult colonists likely will emigrate from existing wetland depressions within the pasture, or from the river's littoral zone. Colonization by larval amphibians also may occur from wetland depressions and littoral areas.

**Means of Evaluation**

Visual Encounter Surveys, larval amphibian sampling (throwtrap), and casual observations (visual and aural) will commence approximately 12 months following implementation of the revised headwaters regulation schedule, assuming that stage elevations within Pool C are sufficient to re-inundate floodplain habitats. Methods will be identical to those outlined in Donnelly et al. (1998) and Koebel et al. (2001), and include monthly sampling of replicate (nine) VES transects and monthly, replicate (ten) throwtrap samples from randomly selected locations within pasture habitat of Pool A and restored broadleaf marsh habitat (currently characterized as pasture) in Pool C. Surveys and samples will be analyzed for species richness, and the presence of characteristic or frequently occurring species, which can be used as indicators of habitat quality. Sampling will continue for three years following reestablishment of a characteristic broadleaf marsh plant community. Additional sampling may follow periodically (e.g., years five - six) to validate that the expectation has been achieved.

Table 19-1. Potential wetland taxa indicating restoration of amphibian and reptile community structure in reestablished broadleaf marsh habitats of the Kissimmee River floodplain. Taxa describe as "characteristic" and "frequent" are expected to comprise at least 75% of total species richness in restored marshes (Carr 1940, Franz et al. 2000).

| Taxa | Characteristic | Frequent | Occasional |
|---|---|---|---|
| Amphibians: | | | |
| *Acric gryllus dorsalis* (Florida Cricket Frog)[3] | X[1] | | |
| *Hyla cinerea* (Green Treefrog)[3] | X[2] | X[1] | |
| *Hyla squirella* (Squirrel Treefrog)[3] | | X | |
| *Pseudacris nigrita verrucosa* (Florida Chorus Frog)[3] | | X[2] | |
| *Pseudacris ocularis* (Little Grass Frog)[3] | X[1] | X[2] | |
| *Rana catesbeiana* (Bullfrog)[3] | | | X[1,2] |
| *Rana grylio* (Pig Frog)[3] | X[1] | X[2] | |
| *Rana sphenocephala* spp. (Florida/Southern Leopard Frog)[3] | X[1,2] | | |
| *Amphiuma means* (Two-Toed Salamander)[3] | | X[1,2] | |
| *Eurycea quadridigitata* (Dwarf Salamander)[3] | | X[2] | |
| *Notopthalmus viridescens piaropicola* (Peninsular Newt)[3] | | X[2] | |
| *Siren intermdeia intermedia* (Eastern Lesser Siren) | | X[2] | |
| *Siren lacertina* (Greater Siren)[3] | X[1] | X[2] | |
| Reptiles: | | | |
| *Alligator mississippinsis* (American Alligator) | X[2] | X[1] | |
| *Anolis carolinensis* (Green Anole)[3] | | X[2] | X[1] |
| *Chelydra serpentine osceola* (Florida Snapping Turtle) | | X[1] | X[2] |
| *Deirochelys reticularia chtysea* (Florida Chicken Turtle) | | X[1] | X[2] |
| *Pseudemys floridana peninsularis* (Peninsula Cooter) | | X[1,2] | |
| *Pseudemys nelsoni* (Florida Red-Bellied Turtle) | | X[1,2] | |
| *Terrapene carolina bauri* (Florida Box Turtle) | | | X[1] |
| *Kinosternon baurii* (Striped Mud Turtle) | | | X[2] |
| *Kinosternon subrubrum steindachneri* (Florida Mud Turtle) | | X[1] | X[2] |
| *Stenothernus odoratus* (Common Musk Turtle) | | X[1] | |
| *Trionyx ferox* (Florida Softshelled Turtle) | | X[1,2] | |
| *Storeria dekayi victa* (Florida Brown Snake) | | X[1,2] | |
| *Thamnophis sirtalis sirtalis* (Eastern Garter Snake) | | X[1,2] | |
| *Thamnophis sauritus sackenii* (Peninsula Ribbon Snake)[3] | X[1] | X[2] | |
| *Nerodia floridana* (Florida Green Water Snake) | X[1] | X[2] | |
| *Regina alleni* (Striped Crayfish Snake) | X[1] | X[2] | |
| *Farancia abacura abacura* (Eastern Mud Snake) | X[1,2] | | |
| *Seminatrix pygaea cyclas* (South Florida Swamp Snake) | X[1] | X[2] | |
| *Lampropelits getula floridana* (Florida Kingsnake) | X[1] | | |
| *Micrurus fulvius fulvius* (Eastern Coral Snake) | | X[1] | |
| *Agkistrodon piscivorus conanti* (Florida Cottonmouth)[3] | | X[1,2] | |
| *Sistrusus miliarius barbouri* (Dusky Pygmy Rattlesnake) | | X[2] | X[1] |

1 = Carr 1940
2 = Franz et al. 2000
3 = Koebel et al. 2001

**Time Course**

During the initial construction phase, it is unlikely that stage elevations within Pool C will be sufficient to inundate pasture habitat for an extended period. A stage sufficient to imitate historic inundation patterns in pasture will occur under the revised headwaters regulation schedule is implemented.

After appropriate hydrologic conditions are established, it is likely that wetland plant species will become established within one to two years (Toth 1993). Aquatic invertebrates also should respond quickly to reestablished hydroperiod, with representative densities of macroinvertebrates occurring within one to three years following inundation.

Restoration of amphibian and reptile community structures within restored broadleaf marsh habitat also is likely to be rapid. It is likely that the stated expectation will be achieved within three years following reestablishment of historic broadleaf marsh vegetation.

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# EXPECTATION 20

## USE OF FLOODPLAIN FOR AMPHIBIAN REPRODUCTION AND LARVAL DEVELOPMENT

### Expectation

Larval amphibians will be present in restored Broadleaf Marsh habitats (those that currently exist as pasture in the channelized system) for at least seven months each year.

### Author

Joseph W. Koebel Jr., South Florida Water Management District

### Date

July 15, 1998; Revised May 2, 2005

### Relevant Endpoints

Restoration - Biological Integrity - Reproductive Success/Recruitment
Restoration - System Functional Integrity - Habitat Quality
Restoration - System Functional Integrity - Habitat Use

### Metrics

Number of months per year with larval amphibians present

### Baseline Condition

Ten replicate 1-$m^2$ throwtrap samples were collected monthly from March 1997 through February 1999 in pasture habitats in Pool A and C. One *Rana sphenocephala* larva was found in pasture habitats in each pool during the only month that water was present in Pool A and C pastures during the March 1998 to February 1999 sampling period.

### Reference Condition

There are no historical data on amphibian abundance and reproductive phenology in the Kissimmee River ecosystem. However, monthly samples from remnant broadleaf marsh in Pools A and C (Table 20-1) provide some useful data on the temporal occurrence of larval amphibians in marsh habitat. When there was water in Pool A broadleaf marsh, larvae were present seven of nine months in 1997–1998 and one of seven months in 1998–1999. When there was water in Pool C broadleaf marsh, larvae were present six of nine months in 1997–1998 and one of seven months in 1998–1999.

The expectation of larval amphibians occurring during at least seven months each year in restored broadleaf marsh is based on limited data from remnant marshes in Pools A and C, which are not sufficient to predict temporal patterns of occurrence for specific taxa. However, in the tropics, amphibian breeding activity often is continuous, with some species in breeding readiness at all times (Stebbins and Cohen 1995). Due to the sub-tropical climate of the Kissimmee River ecosystem, and its historical long-term floodplain inundation frequencies, it is likely that some larval amphibians were present in floodplain marshes throughout much of the year. The seven-month prediction is a conservative estimate based on the occurrence of larval amphibians in remnant, but altered broadleaf marsh habitats of the channelized Kissimmee River. Table 20-2 lists amphibians known to use remnant floodplain habitats for reproduction, and their breeding periods.

**Adjustments for External Constraints**

It is unlikely that any amphibian species were extirpated following channelization. During periods of extreme drought and floodplain drying, larval amphibians will be absent from floodplain wetland habitats. This absence should be viewed as a temporary effect of an unpredictable climatic event (drought), and not an indication that the restoration expectation has not been achieved.

Table 20-1. Monthly occurrence of larval amphibians in altered broadleaf marsh (BLM) and pasture habitats (UP) of the channelized Kissimmee River. Underlined months indicate that water was present on the floodplain.

Pool A BLM

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1997 | | | | | | | | | | | | 1998 | | | | | | |
| | A | M | **J** | J | **A** | **S** | **O** | **N** | **D** | | **J** | **F** | **M** | **A** | M | J | **J** | **A** | **S** | **O** | **N** | D | **J** |
| Anurans | | | | | | | | | | | | | | | | | | | | | | | |
| *Gastrophryne carolinensis* | | | X | | | | | | | | | | | | | | | | | | | | |
| *Hyla cinerea* | | | | | | X | | | | | | | | | | | | | | | | | |
| *Hyla femoralis* | | | | | | | | | | | | | X | | | | | | | | | | |
| *Hyla squirella* | | | | | X | | | | | | | | | | | | | | | | | | |
| Hylidae | | | X | | | | | | | | | | | | | | | | | | | | |
| *Rana catesbeiana* | | | X | | | | | | | | | | | | | | | | | | | | |
| *Rana sphenocephala* | | | | | | | | | X | | | X | | | | | | | | | | | |
| Salamanders | | | | | | | | | | | | | | | | | | | | | | | |
| *Eurycea quadridigitata* | | | | | | | | | X | | X | X | X | | | | | | | | | | X |

Pool C BLM

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1997 | | | | | | | | | | | | 1998 | | | | | | |
| | A | M | **J** | J | **A** | **S** | **O** | **N** | **D** | | **J** | **F** | **M** | **A** | M | J | **J** | **A** | **S** | **O** | **N** | D | **J** |
| Anurans | | | | | | | | | | | | | | | | | | | | | | | |
| *Acris gryllus* | | | | | | | | | | | | | | | | | | X | | | | | |
| *Hyla cinerea* | | | | | | | | | | | | | X | | | | | | | | | | |
| *Hyla femoralis* | | | | | | | | | | | | | | | | | | X | | | | | |
| Hylidae | | | | | | | | | | | | | X | | | | | | | | | | |
| *Pseudacris nigrita* | | | | | | | X | | | | | | | | | | | | | | | | |
| *Pseudacris ocularis* | | | | | | | X | X | X | X | | | | | | | | | | | | | |
| *Rana grylio* | | | | | | | X | | | | | | X | | | | | | | | | | |
| *Rana sphenocephala* | | | | | | | | | X | | | X | X | | | | | | | | | | |

Pool A UP

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1998 | | | | | | |
| | **M** | A | M | J | J | A | S | O | N | D | J | F |
| Anurans | | | | | | | | | | | | |
| *Rana sphenocephala* | X | | | | | | | | | | | |

Pool C UP

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1998 | | | | | | |
| | **M** | A | M | J | J | A | S | O | N | D | J | F |
| Anurans | | | | | | | | | | | | |
| *Rana sphenocephala* | X | | | | | | | | | | | |

### Mechanism for Achieving Expectation

Reestablishment of hydroperiods and variable depth patterns on floodplain pastures will be the impetus for reestablishment of broadleaf marsh vegetation that will support a herpetofaunal community characteristic of permanent wetlands of central Florida. Restored historic floodplain inundation characteristics are expected to provide suitable hydrologic conditions for near year-round reproduction by adult amphibians and successful completion of development by larval amphibians. It is likely that a continuous depth >10 cm will be necessary for completion of larval development for most amphibians.

### Means of Evaluation

Larval amphibian sampling will commence approximately 12 months following implementation of the revised headwaters upper basin regulation schedule, if resultant stages within Pool C are sufficient to re-inundate pasture habitats to a depth >10 cm. Monthly, replicate (ten) throwtrap samples will be taken from randomly selected locations within pasture habitat of Pool A and restored broadleaf marsh habitat (currently characterized as pasture) in Pool C. Samples will be analyzed for the presence of larval amphibians. Sampling will continue for a minimum of three years to confirm that persistent amphibian reproduction is occurring each year.

### Time Course

Inundation of Pool C floodplain habitats to a depth and duration necessary for initiation of amphibian reproduction is likely after the revised headwaters upper basin regulation schedule is implemented. Adult amphibians should quickly respond to restored hydrologic patterns. Reproduction of amphibians likely will be evident within 12 months following restoration of historic inundation frequencies. It is likely that this expectation will be achieved within three years after reestablishment of historic broadleaf marsh vegetation characteristics.

Table 20-2. Florida breeding periods for amphibians likely to colonize restored broadleaf marsh (currently characterized as pasture). Breeding periods are from Mount (1975) and Conant and Collins (1991).

| | Spring | Summer | Autumn | Winter |
|---|---|---|---|---|
| Taxa | X | X | X | X |
| *Acris gryllus dorsalis* | X | X | X | |
| *Gastrophryne carolinensis* | X | X | X | |
| *Hyla cinerea* | X | X | X | |
| *Hyla femoralis* | X | X | X | |
| *Hyla squirella* | X | X | X | |
| *Pseudacris nigrita* | X | X | X | X |
| *Pseudacris ocularis* | X | X | X | X |
| *Rana catesbeiana* | X | X | X | |
| *Rana grylio* | X | X | X | X |
| *Rana sphenocephala* | X | X | X | X |
| *Eurycea quadridigitata* | X | | X | X |

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# EXPECTATION 21

## DENSITIES OF SMALL FISHES WITHIN FLOODPLAIN MARSHES

### Expectation

Mean annual density of small fishes (fishes <10 cm total length) within restored marsh habitats will be ≥ 18 fish/$m^2$.

### Author

J. Lawrence Glenn III, South Florida Water Management District

### Date

March 23, 1999; revised May 2002

### Relevant Endpoints

Restoration - Biological Integrity - Population abundance
Restoration - Biological Integrity - Food Web Structure
Restoration - System Functional Integrity - Habitat Quality
Restoration - System Functional Integrity - Habitat Use
Restoration - System Functional Integrity - River/Floodplain Interactions

### Metrics

Mean annual density of small fishes

### Baseline Condition

Channelization of the Kissimmee River led to drainage of approximately 8,000 ha of floodplain wetlands. Two types of wetlands remain in the channelized system: small, isolated marshes that are shallow and ephemeral (driven by seasonal rainfall); and impounded wetlands in the lower ends of each pool, which also are shallow and lack substantial water level fluctuations. Impounded wetlands are inhospitable for large-bodied (adults >10 cm total length) fishes due to shallow depth, but support populations of small-bodied (adults <10 cm total length) fishes.

Two types of remnant impounded wetlands, Broadleaf Marsh (BLM, Bousquin 2005) and Woody Shrub (*Myrica cerifera* Floating Mat Shrubland Bcode group; S.CMF), were sampled within Pools A, C, and D between August 1996 and January 1999 by collecting ten random $m^3$ throw trap samples. Broadleaf Marsh in Pool A and S.CMF in Pool D served as Control sites, while both habitats in Pool C served as Impact sites. First year sampling was conducted quarterly, with monthly sampling beginning in August 1997 and continuing through January 1999. Pasture (Upland Herbaceous Bcode group; UP) habitat also was sampled because it is expected to revert to BLM following restoration. Pasture in Pools A (Control site) and C (Impact site) was sampled for 11 months between March 1998 and January 1999. For BLM and S.CMF, each sampling year is based on a complete wet (June–November) and dry (December–May) season. Because of changes in frequency of sampling, annual means were calculated from four sample events the first year, ten in the second, and eight in the third. Mean annual fish density, averaged for the three study years, was 1.7 fish/m$^2$ and 1.5 fish/m$^2$ at BLM Control and Impact sites, respectively (Table 21-1). Mean annual fish density was greater within S.CMF and slightly higher at S.CMF Impact sites (5.4 fish/m$^2$) than at S.CMF Control sites (3.9 fish/m$^2$)(Table 21-1). Mean monthly fish density did not exceed 0.3 fish/m$^2$ at pasture sites (Table 21-1).

Table 21-1. Mean ± standard error annual density (fish/m$^2$) of fishes collected from Broadleaf Marsh (BLM) and Woody Shrub (S.CMF) habitats at Control and Impact sites during baseline sampling. Density values for Pasture (UP) habitat are monthly sample means because data were collected only over a single year.

| Habitat | Control | Impact |
|---|---|---|
| BLM | 1.7 ± 1.5 | 1.5 ± 1.1 |
| S.CMF | 3.9 ± 2.5 | 5.4 ± 1.1 |
| UP | 0.3 ± 0.3 | 0.2 ± 0.2 |

**Reference Conditions**

Historical data on floodplain fish community structure of the Kissimmee River are limited to a single sample (FGFWFC 1957) taken one year after extreme drought conditions and therefore may not accurately reflect fish density within historic marsh habitat. However, these data indicate fish use of the historic floodplain. Consequently, reference conditions were derived from quantitative studies from comparable marsh ecosystems of south and central Florida.

Fish density data for marshes of south and central Florida were compiled and summarized from published papers, theses, technical reports, and unpublished data (Jordan et al. 1999). A total of 5314 independent samples were synthesized strictly from enclosure methods with clearly defined sampling areas capable of providing quantitative density estimates. Sample locations included marshes of the Everglades, marshes associated with lakes (including Lake Okeechobee) and canals, and marshes associated with rivers (including the upper St. Johns River). Sample methods included throw traps, Wegner rings, and block nets. Habitat types at sample locations were defined according to dominant vegetation taxa present, and only data for marshes characterized by emergents (i.e., *Pontedaria* sp., *Sagittaria* sp., *Peltandra* sp.) were included for deriving the reference condition for Kissimmee River marshes. Mean fish density was calculated by averaging sample density across studies and was 23.4 (± 0.9) fish/m$^2$ (Figure 21-1).

The success criterion of ≥ 18 fish/m$^2$ is approximately 80% of the mean density of small fishes in marshes of south and central Florida (Figure 21-1). Although conservative, this expected value accounts for the natural variability of floodplain fish communities.

**Adjustment for External Constraints**

None

**Mechanism for achieving restoration**

Reestablishment of historic hydrologic characteristics will restore floodplain habitats, including marsh within areas that currently exist as UP and S.CMF (Toth et al. 1995). Restoration of floodplain fish populations will occur through re-colonization by fish species that occur within inundated floodplain habitats and adjacent river channels.

Marsh fish populations are highly dynamic, and fish density will fluctuate according to water depth, hydroperiod, stem density of emergent vegetation, prey availability, composition of predator assemblages, and areal coverage of floodplain inundation (Welcomme 1979, Kushlan 1980, Savino and Stein 1982, Lowe 1986, Heck and Crowder 1991, Loftus and Eklund 1994, Jordan et al. 1996, 1998). Small fish density is expected to be positively correlated with duration of inundation (Loftus et al. 1990, Loftus and Eklund 1994). In *Eleocharis* marshes (dominant vegetation of *Eleocharis cellulosa*, *Panicum hemitomon*, *Sagittaria* spp., and *Rhynchospora tracyi*) of the southern Everglades, Loftus and Eklund (1994) found annual mean fish density increased from 15.5 fish/m$^2$ (± 1.6 fish/m$^2$) to 30.2 fish/m$^2$ (± 2.8 fish/m$^2$) with increased hydroperiod. Long hydroperiod marshes exhibit increased detrital production that support large numbers of invertebrate prey (Murkin and Kadlec 1986). Increased fish density will be due primarily to increased prey abundance (Jordan 1997).

Although long hydroperiods and increased inundation depths are expected to lead to increased numbers of large predatory fishes on the floodplain (Loftus and Eklund 1994), densities of small fishes are not expected to be influenced by predation during these periods. The expected spatial mosaic of deeper, open areas, and shallower, vegetated areas will provide habitat for both large and small fishes, which will reduce the potential for predation. In the presence of predatory species, small fishes seek cover in dense vegetation, while larger, predatory fishes tend to remain in deeper, open water areas where their movement is not restricted (McIvor and Odom 1988, Savino and Stein 1989, Heck and Crowder 1991, Chick and McIvor 1997).

During periods of limited floodplain inundation, fishes will concentrate in depressions within the marsh landscape, resulting in high densities. Survivors from these events will re-colonize floodplain habitats during more favorable hydrologic conditions.

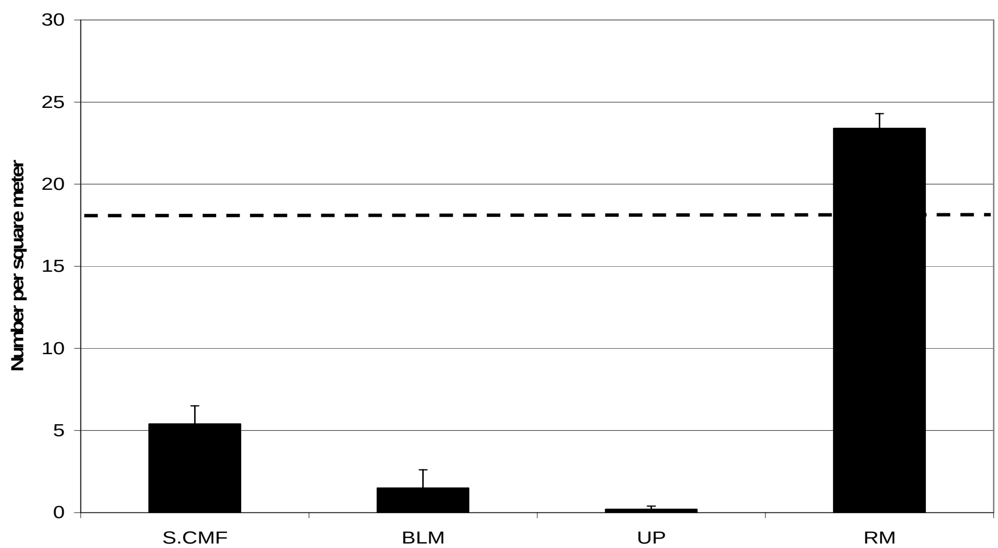


Figure 21-1. Mean density of fishes collected from Broadleaf Marsh (BLM), Woody Shrub (S.CMF), and Pasture (UP) habitats of the Kissimmee River under baseline conditions and from reference marshes (RM) of south and central Florida. Dashed line indicates expected value following restoration.

## Means of Evaluation

Throw trap sampling will begin immediately following inundation of existing marsh habitats. Suitable conditions will be associated with implentation of the planned Headwaters Revitilization Schedule. Post-construction sampling of Woody Shrub and pasture habitats will occur when marsh reestablishes, which is expected two to three years following inundation (Toth et al. 1995). Throw trap sampling provides accurate density estimates of small fishes within heavily vegetated habitats (Kushlan 1981, Freeman et al. 1984, Jacobsen and Kushlan 1987, Chick et al. 1992, Jordan et al. 1997). Methods will be identical to those used for baseline studies (Glenn 2002), including monthly collection of ten random samples in each habitat. A sample mean will be calculated each month by averaging the ten replicate throw trap samples for a habitat. Twelve monthly sample means will be averaged to determine mean monthly density. Sampling will be conducted for three-year periods beginning on the first and sixth years following floodplain inundation associated with implementation of the Final Headwaters Regulation Schedule. Mean annual density will be generated for each three-year block of post-restoration data. The expectation will be achieved when mean annual fish density for any three-year period exceeds 18 fish/m$^2$.

Seasonal effects (especially prolonged floodplain inundation during the wet season) on small fish densities are expected to be reflected in annual means. Although this expectation is based on mean annual density, data also will be analyzed to evaluate the potential significance of seasonality.

**Time Course**

Small fish will begin migrating onto floodplain habitats immediately following inundation. However, maintenance of floodplain fish communities requires restoration of lower trophic levels. Results of the Kissimmee River Demonstration Project (Toth 1993) and test fill project indicate colonization of wetland plant species on re-inundated floodplain can be rapid. Harris et al. (1995) have suggested reestablishment of the historic invertebrate community may take three to eight years. However, this time frame could be considerably shorter (one year) if representative vegetation and associated periphyton communities become established (J. Koebel, SFWMD personal communication). Establishment of small fish populations resembling those of the pre-channelized system is expected to occur within three to eight years following reestablishment of BLM. Restoration time frames may require adjustment if appropriate hydrologic characteristics are not met or are delayed.

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# EXPECTATION 22

# RIVER CHANNEL FISH COMMUNITY STRUCTURE

### Expectation

Mean annual relative abundance of fishes in the restored river channel will consist of ≤1% bowfin *Amia calva*, ≤3% Florida gar *Lepisosteus platyrhincus*, ≥16% redbreast sunfish *Lepomis auritus*, and ≥58% centrarchids (sunfishes).

### Author

J. Lawrence Glenn III, South Florida Water Management District

### Date

May 20, 1999; revised April 2002

### Relevant Endpoint(s)

Restoration - Biological Integrity - Community Structure
Restoration - System Functional Integrity - Habitat Quality
Sociopolitical - Numbers of Game Fish

### Metrics

Percent of total number of fishes collected that are *A. calva*
Percent of total number of fishes collected that are *L. platyrhincus*
Percent of total number of fishes collected that are *L. auritus*
Percent of total number of fishes collected that are centrarchids

### Baseline Conditions

Channelization of the Kissimmee River altered hydrologic, geomorphic, and dissolved oxygen characteristics of the river. Dissolved oxygen regimes of remnant river channels persist at the tolerance threshold (2.0 ppm) for many fish species (Moss and Scott 1961, Davis 1975, Smale and Rabeni 1995, Matthews 1998) and periodically reach critically low levels (<0.5 ppm) during summer months (Toth 1993, Koebel 1995), allowing tolerant species (i.e., *L. platyrhincus*, *A. calva*) to displace less tolerant species (Matthews 1998). Increased coverage of in-channel vegetation also has favored an increase in relative abundance of *A. calva* and *L. platyrhincus*, which prefer densely vegetated, lentic habitats (Lee et al. 1980, Meffe & Snelson 1989).

Annual electrofishing was conducted within remnant river channels from June 1992 to 1994 by Florida Game and Freshwater Fish Commission (FGFWFC). Dominant species (>5% of mean annual relative abundance) at Control sites in Pool A included *L. platyrhincus* (36.8%), *L. macrochirus* (19.9%), *A. calva* (8.4%), and *Micropterus salmoides* (7.9%) (Table 22-1). Community composition at Impact sites (Pool C) was similarly dominated by *L. platyrhincus* (19.6%), *L. macrochirus* (16.5%), and *M. salmoides* (9.5%), but also included *G. holbrooki* (16.9%)

and *Notemigonus crysoleucas* (11.7%) (Table 22-1). Centrarchids accounted for only 31.8% and 38.3% of the fish communities in Pool A and C, respectively (Table 22-1).

Table 22-1. Mean ± standard error annual relative abundance (percentage of total numbers) of fish species sampled during baseline conditions within remnant river channels of the Kissimmee River by electrofishing.

| Species | Common Name | FGFWFC Electrofishing 1992-1994 | |
|---|---|---|---|
| | | Pool A | Pool C |
| *Ameiurus natalis* | yellow bullhead | -- | 0.5 ± 0.2 |
| *Ameiurus nebulosus* | brown bullhead | 0.07 ± 0.07 | 0.3 ± 0.1 |
| *Amia calva* | bowfin | 8.3 ± 2.5 | 4.4 ± 0.7 |
| *Clarias batrachus* | walking catfish | 0.4 ± 0.4 | 1.4 ± 0.4 |
| *Dorosoma cepedianum* | gizzard shad | 0.2 ± 0.2 | -- |
| *Dorosoma petenense* | threadfin shad | 0.06 ± 0.06 | -- |
| *Elassoma okeefenokei* | Okeefenokee pygmy sunfish | -- | 0.1 ± 0.1 |
| *Ennecanthus gloriosus* | bluespotted sunfish | 0.1 ± 0.1 | 0.5 ± 0.2 |
| *Erimyzon sucetta* | lake chubsucker | 1.4 ± 0.5 | 3.9 ± 1.2 |
| *Esox niger* | chain pickerel | 0.3 ± 0.1 | 0.3 ± 0.1 |
| *Etheostoma fusiforme* | swamp darter | -- | 0.1 ± 0.05 |
| *Fundulus chrysotus* | golden topminnow | 0.3 ± 0.2 | 0.4 ± 0.3 |
| *Gambusia holbrooki* | mosquitofish | 4.5 ± 2.4 | 16.9 ± 9.0 |
| *Heterandria formosa* | least killifish | 0.2 ±0.2 | 0.7 ± 0.6 |
| *Jordanella floridae* | flagfish | -- | 0.2 ± 0.2 |
| *Labidesthes sicculus* | brook silverside | 0.2 ± 0.2 | 0.1 ± 0.1 |
| *Lacania goodei* | bluefin killifish | -- | 0.2 ± 0.2 |
| *Lepisosteus osseus* | longnose gar | -- | 0.1 ± 0.05 |
| *Lepisosteus platyrhincus* | Florida gar | 36.8 ± 2.9 | 19.6 ± 3.0 |
| *Lepomis gulosus* | warmouth | 1.6 ± 0.4 | 4.8 ± 1.6 |
| *Lepomis macrochirus* | bluegill | 19.1 ± 4.8 | 16.5 ± 4.0 |
| *Lepomis marginatus* | dollar sunfish | -- | 0.3 ± 0.1 |
| *Lepomis microlophus* | redear sunfish | 2.6 ± 1.0 | 4.4 ± 0.9 |
| *Lepomis punctatus* | spotted sunfish | 0.1 ± 0.1 | 1.5 ± 0.7 |
| *Micropterus salmoides* | largemouth bass | 7.9 ± 3.5 | 9.4 ± 0.7 |
| *Notemigonus crysoleucas* | golden shiner | 14.4 ± 5.5 | 11.7 ± 4.3 |
| *Poecilia latipinna* | sailfin molly | 0.1 ± 0.1 | 0.2 ± 0.1 |
| *Pomoxis nigromaculatus* | black crappie | 0.3 ± 0.1 | 0.9 ± 0.02 |

**Reference Conditions**

Reference conditions were derived from comparable peninsular Florida river systems, including the St. Johns, Withlacooche and Oklawha Rivers.

Electrofishing data from the St. Johns, Withlacoochee, and Oklawaha Rivers were collected annually during the autumn low water period from 1983 to 1990. All three rivers are located entirely within or have headwaters originating in peninsular Florida below the Suwannee and St. Johns drainages, the demarcation between peninsular and northern fish assemblages (Swift et al. 1986, Gilbert 1987). All rivers have undergone varying degrees of anthropogenic alteration that include channelization, impoundment, and point sources of pollution (Bass 1991, Estevez et al. 1991, Livingston 1991, Livingston and Fernald 1991) so are not pristine reference sites for the historic Kissimmee. However, data from these rivers provide information on the composition of riverine fish communities within peninsular Florida.

*Lepomis auritus* and *L. macrochirus* were dominant in each peninsular river with mean annual relative abundance exceeding 18% (range: 18.7–23.2%) and 14% (range: 14.8–35.0%), respectively (Table 22-2). Other centrarchids contributing greater than 5% mean annual relative abundance included *L. punctatus, L. microlophus, L. gulosus*, and *M. salmoides* (Table 22-2). *Gambusia holbrooki* and *Notropis petersoni* were the remaining dominant species in the Withlacoochee River, while *N. crysoleucas* and *Fundulus seminolis* contributed greater than 5% in the St. Johns River (Table 22-2). Centrarchids collectively comprised ≥ 70% of the river channel fish community in all peninsular Florida rivers (Table 22-3).

Four relative abundance metrics show strong differences between baseline and reference conditions (Table 22-4). Relative abundances of *L. platyrhincus* and *A. calva* are typically higher in river systems with degraded water quality (Champeau 1990, Bass 1991). Relative abundance of *L. auritus* is positively correlated with increased flow (Aho and Terrell 1986). Relative abundances of *L. platyrhincus* and *A. calva* are influenced by flow-dependent habitat availability, and both species prefer little to no flow and abundant aquatic vegetation. (Lee et al. 1980, Mettee et al. 1996). Reestablishment of historic sand substrate and sandbars will increase spawning habitat for *L. auritus* and other centrarchids (Carlander 1977, Struber et al. 1982, Aho and Terrell 1986). Increased recruitment will result from reestablishment of the river channel-floodplain linkage that historically provided floodplain habitat as refugia for juveniles (FGFWFC 1957). The remaining metric, percent centrarchid composition, was chosen because peninsular Florida river systems are typically dominated by centrarchids (Swift et al. 1986, Gilbert 1987)(Table 22-3).

Success criteria are approximately 80% of the mean value for each species or family in the reference rivers (Figure 22-1). Although conservative, these expected values account for the natural variability of riverine fish communities and potential use of the river channel by non-indigenous species that were introduced since channelization.

### Adjustments for External Constraints

Increased fishing pressure may impact age structure of centrarchids through removal of larger individuals, because most centrarchid species are commonly sought game fish. Reproductive potential of breeding populations is diminished by the reduction of large individuals because larger fishes are more fecund (Lack 1954, Hubbs et al. 1968, Wooten 1984). This can potentially affect strength of year classes recruiting into breeding populations, thereby reducing the number of potential spawners.

Exotic fish species may impact the centrarchid community through interspecific competition for available resources. Seven species of exotic fishes (*Astronotus ocellatus* - oscar, *Clarias batrachus* - walking catfish, *Ctenopharyngodon idella* - grass carp, *Cyprinus carpio* - common carp, *Hoplosternum littorale* - armored catfish, *Hypostomus plecostomus* - suckermouth catfish, *Oreochromis aureus* - blue tilapia) currently occur within the channelized Kissimmee River system. Several of these species possess adaptations for survival in less than optimal conditions (i.e., capable of breathing air and locomotion over land), and often thrive in newly disturbed habitats (Courtenay and Hensley 1979), such as those that may occur during restoration construction phases. Established exotic communities can outcompete indigenous centrarchid communities for food, spawning areas, and space (Courtenay and Hensley 1979). However, during baseline sampling, exotics comprised only 1.5% of the river channel fish community. Potential impacts of exotic species could increase if new species are introduced into the system (Table 22-5).

### Mechanism for Achieving Restoration

Reestablishment of a fish community similar to the historic Kissimmee River system requires restoration of riverine habitats that match the habitat requirements of the historic community (Sheldon & Meffe 1995). Reestablishment of historic hydrologic characteristics will be the mechanism driving restoration of river channel habitat and associated change in all metrics. Restoration of continuous discharge through reconnected river channels will increase dissolved oxygen levels by turbulent mixing and flushing of accumulated organic deposits, reducing biological oxygen demand (Toth 1993, 1996). Dissolved oxygen profiles are expected to be less stratified (especially during summer months) with higher dissolved oxygen levels throughout the water column. Increased dissolved oxygen levels will allow less tolerant taxa to better compete with tolerant taxa (Matthews

1998). The selective advantage of air breathing gained by *A. calva* and *L. platyrhincus* under baseline conditions will be reduced as increased dissolved oxygen regimes are restored.

Table 22-2. Mean ± standard error annual relative abundance of fishes collected by electrofishing by Florida Game and Fresh Water Fish Commission between 1983 and 1990 in the St. Johns (STJ), Oklawaha (OKL), and Withlacoochee (WIT) Rivers.

| Species | Common Name | STJ | OKL | WIT |
|---|---|---|---|---|
| *Alosa sapidissima* | American shad | 0.02 ± 0.01 | 0.3 ± 0.04 | -- |
| *Ameiurus catus* | white catfish | 0.3 ± 0.2 | 0.1 ± 0.04 | 0.1 ± 0.01 |
| *Ameiurus natalis* | yellow bullhead | 0.1 ± 0.01 | 0.5 ± 0.2 | 0.1 ± .06 |
| *Ameiurus nebulosus* | brown bullhead | 0.3 ± 0.1 | 0.1 ± 0.03 | 0.04 ± 0.02 |
| *Amia calva* | bowfin | 0.6 ± 0.2 | 0.8 ± 0.1 | 1.3 ± 0.4 |
| *Anguilla rostrata* | American eel | 0.2 ± 0.1 | -- | 0.1 ± 0.05 |
| *Aphredoderus sayanus* | pirate perch | 0.03 ± 0.01 | 2.0 ± 0.4 | 0.9 ± 0.4 |
| *Centrarchus macropterus* | flier | 0.01 ± 0.01 | -- | -- |
| *Dorosoma cepedianum* | gizzard shad | 0.9 ± 0.4 | 0.3 ± 0.2 | 0.03 ± 0.02 |
| *Dorosoma petenense* | threadfin shad | 0.3 ± 0.2 | 0.05 ± 0.02 | 0.04 ± 0.03 |
| *Elassoma evergladei* | Everglades pygmy sunfish | -- | 0.01 ± 0.01 | 0.07 ± 0.02 |
| *Elassoma zonatum* | banded pygmy sunfish | -- | 0.01± 0.01 | -- |
| *Ennecanthus gloriosus* | bluespotted sunfish | 0.03 ± 0.02 | 0.02 ± 0.01 | 0.5 ± 0.2 |
| *Erimyzon sucetta* | lake chubsucker | 0.6 ± 0.1 | 2.5 ± 0.3 | 1.6 ± 0.4 |
| *Esox americanus* | redfin pickerel | -- | 0.03 ± 0.01 | 0.2 ± 0.1 |
| *Esox niger* | chain pickerel | 0.08 ± 0.01 | 0.6 ± 0.1 | 0.1 ± 0.03 |
| *Etheostoma fusiforme* | swamp darter | -- | 0.6 ± 0.2 | 0.2 ± 0.08 |
| *Fundulus chrysotus* | golden topminnow | -- | 0.01 ± 0.01 | 0.1 ± 0.06 |
| *Fundulus seminolis* | Seminole killifish | 6.0 ± 1.8 | 0.1 ± 0.07 | 0.1 ± 0.04 |
| *Gambusia holbrooki* | mosquitofish | 0.3 ± 0.2 | 0.5 ± 0.1 | 6.4 ± 2.3 |
| *Heterandria formosa* | least killifish | 0.03 ± 0.03 | -- | 0.1 ± 0.04 |
| *Ictalurus punctatus* | channel catfish | 0.1 ± 0.06 | 0.02 ± 0.01 | 0.03 ± 0.02 |
| *Jordanella floridae* | flagfish | 0.03 ± 0.03 | -- | 0.01 ± 0.01 |
| *Labidesthes sicculus* | brook silverside | 0.4 ± 0.1 | 1.5 ± 0.3 | 2.7 ± 1.2 |
| *Lacania goodie* | bluefin killifish | 0.1 ± 0.05 | 0.03 ± 0.01 | 0.2 ± 0.1 |
| *Lepisosteus osseus* | longnose gar | 0.1 ± 0.03 | 0.2 ± 0.04 | 0.2 ± 0.03 |
| *Lepisosteus platyrhincus* | Florida gar | 2.4 ± 0.4 | 1.3 ± 0.2 | 2.9 ± 0.9 |
| *Lepomis auritus* | redbreast sunfish | 18.7 ± 1.2 | 23.2 ± 1.6 | 19.2 ± 2.9 |
| *Lepomis gulosus* | warmouth | 1.3 ± 0.2 | 4.9 ± 0.5 | 6.1 ± 0.4 |
| *Lepomis macrochirus* | bluegill | 35.0 ± 1.1 | 27.7 ± 2.4 | 14.8 ± 2.8 |
| *Lepomis marginatus* | dollar sunfish | 0.03 ± 0.03 | 0.1 ± 0.04 | 2.5 ± 0.7 |
| *Lepomis microlophus* | redear sunfish | 8.1 ± 1.1 | 9.3 ± 0.6 | 6.7 ± 1.8 |
| *Lepomis punctatus* | spotted sunfish | 3.4 ± 0.3 | 10.7 ± 1.5 | 18.5 ± 2.1 |
| *Lucania parva* | rainwater killifish | 0.05 ± 0.03 | -- | -- |
| *Menidia beryllina* | inland silverside | 0.7 ± 0.3 | 0.01 ± 0.01 | -- |
| *Menidia peninsulae* | tidewater silverside | 0.5 ± 0.4 | -- | -- |
| *Micropterus salmoides* | largemouth bass | 4.8 ± 0.2 | 5.3 ± 0.4 | 5.8 ± 2.3 |
| *Morone saxatilis* | striped bass | 0.02 ± 0.02 | -- | -- |
| *Morone sp.* | sunshine bass | 0.1 ± 0.1 | -- | -- |
| *Mugil cephalus* | striped mullet | 2.7 ± 0.3 | 0.1 ± 0.04 | 0.1 ± 0.07 |
| *Myrophis punctatus* | speckled worm eel | -- | -- | 0.01 ± 0.01 |
| *Mugil curema* | white mullet | 0.03 ± 0.03 | -- | -- |
| *Notemigonus crysoleucas* | golden shiner | 6.3 ± 0.8 | 1.7 ± 0.3 | 0.5 ± 0.1 |
| *Notropis maculates* | taillight shiner | 1.5 ± 2.4 | 0.8 ± 0.2 | 0.6 ± 0.1 |
| *Notropis petersoni* | coastal shiner | 0.01 ± 0.01 | 2.0 ± 0.6 | 5.6 ± 2.3 |
| *Noturus gyrinus* | tadpole madtom | -- | 0.04 ± 0.01 | 0.3 ± 0.1 |
| *Noturus leptacanthus* | speckled madtom | -- | 0.06 ± 0.01 | -- |
| *Opsopoedus emilidae* | pugnose minnow | 0.1 ± 0.1 | 0.01 ± 0.01 | -- |
| *Oreochromis aureus* | blue tilapia | 0.05 ± 0.02 | 0.01 ± 0.01 | -- |
| *Percine nigofasciata* | blackbanded darter | -- | 1.3 ± 0.4 | -- |
| *Poecilia latipinna* | sailfin molly | 0.03 ± 0.03 | 0.1 ± 0.05 | 0.5 ± 0.1 |
| *Pomoxis nigromaculatus* | black crappie | 2.1 ± 0.3 | 0.5 ± 0.1 | 0.3 ± 0.2 |
| *Strongylura marina* | Atlantic needlefish | 0.8 ± 0.3 | 0.05 ± 0.01 | 0.08 ± 0.04 |
| *Trinectes maculates* | hogchoker | 0.03 ± 0.02 | 0.02 ± 0.01 | 0.2 ± 0.1 |

Table 22-3. Percent contribution by centrarchids collected using electrofish sampling within three peninsular Florida Rivers between 1983 and 1990 and the Kissimmee River between 1992 and 1994. (Kissimmee River - KIS, St. Johns River - STJ, Oklawaha River - OKL, Withlacoochee River - WIT).

| Species | KIS | STJ | OKL | WIT |
|---|---|---|---|---|
| *Centrarchus macropterus* | -- | 0.01 ± 0.01 | -- | -- |
| *Ennecanthus gloriosus* | 0.5 ± 0.2 | 0.03 ± 0.02 | 0.02 ± 0.01 | 0.5 ± 0.2 |
| *Lepomis auritus* | -- | 18.7 ± 1.2 | 23.2 ± 1.6 | 19.2 ± 2.9 |
| *Lepomis gulosus* | 4.8 ± 1.6 | 1.3 ± 0.2 | 4.9 ± 0.5 | 6.1 ± 0.4 |
| *Lepomis macrochirus* | 16.5 ± 4.0 | 35.0 ± 1.1 | 27.7 ± 2.4 | 14.8 ± 2.8 |
| *Lepomis marginatus* | 0.3 ± 0.1 | 0.03 ± 0.03 | 0.1 ± 0.04 | 2.5 ± 0.7 |
| *Lepomis microlophus* | 4.4 ± 0.9 | 8.1 ± 1.1 | 9.3 ± 0.6 | 6.7 ± 1.8 |
| *Lepomis punctatus* | 1.5 ± 0.7 | 3.4 ± 0.3 | 10.7 ± 1.5 | 18.5 ± 2.1 |
| *Micropterus salmoides* | 9.4 ± 0.7 | 4.8 ± 0.2 | 5.3 ± 0.4 | 5.8 ± 2.3 |
| *Pomoxis nigromaculatus* | 0.9 ± 0.02 | 2.1 ± 0.3 | 0.5 ± 0.1 | 0.3 ± 0.2 |
| TOTAL | 38.3 | 73.4 | 81.7 | 74.4 |

Table 22-4. Percent change in relative abundance between baseline and expected post-restoration values for selected indicator species and family. Expected post-restoration values for each species and family are 80% of the mean annual abundance in three reference rivers. ("I" denotes an expected increase in mean annual relative abundance from baseline condition, "D" denotes an expected decrease in mean annual relative abundance from baseline condition)

| Indicator Species or Family | Reference condition | Baseline condition | Post-restoration condition | Percent change from baseline |
|---|---|---|---|---|
| *Amia calva* | 0.9 | 4.4 | 1.0 | 77% (D) |
| *Lepisosteus platyrhincus* | 2.2 | 19.6 | 3.0 | 84% (D) |
| *Lepomis auritus* | 20.4 | 0 | 16.0 | 1600% (I) |
| Centrarchidae | 73.0 | 38.3 | 58 | 53% (I) |

*Amia calva* and *L. platyrhincus* prefer heavily vegetated habitats with low flow velocities (Lee et al. 1980). Seasonal high discharges will limit areal coverage of littoral vegetation along the river channel (Williams and Wolman 1984, Ligon et al. 1995). Therefore, the expected decrease in relative abundance of *A. calva* and *L. platyrhincus* within restored river channels will result from loss of suitable habitat.

Reestablishment of continuous flow will facilitate increased mean annual relative abundance of *L. auritus* in restored river channels. *Lepomis auritus* is considered to be a predominantly stream-dwelling species (Lee et al. 1980, Aho and Terrell 1986). Abundance of *L. auritus* increased in Pool B river channels following reestablishment of flow during the Kissimmee River Demonstration Project (Wullschleger et al. 1990). The population of *L. auritus* in Pool B will act as a source for recolonization in Pool C, because the two pools will be connected under restored conditions.

Centrarchid abundance will increase primarily due to increased abundance of *L. auritus*, *L. macrochirus*, and *L. punctatus*. Increased mean annual relative abundance of centrarchid species will be based on increased availability of spawning habitat through reestablishment of historic sand substrate and sandbars, increased recruitment resulting from re-linkage of floodplain habitats that provide refugia for juveniles, increased dissolved oxygen regimes, and reestablishment of the historic aquatic food web.

**Means of Evaluation**

Post-restoration mean annual relative abundance of river channel fishes will be evaluated through electrofish sampling. Although electrofishing has inherent bias against small fishes, this bias will be similar across all studies used to evaluate river channel fish community structure. Block net sampling will not be conducted because it requires zero flow through the river channel, a condition unlikely to occur in the restored system.

Electrofish sampling will be conducted following two years of continuous flow through reconnected channels in Pool C using methods identical to baseline studies (FGFWFC 1996). Sampling will be conducted annually, for three year periods, beginning on the second year following implementation of the Final Headwater Regulation Schedule.

Electrofish samples will be analyzed for mean annual relative abundance of *A. calva*, *L. platyrhincus*, *L. auritus*, and centrarchids calculated from each three-year sampling period. The baseline values for comparing mean annual relative abundance of *A. calva*, *L. platyrhincus*, *L. auritus*, and centrarchids are 4.4%, 19.6%, 0%, and 38.3%, respectively.

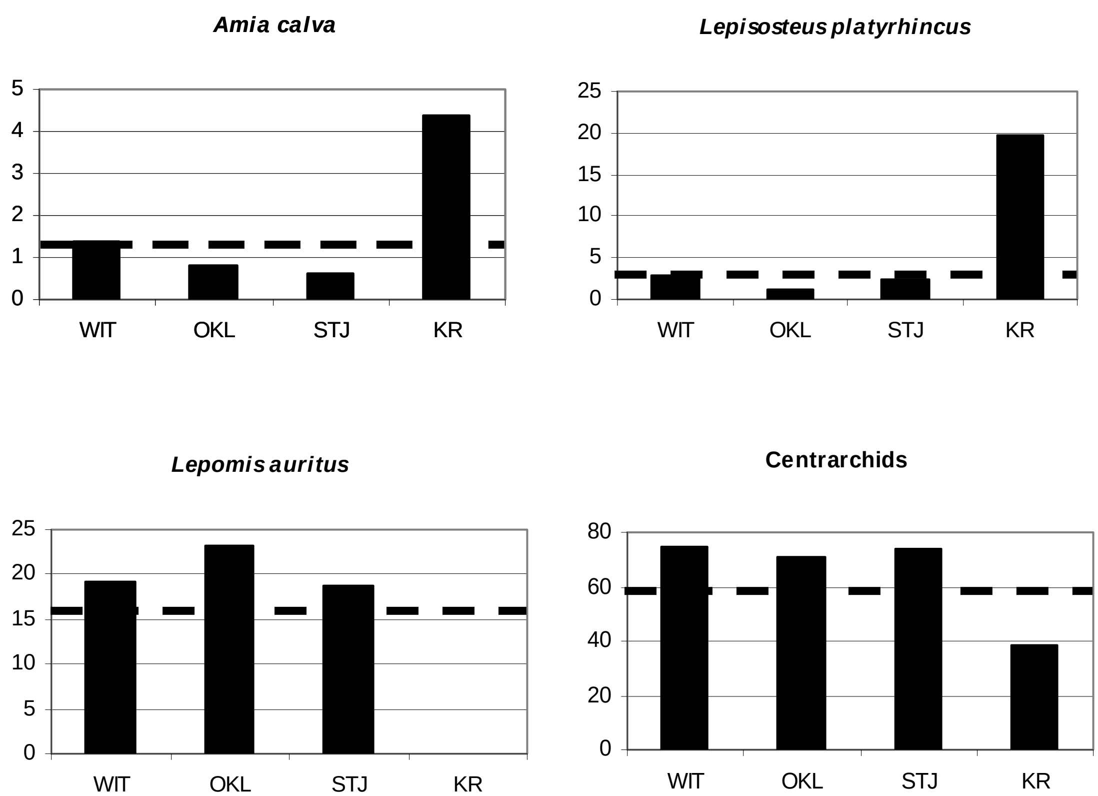


Figure 22-1. Baseline mean annual relative abundance of fish taxa or family that will be used as metrics to evaluate restoration success in reestablishing river channel fish assemblage structure. Dashed line indicates expected value for each taxa or family following restoration. (WIT = Withlacoochee River, OKL = Oklawaha River, STJ = St. Johns River, KR = Baseline data from Kissimmee River).

## Time Course

Recovery rates of lotic systems are determined by rate of reestablishment of specific physical (e.g., hydrology, geomorphology) and chemical (e.g., dissolved oxygen levels) characteristics of the system, and life history characteristics of organisms in the system (e.g., generation times and fecundity) (Cairns 1977, Yount and Niemi 1990). With anthropogenic intervention (i.e., habitat enhancement), recovery rates have ranged between six months to six years (Hunt 1976, Lund 1976, Stork et al. 1981, Edwards et al. 1984). Because restoration of the Kissimmee River includes reestablishment of historic hydrologic and physical river channel characteristics, restoration-associated shifts in mean annual relative abundance of river channel fishes are expected to lag behind physical changes. Shifts in fish assemblages structure are expected to occur within four to six years, but may take as long as ten to 12 years, which considers the lifespan of the longest lived taxa (bowfin and Florida gar). Limited abundance of *L. auritus* within the channelized system might increase projected response times due to limited reproductive potential. Restoration time frames may require adjustment if appropriate hydrologic and geomorphologic characteristics are not met.

Table 22-5. Exotic fish species occurring within South Florida that could invade the restored Kissimmee River ecosystem.

| Species | Common Name |
|---|---|
| *Belonesox belizanus* | pike killifish |
| *Cichlasoma bimaculatum* | black acara |
| *Cichlasoma meeki* | midas cichlid |
| *Cichlasoma citrinellum* | firemouth |
| *Cichla ocellaris* | peacock bass |
| *Cichlasoma uropthalmus* | Jack Dempsey |
| *Cichlasoma octofasciatum* | Mayan cichlid |
| *Hemichromis bimaculatus* | jewelfish |
| *Monopterus albus* | Asian swamp eel |
| *Tilapia mariae* | spotted tilapia |
| *Tilapia mossambica* | Mozambique tilapia |

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# EXPECTATION 23

# GUILD COMPOSITION, AGE CLASSES, AND RELATIVE ABUNDANCE OF FISHES USING FLOODPLAIN HABITATS

### Expectation

Off-channel dependents will comprise >50% of fish assemblage composition in restored floodplain habitats and will be represented by ≥12 taxa. Young-of-the-year or juveniles will comprise ≥30% of the off-channel dependent guild.

### Author

J. Lawrence Glenn III, South Florida Water Management District

### Date

June 2, 1998; revised May 2002

### Relevant Endpoint(s)

Restoration - Biological Integrity - Community Structure
Restoration - Biological Integrity - Reproductive Success/Recruitment
Restoration - Biological Integrity - Population Structure
Restoration - System Functional Integrity - Habitat Quality
Restoration - System Functional Integrity - Habitat Use
Restoration - System Functional Integrity - River/Floodplain Interactions

### Metrics

Percent of total number of fish that belong to the off-channel dependent guild
Number of off-channel dependent taxa present
Percent of total number of fish that are young-of-the-year or juvenile off-channel dependent taxa

### Baseline Conditions

Channelization of the Kissimmee River led to drainage of approximately 8,000 hectares of floodplain wetlands. Two types of wetlands remain in the channelized system: small, isolated marshes that are shallow and ephemeral (driven by seasonal rainfall); and wetlands located at the lower ends of each pool that also are shallow, but are impounded and lack substantial water level fluctuations. Only wetlands located at lower ends of pools were studied. These habitats are inhospitable for large-bodied fish taxa, but support populations of small-bodied species.

Two floodplain habitats, Broadleaf Marsh (BLM, Bousquin 2005) and Woody Shrub (*Myrica cerifera* Floating Mat Shrbland Bcode; S.CMF) within Pools A, C, and D were sampled monthly between August 1997 and January 1999 using a $m^3$ throw trap. Pasture (Upland Herbaceous Bcode group; UP) habitat in Pools A and C was sampled for 11 months between March 1998 and January 1999.

A total of 3159 fishes representing ten species, six families, and three guilds were collected from floodplain habitats during the baseline survey (1996–1999) (Table 23-1). Off-channel dependent refers to species that are found in a variety of habitats, but require access or use of off-channel habitats or are limited to nonflowing, vegetated waters at some point in their life cycle. These species may have significant riverine populations during particular life history stages. The off-channel specialist category refers to species that are almost always found only in off-channel habitats or are described to use limited to non-flowing, vegetated habitats throughout life. Occasionally individuals may be found in the river channel, but the vast majority of information on these fishes pertains to off-channel habitat. All fishes collected, except three individuals (bluegill *Lepomis macrochirus* and walking catfish *Clarias batrachus*), were small-bodied fishes. Large-bodied fishes were collected only during the wet season. Distribution of taxa according to guild included five off-channel specialists (50%), four off-channel dependents (40%), and one habitat generalist (10%) (Table 23-1). The assemblage was dominated in abundance by off-channel specialists (98%), especially least killifish *Heterandria formosa* (42%), Everglades pygmy sunfish *Elassoma evergladei* (32%), and eastern mosquitofish *Gambusia holbrooki* (18%) (Table 23-1). The remainder of the assemblage was comprised of off-channel dependents (1%) and generalists (1%) (Table 23-1). Only a single immature member of the off-channel dependent guild (*Lepomis macrochirus*) was collected. Guild composition was similar among sampling periods for each habitat over the period of study and was dominated by off-channel specialists (Figure 23-1).

Table 23-1. Fish collected from Kissimmee River floodplain habitats in a 1957 survey (FGFWFC 1957) and during the baseline period between 1996 and 1999. Habitats sampled included Broadleaf Marsh (BLM), Woody Shrub (S.CMF) and Pasture (UP).

| Species | 1957 | Number collected 1996-1999 BLM Site 1 | BLM Site 2 | S.CMF Site 1 | S.CMF Site 2 | UP Site 1 | UP Site 2 |
|---|---|---|---|---|---|---|---|
| Esocidae | | | | | | | |
| Ψ Redfin pickerel *Esox americanus* | 5 | | | | | | |
| Cyprinidae | | | | | | | |
| Φ Golden shiner *Notemigonus crysoleucas* | 363 | | | | | | |
| Φ Tailight shiner *Notropis maculatus* | 96 | | | | | | |
| Φ Coastal shiner *Notropis petersoni* | 2 | | | | | | |
| Catostomidae | | | | | | | |
| Φ Lake chubsucker *Erimyzon sucetta* | 13 | | | | | | |
| Ictaluridae | | | | | | | |
| Φ White catfish *Ameiurus catus* | 2 | | | | | | |
| Ψ Brown bullhead *Ameiurus nebulosus* | 1 | | | | | | |
| Φ Channel catfish *Ictalurus punctatus* | 1 | | | | | | |
| Ψ Tadpole madtom *Noturus gyrinus* | 18 | | | | | | |
| Clariidae | | | | | | | |
| Φ Walking catfish *Clarias batrachus* | | | 2 | | | | |
| Aphredoderidae | | | | | | | |
| Φ Pirate perch *Aphredoderus sayanus* | 1 | | | | | | |
| Fundulidae | | | | | | | |
| Λ Golden topminnow *Fundulus chrysotus* | 6 | | | 12 | 13 | | |
| Ψ Bluefin killifish *Lucania goodei* | 15 | 1 | | | | | |
| Poeciliidae | | | | | | | |
| Ψ Eastern mosquitofish *Gambusia holbrooki* | 14 | 50 | 120 | 123 | 263 | 3 | 5 |
| Ψ Least killifish *Heterandria formosa* | 3 | 83 | 47 | 468 | 712 | 13 | 1 |
| Atherinidae | | | | | | | |
| Φ Brook silverside *Labidesthes sicculus* | 12 | | | 1 | 29 | | |
| Elassomatidae | | | | | | | |
| Ψ Everglades pygmy sunfish *Elassoma evergladei* | 7 | 304 | 226 | 361 | 94 | 16 | 16 |
| Ψ Okefenokee pygmy sunfish *Elassoma okefenokee* | | 64 | 12 | 70 | 44 | 3 | |
| Centrarchidae | | | | | | | |
| Φ Bluespotted sunfish *Enneacanthus gloriosus* | 28 | 1 | 1 | | | | |
| Φ Redbreast sunfish *Lepomis auritus* | 298 | | | | | | |
| Φ Warmouth *Lepomis gulosus* | 7 | | | | | | |
| Φ Bluegill *Lepomis machrochirus* | 1 | | | | 1 | | |
| Φ Redear sunfish *Lepomis microlophus* | 9 | | | | | | |
| Φ Largemouth bass *Micropterus salmoides* | 8 | | | | | | |
| Φ Black crappie *Pomoxis nigromaculatus* | 1 | | | | | | |
| Percidae | | | | | | | |
| Λ Swamp darter *Etheostoma fusiforme* | 11 | | | | | | |
| Total | 922 | 503 | 408 | 1035 | 1156 | 35 | 22 |

(Ψ denotes off-channel specialist taxa, Φ denotes off-channel dependent taxa, and Λ denotes habitat generalist taxa).

Milleson (1976) found that the post-channelization fish community of a re-flooded (impounded) marsh in Pool B was dominated (79%) by a single family (Poeciliidae) belonging to the of-channel specialist guild. Off-channel dependent and habitat generalist taxa comprised the remaining 18% of fishes collected. All fishes were <10 cm total length; however, age classes and percent contribution of large-bodied centrarchids was not given. Toth (1991) found the fish community of a revitalized BLM in Pool B also was dominated by the same off-channel specialist family (Poeciliidae), which accounted for 97% of all fishes collected.

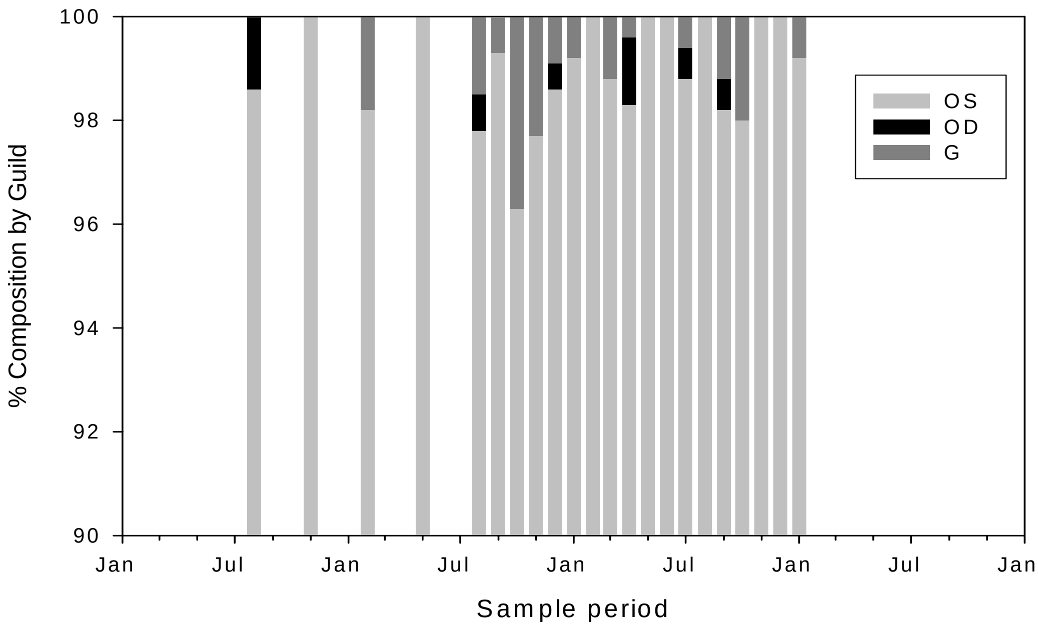


Figure 23-1. Percent composition of fishes collected in floodplain habitats by macrohabitat guild for each sampling period during the baseline survey (1996–1999). Guild include off-channel specialist (OS), off-channel dependent (OD), and habitat generalist (G).

**Reference Conditions**

Historical data on floodplain fish community structure of the Kissimmee River are limited to a single sample (FGFWFC 1957). Consequently, reference conditions were derived from relevant data from the FGFWFC (1957) report, and comparable river/floodplain and marsh ecosystems. The FGFWFC collected 922 individual fish representing 24 taxa, 11 families, and three guilds (Table 23-1). This assemblage included large (adults >80 mm Standard Length; SL) and small-bodied fishes. Distribution of taxa according to guild included seven off-channel specialists (29.1%), 15 off-channel dependents (62.5%), and two habitat generalists (8.3%). The assemblage was dominated in abundance by off-channel dependents (88.1%), especially golden shiner *Notemigonus crysoleucas* (39%) and redbreast sunfish *Lepomis auritus* (32%) (Table 23-1). The remainder of the assemblage was comprised of off-channel specialists (10.1 %) and habitat generalists (1.8%)(Table 23-1). Of the 812 off-channel dependents collected, 39.7% were juvenile or young-of-the-year centrarchids and esocids.

The lower Mississippi River was used as a reference site for floodplain fish assemblages of the historic Kissimmee River because some of the large-bodied taxa that are found in both rivers utilize inundated floodplain habitats when available. Guillory (1979) found 62 taxa utilized inundated floodplain habitats of the lower Mississippi River. Ten large-bodied taxa (*Esox americanus, L. gulosis, L. macrochirus, L. microlophus, L. punctatus, M. salmoides, Pomoxis nigromaculatus, Amia calva*, *Dorosoma cepedianum*, *Lepisosteus platyrhincus*), which also occurred in the historic Kissimmee River, comprised 12.2% of the total number of fishes collected. Seven of these ten taxa (*E. americanus, L. gulosis, L. macrochirus, L. microlophus, P. nigromaculatus, A. calva, D. cepedianum*) were young-of-the-year or adults in spawning condition, indicating that inundated floodplain habitats of the lower Mississippi River serve as spawning and nursery areas.

The Florida Everglades also can serve as a reference site for floodplain fish assemblages of the historic Kissimmee River due to similarities in geology, ecoregion, climate and annual rainfall, wetland marsh hydroperiod and vegetation composition, and zoogeography of the fish fauna. Trexler et al. (in press) found that seven species of centrarchids and esocids (*E. americanus, E. niger, L. gulosis, L. macrochirus, L. microlophus, L. punctatus, M. salmoides*) accounted for 27% of the total number of fishes sampled in the Florida Everglades. Three other large-bodied taxa (*A. calva*, *Erimyzon sucetta*, *Lepisosteus platyrhincus*) comprised approximately 60% of all large-bodied fishes sampled (n = 583). Jordan et al. (1997) found 29 taxa of fishes using wet prairie habitats within Water Conservation Area 3 of the Florida Everglades, 17 of which occurred within the historic Kissimmee River floodplain. Poeciliids (*Gambusia affinis*, *Heterandria formosa*) and Fundulids (*Lucania goodei*) accounted for 86% of the total number of fishes collected. Jordan et al. (1999) found small-bodied fish composition within backwater ponds of the Florida Everglades declined to 40–60% during stage recession periods due to an influx of large-bodied piscivorous fishes seeking deep water refuge (Loftus and Eklund 1994), and an associated increase in predation (Kushlan 1976, 1980; Loftus and Eklund 1994).

The success criteria of >50% assemblage composition, ≥12 taxa (Figure 23-2), and ≥30 % young-of-the-year or juveniles are approximately 80% of historic values. Although conservative, these expected values account for the high natural variability of floodplain fish communities.

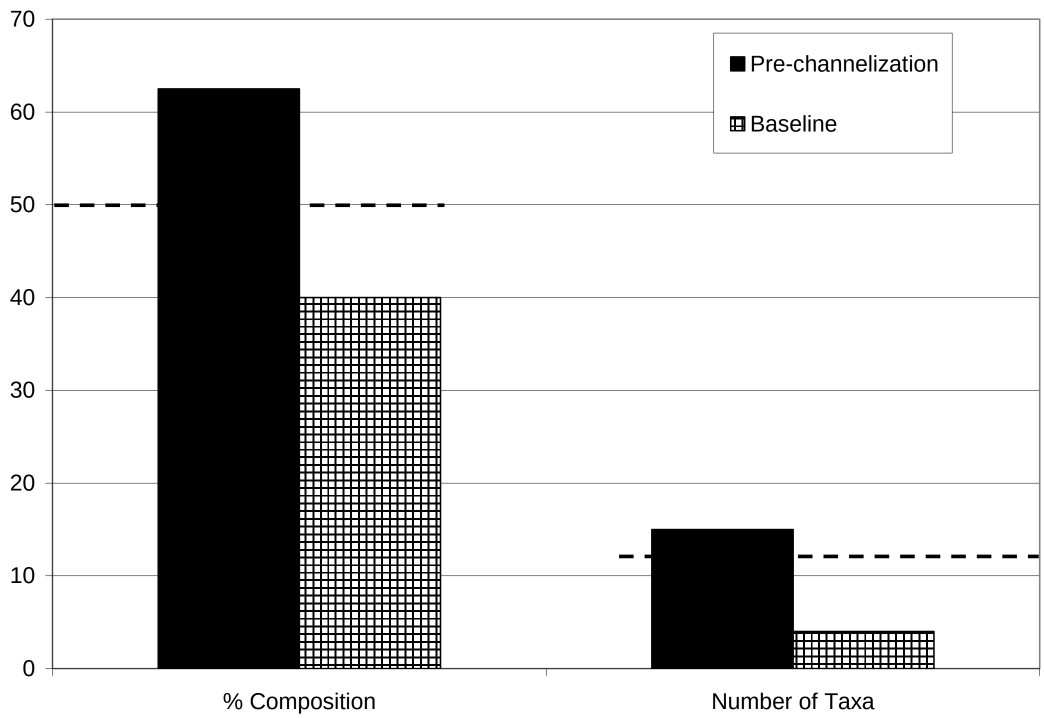


Figure 23-2. Baseline percent composition and number of taxa of off-channel dependent guild members in floodplain fish assemblages of the Kissimmee River. Dashed line indicates expected value for each metric following restoration.

### Adjustment for External Constraints

No species were extirpated from the Kissimmee River ecosystem following channelization. Relative abundance of fish taxa may be affected by increased use of floodplain habitats by non-indigenous fish species. Seven species (*Astronotus ocellatus, Clarias batrachus*, *Ctenopharyngodon idella, Cyprinus carpio, Hoplosternum littorale*, *Hypostomus plecostomus, Oreochromis aureus*) of non-indigenous fishes currently occur within the Kissimmee River system and are believed to have been introduced after channelization. The majority of these species use marsh habitat during a portion of their life cycle (Lever, 1996; McCann et al. 1996; Nico et al 1996).

Numbers of non-indigenous fish may be high during initial periods of physical and chemical change on the floodplain. Several non-indigenous species within the system are capable of breathing air and locomotion over land and often thrive in newly disturbed habitats (Courtenay and Hensley 1979). Established communities of non-indigenous species can outcompete centrarchid communities for food, spawning areas, and space (Courtenay and Hensley 1979). During baseline sampling, non-indigenous species comprised only 0.6% of fishes collected on the floodplain and 1.5% of the river channel fish community. Taxa richness and relative abundance of non-indigenous species could increase if new taxa are introduced into the system.

### Mechanism for Achieving Restoration

Reestablishment of historic hydrologic characteristics will be the mechanism driving restoration of floodplain habitats. Reestablishment of appropriate inundation depths, increased dissolved oxygen levels, and recreation of backwater lakes and ponds (deepwater refuge) are critical to restoration of the floodplain fish community (Welcomme 1979). Reestablishment of both wetland flora and invertebrate fauna are linked to these habitat characteristics and are necessary for sustaining floodplain fish populations.

Newly created and enhanced wetland habitats are expected to sustain fish assemblages similar to those that occurred within the pre-channelized system. Restoration of floodplain fish populations will occur through re-colonization by fish species that occur within the channelized system. Young-of-the-year and juvenile populations will be established within floodplain habitats by fish spawned on the floodplain and by migration from adjacent riverine spawning grounds (Welcomme 1979). Small-bodied fishes will continue to be a dominant component of the floodplain fish community, but their percent composition is expected to decrease with increased usage by large-bodied taxa during periods of prolonged inundation. Immigration of adults of large-bodied species will require floodplain depths ≥ 50 cm (F. Jordan, Loyola University, personal communication,).

Table 23-2. Non-indigenous fish taxa occurring within South Florida that could invade the restored Kissimmee River ecosystem.

| Taxa | Common Name |
|---|---|
| *Belonesox belizanus* | pike killifish |
| *Cichlasoma bimaculatum* | black acara |
| *Cichlasoma citrinellum* | midas cichlid |
| *Cichlasoma meeki* | firemouth |
| *Cichla ocellaris* | peacock bass |
| *Cichlasoma octofasciatum* | Jack Dempsey |
| *Cichlasoma uropthalmus* | Mayan cichlid |
| *Hemichromis bimaculatus* | jewelfish |
| *Hypostomus plecostomus* | suckermouth catfish |
| *Monopterus albus* | Asian swamp eel |
| *Tilapia mariae* | spotted tilapia |
| *Tilapia mossambica* | Mozambique tilapia |

### Means of Evaluation

Throw trap sampling will begin immediately following inundation of floodplain habitats. Throw trap sampling provides accurate estimates of density, size structure, and relative abundance of populations of small fish within heavily vegetated habitats (Kushlan 1981, Freeman et al. 1984, Jacobsen and Kushlan 1987, Chick et al. 1992, Jordan et al. 1997) and provides data comparable to block net sampling (Jordan et al. 1997). Methods will be identical to those utilized for baseline studies, including monthly collection of ten random samples in each habitat. Sampling will be conducted for three-year periods beginning on the first and sixth years following floodplain inundation associated with implementation of the Final Headwaters Regulation Schedule.

Samples will be analyzed for guild composition, age class, and relative abundance. These metrics will document restoration of river channel-floodplain exchange and use of floodplain habitats as spawning and nursery grounds. Age classes of centrarchids and esocids will be based on total body length (Table 23-3).

Table 23-3. Body lengths for age class determination of centrarchid and esocid taxa in the Kissimmee River (modified from Carlander 1977 and Lee et al. 1980).

| Taxa | Common Name | Young-of-the-year | Juvenile |
|---|---|---|---|
| *Esox ameicanus* | redfin pickerel | -- | <250 mm |
| *Esox niger* | chain pickerel | -- | <300 mm |
| *Micropterus salmoides* | largemouth bass | 0–64 mm | 65–120 mm |
| *Lepomis auritrus* | redbreast sunfish | 0–35 mm | 36–60 mm |
| *Lepomis gulosis* | warmouth | 0–32 mm | 33–75 mm |
| *Lepomis machrochirus* | bluegill | 0–45mm | 46–90 mm |
| *Lepomis microlophus* | redear sunfish | 0–56 mm | 57–134 mm |
| *Lepomis punctatus* | spotted sunfish | -- | <55 mm (SL) |
| *Pomoxis nigromaculatus* | black crappie | 0–51 mm | 52–130 mm |

Mean annual relative abundance for all taxa will be based on each two-year block of post-restoration data. Annual means will be derived by averaging monthly relative abundance, generated from total numbers pooled from ten replicates each month. Seasonal effects (especially prolonged floodplain inundation during the wet season) on relative abundance are expected to be reflected in yearly means. Although this expectation is based on mean annual relative abundance, data also will be analyzed by season to evaluate the potential significance of seasonality.

### Time Course

Small fish (<10 cm TL) will move onto the floodplain immediately following inundation (Welcomme 1979), while subsequent immigration by adults of large-bodied species will require greater depths (F. Jordan, Loyola University, personal communication). However, maintenance of floodplain fish communities requires restoration of lower trophic levels and may take between three and twelve years. Results of the Demonstration Project (Toth 1993) and test fill project indicate colonization of wetland plant species on re-inundated floodplain can be rapid. Harris et al. (1995) have suggested reestablishment of the historic invertebrate community may take between three and eight years. However, this time frame could be considerably shorter (one year) if representative vegetation and associated periphyton communities become established (J. Koebel, SFWMD, personal communication). Restoration time frames may require adjustment if appropriate hydrologic characteristics are not met or are delayed.

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# EXPECTATION 24

# DENSITY OF LONG-LEGGED WADING BIRDS ON THE FLOODPLAIN

### Expectation

Mean annual dry season density of long-legged wading birds (excluding cattle egrets) on the restored floodplain will be $\geq$30.6 birds/km$^2$.

### Author

Gary Williams, South Florida Water Management District
Stefani L. Melvin, South Florida Water Management District (*Current affiliation*: U. S. Fish and Wildlife Service)

### Date

May 28, 1998, revised April 2002; revised February 2005

### Relevant Endpoints

Sociopolitical - Number of Birds
Sociopolitical - Aesthetic Values
Restoration - Biological Integrity - Community Structure
Restoration - System Functional Integrity - Habitat Quality
Restoration - System Functional Integrity - Habitat Use

### Metric

Mean annual dry season density of wading birds

### Baseline Condition

Aerial surveys (n=27) of the species and numbers of wading birds using the floodplain (within 100 year floodlines) were conducted monthly from June 1996 to December 1998 along randomly selected transects representing at least 15% of Pools A–D (Williams and Melvin 2005). Density estimates were calculated using the ratio method for unequal plot sizes (Jolly 1969). Survey data were summarized separately for Control and Impact areas (Figure 24-1). Mean (± standard error) annual dry season density of long-legged wading birds in the Impact area varied between years ($t = 3.05$, $P = 0.03$), averaging 3.58 ± 0.86 birds/sq km in 1997 and 14.29 ± 3.37 birds/sq km in 1998 (Figure 24-2). Within the Control area, variability of mean annual dry season density of long-legged wading birds was low, with means of 13.24 ± 4.25 in 1997 and 13.79 ± 1.92 in 1998 ($t = 0.11$, $P = 0.91$).

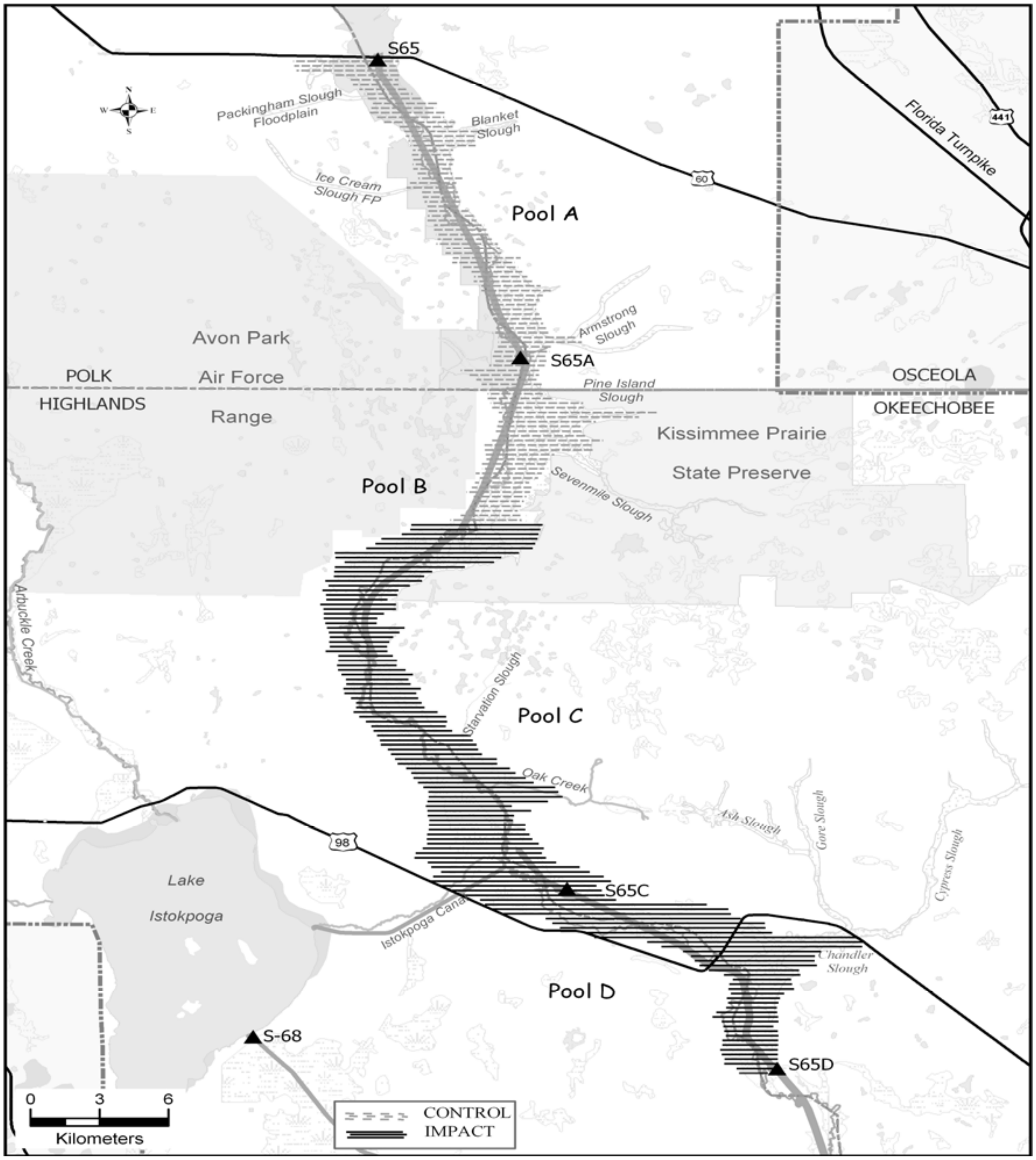


Figure 24-1. Map of transects used for baseline aerial surveys of wading birds. Transects spanned the 100 year floodplain, were oriented east-west, and were spaced at 200 m intervals. Data from aerial surveys were summarized separately for the Control (northern portion) and Impact (southern portion) of the study area.

**Reference Condition**

No quantitative historic data are available on wading bird use of the Kissimmee River floodplain. Therefore, reference conditions were derived from post-channelization surveys of Paradise Run and the Pool B flow-through marsh constructed for the Kissimmee River Demonstration Project (Toland 1990). Paradise Run is located at the downstream end of the Kissimmee River near its outflow into Lake Okeechobee.

Because of its connection to Lake Okeechobee, Paradise Run functions like littoral habitat and experiences some water level fluctuations associated with changes in lake levels. At higher lake stages, this section of river floodplain may be inundated more than other portions of the channelized river (Perrin et al. 1982). The Pool B flow-through marsh was constructed between 1984 and 1985, was subjected to natural fluctuations in water levels due to rainfall, and was first inundated in 1986 (Toth 1991). Aerial surveys (n = 12) conducted during 1987–1988 found average densities of wading birds (excluding cattle egrets) of 27.4 birds/sq km and 33.8 birds/sq km in the flow-through marsh and Paradise Run, respectively; no measures of variability were reported (Toland 1990).

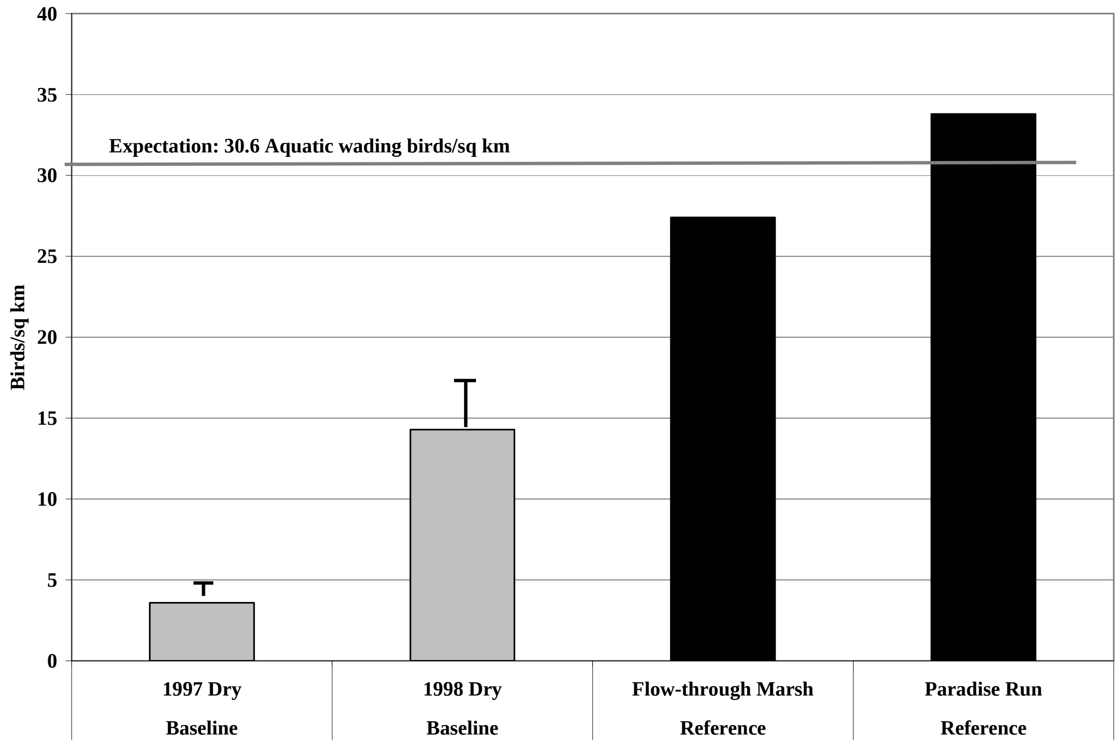


Figure 24-2. Expectation for dry season densities of aquatic wading birds in the Impact area following restoration. The expectation is based on the average density from surveys conducted of the flow-through marsh of the Kissimmee River Demonstration Project and in Paradise Run during 1986–1987 (Toland 1990).

### Adjustments for External Constraints

Wading birds are able to search wide areas for appropriate foraging conditions (Frederick 1995). Thus, habitat conditions outside the Kissimmee floodplain may influence the number of wading birds within the floodplain. If foraging conditions are extremely poor elsewhere, for example, the response by wading birds may be much greater than expected.

### Mechanism for Achieving Expectation

Attainment of expected wading bird densities will depend on restoration of the types and concentrations of prey that individual species require, as well as appropriate water depths for foraging (Weller 1995). Reintroducing fluctuating water levels and seasonal hydroperiods, and reconstructing the physical form of the Kissimmee River is expected to lead to reestablishment of floodplain wetlands (Anderson 2005, Carnal 2005) that will support production of wading bird prey (Glenn 2005, Koebel et al. 2005a, b). Natural hydroperiods will concentrate prey in drying wetlands and improve foraging habitat for wading birds on the floodplain (Kushlan 1976, 1986). With improved wetland conditions and greater prey abundance, wading birds are expected to immigrate into newly created habitat from surrounding areas.

### Means of Evaluation

This expectation will be evaluated via aerial surveys of the floodplain using the protocols described above. Evaluation will be based on a three year average of dry season densities. The expectation will be evaluated across the entire Impact area. Control area data will be used to assess the relative contribution of the restoration project to changes in densities and in the Impact area (Stewart-Oaten et al. 1986).

### Time Course

Because wading birds are very mobile and choose habitat at the landscape scale (Frederick 1995, Frederick et al. 1996), a response to newly available habitat should rapidly occur immediately through immigration of individuals from other areas. However, the persistence of this initial response will depend on prey availability at foraging sites. Five years of post-restoration surveys are planned to both allow time for wetlands and the prey items they support to become reestablished, and to buffer for the effects of natural fluctuations in weather.

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# EXPECTATION 25

# WINTER ABUNDANCE OF WATERFOWL ON THE FLOODPLAIN

### Expectation

Winter densities of waterfowl within the restored area of floodplain will be ≥3.9 ducks/sq km. Species richness will be ≥13.

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### Date

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### Relevant Endpoints

Sociopolitical - Number of Birds
Sociopolitical - Aesthetic Values
Restoration - System Functional Integrity - Habitat Quality
Restoration - System Functional Integrity - Habitat Use

### Metrics

Mean annual density of waterfowl, three-year total of species richness

### Baseline Condition

Aerial surveys of the species and numbers of ducks using the floodplain were conducted monthly during winter (November through March) from 1996 to 1999 along randomly selected transects representing at least 15% of Pools A–D (Figure 25-1) (Williams and Melvin 2005). Density estimates were calculated using the ratio method for unequal plot sizes (Jolly 1969). Monthly mean density was estimated by averaging the density of birds per transect. Monthly mean density was averaged for winter months each year and then averaged over three years to calculate mean baseline winter abundance (n=3). Species richness was estimated by summing the total number of species recorded during all three years of surveys. Estimates were produced separately for Impact and Control areas. Mean baseline winter waterfowl densities were 0.44 ± 0.09 ducks/sq km in the Impact area (Figure 25-2) and 0.61 ± 0.24 ducks/sq km in the Control area. Overall species richness across years was 4 in the Impact area (Figure 25-3) and 3 in the Control area.

**Reference Condition**

Surveys of wintering waterfowl of the Kissimmee River and Upper Basin lakes are available for eight years (1949–1957) prior to construction of the C-38 canal (FGFWFC 1957). Because these surveys violated assumptions of sampling theory (Bancroft and Sawicki 1995), density estimates were not used as reference data; only species richness data were used. Survey reports pooled data from the Kissimmee River and Upper Basin lakes.

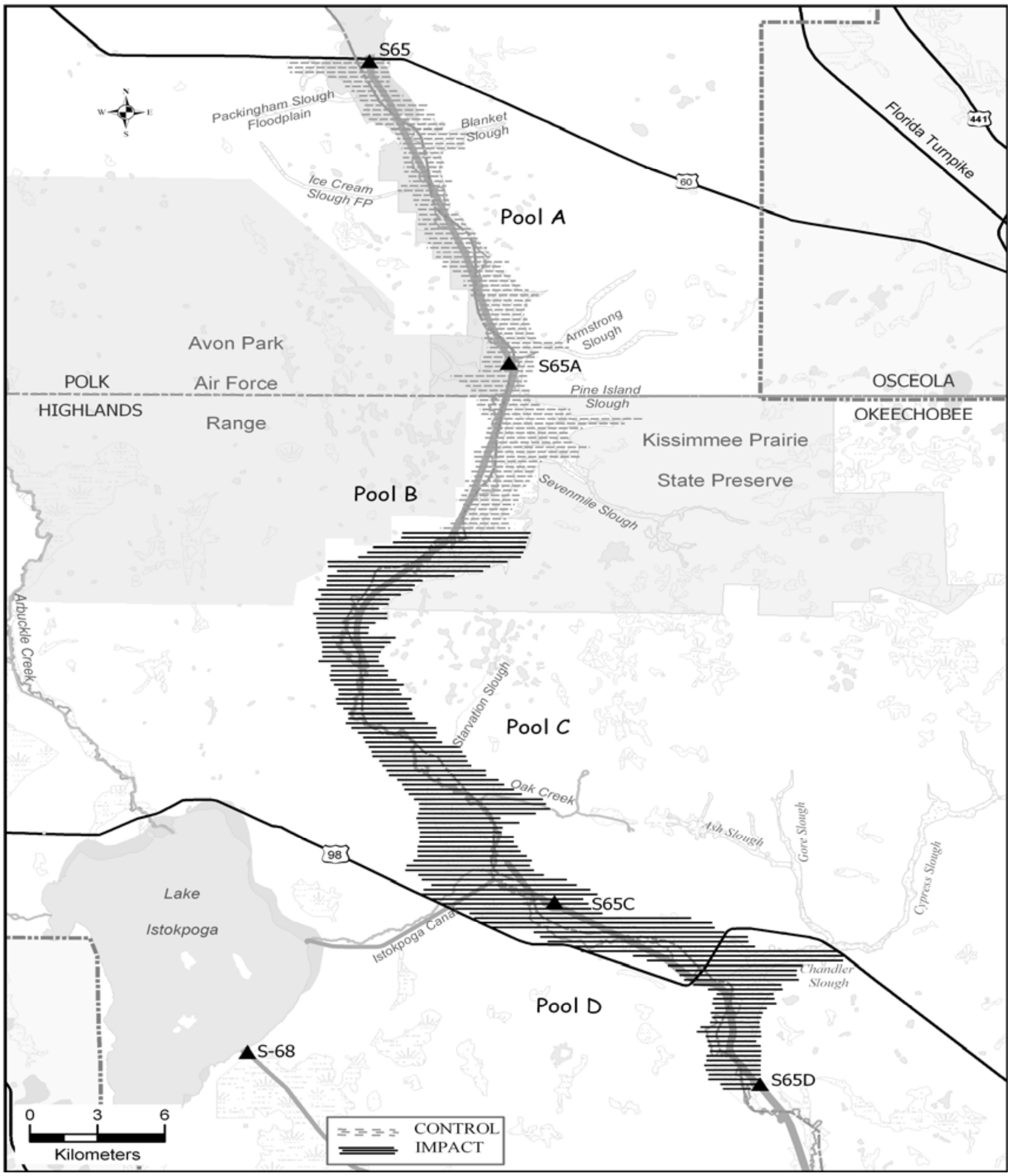


Figure 25-1. Map of transects used for baseline aerial surveys of waterfowl. Transects spanned the 100 year floodplain, were oriented east-west, and were spaced at 200 m intervals. Data from aerial surveys were summarized separately for the Control (northern portion) and Impact (southern portion) of the study area.

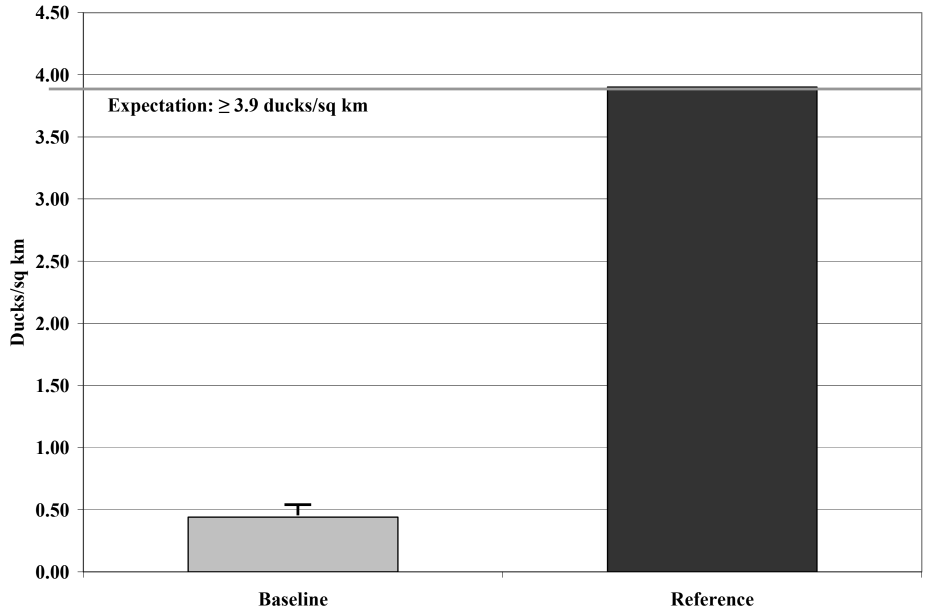


Figure 25-2. Expected waterfowl density on the restored Kissimmee River floodplain.

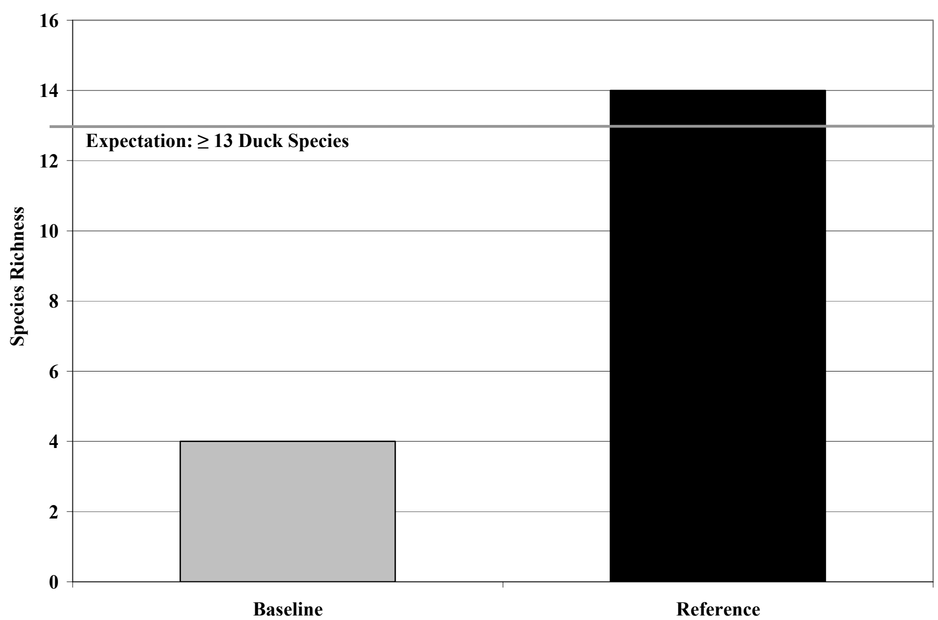


Figure 25-3. Expected species richness of waterfowl on the restored Kissimmee River floodplain.

Nineteen species of waterfowl were encountered, some of which were likely to be restricted to lakes. Based on habitat requirements, 14 of these species were likely to have regularly used the Kissimmee River floodplain. One of these species, the American black duck, no longer winters in significant numbers in Central Florida (Stevenson and Anderson 1994). Toland (1990) conducted aerial surveys of waterfowl using the flow-through marsh of the Kissimmee River Demonstration Project during 1987–1988. The flow-through marsh was designed and manipulated to mimic hydrologic characteristics of the pre-channelized floodplain. Average duck density across surveys (n=12) was 3.9 ducks/sq km. Species richness was 3. No measures of variability were reported.

**Adjustments for External Constraints**

Factors not associated with restoration, such as habitat conditions on breeding areas, and local and regional weather, can have a significant effect on the numbers and species of waterfowl that use the Kissimmee River floodplain during winter (Bellrose 1980).

**Mechanism for Achieving Expectation**

Reestablishment of waterfowl populations will depend on restoration of the plant, invertebrate, and fish resources that individual species require (Weller 1995). Reestablishment of the flood-pulse will produce the hydroperiods and hydropatterns necessary for restoring these wetland resources. Densities and species richness of ducks will increase as appropriate foraging conditions and preferred food items become available.

**Means of Evaluation**

This expectation will be evaluated via aerial surveys of the floodplain using the protocols described above. Evaluation of the expectation for density will be based on a three year average, and the species richness expectation will be evaluated based on three year species totals. Expectation metrics will be evaluated across the entire Impact area. Control area data will be used to assess the relative contribution of the restoration project to changes in waterfowl densities and species richness in the Impact area (Stewart-Oaten et al. 1986).

**Time Course**

Surveys will be conducted for at least five years following completion of each phase of restoration. Because waterfowl are highly mobile, species that prefer annual plants or other rapidly available foods (e.g., blue-winged teal and mottled duck) should respond within one year after each phase of restoration. Other waterfowl species should return as their preferred food items become reestablished. Five years of post-restoration surveys are needed to allow time for some preferred waterfowl foods to become reestablished and to buffer for the effects of natural fluctuations in both waterfowl populations and weather.

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