Chapter 9: Kissimmee River Restoration and Other Kissimmee Basin Initiatives

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SUMMARY

The Kissimmee Basin experienced average to slightly above average rainfall in Water Year 2019 (WY2019; May 1, 2018–April 30, 2019). Rainfall totals of 52.9 inches over the Upper Kissimmee Basin and 44.8 inches over the Lower Kissimmee Basin were 2.8 inches and 0.4 inches above their long-term averages, respectively. Despite overall normal conditions, operation of the S-65 water control structure faced challenges from periods of heavy rainfall and efforts to balance multiple and sometimes competing objectives. The IS-14-50.0 discharge plan for the S-65/S-65A water control structures was successfully implemented in the 2018 wet season; although it did not result in duration of floodplain inundation comparable to the reference period, it produced a single 108-day period with bankfull discharge or greater. An emerging challenge in the 2018 wet season was the occurrence of Everglade snail kite (*Rostrhamus sociabilis plumbeus*) nesting in the Kissimmee River floodplain. Operations to maintain enough water under the nests to discourage predation aligned with the Kissimmee River Restoration Project (KRRP) goal of extended floodplain inundation, but discharge for flood control in the Headwaters Lakes (Lakes Kissimmee, Cypress, and Hatchineha) had to be limited to avoid flooding nests. Requests to moderate lake ascension and recession rates to the extent possible were implemented in the Headwaters Lakes, Lake Tohopekaliga, and East Lake Tohopekaliga to benefit fish and wildlife.

The KRRP entered the eighteenth year of an Interim Period that began with completion of the first phase of construction and is expected to continue until late 2020, when construction and land acquisition are scheduled for completion and the Headwaters Revitalization Schedule (HRS) will be implemented.

Since 2005, this chapter has reported results of numerous monitoring studies being conducted in the Lower Kissimmee Basin (LKB) as part of the Kissimmee River Restoration Evaluation Program (KRREP) by the South Florida Water Management District (SFWMD or District) and in the Upper Kissimmee Basin (UKB) by SFWMD and partner agencies. Results are reported as new data and analyses become available in a given year. Brief abstracts of study findings are presented in this summary section; for results and other details such as study methods, refer to the corresponding subsections later in the chapter.

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LOWER KISSIMMEE BASIN

- **KRREP Hydrology**. Targets for KRREP Expectation 3: Hydroperiod Requirements for Broadleaf Marsh (BLM), the dominant and most characteristic wetland plant community of the pre-channelization floodplain, and Expectation 4: Recession Events, were evaluated. Two floodplain inundation events met the depth criterion of at least 1 foot (ft); these events lasted only 63 days and 15 days, respectively, far shorter than the 210-day duration criterion. Multiple recession events occurred, partly due to repeated instances of discharge for flood control, instead of the single recession event that was typical of pre-channelization. For three events the recession rate was less than the 1 ft per 30 days maximum recession rate criterion; one event had a rate of 2.65 ft per 30 days – well in excess of the maximum rate criterion. Consequently, the targets were not met for either expectation. The targets for Expectations 3 and 4 have not been met in any year of the Interim Period (2001–2019). While it may not be possible to fully meet these targets prior to implementation of the HRS, performance can be improved now by implementation of discharge plans that use 1,400 cubic feet per second (cfs) as a minimum discharge when Headwaters Lakes stage is above a specified threshold stage.

- **KRREP Dissolved Oxygen (DO).** Concentrations of daytime DO in the river channel of the Phase I restoration area continued to be higher in the past year than pre-restoration levels. All four metrics used to evaluate DO response were met. Mean daytime DO concentrations exceeded the dry season (November 2018–May 2019) and wet season (June–October 2018) target ranges. The third metric, frequency of DO concentration > 1 milligram per liter (mg/L) within 1 meter (m) of the channel bottom, exceeded its 50% target. The fourth metric, frequency of concentrations > 2.0 mg/L, exceeded its 90% target. Despite these successes, short-lived declines in DO concentration sufficient to impact fish population continue to occur, most recently in June 2019 when DO declined to 0 mg/L for 10 days, resulting in a large fish kill.

- **KRREP Wading Bird Abundance.** Mean monthly wading bird abundance within the restored portions of the river during the 2018–2019 season was 42.0 ± 7.8 birds per square kilometer (bird/km^2), bringing the three-year (2017–2019) running average to 37.8 ± 12.2; not significantly greater than the restoration expectation of 30.6 birds/km^2. The long-term annual three-year running mean (2002–2019) is 40.9 ± 3.4 birds/km^2, significantly greater than the restoration expectation of 30.6 birds/km^2.

- **KRREP Waterfowl Abundance and Species Richness.** Waterfowl abundance during the 2018–2019 survey was 10.1 ± 6.4 ducks per square kilometer (ducks/km^2), bringing the three-year (2017–2019) running average to 21.1 ± 10.5 ducks/km^2; although not significantly greater than the restoration expectation of 3.9 ducks/km^2 due to high inter-annual variability. The long-term mean annual three-year running average (2002–2019) of waterfowl abundance is 11.7 ± 1.3 birds/km^2, significantly greater than the restoration expectation of 3.9 birds/km^2. The three-year species total for 2017–2019 was 8, below the restoration target for waterfowl species richness of ≥13 (three-year species total).

- **KRREP Wading Bird Nesting.** Wading bird nesting colonies within the Kissimmee River Restoration Project and Lakes Istokpoga and Kissimmee were not surveyed during the 2018-2019 dry season due to weather and helicopter flight scheduling conflicts.

- **KRREP Wading Bird and Waterfowl Food Availability.** Small fish and aquatic invertebrate density, abundance, richness, and diversity are greater now than during the Baseline (pre-construction) Period. Small fish densities and biomass were rather high when compared to marsh sites in the Everglades and appear to be more similar to values reported for the Lake Okeechobee littoral zone (Sharfstein and Zhang 2017). Over 27% of the total biomass collected was made up of exotic species. Size of individual fish captured in throw traps was like sites in the Everglades. Aquatic invertebrate densities appear to be greater than those reported for the littoral marshes of Lake Okeechobee, indicating a highly productive floodplain food web that is more eutrophic than the marshes of the southern Everglades. Over 69% of the invertebrate biomass was comprised of the invasive exotic island apple snail (*Pomacea insularum*).

- **KRREP Floodplain Vegetation Management.** In the past year, prescribed fire, herbicide application, and biocontrol agents were used to control invasive plants in the Kissimmee River floodplain. Approximately 1,415 acres of wet prairie were burned within the Kissimmee River Restoration Area (KRRA) and fire effects on vegetation are being monitored using permanent photo monitoring points. Two experimental herbicide treatments were conducted near Oak Creek. Post-treatment data are being collected to guide future management actions to control these invasive species. Populations of the brown lygodium moth (*Neomusotima conspurcatalis*) are being released to combat the invasive exotic old-world climbing fern (*Lygodium microphyllum*).

UPPER KISSIMMEE BASIN

- **Vegetation Monitoring.** The District completed the fourth year of data collection in long-term vegetation monitoring plots in East Lake Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee. The plots are intended to establish baseline conditions for comparison with data collected after completion of the KRRP, which will coincide with HRS implementation.
- **Fisheries.** The Florida Fish and Wildlife Conservation Commission (FWC) conducted electrofishing to collect fish community data and largemouth bass (*Micropterus salmoides*) population data in fall 2017 and spring 2018, respectively. Community data resulted in more forage fish and fewer sunfish and gamefish than average sampled on Lake Kissimmee. On Lake Tohopekaliga, results were closer to average. Simpson's diversity and species richness were also about average on both lakes. Lakes Kissimmee and Tohopekaliga showed more favorable conditions within subadult and adult bass populations than last years' effort. Lake Kissimmee had higher numbers of both subadults (< 25 centimeters [cm]) and adult bass (> 25 cm). Lake Tohopekaliga data showed high numbers of subadult and adult bass, up from 2017 when numbers of adult bass sampled were very low.
- **Everglade Snail Kites.** Overall, the 2018 snail kite breeding season was dramatically more successful than last year with the second highest number of active nests statewide since 2006. However, most nesting activity occurred in areas outside of what, in previous years, has been the core nesting area, particularly in the Rotenberger Wildlife Management Area (WMA) and the Kissimmee River floodplain. The Kissimmee Chain of Lakes (KCOL) only supported 18% of the statewide nesting activity; this represented an average to above average number of active nests (132) for the region. Consistent with shifting patterns seen in snail kite use of habitats across South Florida, the KCOL has had fewer total nests, successful nests, and fledglings produced in the past few years than other regions in the state (in contrast to 2007-2013 when KCOL had much higher numbers than any other region). This trend is primarily due to increases in total nests and successful nests in other areas of the state and decreases on East Lake Tohopekaliga and Lake Tohopekaliga. Lake Kissimmee had a stellar year in terms of nest initiation, with the most nests since at least 2006, apparently due to use of floating islands for nesting.

- **Alligators.** FWC monitors American alligator (*Alligator mississippiensis*) populations using spotlight surveys at night, which showed very high populations on Lakes Tohopekaliga, Kissimmee, and Hatchineha for the 2018 sampling period. Populations fell slightly from 2017, when alligator populations on these lakes reached record highs, but they follow an increasing trend over the last 9 to 12 years. East Lake Tohopekaliga has a very small alligator population (around 100 individuals) compared to other lakes. East Lake Tohopekaliga and Lake Cypress alligators continue to show stable populations with modest decreases in this year's population compared to initial surveys in the early-2000s.

INTRODUCTION

The District continues to coordinate with the United States Army Corps of Engineers (USACE) on KRRP construction and is integrating KRRP and KRREP with management activities throughout the Kissimmee Basin and Northern Everglades region. The primary goals of these efforts are to (1) restore ecological integrity to the Kissimmee River and its floodplain, (2) collect ecological data to evaluate river restoration and support water management decision making for river restoration and other goals, (3) enhance and sustain natural resource values in the KCOL, and (4) retain the flood reduction benefits of the Central and South Florida Flood Control Project (C&SF Project) in the Kissimmee Basin. In addition to projects under the KRREP, SFWMD also manages the KCOL and Kissimmee Upper Basin Monitoring and Assessment Project. See Koebel et al. (2018) for historical information about development of the KRRP and KRREP. The geographic scopes of projects in the Kissimmee Basin are shown in **Figure 9-1**.

This year's update on the KRREP evaluations includes analyses of newly available data from studies of hydrology, DO, fish, wading birds, waterfowl, and avian prey availability. This subset of restoration evaluation studies assesses the level of response of critical ecosystem components to physical restoration under Interim (pre-project completion) hydrologic conditions based on new data that have not been reported in previous *South Florida Environmental Report* (SFER) chapters. Results from these studies provide information for sound water management decision making as the KRRP progresses and will guide water management after the project is complete.

The Kissimmee Basin includes more than two dozen lakes in the KCOL, their tributary streams and associated marshes, and the Kissimmee River and floodplain (**Figures 9-2** and **9-3**). The basin forms the headwaters of Lake Okeechobee and the Everglades; together, they comprise the Kissimmee-Okeechobee-Everglades system. In the 1960s, the C&SF Project extensively modified the Kissimmee Basin's water resources by constructing canals and installing water control structures for flood control. In the LKB, construction of the 56-mile long C-38 canal through the Kissimmee River resulted in profoundly negative ecological consequences caused by elimination of flow in the original river channel, which also prevented seasonal inundation of the river's floodplain. These and other environmental losses led to legislation authorizing the federal-state KRRP, for which ground was broken for the first construction phase in 1999. The District has been working since the early 1990s to collect baseline data and to evaluate and operate completed phases of the KRRP through KRREP. See Koebel and Bousquin (2014) for more details regarding environmental losses in the LKB.

This chapter is an update to Chapter 9 of the 2019 SFER – Volume I (Koebel et al. 2019). Its purpose is to report new results from Kissimmee Basin monitoring studies that were active in Planning Window 2018-2019 (PW2019; June 1, 2018–May 31, 2019), specifically those conducted under the District's KRREP and several projects in the KCOL. The chapter also summarizes Kissimmee Basin hydrologic conditions and water management in PW2019, as well as construction and management activities and the status of various other projects throughout the Kissimmee Basin.

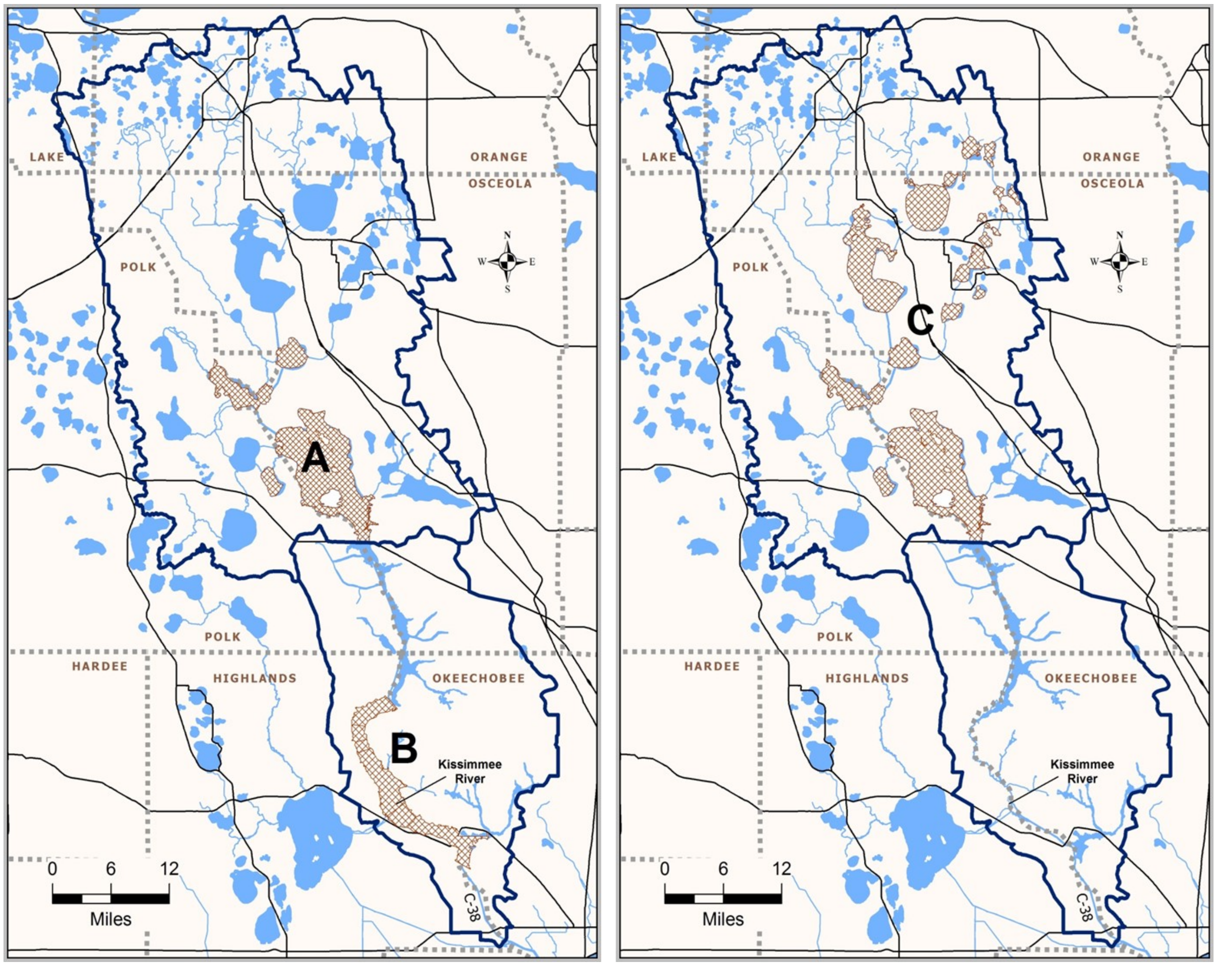


Figure 9-1. Geographic scopes (colored, hatched areas on maps) of major initiatives in the Kissimmee Basin including the (A) Headwaters Lakes components of KRRP, (B) KRRP, and (C) KCOL and Kissimmee Upper Basin Monitoring and Assessment Project.

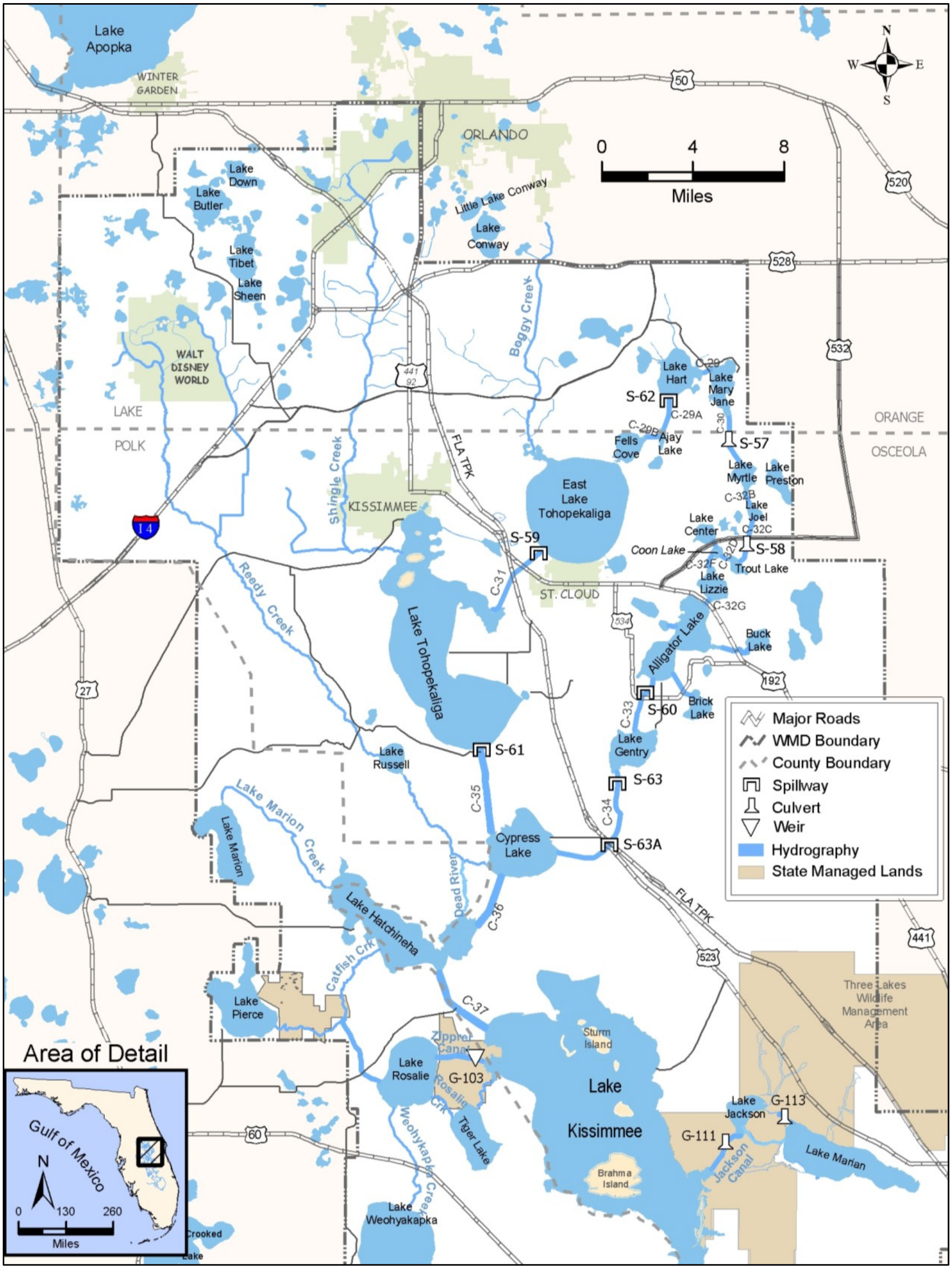


Figure 9-2. Upper Kissimmee Basin. (Note: WMD – South Florida Water Management District.)

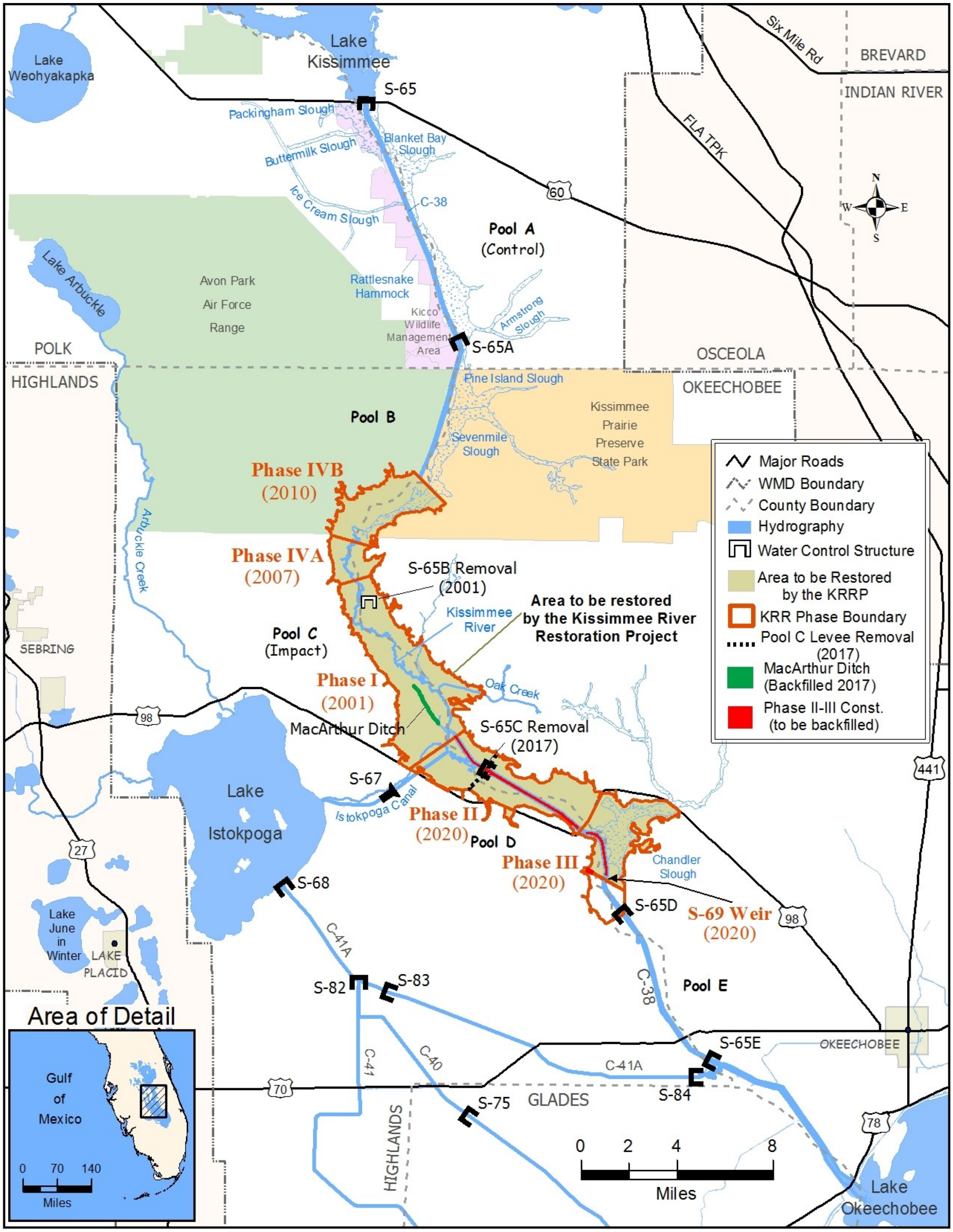


Figure 9-3. Lower Kissimmee Basin with actual and projected completion dates of construction phases. (Note: KRR – Kissimmee River Restoration.)

KISSIMMEE RIVER RESTORATION PROJECT UPDATE

Reconstruction of the river floodplain's physical template is being implemented in four construction phases (**Table 9-1**), currently projected for completion in 2020. Reaches 2 and 3 (Phases II and III) are the last major phases of construction. Reach 3 began in 2015 and was completed in 2016. The Reach 2 contract was awarded in January 2016 and is scheduled for completion in 2020. Construction of the S-69 weir, which will serve as the terminus of the backfilled sections of canal, was awarded in 2019 and is projected for completion in 2020. See Koebel et al. (2018) for more details regarding restoration construction.

Table 9-1. Sequence of backfilling construction phases of KRRP with selected benefits.

Construction Sequence	Name of Construction Reach	Timeline	Backfilled Canal (miles)	River Channel Recarved (miles)	River Channel to Receive Reestablished Flow (miles)	Total Area (acres)	Wetland Gained (acres)	Location and Other Notes
1	Reach 1 Project Area	1999–2001 (complete)	7.5	1	14	9,506	5,792	Most of Pool C, small section of lower Pool B
2	Reach 4A Project Area	2006–2007 (complete)	2	1	4	1,352	512	Upstream of Reach 1 in Pool B to Weir #1
3	Reach 4B Project Area	2008–2010 (complete)	3.5	4	6	4,183	1,406	Upstream of Reach 4A in Pool B (upper limit near location of Weir #3)
4	Reaches 2 and 3 Project Areas	2015–2020 (projected)	9	4	16	9,921	4,688	Downstream of Reach 1 (lower Pool C and Pool D south to the CSX Railroad bridge)
Restoration Project Totals			**22**	**10**	**40**	**24,963**	**12,398**	

The KRRP will culminate with a major modification to operation of the S-65 water control structure at the outlet of Lake Kissimmee. The HRS will allow lake water levels to rise 1.5 ft higher than the current S-65 schedule and will increase the water storage capacity of the Headwater Lakes and Tiger Lake by approximately 100,000 acre-feet (ac-ft). This will allow storage of water for delivery of flows that more closely approximate the historical flows needed for restoration of the Kissimmee River and its floodplain wetlands. Ninety-nine percent of the 36,612 acres (ac) of land in the UKB that will be affected by the higher water levels have been acquired, and all projects needed to increase the conveyance capacity of UKB canals and structures are in place to accommodate the larger storage volume. The few remaining lands are expected to be acquired in 2020.

Because of the time lag between completion of the first reach of construction and implementation of the HRS, USACE authorized an interim regulation schedule in 2001 for S-65 that allows SFWMD to make releases from S-65 when its headwater stage is within a certain range, termed "Zone B", below the maximum regulated stage. Zone B allows releases from S-65 for environmental purposes when flood control releases (stage above the regulation line or Zone A) are not needed. It is used to maintain flow in the reach of the restored river channel downstream throughout the year and to allow seasonal variability including periods of moderate-to-high discharge that are unrelated to flood control releases for the purpose of inundation of the Kissimmee River floodplain. Environmental releases according to this interim schedule began in July 2001, after Reach 1 construction was completed, and lake levels began to rise following the 2000–2001 drought. Zone B releases have allowed continuous flow to the river since that time except for a 252-day period of drought in 2006–2007. The use of Zone B releases has been beneficial to the hydrology of completed sections of the KRRP, but it does not provide the full benefits the HRS is expected to provide when implemented. See the *Hydrology* section below for more information on the regulation schedules and how Zone B releases are used to benefit the Kissimmee River and the Headwaters Lakes.

CONSTRUCTION STATUS

The Reach 2 backfilling contract was awarded by USACE in 2016. Backfilling of the C-38 canal in the Reach 2 area for this contract began in January 2017 and will continue into 2020. The $26.13 million Reach 2 contract is filling an additional 7 miles of the C-38 canal and removed water control structure S-65C, routing water to the native channel and floodplain of the Kissimmee River, which reestablishes hydrologic continuity between the river and floodplain in former Pools C and D for the first time since the C-38 canal was completed in 1971. Reach 2 backfilling was nearly complete in early September 2017 when Hurricane Irma produced extremely high discharge and flooding throughout the Reach 2 construction area resulting in severe erosion of the recent backfill. The high water and discharge associated with Hurricane Irma also caused erosion in the Reach 3 construction area, which was previously completed in 2016. Both areas are being surveyed for erosion and evaluated for repair. Repairs for Reach 2 and Reach 3 are scheduled to be completed by 2020. **Table 9-2** provides brief descriptions of remaining construction activities. A complete list can be found in Koebel et al. (2017).

Table 9-2. Remaining KRRP construction. [a]
See Koebel et al. (2017) for a complete chronology of construction events.

Contract Number	Project Name and Description	Status	Construction Projected or Actual Start Date	Construction Projected or Actual End Date	Cost
10	Reach 2 Backfilling – New channels will be dredged, 6.5 miles of the C-38 canal will be backfilled, and the S-65C structure will be removed.	Under construction	January 2017	December 2020	$26.1 million
12A	S-69 Weir – The S-69 weir will serve as the terminus of the C-38 canal backfill, maximizing the area of wetlands to be rehydrated in the Kissimmee River floodplain. The weir will dissipate the energy of flood flows as they transition from the Kissimmee River floodplain to the remnant C-38 channel.	Under construction	January 2019	October 2020	$15–$25 million

a. Dates and costs do not include repair costs for erosion damages in Reach 2 and Reach 3 backfilling caused by Hurricane Irma.

Construction of the S-69 Weir and backfill began in 2019 (**Figure 9-4**). The S-69 weir will serve as the terminus of the C-38 canal backfill, maximizing the area of wetlands to be rehydrated in the southern Kissimmee River floodplain. The weir will dissipate the energy of flood flows as they transition from the Kissimmee River floodplain to the remnant C-38 channel downstream.

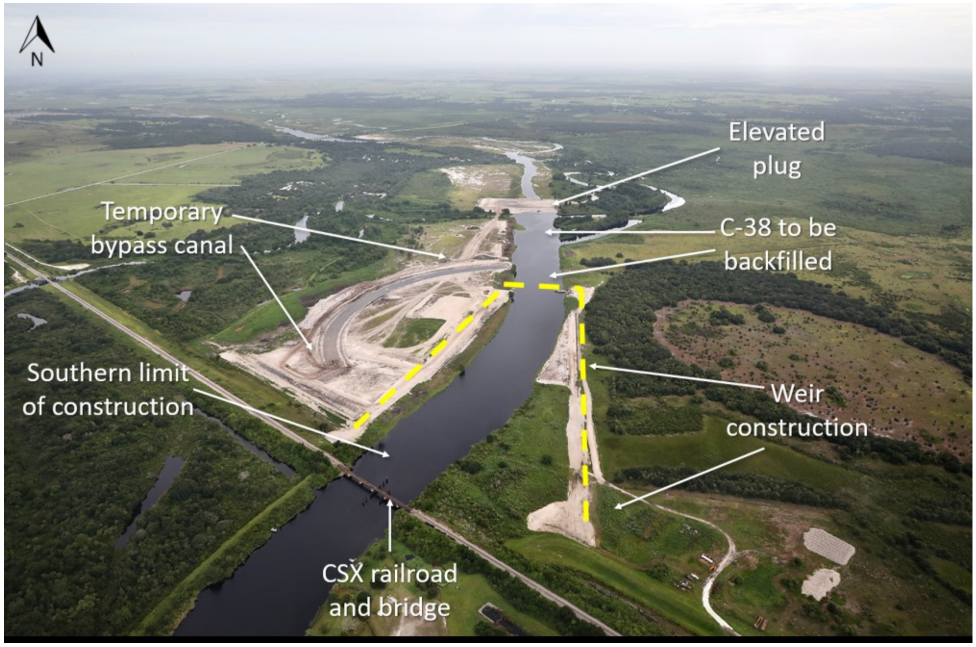


Figure 9-4. KRRP S-69 Weir construction progress.
The yellow dashed line represents the approximate outline of the completed weir.

KISSIMMEE BASIN HYDROLOGIC CONDITIONS AND WATER MANAGEMENT IN PLANNING WINDOW 2018-2019

This section describes hydrologic conditions in the UKB and LKB and their relationship to water management activities in Planning Window 2018-2019 (PW2019; June 1, 2018–May 31, 2019). The planning window is used in this section and the following *KRREP* section in lieu of water year for alignment with KRREP operational planning, seasonal recommendations, and ecological monitoring schedules, all of which are tied to the wet (June–October) and dry (November–May) seasons, whereas the water year is not. Lake regulation schedules in the UKB reach their low pool stages on May 31, coincident with the beginning of the wet season.

The discussion within this section focuses on the timing and quantity of rainfall in the Kissimmee Basin, environmental recommendations for water management in the basin, and the rainfall- and water management-driven temporal patterns of discharge and stage that resulted.

In the LKB, SFWMD uses water control structures S-65, S-65A, and S-65D to manage flow to and water levels in the Kissimmee River and its floodplain (**Figure 9-2**) within the KRRP. Operation of these structures is intended to allow restoration of the river-floodplain ecosystem with consideration of other authorized environmental and flood control project objectives in the LKB and UKB.

In the UKB, water control structures divide the KCOL into seven groups of one or more lakes interconnected by canals (**Figure 9-2**), each with its own regulation schedule (**Figure 9-5**). Surface water from the northern UKB flows to the Headwaters Lakes before being discharged through water control structures S-65 and S-65A to the C-38 canal, which flows to reconstructed sections of the KRRP (**Figure 9-3**). Completion of restoration construction in 2020 and implementation of the HRS are expected to provide additional upstream water storage for discharge to the Kissimmee River and its floodplain. However, appropriate water management during the Interim Period should realize substantial ecological benefits in the northern Phase I and Phase IV floodplain (**Figure 9-3**), where restoration construction has been completed.

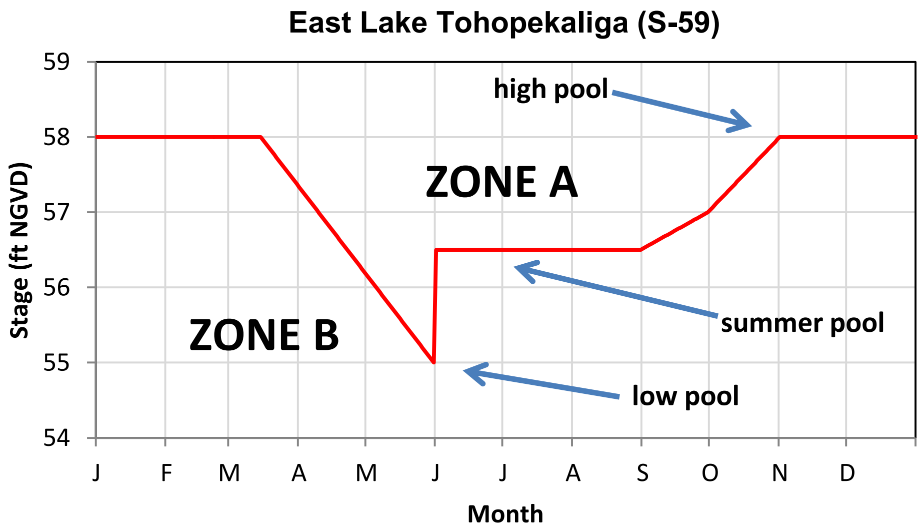


Figure 9-5. Example regulation schedule (East Lake Tohopekaliga) showing the regulation line (red) that separates Zone A (above the line) from Zone B (below the line). When lake stage is in Zone A, releases are mandatory for flood control; when stage is in Zone B, releases are discretionary for environmental purposes. All lakes in the KCOL have a similar schedule with a Zone A and Zone B.

Via S-65 and S-65A, the Headwaters Lakes are the main source of flow to reconstructed sections of the Kissimmee River and its floodplain. As water is released, stage in the Headwaters Lakes declines unless rainfall and runoff into the lakes offsets the volume of water released. Releases from other water bodies upstream of the Headwaters Lakes, especially Lake Tohopekaliga and East Lake Tohopekaliga (e.g., for flood control in those lakes or to meet stage targets) in turn raise stages in the Headwaters Lakes. Therefore, discharge operations at S-65 and S-65A affect both stage in the Headwaters Lakes and flow to and stage in the Kissimmee River. Operation of structures for lake groups north of the Headwaters Lakes also affect stage in the Headwaters Lakes in addition to indirectly affecting water management operations for the KRRP.

One challenge in the management of flow to the Kissimmee River is the limited storage in Pool A. This is due to the narrowness of the C-38 canal in Pool A (only 250 ft wide) and the limited range of headwater stage fluctuation that is currently allowed at S-65A. Consequently, direct rainfall and local basin runoff from even small rainfall events can cause water levels in the C-38 canal to rise rapidly, which can necessitate a reduction in the inflow at S-65 and a rapid increase in the outflow at S-65A, or both, to control rising water levels. Increases in S-65A discharge must therefore often exceed the recommended maximum rates of discharge increases for KRREP (and similarly for rates of decrease). Because S-65A is the primary source of flow to the KRRP, this can have major consequences for restoration. If a rapid increase in discharge occurs after a period of low discharge, it can result in a rapid rise in water levels in the Kissimmee River causing sudden floodplain inundation, resulting in a "crash" in DO due to reduced photosynthesis and increased biological oxygen demand, which can cause a fish kill. The lack of storage in Pool A will continue to pose a challenge for water management after the KRRP is completed.

In addition to other divergent demands, in managing water operations for the KRRP, SFWMD must maintain the pre-KRRP level of flood control and work within the physical limitations of the system (e.g., the operational constraints and conveyance capacities of structures) and environmental conditions (e.g., rainfall) to achieve the best possible outcomes. Thus, the Kissimmee Basin is an ecosystem in which the progress and success of a federally-authorized $800 million ecosystem restoration project with mandated hydrologic and ecological goals (KRRP), nesting habitat for an endangered species (the Everglade snail kite in the KCOL and Kissimmee River), and concerns about downstream ecosystems (including Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries) are factors in water management decisions. In addition to the KRRP, three of the UKB lake groups—the Headwaters Lakes, Lake Tohopekaliga, and East Lake Tohopekaliga—are a focus of discretionary water management in the Kissimmee Basin, which may involve manipulation of discharge from these lakes. In some recent years, an additional factor has been in play with ongoing KRRP construction activities that at times can benefit from river flow rates that are less than required to inundate the floodplain.

THE 1,400-CFS DISCHARGE PLANS IN INTERIM OPERATIONS

The 1,400-cfs discharge plans were originally developed to improve on the duration and continuity of floodplain inundation in the Kissimmee River during the Interim Period but have also been adapted for the future system under HRS. Sustained floodplain inundation almost fully depends on discharge from S-65 via S-65A because most of the volume of water passing through KRRP originates in the UKB and because water levels cannot be maintained on the sloping Kissimmee River floodplain by the downstream water control structure (Anderson 2014). Prior to the use of the 1,400-cfs discharge plans, S-65 operations tended to alternate (often multiple times per year) between brief periods of high discharge for flood control as stage in the Headwaters Lakes rose to or above the regulation line, followed by rapid reductions in discharge to avoid subsequent stage declines in the lakes. The undesirable effect of such operations for the Kissimmee River, clearly visible in stage/discharge hydrographs (e.g., **Figure 9-6**), was sudden inundation of the floodplain followed by rapid termination of the flood event as discharge was reduced below river channel bankfull (approximately 1,400 cfs). The resulting pattern of intermittent, sudden floodplain inundation followed by rapid drying (often within a timeframe of weeks) was quite different from the single long, continuous flood event characteristic of the natural flood pulse, which occurred seasonally in the pre-channelized system (Koebel et al. 2019). Such operations affected floodplain water levels in both the wet and dry seasons. Rapid depth fluctuations in the Kissimmee River floodplain interfere with fish reproduction and recruitment that depend on river channel/floodplain connectivity during the breeding season, disrupt wading bird foraging on the floodplain, and are unnatural and contrary to restoration goals, especially during the dry season (bird and centrarchid fish breeding season).

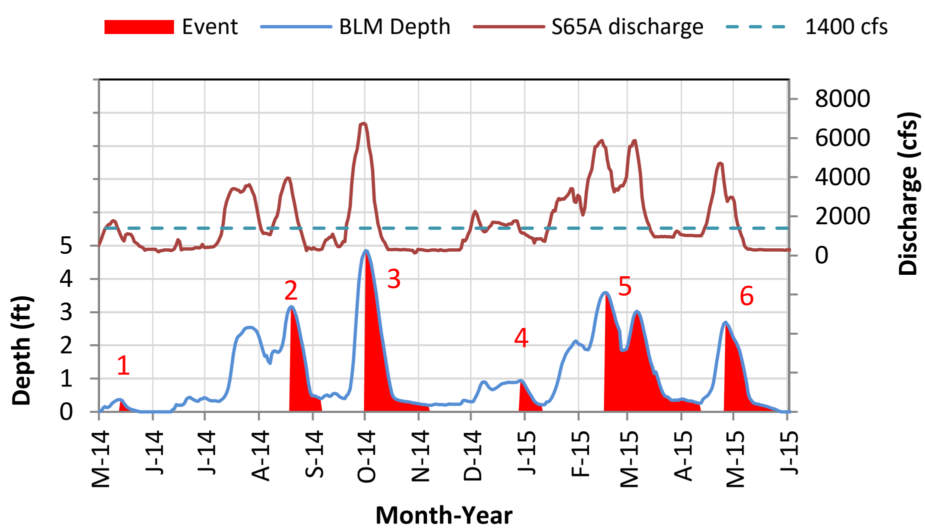


Figure 9-6. An example from PW2015 of unsuitable operations for Kissimmee River restoration. In this case, large, rapid increases in S-65A flood control levels of discharge driven by the regulation line in the Headwaters Lakes were followed by rapid reductions in discharge to maintain high stage in the lakes, causing six discrete floodplain inundation and recession events in the Kissimmee River. These events are described in more detail in Koebel et al. (2019) and other previous SFER chapters.

The 1,400-cfs discharge plans are weather-driven in that changes in discharge are linked to changes in stage in the Headwaters Lakes (i.e., discharge is increased only after rainfall has caused lake stage to rise above a threshold and is not reduced unless rainfall is insufficient to keep stage above the threshold). The plans include limits on the rate of discharge increase and decrease. The rates of change and range of discharges used in the plans are conservative relative to the hydrologic needs of restoration, as discussed in Koebel et al. (2019) and previous chapters. The discharge plans are not intended to fully meet restoration targets for the Kissimmee River during the current, Interim Period. However, variants of the 1,400-cfs discharge plans have been found to improve on prior operations, moving toward better performance in a crucial aspect of the hydrologic requirements for restoration and floodplain inundation. Because similar river/lake tradeoffs will also exist under the future HRS, similar plans have been incorporated into planning for HRS implementation.

METHODOLOGY

Hydrologic conditions were quantified with data collected by SFWMD's hydrologic monitoring program at water control structures throughout the Kissimmee Basin (**Figures 9-2** and **9-3**) and stage monitoring locations distributed in the Kissimmee River channel and floodplain (**Figure 9-7**). The section follows the conventions of SFWMD and USACE water managers by reporting hydrologic variables in English units—inches for rainfall, ft National Geodetic Vertical Datum of 1929 (NGVD29) for stage and depth, and cfs for discharge.

Hydrology in the KRRP Phase I floodplain is complex; its dynamics were characterized for PW2019 using the metric: mean depth at floodplain BLM sites (referred to as **BLM Depth**). BLM is a vegetation type with very long hydroperiod requirements (see the *Hydroperiod Evaluation (Expectation 3) in PW2019 and the Interim Period* subsection of the *Kissimmee River Restoration Evaluation Program* section). It was the dominant wetland plant community on the floodplain prior to channelization and is expected to cover more than 50% of the Kissimmee River floodplain once historic hydroperiods are reestablished. Mean daily stage (water surface elevation) from recorders at each BLM site was converted to water depth by subtracting the average ground elevation within a 100-ft radius centered on the stage recorder in a surveyed digital elevation model.

BLM Depth was calculated as the average depth at five stations in the northern floodplain at which BLM vegetation occurred prior to regulation (pre-1962, i.e., before construction of the C-38 canal) and where BLM is expected to reestablish after restoration construction is completed and historic hydrology is restored (see *Hydrology* subsection of the *Kissimmee River Restoration Evaluation Program* section of this chapter). The five stations used for calculation of BLM Depth were selected because they are in the northern floodplain of the Phase I area and thus are outside the direct influence of the headwater stage of the former (through February 2017) downstream water control structure (S-65C), and for concurrence with Expectation 3, which is evaluated in the *Kissimmee River Restoration Evaluation Program* section later in this chapter.

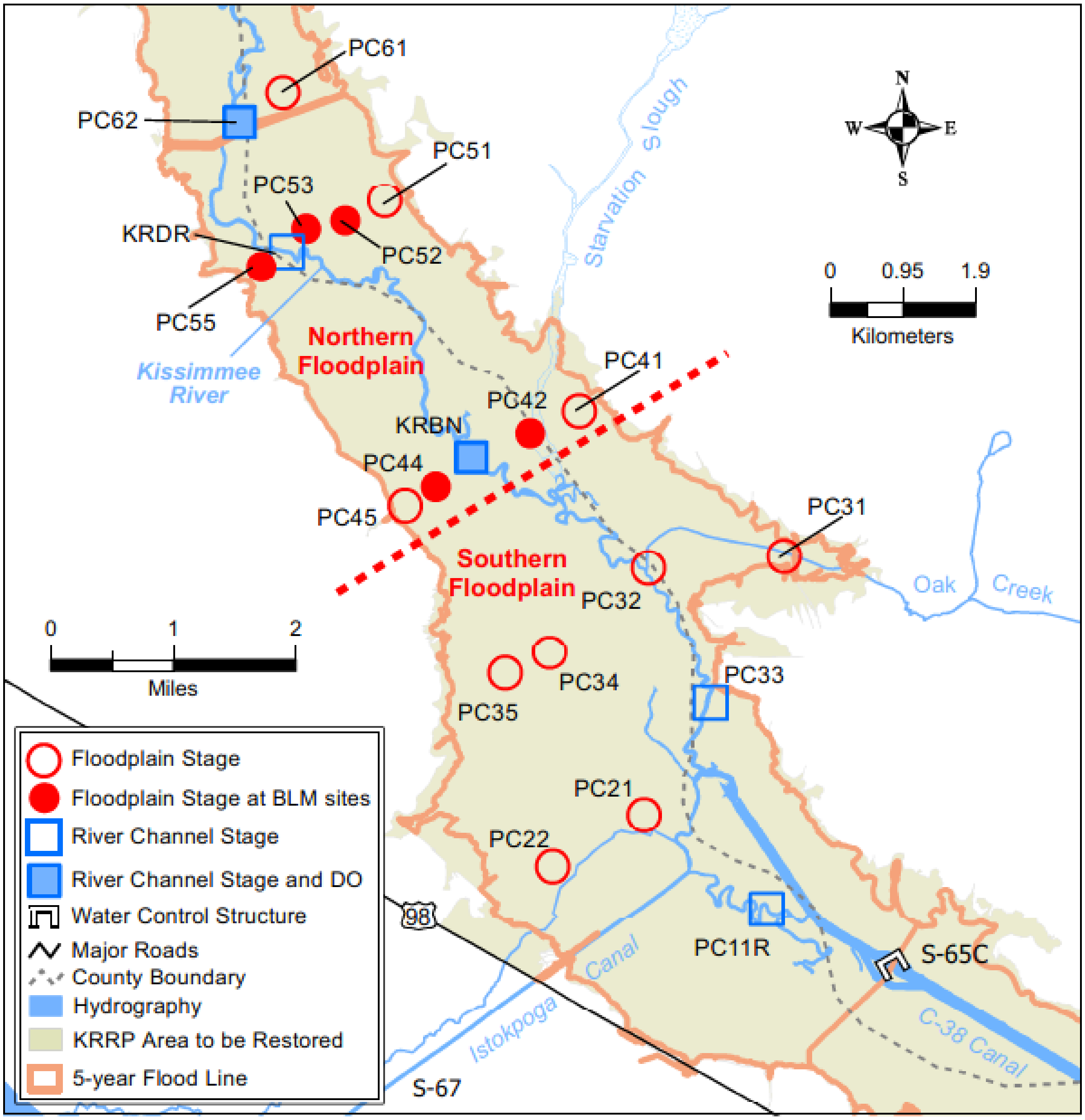


Figure 9-7. Locations of hydrologic monitoring sites in Pool C used to guide operations and evaluate restoration expectations.

RAINFALL

Total rainfall was below average in the UKB and LKB for PW2019 (**Figure 9-8**). The below average rainfall in PW2019 is in contrast to above average rainfall in WY2019; the difference is due to the inclusion of May 2018 in the water year, which had more than double the long-term average rainfall for the month. Total rainfall in the UKB for PW2019 was 46.2 inches (92% of the long-term average), and the LKB had 39.3 inches (82% of average). Approximately 60% of the planning window rainfall fell during the June–October wet season. Wet season rainfall totaled 28.9 inches (90% of average) in the UKB and 23.6 inches (74% of average) in the LKB. Dry season rainfall totaled 17.4 inches (96% of average) in the UKB and 15.8 inches (99% of average) in the LKB.

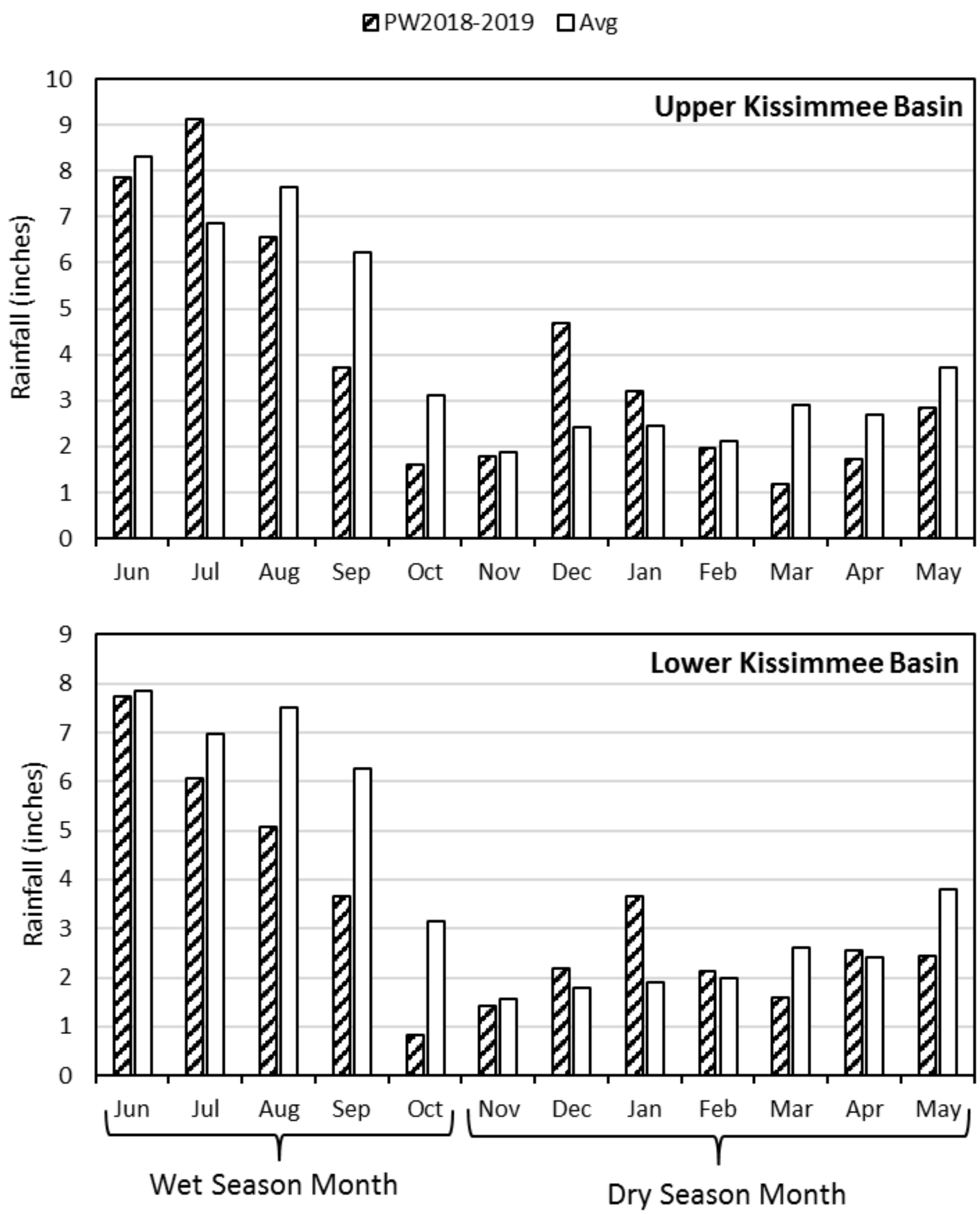


Figure 9-8. Monthly rainfall for PW2019 and average rainfall (1989–2018) in the UKB (top panel) and the LKB (bottom panel).

OPERATIONAL REQUESTS AND OUTCOMES

Seasonal Operational Planning

KRREP scientists collect input from partner agencies (SFWMD and USACE for KRRP, and from FWC, United States Fish and Wildlife Service [USFWS], and SFWMD for the KCOL) to develop wet and dry season recommendations that balance KRRP needs with other considerations within the Kissimmee Basin. Throughout this process, KRREP scientists work closely with the District's water managers to implement seasonal recommendations and coordinate Kissimmee Basin operations with other C&SF Project purposes.

KRREP wet and dry season planning typically involves modeling to determine how proposed operations are likely to affect water levels in the Headwaters Lakes, discharge to the Kissimmee River, and the volumes of water originating in the UKB that are released to Lake Okeechobee via the Kissimmee River and C-38 canal. These analyses provide a better understanding of the tradeoffs among operational plans and the probable frequency of occurrence of desired conditions over long periods of time, rather than targeting goals to be met in years in which conditions may not be suitable to achieve them.

2018 Wet Season Water Management Outcomes

IS-14-50.0 Discharge Plan

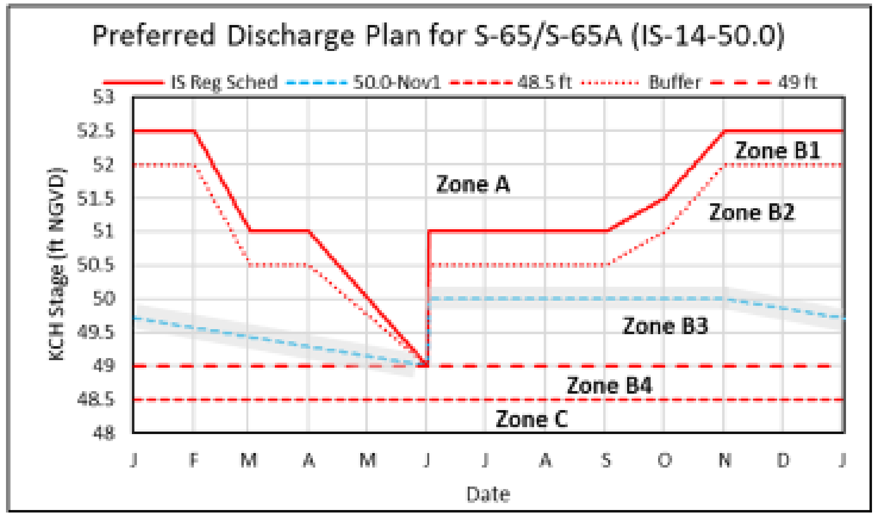
Implementation of the IS-14-50.0 discharge plan (**Figure 9-9**) was delayed for almost a month by the transition from operations during the preceding dry season that were intended to lower stage in the Headwaters Lakes to the low pool of the regulation schedule. Stage rose above the regulation schedule in mid-May; discharge was increased to 1,100 cfs to limit the stage rise in the Headwaters Lakes. The 2018 wet season began on June 1 with the Headwaters Lakes at 49.8 ft NGVD29 and S-65 and S-65A discharge at 1,100 cfs (**Figure 9-10B**). Thus, the wet season began with lake stage below the 50 ft discharge plan threshold line at which discharge would be raised to at least 1,400 cfs but with discharge well above the 300 cfs that was recommended in the discharge plan (**Figure 9-9**). Discharge was held at 1,100 cfs until mid-June, when a series of discharge reductions were made to help slow a decline in DO (see **Figure 9-10D** and the *Wet Season Dissolved Oxygen* section below) and a stage decline in the Headwaters Lakes. By the end of June, discharge had been reduced to 362 cfs. However, per the discharge plan, flow was increased to 1,400 cfs once stage in the Headwaters Lakes rose to 50 ft and was above 1,400 cfs through most of the wet season. As stage declined to the 50.0 ft NGVD29 threshold in late October, S-65 and S-65A discharge was reduced to 300 cfs and S-65A discharge was held at 300 cfs for the remainder of the wet season. The reduction in discharge slowed the rate of stage decline in the Headwaters Lakes (**Figure 9-10B**).

Kissimmee Basin 2018 Wet Season with revised discharge table

Stage and Discharge Guidance for Wet Season 2018.		
Zone	**KCH Stage (ft NGVD)**	**S-65/S-65A Discharge***
A	Above regulation schedule line.	Flood control releases as needed.
B1	In flood control buffer zone (0.5 ft below the schedule line).	Adjust S-65 discharge so that S-65A discharge is between 1400 cfs at the buffer zone line and 3000 cfs at the schedule line.
B2	Between the Flood Control Buffer and the 50.0 ft line.	Adjust S-65 discharge to maintain at least 1400 cfs at S-65A. Use ± 0.2 ft buffer (gray band) above and below the 50.0 ft line to decide when to begin ramping up to 1400 cfs or down to 300 cfs.
B3	Between the 50.0 ft line and 49 ft.	Adjust S-65 discharge to maintain at least 300 cfs at S-65A.
B4	Between 48.5 ft to 49 ft.	Adjust S-65 discharge to maintain S-65A discharge between 0 cfs at 48.5 ft and 300 cfs at 49 ft.
C	Below 48.5 ft.	0 cfs.

*Changes in discharge should not exceed limits in inset table below.

Discharge Rate of Change Limits for S65/S65A (revised 7/13/18).		
Q (cfs)	Maximum rate of increase (cfs/day)	Maximum rate of decrease (cfs/day)
0-300	50	-50
301-650	75	-75
651-1400	150	-150
1401-3000	300	-600
>3000	1000	-2000



Other Considerations

- When possible, limit lake ascension rate in the Jun 1 - Aug 15 window to 0.5 ft per 14 days in Lakes Kissimmee, Cypress, Hatchineha (S-65), East Toho (S-59) and Toho (S-61).
- If outlook is for extreme dry conditions meet with KB staff to discuss modifications to this plan.

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Figure 9-9. The IS-14-50.0 discharge plan for wet season 2018. The table insert specifies limits on rates of discharge increase and decrease at S-65 and S-65A. The plan uses the IS regulation line. Source: KB-2018-Wet Season Planning Presentation (April 19, 2018); the discharge rate of change limits table was modified on July 13, 2018, to allow faster rates of decrease when discharge is greater than 1,400 cfs. (Note: KB – Kissimmee Basin and KCH – Headwaters Lakes.)

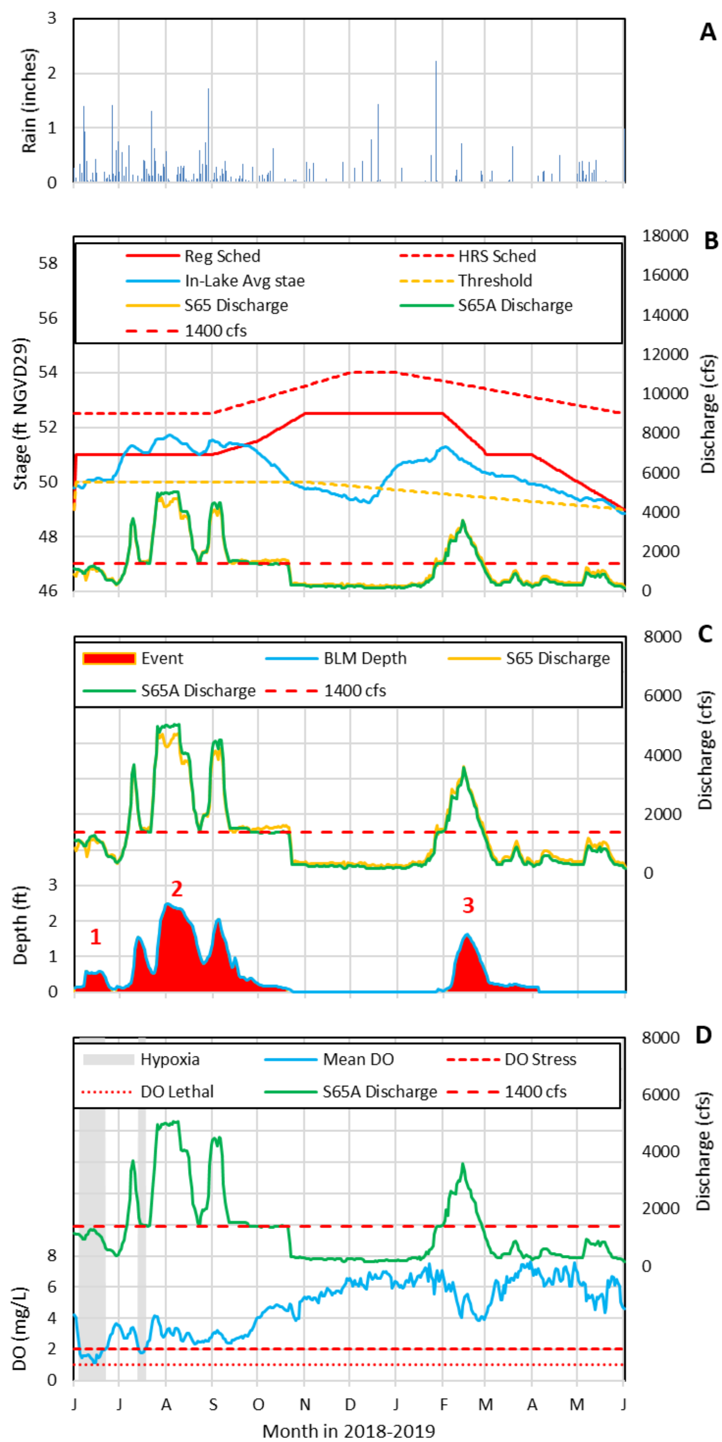


Figure 9-10. (A) Basin rainfall in the Headwaters Lakes, (B) regulation schedule, HRS regulation schedule, lake stage, and discharge from the Headwaters Lakes; (C) BLM Depth at five stations (PC52, PC55, PC53, PC44, and PC42) in the northern floodplain where BLM occurred pre-channelization and is expected to reestablish after restoration is completed in relation to mean daily discharge at S-65A; and (D) mean daily DO (calculated from 15-minute measurements) in the river channel at PC33 and PC62, and discharge at S-65A during June 2018–May 2019 planning window. Red numbers in Panel C identify three floodplain flood events that are described in the text. See **Figure 9-7** for locations of hydrologic monitoring sites and the *Kissimmee River Restoration Evaluation Program* section's *Hydrology* subsection for more information.

Wet Season Floodplain Inundation

Three floodplain inundation events (BLM Depth > 0.1 ft) occurred in PW2019 (**Figure 9-10C**): two wet season events are described here and the third, a dry season event, is described below. The first event was the result of discharge of 1,100 cfs combined with rainfall. It lasted 25 days (June 1 to 25, 2018). BLM Depth peaked at 0.6 ft on June 9, 2018. The second floodplain inundation event resulted from implementation of the IS-14-50.0 discharge plan. S-65A discharge was at or above the estimated bankfull discharge of 1,400 cfs for 108 days (July 6–October 21, 2019) (**Figure 9-10B**). This period of bankfull or greater discharge corresponded to 113 days (June 29–October 19, 2018) with a BLM Depth of at least 0.1 ft (**Figure 9-10C**). During this period, discharge was increased for flood control when stage in the Headwaters Lakes exceeded the regulation schedule. Flood control discharges were moderate compared to previous years, with a peak discharge of just over 5,000 cfs, which resulted in a maximum BLM Depth of 2.49 ft. The first flood control release (peak of 3,700 cfs) was continuous with the initial discharge increase to 1,400 cfs; the depth recession from this event was interrupted by the second (maximum of 5,000 cfs) and third (maximum of 4,500 cfs) event, which resulted in BLM Depth reversals of 1.98 ft and 1.25 ft, respectively. The first reversal exceeded the 1.5 ft criterion used to identify a new recession event (see the *Hydroperiod Evaluation (Expectation 3) in PW2019 and the Interim Period* subsection of the *Kissimmee River Restoration Evaluation Program* section). Implementation of IS-14-50.0 in the 2018 wet season produced a single continuous period of inundation but the recession from this event was disrupted by flood control releases that resulted in large depth reversals.

Wet Season Dissolved Oxygen

Two periods of hypoxia (DO less than 2 mg/L) occurred during the 2018 wet season (**Figure 9-10C**). Both events were relatively short compared to past wet seasons with the first lasting 17 days (June 5 to 21, 2019) and the second only 5 days (July 14 to 18, 2018). Mean daily DO remained above 1 mg/L during the first event and above 1.7 mg/L in the second. Further details are provided in the *Dissolved Oxygen* subsection of the *Kissimmee River Restoration Evaluation Program* section, below.

Everglade Snail Kite Nesting in the Kissimmee River Floodplain

The endangered Everglade snail kite nested successfully in the Kissimmee River floodplain during the 2018 wet season, only the second known nesting effort in the floodplain. Nests were first observed in July 2018 after floodplain inundation began. New nests were being initiated as late as early September, and a few active nests were still active in mid-October. Once nesting was judged to have ended in late October, S-65A discharge was reduced below 1,400 cfs. Over the season, snail kites initiated 93 nests, approximately one-third of which successfully fledged offspring. Once the floodplain was inundated, District water management contributed to nesting success by maintaining floodplain water levels that were sufficiently deep to discourage terrestrial predators but not deep enough to flood active nests. KRREP scientists developed tools to track water levels under the nests to help guide recommendations for water management as conditions changed. The IS-14-50.0 discharge plan attempts to increase the duration of floodplain inundation aligned with the need to maintain water under the nests, but releases from S-65 and S-65A for flood control in the Headwaters Lakes had to be constrained to avoid inundating the nests during times of heavy rainfall.

Ascension Rates in the Kissimmee Chain of Lakes

Stage ascension rates were calculated daily for the June 1–August 15 window as the difference between current stage and stage 14 days prior. The preferred stage ascension rate of 0.5 ft per 14 days was exceeded on 20 days in East Lake Tohopekaliga, 19 days in Lake Tohopekaliga, and 19 days in the Headwater Lakes. All exceedances occurred in July and early August and resulted from above average rainfall in the UKB during July (**Figure 9-8**). As had been requested by FWC and USFWS in prior years, water was released from East Lake Tohopekaliga and Lake Tohopekaliga, as conditions permitted, to slow stage ascension so that it did not exceed the preferred rate (**Figure 9-9**). In June, releases were being made from the Headwaters Lakes per the IS-14-50.0 discharge plan (**Figure 9-9**) to provide flow to the Kissimmee River (**Figure 9-10B**); these releases were adequate to keep the stage ascension rate below the preferred maximum rate, but later in the summer even large flood control releases were not sufficient to prevent exceedances of the preferred maximum rate in July and early August.

2018-2019 Dry Season Water Management Outcomes

Lake Stage Recession

Recessions began as requested by FWC on January 15 in East Lake Tohopekaliga and Lake Tohopekaliga with lake stage at 57.56 and 54.59 ft NGVD29, respectively, and ended on June 1 at approximately the low pool of the regulation schedule (**Figure 9-9**). The recession in the Headwaters Lakes began on February 15 as requested with stage at 50.77 ft NGVD29 and reached the low pool of 49 ft NGVD29 on May 28 (**Figure 9-10**). Between the recession start dates and June 1, recessions were generally slower the preferred maximum of 0.2 ft per 7 days, with all three water bodies having a mean recession rate of 0.13 ft per 7 days. There were no large stage reversals, with maximum reversals of 0.07 ft in East Lake Tohopekaliga, 0.11 ft in Lake Tohopekaliga, and 0.09 ft in the Headwaters Lakes.

Floodplain Inundation

After S-65A discharge was reduced to 300 cfs in late October, discharge remained well below the bankfull discharge of 1,400 cfs at S-65A and flow was confined to the river channel for most of the dry season. The exception was a 29-day period (January 29–February 26, 2019), when S-65A discharge was between 1,400 and 3,600 cfs. Discharge was increased to lower stage in the Headwaters Lakes prior to the start of the recession on February 15. The increase in discharge resulted in water on the floodplain (BLM Depth greater than 0.1 ft) for 61 days (February 3–April 4, 2019) and BLM Depth greater than 1 ft for 15 days, with a maximum depth of 1.63 ft (**Figure 9-10C**). During this period, large numbers of Everglade snail kites were observed in the Kissimmee River floodplain, although discharge was reduced before nesting was initiated, drying the floodplain.

Construction

Flow conditions less than 1,000 cfs were requested by USACE during construction of S-69, and were provided for most of the dry season. S-65D discharge was less than 1,000 cfs for 170 days and less than 600 cfs for 134 days; it only exceeded 1,000 cfs for a 40-day period (January 27–March 7, 2019).

Summary of Planning Window 2018-2019 Water Management Operations

The IS-14-50.0 discharge plan was successfully implemented in the 2018 wet season, producing a single 108-day period with bankfull discharge or greater. The long period of floodplain inundation was critical for the successful Everglade snail kite nesting that occurred in the floodplain during the 2018 wet season.

PW2019 is the third implementation of a version of a 1,400-cfs discharge plan since the 2015 wet season. It represented a substantial increase in the duration of above bankfull discharge over the two previous implementations (**Table 9-3**). Several factors contributed to the longer durations in PW2019 compared to previous years. First, the stage threshold (50.0 ft) was lower than the threshold used in 2015 (50.5 ft). Second, the discharge plan was more consistently followed than in 2017, a year in which discharge was reduced to 300 cfs while stage in the Headwaters Lakes was well above the threshold. Third, the PW2019 wet season began with stage in the Headwaters Lakes 0.8 ft above low pool instead of at low pool, which compensated for the 2018 wet season having the lowest total rainfall in the UKB of the three years that the discharge plan was implemented. Interestingly, the 2016 wet season, in which the plan was recommended but not implemented (**Table 9-3**), would likely have resulted in a much longer interval of flow above 1,400 cfs. A spreadsheet simulation of the 2016 wet season indicated that following the recommended plan would have resulted in a single 182-day event (May 10–November, 2016) instead of the two widely separated events that resulted from flood control releases for 50 days (May 10–June 28, 2016) and 36 days (September 3–October 10, 2016) (Koebel et al. 2018).

Table 9-3. Outcomes of wet season recommendations to implement a 1,400-cfs discharge plan.

Year Recommended for Implementation	Recommended Plan	Outcome	Event Number	Above Bankfull Discharge Duration (days)
2015	IS-14-50.5	Produced a single wet season floodplain inundation event.	1	75
2016	IS-14-50.5	Not implemented due to non-standard emergency operations that attempted to hold as much water in the UKB to reduce flow to Lake Okeechobee and possibly the coastal estuaries. Flood control releases resulted in two widely separated events.	1 2	50 30
2017	HRS-14-50.0	Produced a single wet season floodplain inundation event. Event duration would have been longer except discharge was reduced to 300 cfs while the lake stage was almost 2 ft above the threshold stage.	1	75
2018	IS-14-50.0	Produced a single wet season floodplain inundation event.	1	108

The preferred maximum ascension rate was exceeded in the 2018 Wet Season between 19 and 20 days in East Lake Tohopekaliga, Lake Tohopekaliga, and the Headwaters Lakes. Such exceedances are not unexpected; as reported in Chapter 9 of the 2016 SFER – Volume I (Koebel et al. 2016), attempts to control early wet season ascension rates can—and often will—be overwhelmed by rainfall events; as shown earlier, ascension rates exceeding 0.5 ft using the 14-day difference method occurred frequently prior to regulation. A higher frequency of exceedances is expected in all lakes, but particularly in the Headwaters Lakes because of interactions between East Lake Tohopekaliga and Lake Tohopekaliga and the effects of discharge from those lakes on stage in the Headwaters Lakes. Inflow into the Headwaters Lakes is increased by efforts to reduce ascension rates upstream in East Lake Tohopekaliga and Lake Tohopekaliga (S-59 and S-61, respectively) and complicates maintaining moderate rates of discharge change at S-65 and S-65A downstream to protect the KRRP from rapid changes in stage. For example, excessively fast increases in water levels can cause DO declines, and excessively fast reductions can strand aquatic organisms on the floodplain. This illustrates the strong potential for operational conflicts among these three water bodies, complicating the implementation of lake stage target requests, including both ascension and recession rates.

The 2018-2019 dry season was the third consecutive dry season with below average rainfall, especially during March, April, and May, in the UKB. These dry conditions contributed to steady recessions with generally small reversals (less than 0.1 ft).

The period of floodplain inundation that occurred in the 2018-2019 dry season was probably too brief and too isolated from the previous and subsequent periods of inundation to be of much value to restoration of the Kissimmee River. Such brief events may be harmful by providing a false signal to biota that the floodplain will be inundated. Prior to channelization, the floodplain was often inundated during at least a portion of the dry season; this was typically the continuation of a single inundation event that had begun late in the preceding wet season. The resulting long period of floodplain inundation provided important foraging habitat for wading birds and waterfowl, nursery areas for important game fish, and was necessary to meet the hydroperiod requirements for the dominant wetland vegetation. Managing for a single, continuous floodplain inundation continues to be a focus of efforts to manage the Kissimmee River. Simulations suggest that consistent adherence to 1,400-cfs discharge plans will result in improvements in floodplain inundation while balancing benefits to the Headwaters Lakes.

LOWER KISSIMMEE BASIN – KISSIMMEE RIVER RESTORATION EVALUATION PROGRAM

A major component of the KRRP is assessment of restoration success by the Kissimmee River Restoration Evaluation Program (KRREP), a comprehensive ecological monitoring program (Bousquin et al. 2005, Williams et al. 2007, Koebel and Bousquin 2014) mandated and designed to evaluate the ongoing status and ultimate success of the KRRP in meeting its environmental goals. Restoration evaluation was identified as SFWMD's responsibility in its cost-share agreement with USACE for the KRRP (Department of the Army and SFWMD 1994).

Only studies that collected new data in WY2019 are updated in this section. New results from studies of floodplain hydrology, DO, fish, wading birds and waterfowl, and floodplain prey availability document the status of these ecosystem components. Where applicable, results are evaluated in relation to the associated KRREP restoration expectations. An additional report is presented on floodplain vegetation management efforts. **Table 9-4** provides a directory of KRREP monitoring study updates that have been presented in the SFER since 2005.

Table 9-4. Directory of KRREP Phase I restoration response monitoring study updates in the 2005–2020 SFERs. [a]

KRREP Monitoring Study or Project	Expectation Number	Beginning Page Number in 2005–2020 SFERs — Volume I															
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Kissimmee River Restoration Evaluation Program		11-8	11-37	11-22	11-28	11-36	11-26	11-25	9-16	9-19	9-20	9-22	9-27	9-29	9-27	9-27	9-22
Hydrology																	
Stage-discharge relationships	None	11-20															
Continuous river channel flow	1	**11-18**				**11-39**	**11-29**	**11-29**	**9-20**	**9-23**	**9-22**	**9-26**					
Variability of flow	2					**11-40**	**11-31**	**11-32**	**9-20**	**9-23**	**9-23**	**9-28**					
Stage hydrograph	3	**11-22**				**11-41**	**11-32**	**11-33**	**9-21**	**9-24**	**9-24**	**9-30**	**9-37**	**9-38**	**9-37**	**9-37**	**9-25**
Stage recession rate	4	**11-23**	11-23	11-16	11-19	**11-42**	**11-34**	**11-35**	**9-24**	**9-27**	**9-28**	**9-33**	**9-41**	**9-42**	**9-41**	**9-41**	**9-27**
Flow velocity	5	**11-25**					**11-35**	**11-37**	**9-24**								
Broadleaf marsh indicator	None					11-43						9-33	9-37				
Geomorphology																	
River bed deposits	6	**11-26**						**11-70**									
Sandbar formation	7	**11-26**						**11-70**									
Channel monitoring	None					11-54		11-68									
Sediment transport	None							11-71									
Floodplain processes	None							11-72									
Dissolved Oxygen	8	**11-28**	**11-44**	**11-25**	**11-28**	**11-45**	**11-36**	**11-38**		**9-27**	**9-30**	**9-36**	**9-45**	**9-47**	**9-45**	**9-45**	**9-32**
River Channel Metabolism	None				11-35												
Phosphorus	None	11-33	11-52	11-30	11-32	11-51	11-43	11-43	9-25	9-31	9-34	9-40	9-50				
Turbidity	9	**11-30**	**11-48**	**11-27**													
Periphyton	None	11-46															
River Channel Vegetation																	
Width of littoral vegetation beds	10	**11-36**				**11-59**											
River channel plant community structure	11	**11-37**				**11-59**											
Floodplain Vegetation																	
Areal coverage of floodplain wetlands	12	**11-39**			**11-35**			**11-47**			**9-42**	**9-50**				**9-55**	
Areal coverage of broadleaf marsh	13	11-40			**11-35**			**11-47**			**9-43**	**9-51**				**9-56**	
Areal coverage of wet prairie	14	11-40			**11-35**			**11-47**			**9-43**	**9-51**				**9-56**	

Table 9-4. Continued.

KRREP Monitoring Study or Project	Expectation Number	Beginning Page Number in 2005–2020 SFERs — Volume I															
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Invertebrates																	
Macroinvertebrate drift composition	15	**11-45**	11-57														
Snag invertebrate community structure	16	**11-46**	11-55			11-62											
Aquatic invertebrate community structure in broadleaf marsh	17		11-57														
Benthic invertebrate community structure	18	**11-45**	11-58			11-62											
Native and nonnative bivalves	None							11-52									
Fish																	
Impact of hypoxic events on largemouth bass and bluegill	None															9-58	
Herpetofauna																	
Floodplain reptiles and amphibians	19	11-48	Response data will be collected after implementation of the Headwaters Regulation Schedule (HRS).								9-47						
Floodplain amphibian reproduction and development	20	11-48	Response data will be collected after implementation of the HRS								9-47						
Fish Communities																	
Small fishes in floodplain marshes	21	11-50	Response data will be collected after implementation of the HRS.														
River channel fish community structure	22	11-52	**11-59**			**11-66**			**9-29**								
Mercury in fish	None					11-20											
Floodplain fish community composition	23	11-50	Response data will be collected after implementation of the HRS.														
Birds																	
Wading bird abundance	24	**11-58**	**11-71**	**11-32**	**11-44**	**11-72**	**11-50**		**9-36**	**9-41**	**9-53**	**9-57**	**9-51**	**9-55**	**9-57**	**9-60**	**9-38**
Waterfowl	25		**11-67**	**11-35**		**11-73**	**11-52**		**9-37**	**9-42**	**9-55**	**9-59**	**9-54**	**9-57**	**9-59**	**9-64**	**9-42**
Shore birds	None	11-57															
Wading bird nesting	None		11-68		11-40	11-72	11-47		9-33	9-38	9-47	9-53	9-56	9-51	9-53	9-66	9-46
Wading bird and waterfowl prey availability	None														9-62		**9-46**
Threatened and Endangered Species	None	11-60															

a. Bolded page numbers indicate a major update in reference to the status of a restoration expectation (performance measure).

HYDROLOGY

This section evaluates metrics for Expectations 3 (hydroperiod) and 4 (recession events) in PW2019 and provides an overall assessment of progress towards meeting these expectations during the post-Phase I construction Interim Period (PW2002–PW2019). The reference conditions used to develop these expectations and the effect of channelization on BLM Depth and recession events were summarized in last year's *Hydrology* subsection (Koebel et al. 2019). These expectations have been especially challenging to address operationally in the Interim Period. The section concludes with recommendations for changes in discharge management that can improve performance for these expectations during the remainder of the Interim Period.

Hydroperiod Evaluation (Expectation 3) in Planning Window 2018-2019 and the Interim Period

Expectation 3 (Hydroperiod Requirements for Broadleaf Marsh)

Stage hydrographs that result in floodplain inundation frequencies comparable to pre-channelization hydroperiods, including seasonal and long-term variability characteristics.

- Component A: 59% of water years will have a BLM depth ≥ 1 ft for 210 consecutive days.
- Component B: 40% of water years will have BLM depth ≥ 1 ft for 210 consecutive days in the August–February window.

BLM Depth ≥ 1 ft occurred during two widely separated events in PW2019 (**Figure 9-11**). The first lasted 63 days (July 11–September 11, 2018) and was associated with flood control releases during implementation of the IS-14-50.0 discharge plan. The first event included two brief intervals when BLM depth decreased below 1 ft: (1) 8 days (July 18–25, 2018) and (2) 5 days (August 24–28). BLM Depth remained above 0.5 ft during both intervals. The second event with BLM Depth ≥ 1 ft occurred several months later and only lasted 15 days (February 10–February 24, 2019). It was associated with increases in discharge to begin the recession in the Headwaters Lakes for Everglade snail kites. Both events were far shorter than the desired duration of 210 days. Neither event in PW2019 met the criterion of BLM Depth ≥ 1 ft for 210 days for the water year (Component A) or the August–February window (Component B).

BLM depth exceeded 1 ft in every year of the Interim Period even in drought years and sometimes for multiple events as happened in PW2019. The longest event in the Interim Period was only 169 consecutive days, far short of the 210-day criterion and barely exceeded the 25th percentile for years in the Reference Period (**Figure 9-12**). Therefore, none of the events in the Interim Period have met the 210-day criterion (Component A) or the criterion for the more restrictive August–February window (Component B). Only one year in the Interim Period (PW2006, in which Hurricane Wilma passed over the basin at the end of wet season), came close to meeting the criterion for that water year (Component A) or the seasonal window (Component B). However, for PW2006 to have met the 210-consecutive day criterion for Component A, the two longest periods of continuous BLM depth of at least 1 ft would have had to have been connected by disregarding a gap of 21 days (**Figure 9-12**). To have met the criterion during the August–February window (Component B), a second gap of 28 days also would have had to have been disregarded.

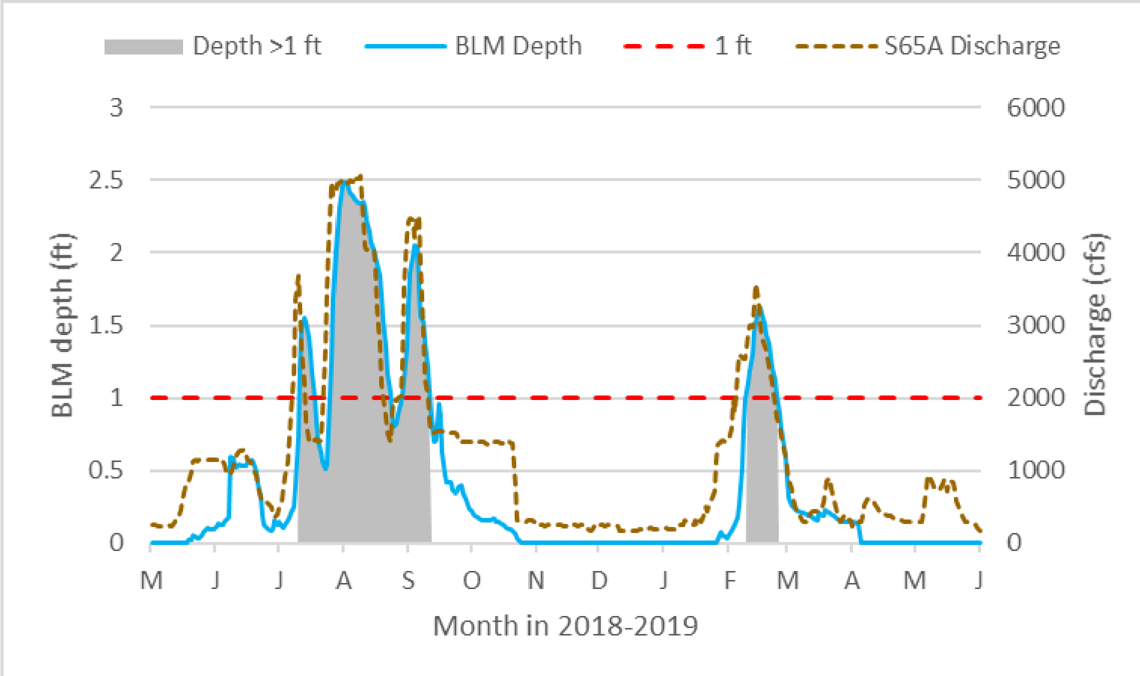


Figure 9-11. BLM Depth and S-65A discharge during PW2019. Gray shading indicates intervals of time when BLM depth was at least 1 ft. BLM depth is the average of mean depth at five stage recorders in the northern Phase I area floodplain.

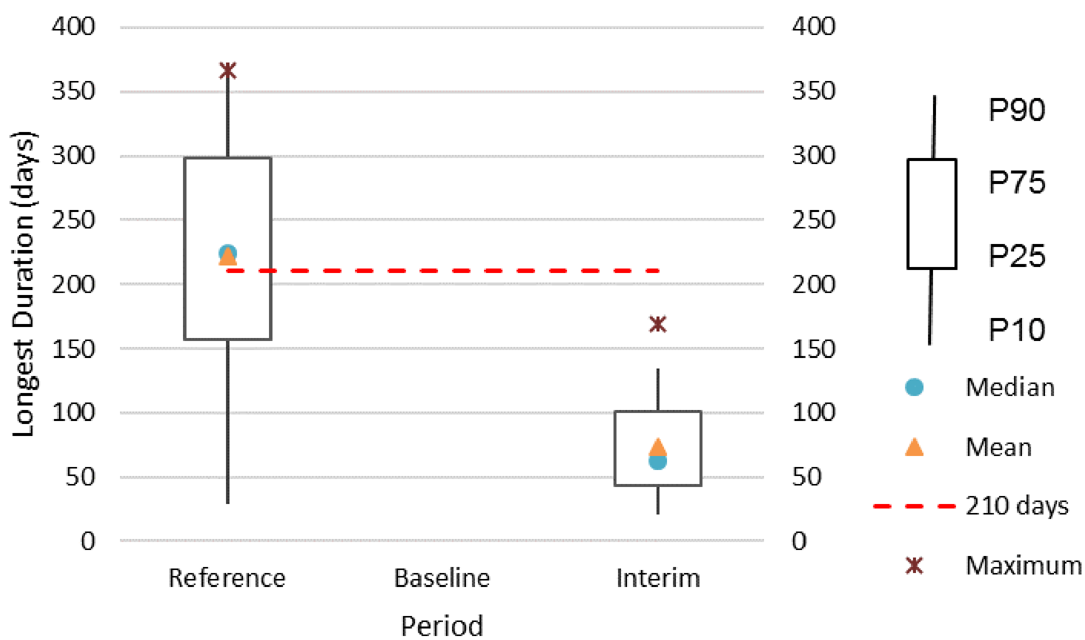


Figure 9-12. Longest duration (consecutive days) with BLM depth ≥1 ft in the Kissimmee River floodplain for 32 Reference Period years, 28 Baseline Period years, and 18 Interim Period years. No events occurred in the Baseline Period. Dashed red line indicates the 210-day criterion for the expectation. Box plots show the 90^{th}, 75^{th}, 25^{th} and 10^{th} percentiles.

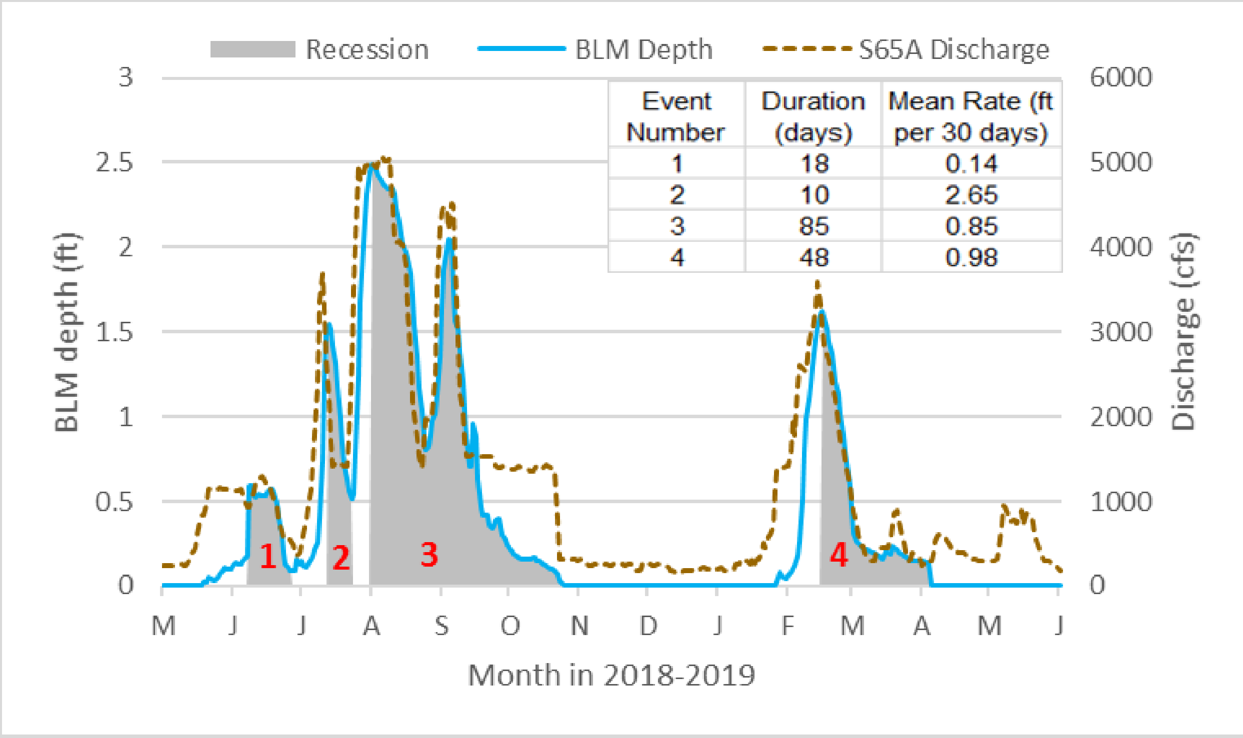
Recession Events (Expectation 4) in the Interim Period

Expectation 4 (Recession Events)

Stage hydrographs that result in floodplain recession events with rates of water level decrease, duration, and timing that are comparable to pre-channelization events, including seasonal and long-term variability characteristics.

- Component A: 72% of recession events will have a mean recession rate < 1 ft per 30 days.
- Component B: 100% of recession events will have a mean recession rate < 2 ft per 30 days.

PW2019 had four recession events (**Figure 9-13**) that were associated with the three floodplain inundation events that were described in the *Kissimmee Basin Hydrologic Conditions and Water Management in Planning Window 2018-2019* section earlier in this chapter. The additional recession event resulted from the abrupt termination of the second recession event by a stage reversal of 2 ft that exceeded the 1.5 ft criterion that is used to identify a new recession event; the second recession event lasted only 10 days and had a mean recession rate of 2.65 ft per 30 days. The third recession event was also interrupted by a large increase in discharge for flood control that caused a 1.2 ft reversal in BLM Depth only slight less than the 1.5-ft criterion used to identify a new recession event. Recession rates for these four events ranged from 0.14 ft per 30 days to 2.65 ft per 30 days (**Figure 9-13**). Three events had a rate < 1 ft per 30 days, and the fourth was > 2 ft per 30 days. These four recession events brought the Interim Period total to 36 recession events, or an average of two events per year.



Event Number	Duration (days)	Mean Rate (ft per 30 days)
1	18	0.14
2	10	2.65
3	85	0.85
4	48	0.98

Figure 9-13. BLM Depth and S-65A discharge during PW2019. Four recession events are indicated by gray shading and identified by red numbers. Duration and mean recession rate for each event are shown in the table. BLM Depth is the average of mean depth at five stage recorders in the northern Phase I area floodplain.

During the Interim Period, mean recession rates for recession events ranged from 0.14 to 5.13 ft per 30 days, with a mean rate over all events of 1.82 ft (± 0.21 standard error [SE]) per 30 days (**Figure 9-14**). The duration of recession events ranged from 10 to 203 days and averaged 72 days (± 9 SE). Recession rates were < 1 ft per 30 days for 31% of the recession events and < 2 ft per 30 days for 69% of events – both values well below their respective targets of 72% for Component A and 100% for Component B. As a result, Interim Period values to date for the two recession rate metrics did not meet the expectation targets based on the Reference Period data (**Figure 9-15**). Nearly a third of Interim Period recession events were faster than any that occurred in the Reference Period.

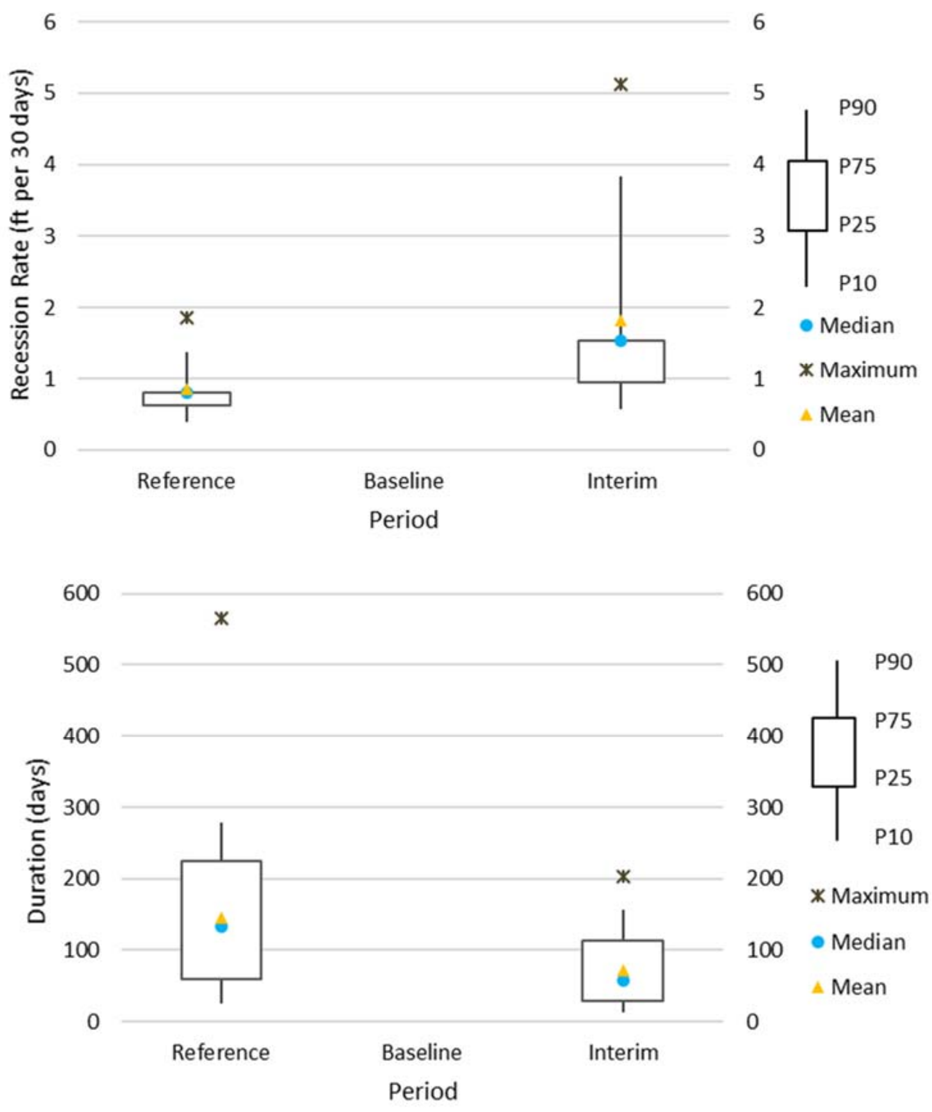


Figure 9-14. (A) Recession rates and (B) event duration for recession events during the Reference Period (PW1931–PW1962) and the Interim Period (PW2002–PW2019) in the Kissimmee River floodplain. No recession events occurred in the Baseline Period (PW1972–PW1999).

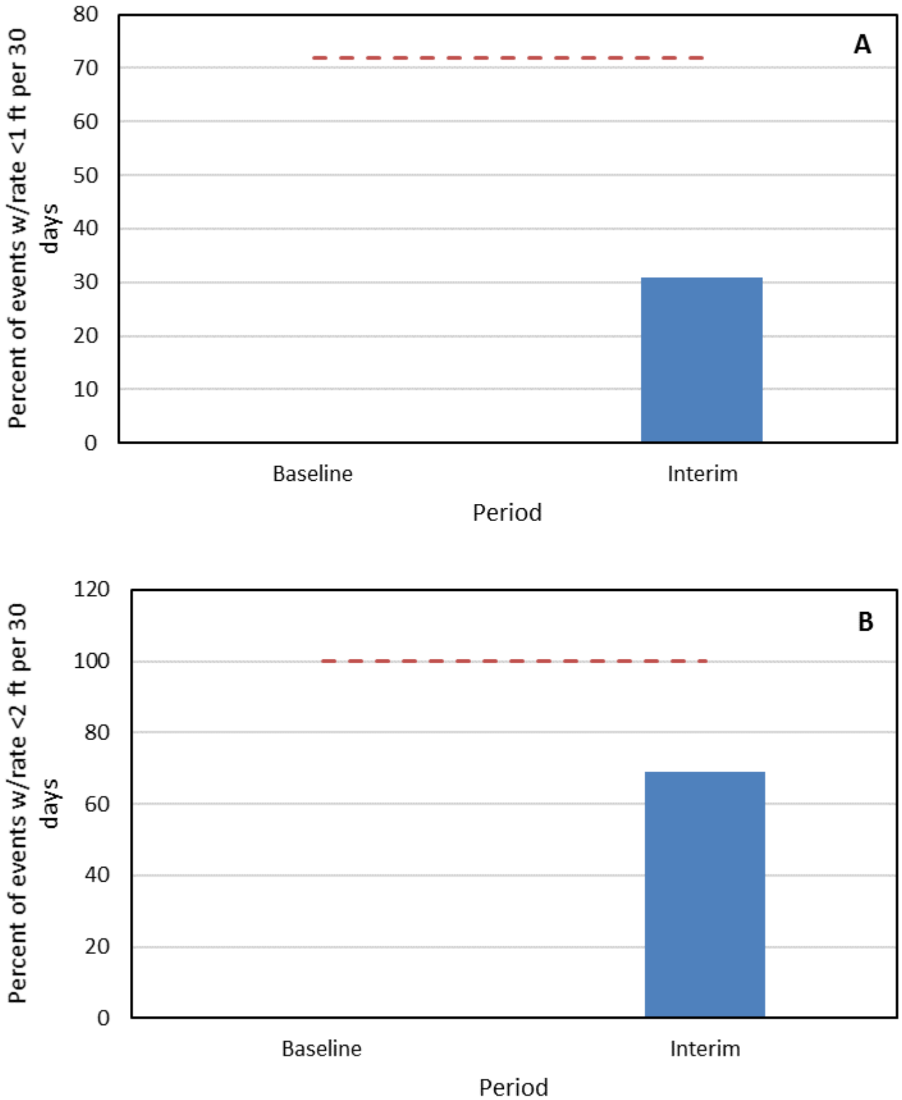


Figure 9-15. Comparison of the percent of Kissimmee River floodplain recession events that had rates (A) < 1 ft per 30 days (Component A) and (B) < 2 ft per 30 days (Component B) during the Baseline Period (PW1972–PW1999) and Interim Period (PW2002–PW2019). Dashed red lines are the target percentages based on the frequency of events during the pre-channelization Reference Period (PW1932–PW1962). Frequent reductions to low discharge result in disjunct floodplain inundation events separated by periods of floodplain drying.

Reestablishment of flow through the river channel by backfilling of the C-38 allows water levels to fluctuate in response to variable flow, providing intervals of floodplain inundation and recession during the Interim Period (Anderson 2014). This is an improvement over the stabilized water levels of the channelized Baseline Period. However, water management has not yet reestablished in even one year the single, long period of floodplain inundation ending with a slow stage recession that typified most years of the pre-channelization Reference Period. Evaluation of the hydrologic expectations show that even the longest period of inundation with BLM Depth ≥ 1 ft in the Interim Period is only about the 25th percentile of pre-channelization events; concomitantly recessions are too rapid.

Excessively fast floodplain recession rates have important implications for restoration success. A slow recession rate was an important characteristic of floodplain inundation events during the Reference Period and interacted with other aspects of the hydrologic regime to produce the long hydroperiods or flood pulses typical of the unregulated ecosystem (i.e., slow floodplain recession rates were a consequence of the characteristic gradual decline in flow from the headwaters lakes). Faster recession rates, as seen in the Interim Period and especially in recent years, are largely due to operations that impose unnatural demands on the system. These operations disrupt the continuity and duration of flood pulses, with the consequence of pronounced intervals of dry conditions that are unsuitable for the floodplain's signature marshes (Spencer and Bousquin 2014). If continued, such operations will inhibit recovery of the Kissimmee River and floodplain.

Also characteristic of the Interim Period are extreme changes in Kissimmee River floodplain stage (stage reversals) due to rapid increases in discharge at S-65 and S-65A (e.g., **Figures 9-6** and **9-13**). For example, during PW2019, large discharge increases for flood control twice interrupted the floodplain recession. These reversals were a potential threat to Everglade snail kites that were nesting in the floodplain at the time. Such flood control releases result from lake stage being at or near regulation schedule, often to maintain high lake stage, so that even minor rainfall events can trigger flood control releases. These are not a consequence of the 1,400-cfs discharge plan, which tends to keep lake stage below the regulation line. Large increases in discharge have been identified as a problem for restoration of the Kissimmee River (Cheek et al. 2014) and may now threaten Everglade snail kites nesting there. Floodplain reversals as small as 0.3 ft (much smaller than the 1.5-ft reversal used here to identify new recession events) have been associated with abandonment of nests by wading birds (Frederick and Collopy 1989, Smith et al. 1995).

Relationship of Hydroperiod and Recession Events to Discharge

BLM Depth is influenced, to a small extent, by direct rainfall and associated LKB runoff, but sustaining prolonged periods of inundation almost completely depends on inflow discharge through S-65 via S-65A (Anderson 2014). Thus, the way these structures are operated directly influences floodplain inundation characteristics in the Phase I area as evaluated by Expectations 3 and 4, and therefore the extent to which the hydrologic criteria can be met. Thus, recovery of the biota that depend on improvement in and eventual reestablishment of pre-regulation hydrology for recovery is strongly influenced by water management operations.

Recommendations to modify S-65 operations have been made every wet season beginning in 2015; these recommendations have involved the use of a 1,400-cfs discharge plan to address the hydroperiod and recession expectations to improve hydrologic performance for KRRP as required by USACE (1991, 1996). For the 2018 wet season, the recommendation was to implement the IS-14-50.0 discharge plan as described in the *Kissimmee Basin Hydrologic Conditions and Water Management in Planning Window 2018-2019* section earlier in this chapter. Although the plan is intended to improve hydrologic performance for Expectations 3 (hydroperiod) and 4 (recession events), it is not expected to fully meet the criteria for either expectation in the Interim Period. Similar discharge plans are being applied to the future HRS; how well the plans improve hydrologic performance before or after the HRS is implemented will be influenced by how consistently they are implemented.

Implementation of discharge plans during the 2015, 2017, and 2018 wet seasons resulted in a single floodplain inundation and recession event during each wet season, with BLM hydroperiods of 76, 63, and 63 days, respectively. Holding discharge at 1,400 cfs during these events extended the period BLM Depth was at least 1 ft, although the resulting durations were well short of the target duration of 210 days, partly due to rainfall. This underscores the importance of plan implementation across all years to capitalize on years of enough rainfall to provide prolonged floodplain inundation and periods of higher stage in the Headwaters Lakes using balanced discharge plans. Even so, this outcome suggests a promising direction for Kissimmee Basin operations when balancing stage in the Headwaters Lakes against S-65 discharge to achieve benefits in both systems without harming either. Holding discharge at 1,400 cfs during the discharge ramp down also improved hydrologic performance for Expectation 4 by increasing the duration of the recession event and slowing the recession rate. No negative effects on the lakes have been noted except slightly lower stages over the period of implementation.

SFWMD will continue to evaluate, refine and implement 1,400-cfs discharge plans in future years. Modeling suggests that consideration should be given to extending a modified version of a discharge plan throughout the year as well as potentially lowering the threshold stage to 49.5 ft to further improve performance. The plans are examples of hydrologically and ecologically balanced operations designed to link discharge for the KRRP to rainfall via upstream lake stage to achieve mutually beneficial operations for these two inextricably connected parts of the Kissimmee Basin ecosystem. The plan does not attempt to fully meet the KRRP expectations for hydroperiod and recession events during the Interim Period, although implementations of 1,400-cfs discharge plans have demonstrated that substantial improvements in performance for the hydrologic expectations can be made without the additional storage that will be provided by the HRS.

Under many circumstances, implementation of plans of this kind will require that discharge not be reduced to low levels to reach short-term goals such as forcing slightly higher stages or maintaining stable stages in the Headwaters Lakes. In some years, this will mean lower average lake stages than would occur without use of a stage-discharge relationship, but for the lakes, the resulting relationship of variation in lake stage with discharge would be more similar to what happened in the pre-channelization system (see Figure 9-10 in the *Kissimmee Basin Hydrologic Conditions and Water Management in Water Year 2015* section in Chapter 9 of the 2016 SFER – Volume I; Koebel et al. 2016) and would better approximate both the natural relationship of lake stage to flow and the natural variability in lake stage that is characteristic of healthy lakes (NRC 1992).

Extension of Discharge Plans through the Dry Season

Implementation of 1,400-cfs discharge plans during the 2015, 2017, and 2018 wet seasons resulted in promising improvements in the performance of Expectations 3 and 4 that could have been enhanced by continuing to follow the plan into the dry season. For example, the simulation of PW2019 presented in the *Kissimmee Basin Hydrologic Conditions and Water Management in Planning Window 2018-2019* section above showed that continuing to follow the plan into dry season would have greatly increased the duration of inundation during the dry season and might have allowed Everglade snail kites that were present on the floodplain early in the nesting season to nest (discharge was reduced, draining the floodplain, before mating and nesting began).

Extension of discharge plans through the dry season would help address another issue identified in previous years—that rapid changes in discharge to manipulate stage in the Headwaters Lakes can result in harmful depth fluctuations in the Kissimmee River and floodplain. Current KRREP operational guidelines allow maximum rates of discharge decrease and increase that are relaxed to consider realistic operational needs; however, the rates of change are much faster than occurred in the Reference Period. Operations to achieve and maintain high stages near the regulation line in the Headwaters Lakes (and to a lesser extent in East Lake Tohopekaliga and Lake Tohopekaliga), or to precisely follow dry season stage recession lines without stage reversals in these lakes, create conditions under which all or most inflow from rainfall events must be quickly discharged to the river, rather than balancing the stage reversals that inevitably result from rainfall between the lakes and the river. The resulting abrupt reductions and increases in depth on the Kissimmee River floodplain are harmful, inhibiting improvements in performance of the KRRP hydrologic goals, as well as impacting wading bird foraging and nesting and fish breeding. Modeling suggests that such operations may also inhibit a more natural range of stage fluctuation in the Headwaters Lakes.

Summary

The performance of hydrologic Expectations 3 (hydroperiod) and 4 (recession events) in PW2019 was influenced by the implementation of the IS-14-50.0 during the 2018 wet season and the below average wet season rainfall.

Expectation 3

- The targets for Expectation 3 (hydroperiod) were not met in PW2019 or in any year of the Interim Period thus far (PW2002–PW2019).
- Performance for Expectation 3 (hydroperiod) can be improved by implementing operations designed to increase the number of consecutive days that inflow discharge of 1,400 cfs or greater is maintained.

Expectation 4

- The targets for Expectation 4 (recession events) were not met in PW2019 or in any year of the Interim Period thus far (PW2002–PW2019).
- Performance for Expectation 4 (recession events) can be improved by slowing the rate of recession, especially by eliminating the practice of decreasing discharge to low levels to hold the Headwaters Lakes stable at high stages for extended periods.

Use of discharge plans such as the one implemented in PW2019 can improve hydrologic conditions for Expectations 3 (hydroperiod) and 4 (recession events) and create conditions for recovery of the biotic components of the river/floodplain ecosystem.

DISSOLVED OXYGEN

Dissolved oxygen (DO) directly affects aquatic life through oxygen (O_2) availability and the metabolism of aquatic ecosystems (Colangelo 2007, Hauer and Lamberti 2007). DO concentration can influence the growth, distribution, and structural organization of aquatic communities and thereby impact the productivity of aquatic ecosystems (Wetzel 2001). For these reasons, DO was chosen as one of the metrics used in KRREP expectations for evaluation of the status and success of the KRRP (Colangelo and Jones 2005).

DO in the Kissimmee River channel is a function of the balance between primary production, respiration, and reaeration (Chen 2019), which are influenced by many physical factors, including temperature, water depth, stage, flow (discharge) at water control structure S-65A and the former structure S-65C (Chen et al. 2016), and rainfall. Operation of the structures that control flow to the project area thus has important implications for reduction of the severity and/or duration of hypoxic and anoxic events in partially restored sections of the Kissimmee River.

Evaluation of Expectation 8

Expectation Components: Mean daytime concentration of DO in the Kissimmee River channel at 0.5- to 1.0-m depth will increase

(a) from < 1–2 mg/L to 3–6 mg/L during the wet season (June–October) and

(b) from 2–4 mg/L to 5– 7 mg/L during the dry season (November–May).

(c) Mean daytime DO concentrations within 1 m of the channel bottom will exceed 1 mg/L more than 50% of the time.

(d) Mean daily (24-hour) DO concentrations will be > 2 mg/L more than 90% of the time (updated from Colangelo and Jones 2005).

Reference (Pre-Channelized Period) and Baseline (Channelized Period) Data

Based on Reference and Baseline periods' data, restoration of the Kissimmee River is expected to improve DO concentrations in the river channel primarily by reintroducing flow, which is expected to reduce the amount of organic matter that accumulated on beds of non-flowing (remnant) channels after construction of the C-38 canal (Colangelo and Jones 2005). DO data from the Kissimmee River were not available prior to channelization. For this reason, available daytime DO data from nearby free-flowing blackwater streams where DO had been measured frequently from 1973 to 1999 were used to estimate reference (pre-channelization) conditions for the Kissimmee River (**Table 9-5**). For some of these streams, more than 10 years of data were available (Colangelo and Jones 2005). Baseline (channelized) Period DO data were obtained from monitoring stations in non-flowing remnant river runs of the Kissimmee River and the C-38 canal prior to Phase I construction. For these data, grab samples were collected monthly within a time window between 10 am and 2 pm from PW1996 to PW1999. Expectation 8 components a, b, and d were developed based on these reference and baseline data. Component c was developed based on weekly DO depth profiles sampled in Micco Bluff Run and Montsdeoca Run in the Phase I project area of the Kissimmee River from May to October 1999. Details and summaries of Reference and Baseline periods' data and expectation development are available in Colangelo and Jones (2005).

Table 9-5. Reference, Baseline, and Post-construction periods DO sampling for performance evaluation in the KRRP.

Period	Sampling Type and Frequency	Depth	Dates Collected	Location	Purpose
Reference (Represents the pre-channelized condition)	Grab, daytime; monthly	0.5–1.0 m	1973–1999	Reference nearby free-flowing blackwater straits	Expectation and target development
Baseline	Grab, daytime; monthly	0.5–1.0 m	1996–1999	Non-flowing remnant runs in the Kissimmee River	Establish baseline for comparison with restored condition
Post-Phase I Construction – Interim and Final	Sonde; continuous	0.5–1.0 m	2002–present	KRRP Phase I area	Expectation evaluation; hypoxia/anoxia investigations
Post-Phase I Construction – Interim and Final	Grab, daytime; monthly	0.5–1.0 m and within 1 m of the channel bottom	2002 – present	Remnant runs in the Kissimmee River	Expectation evaluation

Interim (Post-Phase I Construction) Data

DO monitoring has continued in the Phase I Interim Period (post-Phase I construction) at some of the stations that were used to establish Reference and Baseline DO conditions. The same or similar grab sampling methods have been used to collect data for evaluating changes in DO before and after restoration construction (**Table 9-5**). Grab samples used for evaluation of Components a and b were collected monthly from sampling stations KREA91, KREA92, and KREA97 in Pool A and KREA93, KREA94 and KREA98 in the Phase I area between 10 am and 2 pm. Daytime DO concentrations within 1 m of the channel bottom were also measured at stations KREA94 and KREA98 in the Phase I area for evaluation of Component c. Daytime only measurements were used for compatibility with the available reference data as described earlier and in Colangelo and Jones (2005).

For evaluation of Component d during the Interim Period, continuous monitoring of daily (24-hour) DO at stations PC33 and PC62 was conducted using stationary DO sondes at a depth of 0.5−1 m from the water surface in the Phase I river channel (**Table 9-5**). The data were collected continuously at 15-minute intervals, day and night. Data from these stations also are used to provide technical guidance for adaptive management of discharge at water control structures S-65 and S-65A.

For statistical evaluations of a restoration effect on DO, the difference (ICd) between the Impact (Pool BC of the Phase I area where flow was reestablished in 2001) and the Control (Pool A, which was not altered by restoration construction) area means was calculated for daytime DO collected monthly at the KREA stations using a before-after-control impact paired series (BACIPS) sampling design (Osenberg et al. 2006, Bousquin and Colee 2014). The ICd data were tested for autocorrelation using a Durbin-Watson test, which indicated no significant autocorrelation. A t-test was used to test the difference between the ICd means for daytime DO in the before (Baseline) and after (Interim) periods (Stewart-Oaten et al. 1992). Statistical significance was evaluated at $\alpha = 0.05$.

Post-Construction Dissolved Oxygen through May 2019

Since completion of Phase I construction (PW2002-–PW2019), DO in the Phase I Impact area (Pool BC) has averaged 2.84 ± 0.11 mg/L (SE) during the wet season and 6.54 ± 0.09 mg/L during the dry season (**Figure 9-16**). By comparison, post-construction DO in the Control area (Pool A) was significantly lower at 1.82 ± 0.11 and 3.52 ± 0.12 mg/L during the wet and dry seasons, respectively ($p < 0.01$). Mean annual daytime DO has been significantly higher in the Phase I area, 5.00 ± 0.17 mg/L than in Pool A, 2.81 ± 0.18 mg/L for the 18 years since completion of Phase I construction ($p < 0.01$) (**Figure 9-17**).

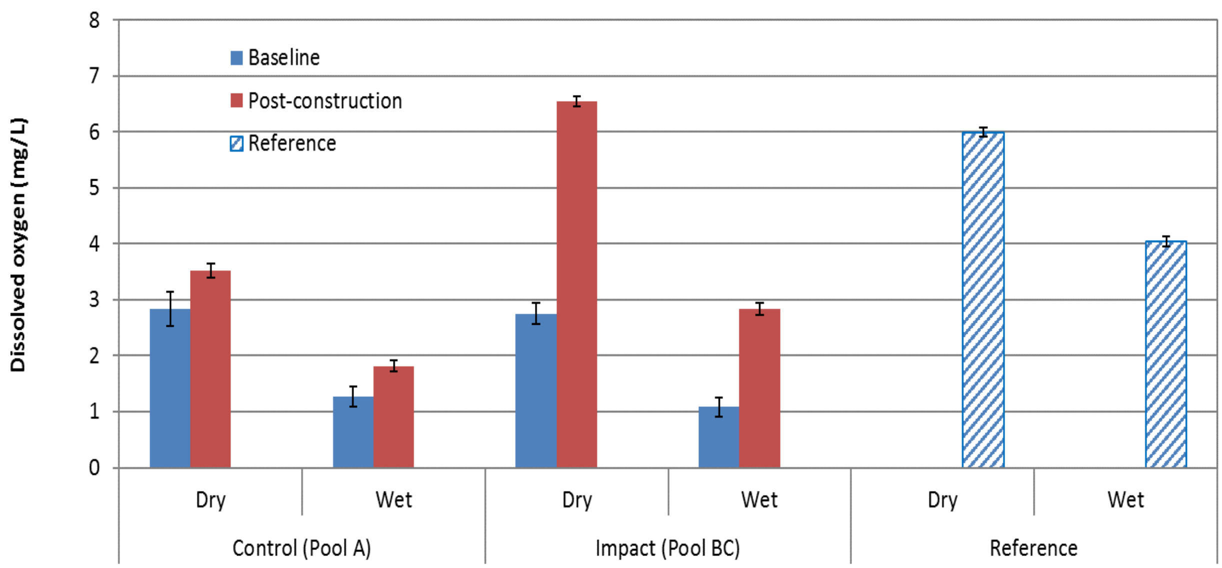


Figure 9-16. Daytime DO concentrations (mean ± SE) in reference streams (period of record = PW1973–PW1999) and Control and Impact areas in wet and dry seasons during the Baseline (PW1997–PW1999) and Post-Phase I construction (PW2002–PW2019) periods. Impact areas in Pool BC have had reestablished flow since Phase I construction was completed in 2001; Control areas in Pool A have not been altered by KRRP construction activities and, therefore, remain non-flowing.

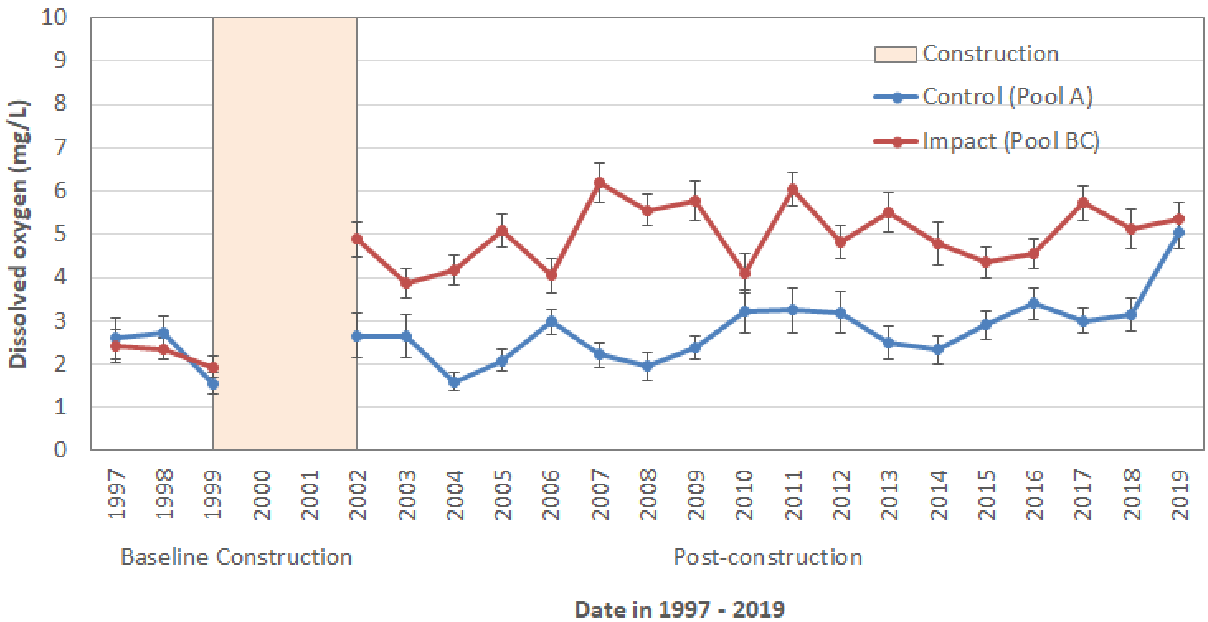


Figure 9-17. Daytime DO concentrations (mean ± SE) of sampling stations KREA91, KREA92, and KREA97 in Pool A and sampling stations KREA93, KREA94, and KREA98 in the Phase I Impact area (Pool BC) of the Kissimmee River for each year during the Baseline (PW1997–PW1999) and Post-Phase I construction periods (PW2002–PW2019).

A t-test on the ICd means of Baseline and Post-Phase I construction samples indicated that DO greatly improved in the Phase I Impact area during Post-Phase I Period compared to the Control area. The ICd for DO was significantly higher for the Post-construction Period (2.19 ± 0.17 mg/L) than for the Baseline Period (-0.18 ± 0.19 mg/L) ($p < 0.01$).

In PW2019, the four components of Expectation 8 were met (**Table 9-6**). Mean daytime DO concentration in the wet season in the Phase I area increased from 2.43 mg/L in PW2018 to 3.10 mg/L in PW2019 ($p < 0.01$), meeting component a's requirement of 3–6 mg/L. Mean daytime DO concentration in the dry season in the Phase I area continued to be high in PW2019, as it was in PW2018, meeting component b's requirement of 5–7 mg/L. The percentage of time that mean daytime DO concentrations within 1 m of the channel bottom were > 1 mg/L was 100% in PW2019, exceeding its 50% target (component c). For component d, the percentage of time that mean daily DO concentrations were > 2 mg/L in the river channel in PW2019 was 95%, meeting component d's target of > 90% of the time annually.

Table 9-6. Restoration expectation component metrics and PW2019 values for DO.

Expectation Components	PW2019 Value	Metric Achieved in PW2019	Data Source
a. Mean daytime DO concentration in the river channel at 0.5- to 1.0-m depth will increase from < 1–2 mg/L to 3–6 mg/L during the wet season (June–October).	3.10 ± 0.31 mg/L	YES	KREA93, KREA94, and KREA98 (grabs)
b. Mean daytime DO concentration in the river channel at 0.5- to 1.0-m depth will increase from 2–4 mg/L to 5–7 mg/L during the dry season (November–May).	7.00 ± 0.25 mg/L	YES	KREA93, KREA94, and KREA98 (grabs)
c. DO concentrations within 1 m of the channel bottom will be > 1 mg/L for more than 50% of the time annually.	100%	YES	KREA94 and KREA98 (grabs)
d. Mean daily DO concentrations in the river channel will be > 2 mg/L for more than 90% of the time annually.	95%	YES	Sondes at PC33 and PC62 (continuous)

As in previous years, monthly daytime and daily mean DO concentrations in PW2019 showed a seasonal pattern with high DO levels in the dry season and lower DO in the wet season (**Figures 9-18** and **9-19**) that was not seen prior to reestablishment of flow (Chen et al. 2016). DO in the river channel was lower in the 2018 wet season (June through October) and higher in the 2018-2019 dry season (November through May), which, in addition to the seasonal effect, was influenced by S-65A discharge (**Figure 9-18**); DO declined greatly but briefly by about 4 mg/L when S-65A discharge was rapidly increased to 3,600 cfs in February and March 2019, recovering after discharge was reduced.

PC33 DO was at times lower than PC62 from June to September 2018, particularly when S-65A discharge was 1,100 cfs or higher. Inflow from Oak Creek, a tributary entering to the north of PC33, may have influenced DO concentration at PC33. DO at PC33 dropped well below 2 mg/L for 10 days or more twice in the 2018 wet season but recovered after reductions in S-65A discharge. These sags occurred on June 4, 2018, and July 13, 2018, respectively. We note that the Component [d] target was met in a year in which the river experienced deep DO sags (**Table 9-6**), which, although they were brief, were capable of harming fish populations. Because of the relative brevity of these events, they were not detected by the current expectation, which targets > 2 mg/L at least 90% of the time. This suggests that the Component [d] target needs to be revisited to better capture brief events. The result of this reevaluation of the DO expectation will be reported in Chapter 9 of the 2021 SFER.

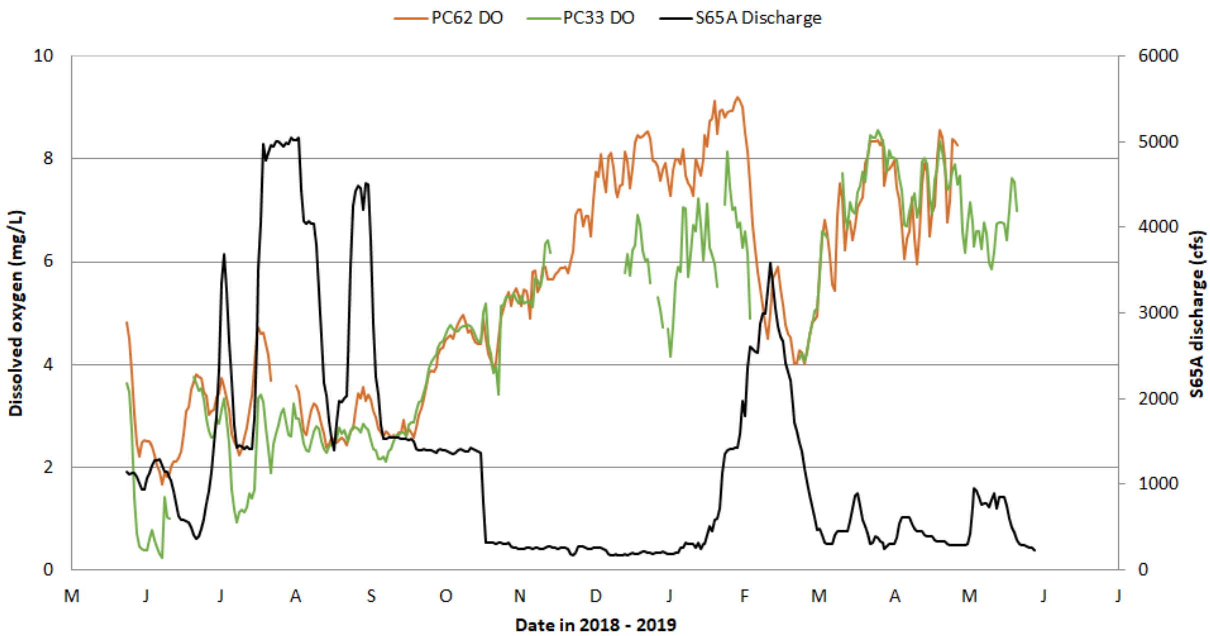


Figure 9-18. Daily mean DO concentrations at sampling stations PC33 and PC62 in the river channel of the Phase I Impact area in PW2019. Used for evaluation of Expectation 8, Component d.

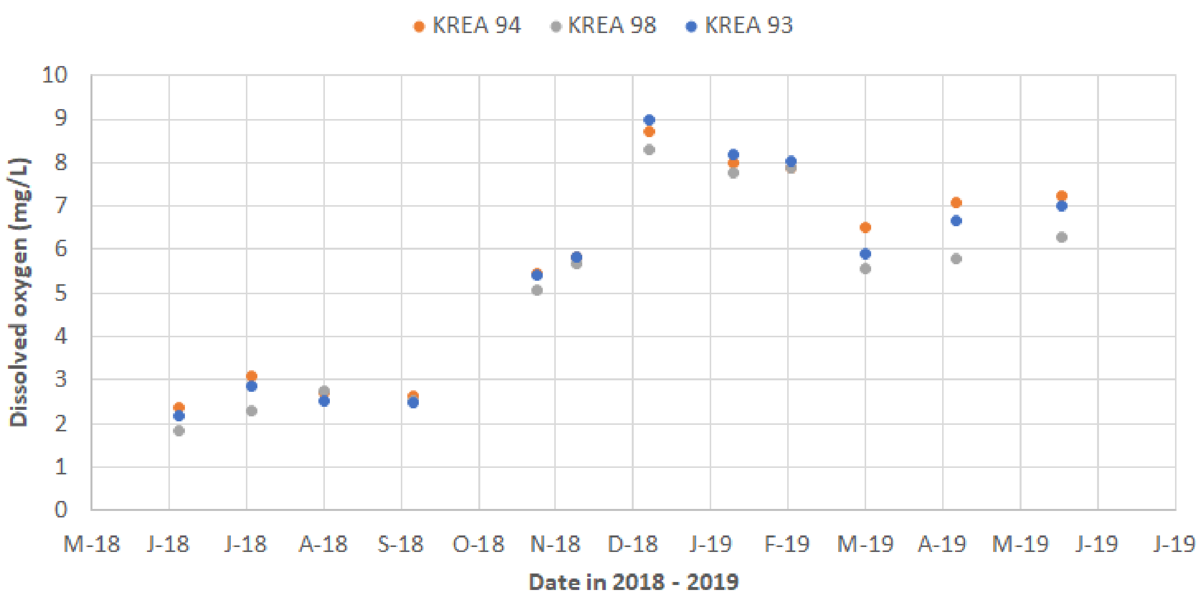


Figure 9-19. Monthly daytime DO concentrations in sampling stations KREA93, KREA94, and KREA98 in the river channel of the Phase I Impact area (Pool BC) in PW2019.

WADING BIRDS AND WATERFOWL

Birds are integral to the Kissimmee River floodplain ecosystem and highly valued by the public. While quantitative pre-channelization data are sparse, available data and anecdotal accounts suggest that the system supported an abundant and diverse bird assemblage (National Audubon Society 1936–1959, FGFWFC 1957). Restoration of the Kissimmee River and floodplain is expected to reproduce the necessary conditions to once again support such an assemblage. Because many bird groups (e.g., wading birds and waterfowl) exhibit a high degree of mobility, they are likely to respond rapidly to restoration of appropriate habitat (Weller 1995). Detailed information regarding the breadth of the avian evaluation program and the initial response of avian communities to Phase I restoration can be found in Chapter 11 of the 2005 SFER – Volume I (Williams et al. 2005) and a research article published in the journal *Restoration Ecology* (Cheek et al. 2014). The objective of this section is to highlight portions of the avian evaluation studies for which data were collected during the dry season 2018-2019 within PW2019, and compare recent data to the KRREP avian restoration expectations. Statistical significance was evaluated at $\alpha = 0.05$.

Wading Bird Abundance

Expectation 24

Mean annual dry season density of long-legged wading birds (excluding cattle egrets) on the restored floodplain will be ≥ 30.6 birds per square kilometer (birds/km^2; Williams and Melvin 2005b).

Monthly aerial surveys were used to estimate foraging wading bird abundance. Prior to the restoration project, dry season abundance of long-legged wading birds in the Phase I restoration area averaged (±SE) 3.6 ± 0.9 birds/km^2 in 1997 and 14.3 ± 3.4 birds/km^2 in 1998. Since completion of Phases I, IVA, and IVB of restoration construction in 2001, 2007, and 2009, respectively, annual abundance has ranged from 102.3 ± 31.7 birds/km^2 to 11.0 ± 1.9 birds/km^2 (mean for 2002–2019 = 41.5 ± 5.5 birds/km^2; **Figures 9-20** and **9-21**). The long-term annual three-year running mean (2002–2019) is 40.9 ± 3.4 birds/km^2, significantly greater than the restoration expectation of 30.6 birds/km^2 (t-test, $p = 0.005$, Williams and Melvin 2005b). However, only the three-year running means for the periods 2002–2005 and 2004–2006 were significantly greater than the restoration target of 30.6 birds/km^2 when examined on an annual basis. Mean monthly wading bird abundance within the restored portions of the river during the 2018–2019 season was 42.0 ± 7.8 birds per square kilometer (km^2), bringing the three-year (2017–2019) running average to 37.8 ± 12.2; not significantly greater than the restoration expectation of 30.6 birds/km^2 (**Figure 9-21**).

Rainfall during the 2018-2019 dry season was approximately average, while the preceding wet season was average in the UKB (95% of average) and below average in the LKB (71% of average). The below average wet season rainfall in the LKB led to below average floodplain depths at the start of the dry season (< 0.25 ft deep on November 1; **Figure 9-22**). This provided optimum foraging depths and prey availability across much of the floodplain during the November 13, 2018, survey flight, when the seasonal peak of 165 birds/km^2 was observed. However, after that time, the floodplain receded to an average of 0.07 ft by January 11, 2019, and bird numbers declined, although still above the restoration target of 30.6 birds/km^2 (Godin 2012).

Water depths on the floodplain began to increase with increased discharge out of S-65A starting around January 25, 2019, reaching a peak of approximately 1.3 ft deep on February 18, 2019. Wading bird numbers increased slightly during the February 12, 2019, survey with an influx of white ibis (*Eudocimus albus*). The white ibis were possibly taking advantage of newly available prey (terrestrial invertebrates) on the floodplain as it was inundated by the rising water. Bird numbers rose again slightly by the March 12, 2019, survey as the flood waters receded back to a depth of approximately 0.25 ft. Bird numbers then declined during the final two surveys of the season (April 2 and May 22, 2019) as the water level continued to recede.

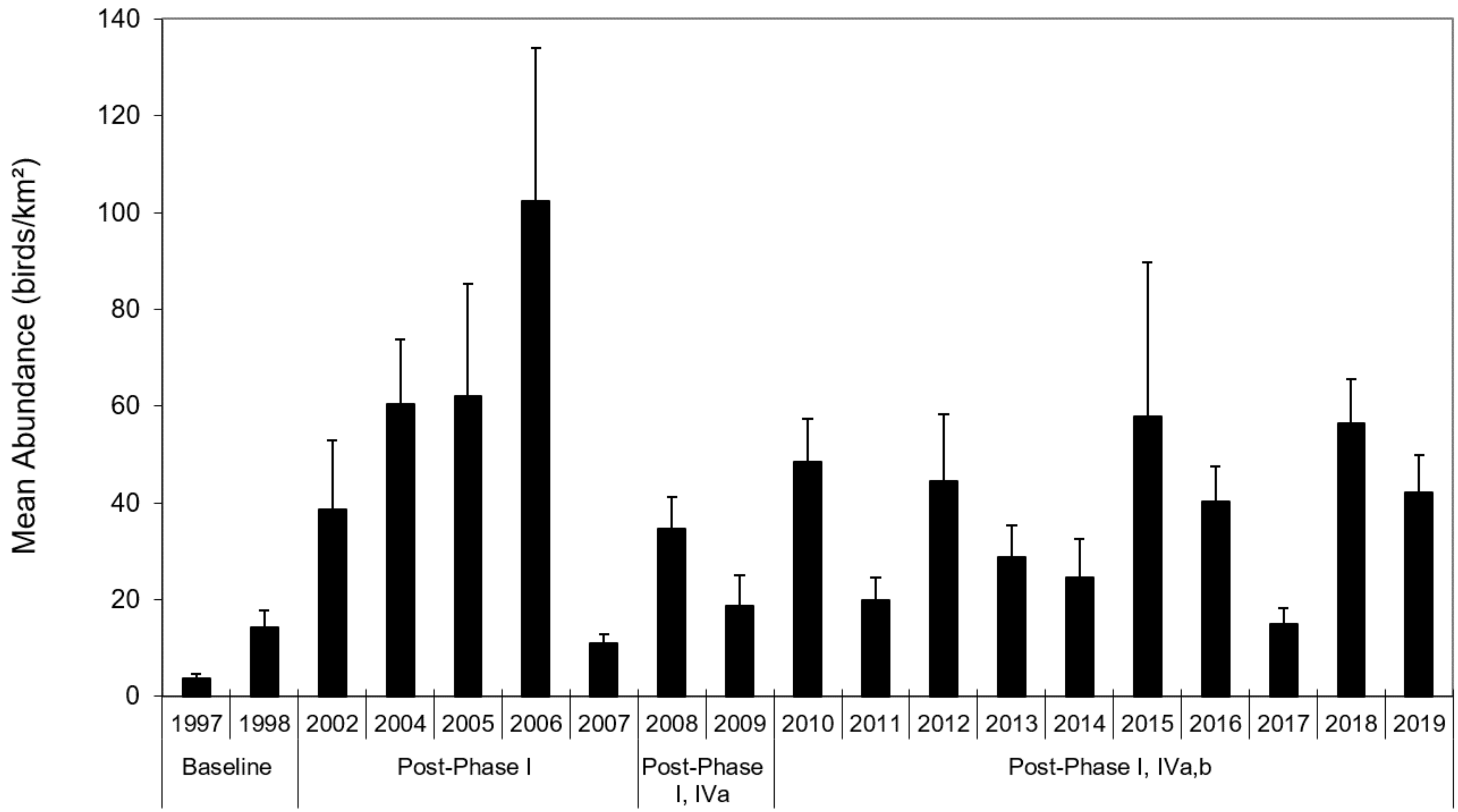


Figure 9-20. Baseline and post-Phases I, IVA, and IVB mean abundance ± SE of long-legged wading birds/km^2, excluding cattle egrets, during the dry season (December–May) within the 100-year flood line of the Kissimmee River.

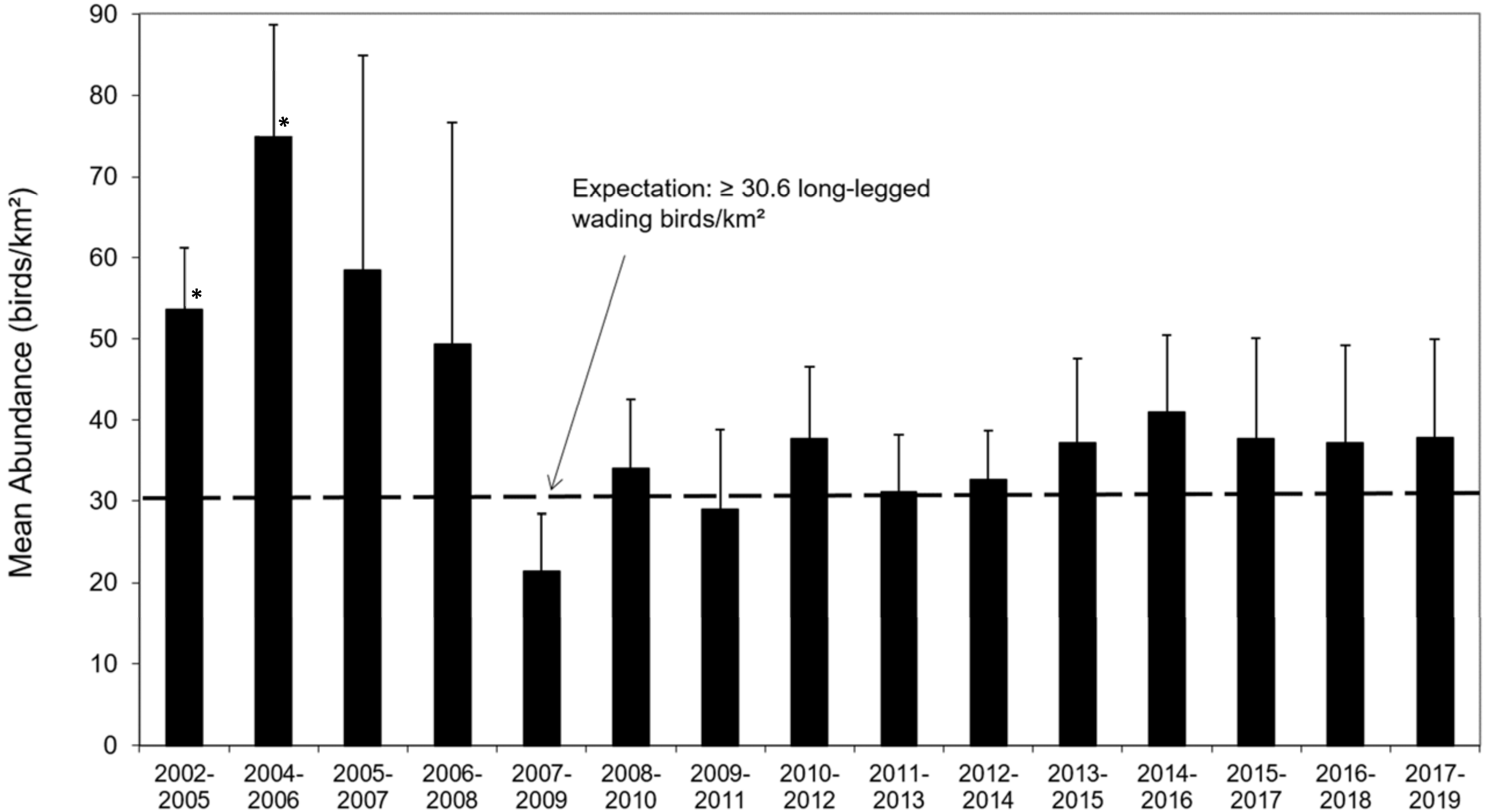


Figure 9-21. Post-restoration abundance as three-year running averages ± SE of long-legged wading birds/km^2, excluding cattle egrets, during the dry season (December–May) within the Phase I, IVA, and IVB restoration areas of the Kissimmee River. (Note: an asterisk [*] indicates the mean is significantly greater than the restoration expectation of 30.6 birds/km^2 [t-test]).

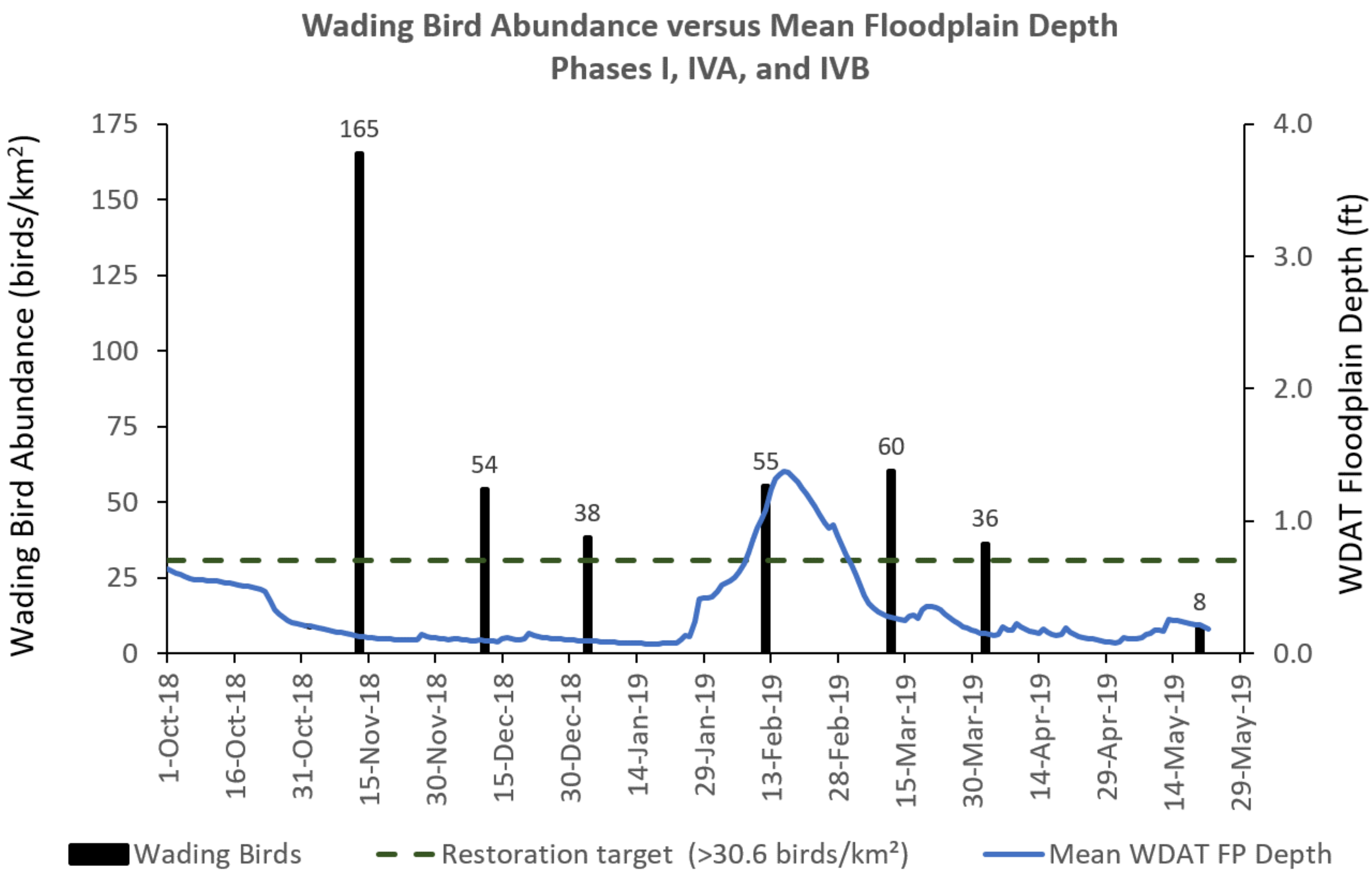


Figure 9-22. Wading bird abundance versus mean floodplain (FP) depth in the KRRA (Phases I, IVA, and IVB) during the 2018-2019 dry season (December–May). Floodplain depth is obtained from the South Florida Water Depth Assessment Tool (WDAT; Godin 2012).

As in previous years, white ibis dominated the surveys numerically (2,519, 52.0%), followed in order of abundance by great egret (*Ardea alba*; 594, 12.3%), small white herons (snowy egrets [*Egretta thula*] and juvenile little blue heron [*Egretta caerulea*]) (441, 9.1%), wood stork (*Mycteria americana*; 422, 8.7%), glossy ibis (*Plegadis falcinellus*; 284, 5.9%), great blue heron (*A. herodias*; 262, 5.4%), roseate spoonbill (*Platalea ajaja*; 139, 2.9%), black-crowned and yellow-crowned night herons (*Nycticorax* and *Nyctanassa violacea*, respectively;114, 2.4%), small dark herons (tri-colored herons [*Egretta tricolor*] and adult little blue heron; 66, 1.4%).

Waterfowl Abundance and Species Richness

Expectation 25

Winter densities of waterfowl within the restored area of the floodplain will be ≥ 3.9 ducks per square kilometer (ducks/km^2). Species richness will be ≥ 13 (Williams et al. 2005a).

Four duck species, blue-winged teal (*Anas discors*), green-winged teal (*A. crecca*), mottled duck (*A. fulvigula*), and hooded merganser (*Lophodytes cullulatus*), were detected during baseline aerial surveys. During the same period, casual observations of wood ducks (*Aix sponsa*) were made during ground surveys for other projects (Williams and Melvin 2005a). Mean annual abundance ± SE was 0.4 ± 0.1 ducks/km² in the Phase I area during the Baseline Period, well below the restoration expectation of 3.9 ducks/km². The long-term mean annual three-year running average (2002–2019) of waterfowl abundance is 11.7 ± 1.3 birds/km², significantly greater than the restoration expectation of 3.9 birds/km² (t-test, $p < 0.0001$). When examined on an annual basis, each of the three-year running averages for periods 2010–2012, 2011–2013, 2013–2015, and 2015–2017 were significantly greater than the restoration target of 3.9 birds/km² (t-test, p-values = 0.038, 0.026, 0.033, 0.025, respectively).

Waterfowl abundance during the 2018–2019 survey was 10.1 ± 6.4 ducks/km², bringing the three-year (2017–2019) running average to 21.1 ± 10.5 ducks/km², although this was not significantly greater than the restoration target of 3.9 ducks/km² due to the large variability of annual means between years, in particular last season's extreme high of 42.0 (t-test, p-value = 0.12, SAS Institute 2016) (**Figures 9-23** and **9-24**). Since 2001, annual duck abundance has ranged from 42.0 ± 11.2 ducks/km^2 to 1.3 ± 1.3 ducks/km^2 (mean for 2002–2019 = 12.6 ± 2.5 birds/km^2) (**Figures 9-23** and **9-24**).

Only two (November and December) of the seven surveys during winter 2018-2019 were above the restoration target of 3.9 ducks/km^2. However, their values were great enough to hold the seasonal average significantly above the restoration target despite low values for January–March (**Figure 9-25**). As is typical of aerial surveys of flocking species, the variance among survey dates was high, but the overall mean was above the restoration target because of large, patchily distributed flocks composed mostly of blue-winged teal, particularly in November.

As in previous years, teal (*Anas* sp.) dominated the surveys numerically (397, 66.3%), followed in order of abundance by mottled duck (198, 33.1%), and wood duck (4, 0.7%). No other duck species were observed this year on the floodplain. The three-year species total for 2017–2019 was 8, below the restoration target for waterfowl species richness of ≥ 13 (three-year species total).

Although the American wigeon (*Mareca americana*), northern pintail (*Anas acuta*), northern shoveler (*A. clypeata*), ring-necked duck (*Aythya collaris*), and black-bellied whistling duck (*Dendrocygna autumnalis*) were not detected during the 2018-2019 baseline surveys, they have been present following restoration construction. However, these species are not regularly observed; therefore, the restoration target for waterfowl species richness (≥ 13 species) has yet to be reached on an annual or cumulative basis. Blue-winged teal and mottled duck remain the two most commonly observed species, accounting for more than 93% of observations since 2001 (67.3% and 26.3%, respectively).

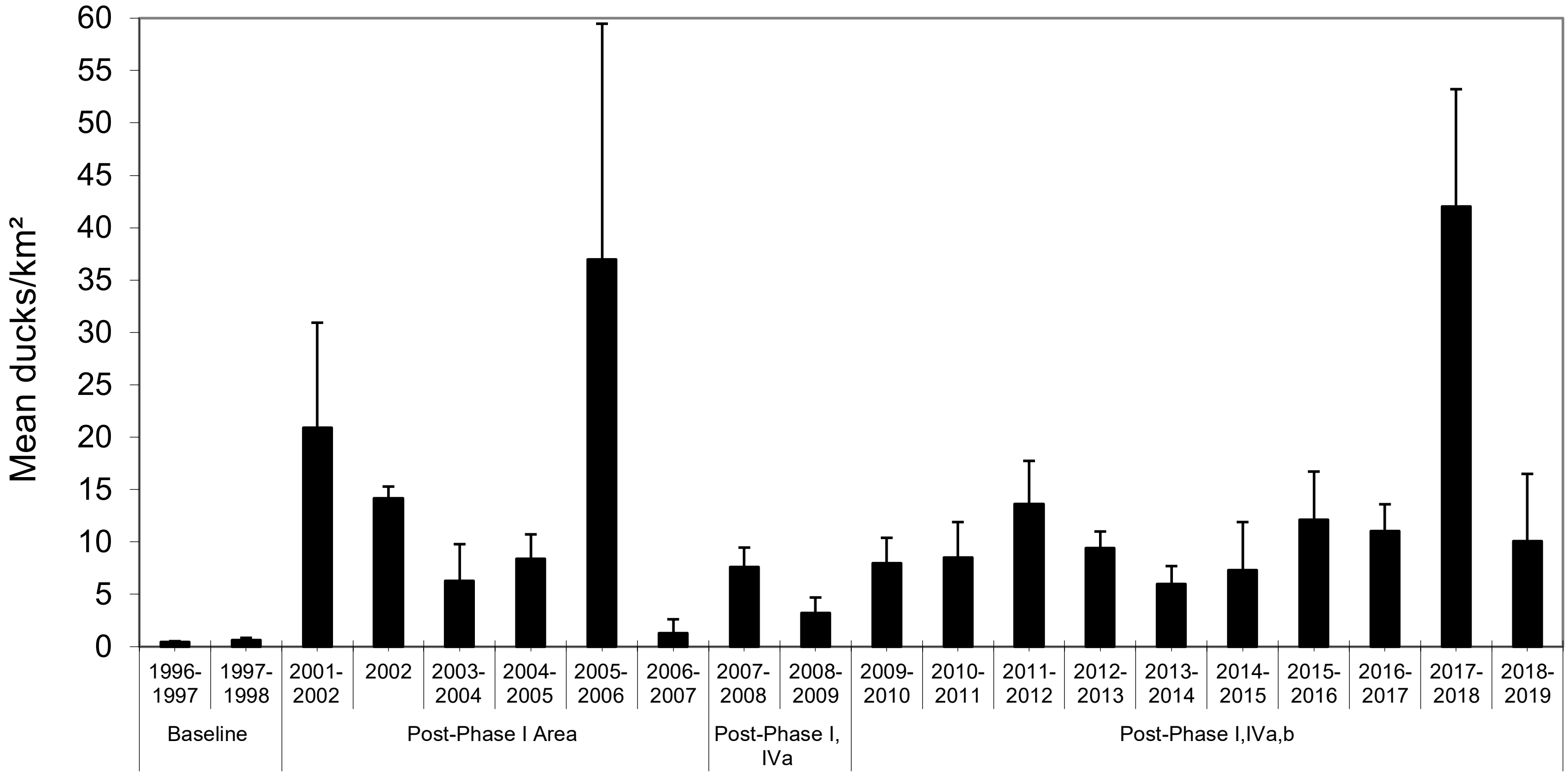


Figure 9-23. Baseline and post-Phases I, IVA, and IVB mean abundance ± SE of waterfowl during winter (November–March) within the 100-year flood line of the Kissimmee River. Baseline abundance was measured in the Phase I area prior to restoration. Measurement of post-restoration abundance began approximately nine months following completion of Phase I.

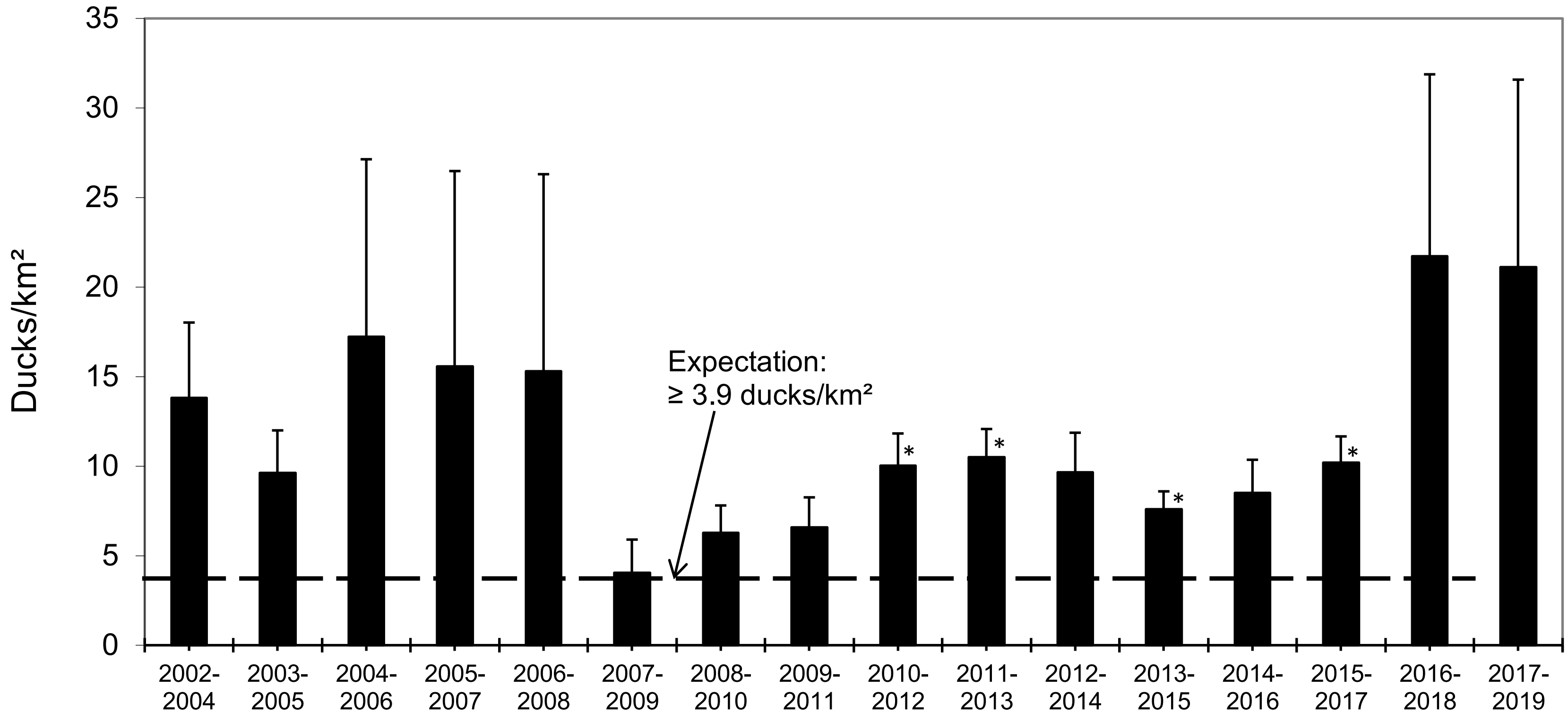


Figure 9-24. Post-restoration abundance as three-year running averages ± SE of waterfowl (ducks/km^2) during the winter (November–March) within the Phase I, IVA, and IVB restoration areas of the Kissimmee River. (Note: an asterisk [*] indicates the mean is significantly greater than the restoration expectation of 3.9 ducks/km^2 [t-test]).

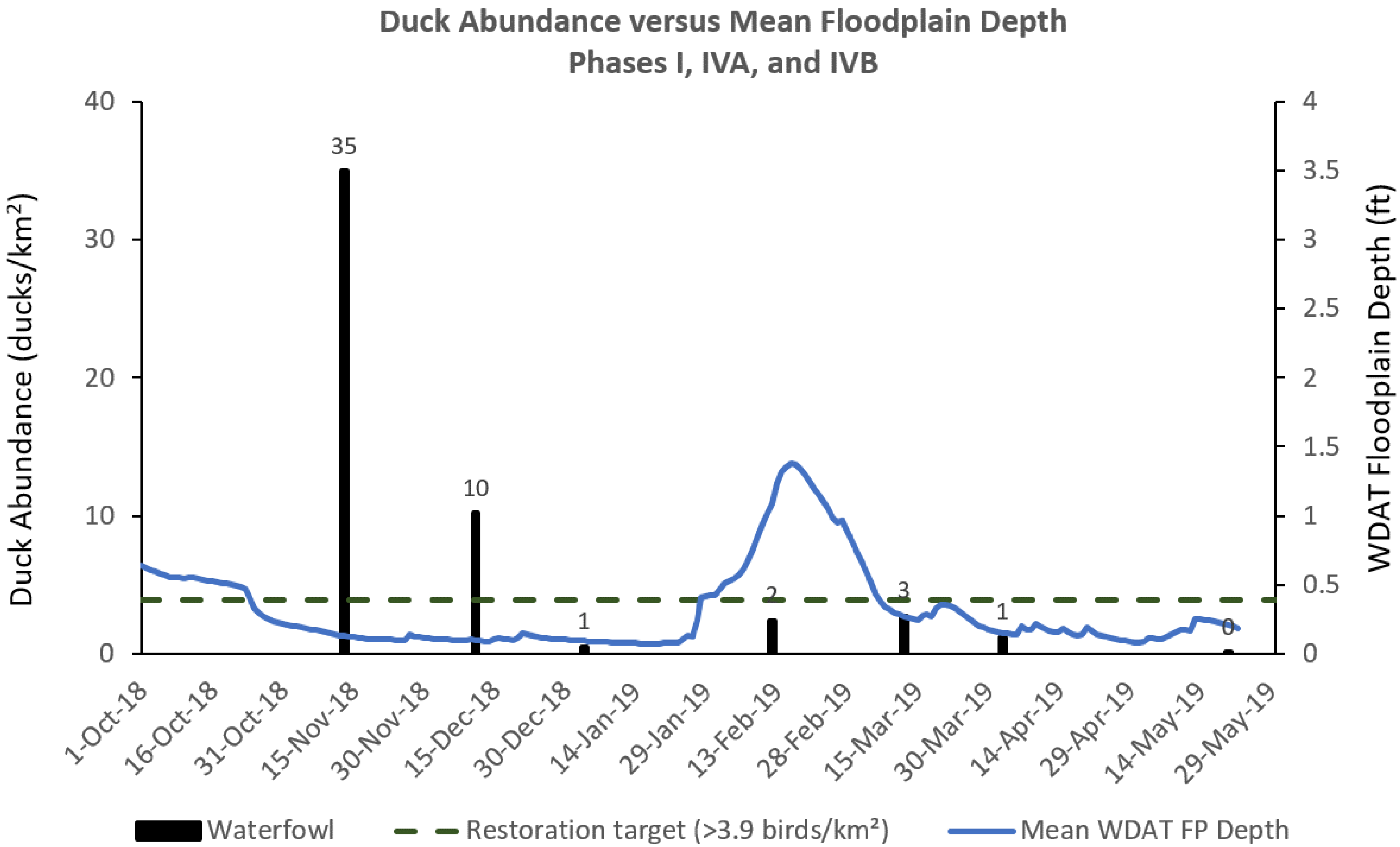


Figure 9-25 Waterfowl abundance versus mean floodplain depth in the KRRA (Phases I, IVA, and IVB) during the 2018-2019 dry season (November 2018–May 2019). Source of floodplain depth data is the South Florida Water Depth Assessment Tool (WDAT; Godin 2012).

Restoration of the physical characteristics of the Kissimmee River and floodplain, along with improvements in the hydrologic characteristics of inflows under the HRS, are expected to produce hydropatterns and hydroperiods that will lead to the development of extensive areas of wet prairie and BLM, two preferred waterfowl habitats (Chamberlain 1960, Bellrose 1980). Changes in the species richness and abundance of waterfowl within the Kissimmee River Restoration Area (KRRA) are likely to be directly linked to the development of floodplain plant communities and the faunal elements they support, particularly populations of aquatic invertebrates (Harris et al. 1995). Extrinsic factors such as annual reproductive output on summer breeding grounds and local and regional weather patterns also may play a role in the speed of recovery of the waterfowl community.

Wading Bird Nesting Colonies

Expectation

No formal expectation has been established for wading bird nesting colonies.

Wading bird nesting colonies within the KRRA and Lakes Istokpoga and Kissimmee were not surveyed during dry season 2018-2019 due to weather and helicopter flight scheduling conflicts.

Wading Bird and Waterfowl Food Availability

Expectation

No formal restoration expectation has been established for wading bird and waterfowl food availability.

In addition to the bird surveys described above, the *Final Integrated Feasibility Report and Environmental Impact Statement for the Restoration of the Kissimmee River, Florida* (USACE 1991) explicitly requires monitoring of wading bird and waterfowl food populations to evaluate restoration success and the environmental impacts of construction activities. This study evaluates how the food base for wading birds and waterfowl is responding to habitat restoration and how bird abundance is related to prey abundance, biomass, diversity, and richness. It is the first field sampling effort to evaluate the food base currently available to wading birds and waterfowl within the floodplain since completion of restoration Phases I, IVa, and IVb. Ultimately, it will also compare pre- and post-restoration conditions in the Phase II/III area. Study objectives include the following:

- Determining the dry season species richness, diversity, density (individuals per square meter [ind/m²]), standing crop wet biomass (grams per square meter [g/m²]), and individual wet mass of aquatic invertebrates, small fish, and other vertebrates available to wading birds and waterfowl in the range of floodplain habitats within the Phase I and Phase II/III restoration area.
- Examining relationships between prey abundance and wading bird and waterfowl abundance and how these relate to hydrological variables including river discharge, basin rainfall, floodplain depth, recession rate, days since drydown, number of reversals, and hydroperiod.

A detailed introduction and description of methods for this study can be found in the *Wading Bird and Waterfowl Prey Availability* section in Chapter 9 of the 2018 SFER (Koebel et al. 2018). Sampling occurs only during the dry season for several reasons. First, prey availability during this time is critical to wading bird reproduction and can limit reproductive effort in nesting colonies. Second, migratory waterfowl are present during this time of year and utilize the floodplain marshes for overwintering when habitat conditions are suitable. Lastly, aerial surveys conducted for wading bird and waterfowl abundance are conducted during this time and bird numbers can be related to trends in prey availability. The following update provides a data summary from 2010 to 2018 dry seasons (November–May).

Results

A total of 716 throw traps were sampled from 2010 through 2018; 127 (17.7%) of which contained no fish, 16 (2.2%) of which contained no invertebrates, and only 1 that was completely devoid of both small fish and invertebrate prey items. A total of 55,134 fish and 76,451 aquatic invertebrates were collected and processed. Data were also collected on vegetation, soil, DO, and water depth, but only results from the small fish and aquatic invertebrate data is presented in this section.

Fish. A total of 33 species of fish were collected on the floodplain, none of which are state or federally listed species and 6 of which are invasive exotics. The mean number of species collected per throw trap sample was 2.5 (± 0.07), with a maximum of 9 species and 3,175 individuals per sample. The Shannon's H measure of fish diversity was H = 1.04 and the Buza's measure of eveness was E = 0.086. Mean density (ind/m²) and wet biomass (g/m²) of small fish is reported ± SE in **Figures 9-26** through **9-28**, and individual wet biomass is reported in **Figures 9-29** through **9-31**. The mean density and wet biomass of small fish for the period 2011–2018 was 77.1 ± 6.6 ind/m² and 22.4 ± 3.7 g/m². Mean wet biomass of individual fish on the floodplain was 0.29 ± 0.03 grams.

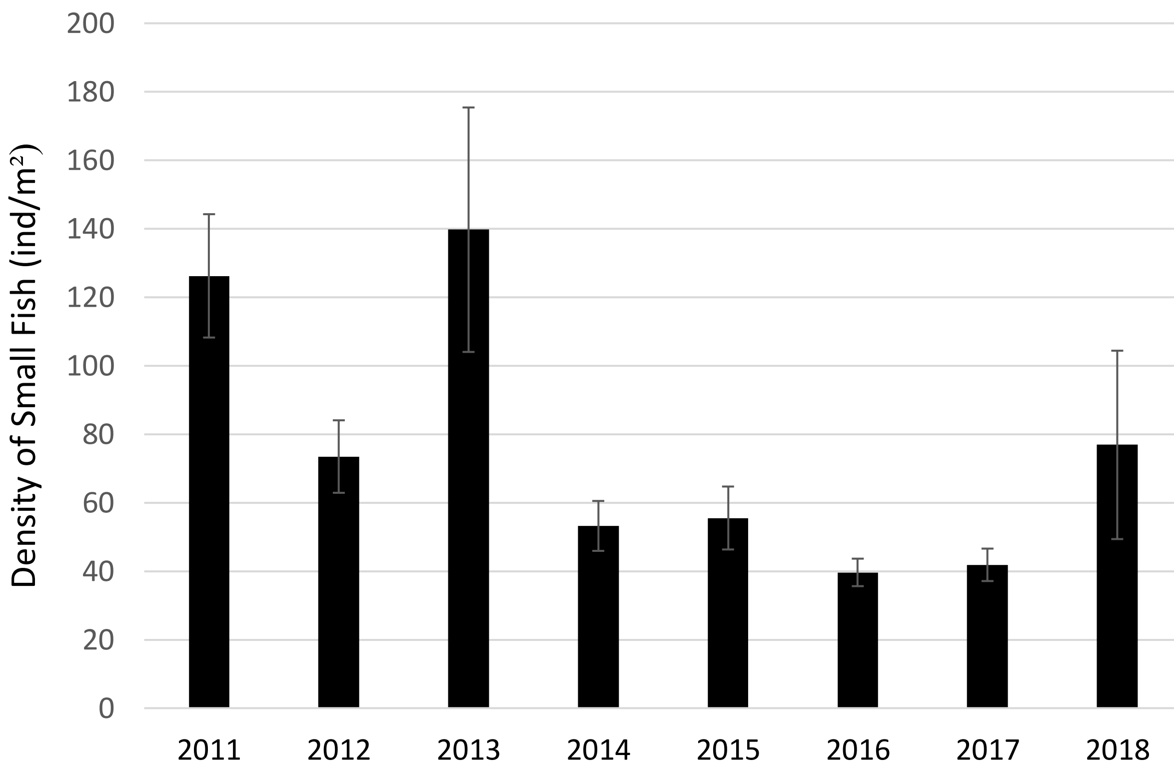


Figure 9-26 Mean annual dry season (November–May) density (ind/m² ± SE) of small fish in the floodplain of the KRRP area (Phases I and IVA).

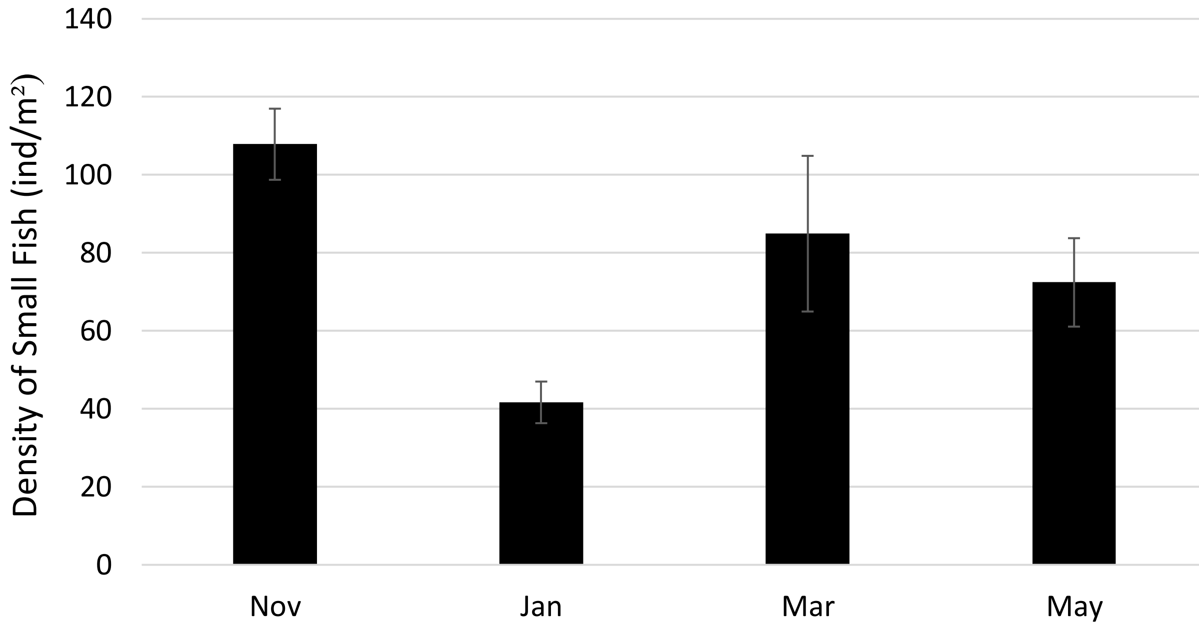


Figure 9-27. Mean monthly dry season (November–May) density (ind/m² ± SE) of small fish in the floodplain of the KRRP area (Phases I and IVA) from 2011 through 2018.

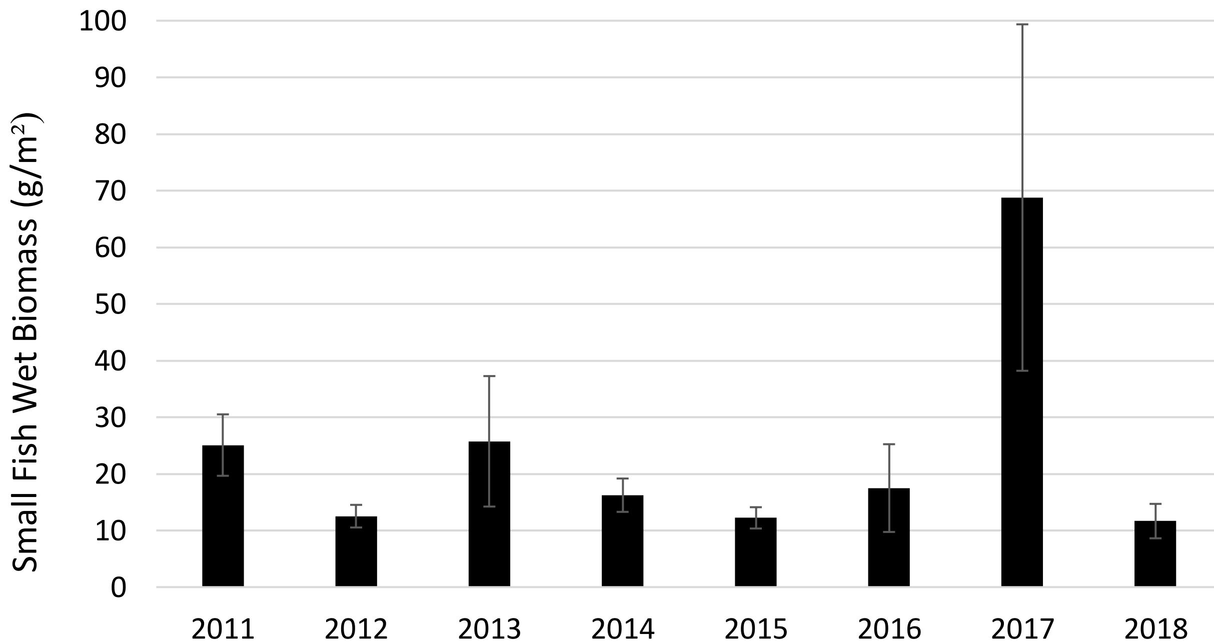


Figure 9-28. Mean annual dry season (November–May) biomass (g/m² ±SE) of small fish in the floodplain of the KRRP area (Phases I and IVA) from 2011 through 2018.

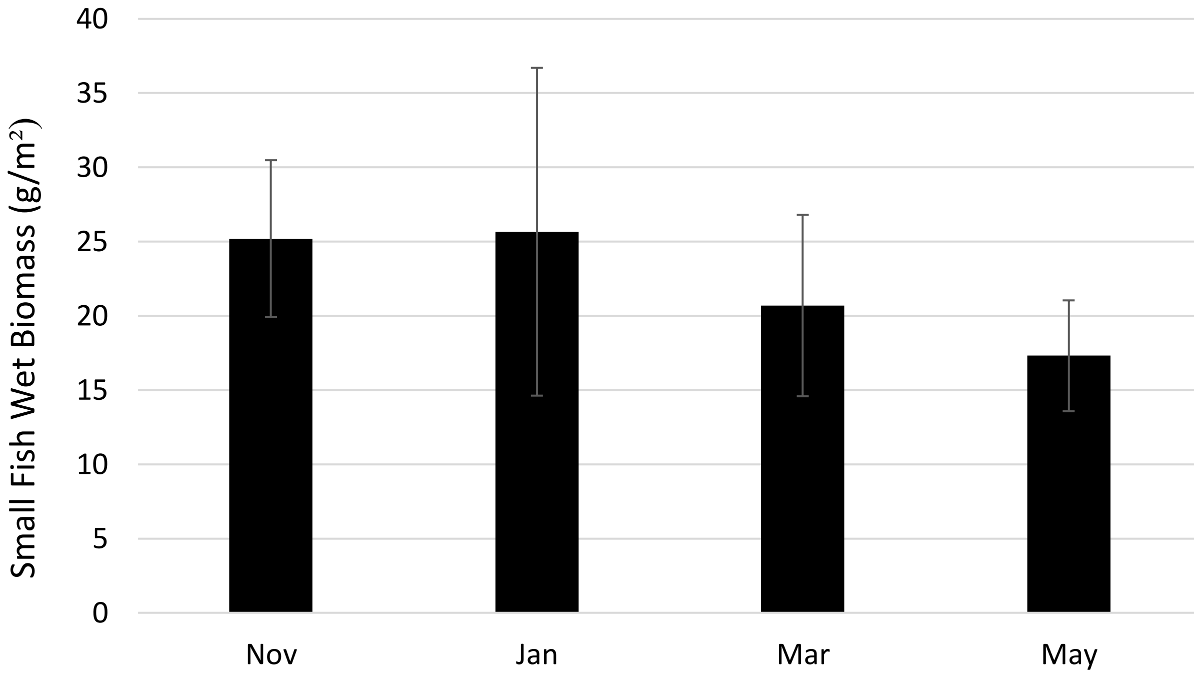


Figure 9-29. Mean monthly dry season (November–May) biomass (g/m² ±SE) of small fish in the floodplain of the KRRP area (Phases I and IVA) from 2011 through 2018.

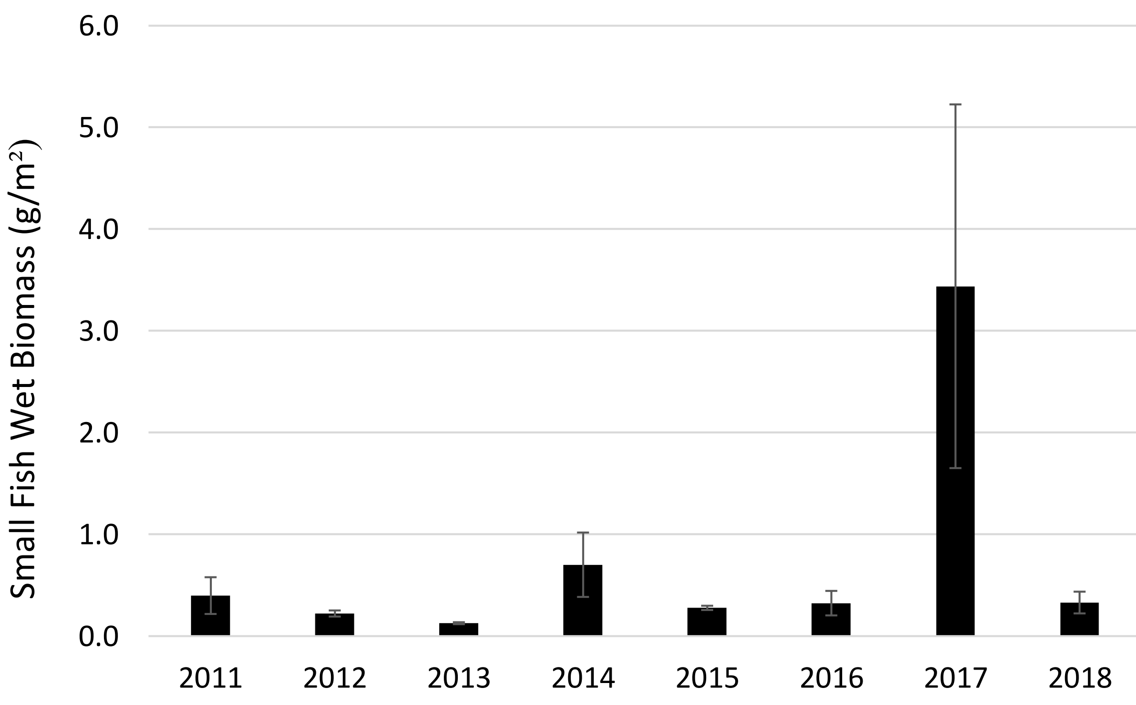


Figure 9-30. Mean annual dry season (November–May) individual biomass (g/m² ±SE) of small fish in the floodplain of the KRRA (Phases I and IVA) from 2011 through 2018.

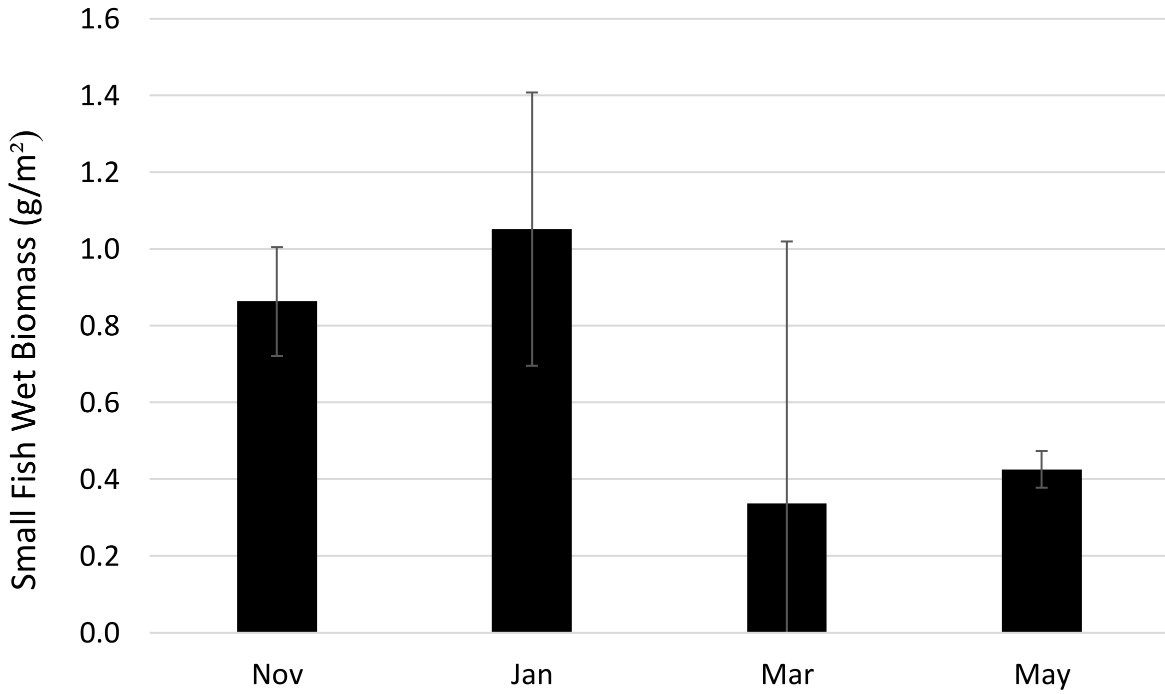


Figure 9-31. Mean monthly dry season (November–May) individual biomass (g/m² ±SE) of small fish in the floodplain of the KRRA (Phases I and IVA) from 2011 through 2018.

Species composition and biomass of small fish captured during throw trap sampling is shown in **Tables 9-7** through **9-9**. A total of 55,134 individual fish comprised of 33 species were captured and processed, 6 of which are classified as invasive exotics (1.5% of individuals) and none that are state or federally listed species. Density was dominated by two native species, mosquitofish (*Gambusia holbrooki*) and least killifish (*Heterandria formosa*) at 66.4% and 22.9%, respectively, followed by Florida flagfish (*Jordanella floridae*; 3.6%), sailfin molly (*Poecilia latipinna*; 3.4%), and 1% or less of the remaining 29 species.

Biomass was also dominated by mosquitofish (37.8%), followed by an invasive exotic species (brown hoplo (*Hoplosternum littorale*) at 15.3%, warmouth (*Lepomis gulosis*; 11.0%), sailfin molly (7.8%), least killifish (6.8%), the exotic blue tilapia (*Oreochromis aureus*; 6.6%), Florida flagfish (5.6%), the exotic vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*; 5.1%), yellow bullhead (*Ameiurus natalis*; 1.4%), and 1% or less of the remaining 24 species. Over 27% of the total biomass collected was made up of exotic species.

Table 9-7. Species distribution of small fish in the floodplain of the KRRP area (Phases I and IVA) during dry season (November–May) throw trap sampling from 2011 through 2018. (Note: an asterisk [*] indicates a non-native invasive exotic species.)

Common Name	Scientific Name	Total Number Sampled	Percent of Total Number (%)
Mosquitofish	*Gambusia holbrooki*	36,632	66.442
Least killifish	*Heterandria formosa*	12,616	22.882
Florida flagfish	*Jordanella floridae*	1,970	3.573
Sailfin molly	*Poecilia latipinna*	1,878	3.406
Bluefin killifish	*Lucania goodei*	783	1.420
Brown hoplo*	*Hoplosternum littorale*	366	0.664
Blue tilapia*	*Oreochromis aureus*	245	0.444
Mayan cichlid*	*Cichlasoma urophthalmus*	124	0.225
Golden topminnow	*Fundulus chrysotus*	114	0.207
Everglades pygmy sunfish	*Elassoma evergladei*	79	0.143
Vermiculated sailfin catfish*	*Pterygoplichthys disjunctivus*	59	0.107
Bluegill	*Lepomis macrochirus*	38	0.069
Warmouth	*Lepomis gulosis*	31	0.056
Okefenokee pygmy sunfish	*Elassoma okefenokee*	30	0.054
Swamp darter	*Etheostoma fusiforme*	30	0.054
Largemouth bass	*Micropterus salmoides*	22	0.040
Yellow bullhead	*Ameiurus natalis*	17	0.031
Leopard sailfin catfish*	*Pterygoplichthys pardalis*	15	0.027
Walking catfish*	*Clarias batrachus*	15	0.027
Brook silverside	*Labidesthes sicculus*	11	0.020
Golden shiner	*Notemigonus crysoleucas*	11	0.020
Taillight shiner	*Notropus maculatus*	9	0.016
Florida gar	*Lepisosteus platyrhincus*	8	0.015
Seminole killifish	*Fundulus seminolis*	7	0.013
Pugnose minnow	*Opsopoeodus emiliae*	5	0.009
Lake chubsucker	*Erimyzon sucetta*	4	0.007
Tadpole madtom	*Noturus gyrinus*	4	0.007
Bowfin	*Amia calva*	3	0.005
Spotted sunfish	*Lepomis punctatus*	3	0.005
Brown bullhead	*Ameriurus nebulosus*	2	0.004
Lined topminnow	*Fundulus lineolatus*	1	0.002
Pirate perch	*Aphredoderus sayanus*	1	0.002
Redear sunfish	*Lepomis microlophus*	1	0.002
Totals	**33 species**	**55,134 individuals**	**100**

Table 9-8. Biomass distribution of small fish in the floodplain of the KRRP area (Phases I and IVA) during dry season (November–May) throw trap sampling from 2011 through 2018. (Note: an asterisk [*] indicates a non-native invasive exotic species.)

Common Name	Scientific Name	Total Biomass Collected (g)	Percent of Total Biomass (%)
Mosquitofish	*Gambusia holbrooki*	6,069.30	37.768
Brown hoplo*	*Hoplosternum littorale*	2,452.20	15.259
Warmouth	*Lepomis gulosis*	1,764.26	10.979
Sailfin molly	*Poecilia latipinna*	1,259.28	7.836
Least killifish	Heterandria Formosa	1,095.31	6.816
Blue tilapia*	*Oreochromis aureus*	1,061.03	6.603
Florida flagfish	*Jordanella floridae*	899.55	5.598
Vermiculated sailfin catfish*	*Pterygoplichthys disjunctivus*	813.79	5.064
Yellow bullhead	*Ameiurus natalis*	228.61	1.423
Bluefin killifish	*Lucania goodei*	141.19	0.879
Mayan cichlid*	*Cichlasoma urophthalmus*	66.970	0.417
Golden topminnow	Fundulus chrysotus	52.12	0.324
Leopard sailfin catfish*	*Pterygoplichthys pardalis*	47.36	0.295
Bluegill	*Lepomis macrochirus*	23.48	0.146
Seminole killifish	*Fundulus seminolis*	13.93	0.087
Spotted sunfish	*Lepomis punctatus*	13.26	0.083
Everglades pygmy sunfish	*Elassoma evergladei*	11.44	0.071
Brown bullhead	*Ameriurus nebulosus*	10.64	0.066
Okefenokee pygmy sunfish	*Elassoma okefenokee*	9.12	0.057
Walking catfish*	*Clarias batrachus*	8.16	0.051
Swamp darter	*Etheostoma fusiforme*	6.79	0.042
Lake chubsucker	*Erimyzon sucetta*	6.58	0.041
Largemouth bass	*Micropterus salmoides*	5.18	0.032
Lined topminnow	*Fundulus lineolatus*	3.45	0.021
Tadpole madtom	*Noturus gyrinus*	2.05	0.013
Golden shiner	*Notemigonus crysoleucas*	1.5	0.009
Pugnose minnow	*Opsopoeodus emiliae*	1.2	0.007
Bowfin	*Amia calva*	0.93	0.006
Florida gar	*Lepisosteus platyrhincus*	0.62	0.004
Brook silverside	*Labidesthes sicculus*	0.38	0.002
Taillight shiner	*Notropus maculatus*	0.26	0.002
Redear sunfish	*Lepomis microlophus*	0.03	0.000
Pirate perch	*Aphredoderus sayanus*	0.02	0.000
Totals	**33 species**	**16,070.00 g**	**100%**

Table 9-9. Mean individual mass of small fish in the floodplain of the KRRA (Phases I and IVA) during dry season (November–May) throw trap sampling from 2011 through 2018. (Note: an asterisk [*] indicates a non-native invasive exotic species.)

Common Name	Scientific Name	Mean Individual Mass (g)
Warmouth	*Lepomis gulosis*	56.91
Vermiculated sailfin catfish*	*Pterygoplichthys disjunctivus*	13.79
Yellow bullhead	*Ameiurus natalis*	13.45
Brown hoplo*	*Hoplosternum littorale*	6.70
Brown bullhead	*Ameriurus nebulosus*	5.32
Spotted sunfish	*Lepomis punctatus*	4.42
Blue tilapia*	*Oreochromis aureus*	4.33
Lined topminnow	*Fundulus lineolatus*	3.45
Leopard sailfin catfish*	*Pterygoplichthys pardalis*	3.38
Seminole killifish	*Fundulus seminolis*	1.99
Lake chubsucker	*Erimyzon sucetta*	1.64
Sailfin molly	*Poecilia latipinna*	0.67
Bluegill	*Lepomis macrochirus*	0.62
Walking catfish*	*Clarias batrachus*	0.54
Mayan cichlid*	*Cichlasoma urophthalmus*	0.54
Tadpole madtom	*Noturus gyrinus*	0.51
Golden topminnow	*Fundulus chrysotus*	0.46
Florida flagfish	*Jordanella floridae*	0.46
Bowfin	*Amia calva*	0.31
Okeefenokee pygmy sunfish	*Elassoma okefenokee*	0.30
Pugnose minnow	*Opsopoeodus emiliae*	0.24
Largemouth bass	*Micropterus salmoides*	0.24
Swamp darter	*Etheostoma fusiforme*	0.23
Bluefin killifish	*Lucania goodei*	0.18
Mosquitofish	*Gambusia holbrooki*	0.17
Everglades pygmy sunfish	*Elassoma evergladei*	0.14
Golden shiner	*Notemigonus crysoleucas*	0.14
Least killifish	*Heterandria formosa*	0.09
Florida gar	*Lepisosteus platyrhincus*	0.08
Brook silverside	*Labidesthes sicculus*	0.03
Redear sunfish	*Lepomis microlophus*	0.03
Taillight shiner	*Notropus maculatus*	0.03
Pirate perch	*Aphredoderus sayanus*	0.02

Invertebrates. A total of 43 families of aquatic invertebrates (sample size [n] = 76,451 individuals) were collected on the floodplain, none of which are state or federally listed species and 1 of which is an invasive exotic (island apple snail, *Pomacea insularum*). This invasive exotic comprised over 69% of the total invertebrate biomass captured during sampling. Eight additional families were collected since the last update in 2016. The mean number of families collected per throw trap sample was 4.8 (± 0.1), with a maximum of 14 families occurring in one sample trap. The Shannon's H measure of aquatic invertebrate diversity was H = 2.03 and the Buza's measure of evenness was E = 0.177. Mean density (ind/m²) and biomass (g/m²) of aquatic invertebrates is reported (± SE) in **Figures 9-32** through **9-35**. The mean density and biomass of aquatic invertebrates on the floodplain for the period from 2011 through 2018 was 107.8 (± 6.9) ind/m² and 18.3 (± 2.8) g/m².

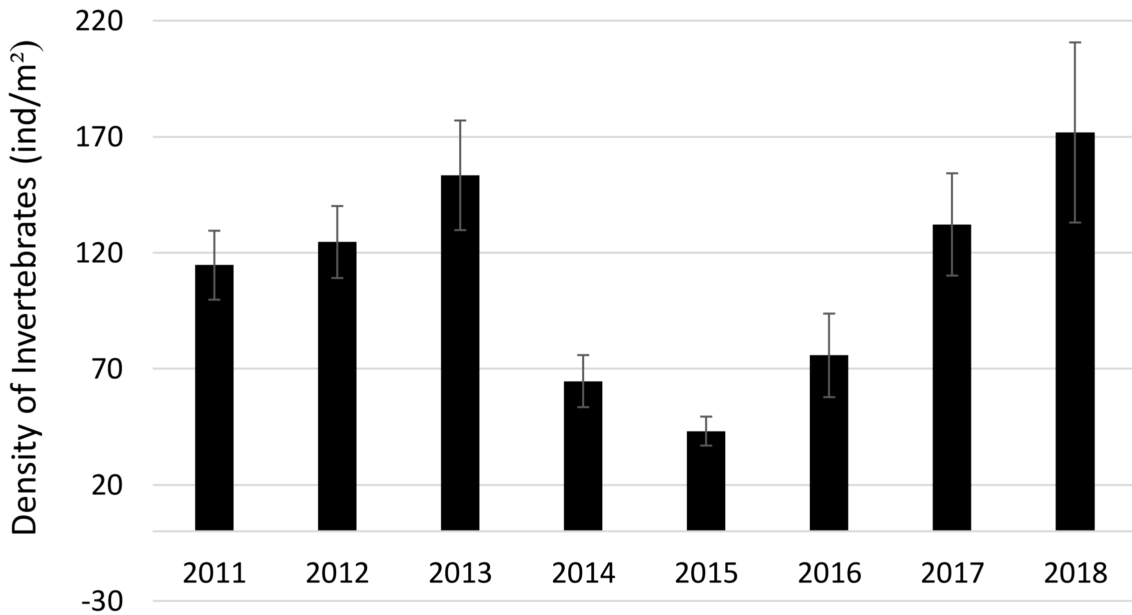


Figure 9-32. Mean annual dry season (November–May) density (ind/m² ± SE) of aquatic invertebrates in the floodplain of the KRRA (Phases I and IVA).

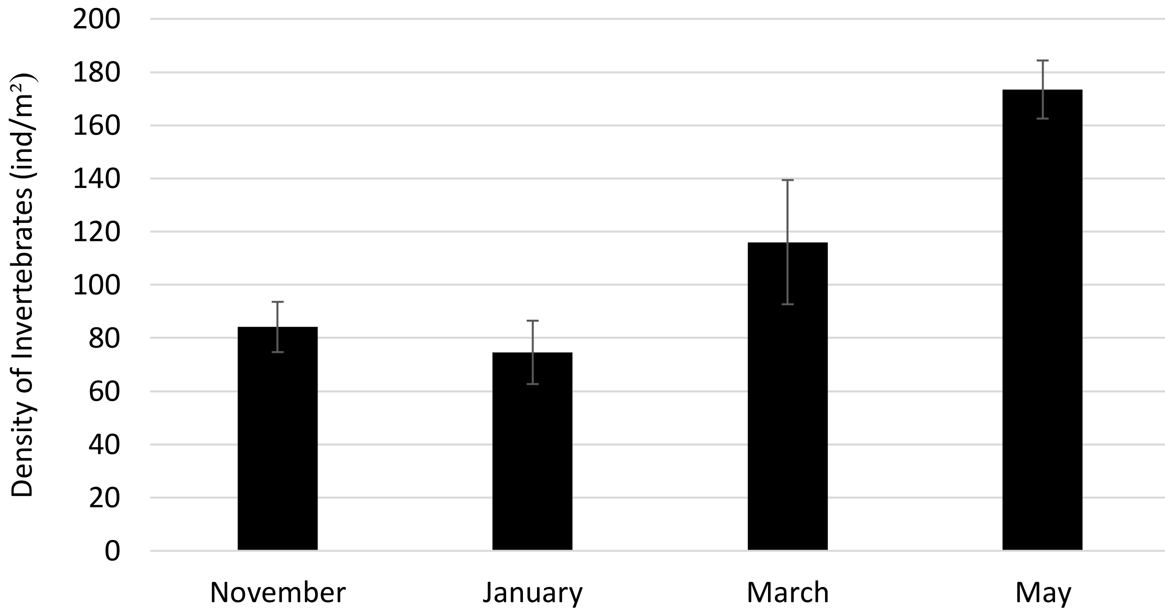


Figure 9-33. Mean monthly dry season (November–May) density (ind/m² ± SE) of aquatic invertebrates in the floodplain of the KRRA (Phases I and IVA) from 2011 through 2018.

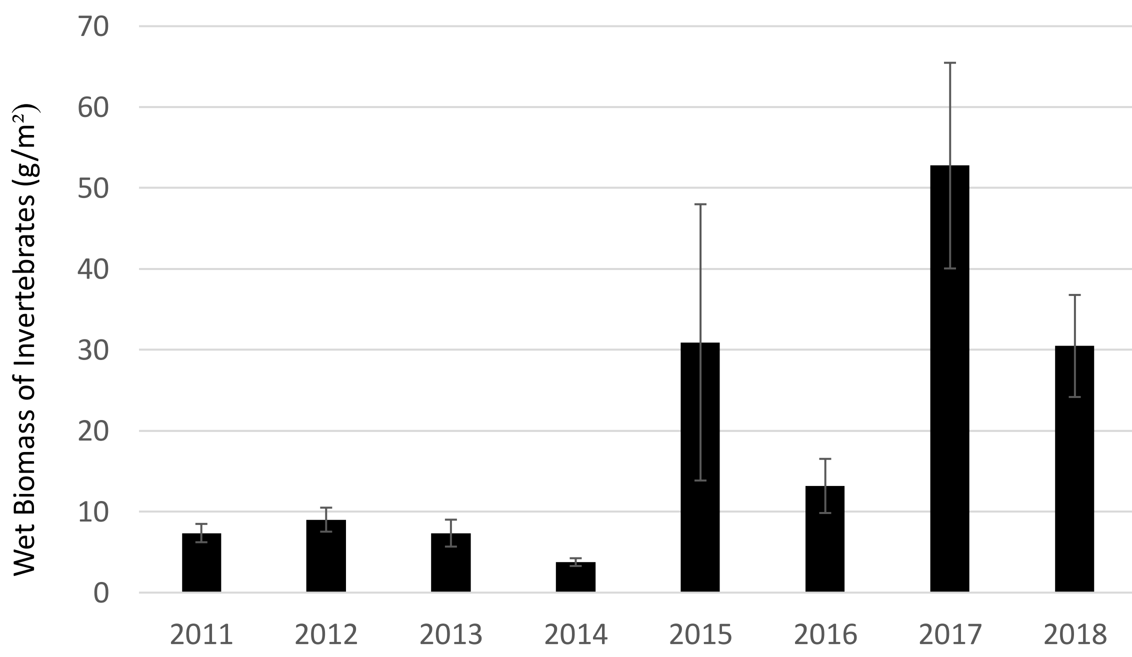


Figure 9-34. Mean annual dry season (November–May) biomass (g/m² ± SE) of aquatic invertebrates in the floodplain of the KRRA (Phases I and IVA) from 2011 through 2016.

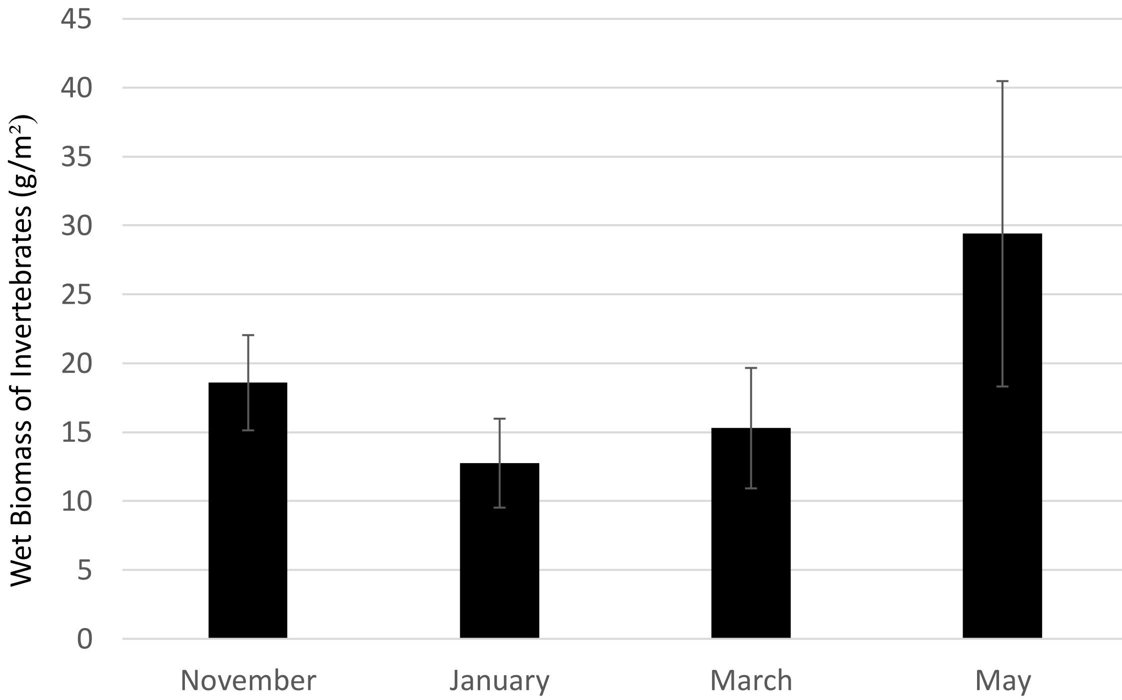


Figure 9-35. Mean monthly dry season (November–May) biomass (g/m² ± SE) of aquatic invertebrates in the floodplain of the KRRP area (Phases I and IVA) from 2011 through 2016.

Discussion

Small fish and aquatic invertebrate density, abundance, richness, and diversity are greater now than during the Baseline (pre-construction) Period. Wading bird and waterfowl prey abundance values were assumed to be zero during the Baseline Period due to the general absence of inundated habitat for aquatic species (see Chapter 9 of the 2018 SFER for methods; Koebel et al. 2018). Small fish densities and biomass were rather high when compared to marsh sites in the Everglades, where mean values ranged from less than 7 ind/m^2 (Trexler et al. 2002) to 34.5 ind/m² and 2.3 to 4.5 g/m², respectively (Loftus and Eklund 1994). Size of individual fish captured in throw traps was similar to sites in the Everglades, where mass ranged from 0.1-0.4 g (Loftus and Eklund 1994). Small fish densities in the Kissimmee River floodplain appear to be more similar to values reported for the Lake Okeechobee littoral zone, where densities ranged from 44.2 to 128 ind/m² (Sharfstein and Zhang 2017). Aquatic invertebrate densities appear to be greater than those reported for the littoral marshes of Lake Okeechobee, where densities ranged from 3.3 to 27 (Sharfstein and Zhang 2017). This indicates a highly productive floodplain food web that is more eutrophic than the marshes of the southern Everglades.

These summary values indicate that prey density and biomass do not appear to be limiting factors in precluding wading bird foraging within the KRRA and wading bird nesting within 10 kilometers (km) of the project area. The abundance of prey appears to be sufficient to sustain wading bird foraging during the breeding season if other conditions are suitable for bird reproduction. However, given the conspicuous lack of significant wading bird breeding colonies within 10 km of the partially restored Kissimmee River, where they were known to occur historically, other factors such as prey availability and suitable nesting sites may be limiting local breeding. Prey availability is not only the density and abundance of prey, but also a suite of other environmental factors that can limit the birds' access to suitable prey including prey size and type, water depth, vegetation type, and seasonality (Gawlik 2002). Statistical models are being developed that will examine these factors in greater detail. These models are expected to yield a better understanding of the drivers affecting wading bird and waterfowl food availability on the floodplain and the wading bird and waterfowl response to restoration. The results of this study may also assist water managers in applying adaptive management techniques that may enhance the suitability of floodplain habitats for bird foraging and reproduction while concurrently supporting the overarching goal of restoring ecological integrity.

FLOODPLAIN VEGETATION MANAGEMENT ACTIVITIES

During what is referred to as the Interim Period of the KRRP (the period of active restoration construction from 2001 through estimated completion by 2020) several significant vegetation management issues have arisen that require adaptive management action. The primary vegetation management issues within the KRRA management area are as follows:

- Invasion of floodplain wet prairie and BLM habitat by exotic grasses listed on the Florida Exotic Pest Plant Council's List of Invasive Plant Species 2019 (FLEPPC 2019). These grasses are primarily paragrass (*Urochloa mutica*; Category II), limpo grass (*Hemarthria altissima*; Category I), and West Indian marsh grass (*Hymenachne amplexicaulis*; Category I) and they are displacing native species.
- Invasion of former spoil areas, the backfilled C-38 canal, and other disturbed soils by Carolina willow (*Salix caroliniana*) and Peruvian primrosewillow (*Ludwigia peruviana*).
- Invasion of wet prairie and former BLM habitat by wax myrtle (*Myrica cerifera*) and other facultative shrubs (Rule 62-340.450, Florida Administrative Code [F.A.C.]; available online at https://floridadep.gov/water/submerged-lands-environmental-resources-coordination/content/wetland-delineation-vegetative.).

The long-term management goal for the KRRA is to rely primarily on hydrologic change and prescribed fire to restore and maintain the historical floodplain marshes, only using herbicide and mechanical treatments when necessary to achieve restoration goals. No single management tool is used in isolation and each management unit is evaluated individually to determine which combination and sequence of management actions will best achieve the goals for floodplain vegetation. Management actions to address the abovementioned vegetation issues will be a combination of the following, again with the focus being primarily on hydrologic change and prescribed fire:

- Hydrologic change through implementation of the HRS by 2020. Expected changes include longer hydroperiods, greater stage amplitude, slower rates of stage change, and a more natural seasonality in discharge to the river from its headwaters lakes.
- Prescribed fire through a well planned and documented prescribed burning program that focuses on early lightning season burning, when possible, to promote the return of historic wet prairie and BLM habitats.
- Herbicide treatments of target species to reduce and control exotic and invasive infestations and encourage recruitment of native species. Treatments are documented and coordinated with other management activities.
- Mechanical treatments such as mowing, roller-chopping, and shredding to reduce facultative and/or invasive shrubs and trees as needed in wet prairie and BLM habitats.
- Biological control using host-specific natural enemies from the native range of the invasive exotic species and introducing them to District lands to provide a natural regulation of the pest plant. Examples of state and federally approved biocontrol agents include the melaleuca weevil (*Oxyops vitiosa*), white lygodium moth (*Austromusotima camptozonale*), waterhyacinth planthopper (*Megamelus scutellaris*), and waterhyacinth weevils (*Neochetina* spp.).

In PW2019, prescribed fire, herbicide application, and biocontrol agents were used to begin to address the vegetation management issues described above.

Prescribed Fire

As part of a concerted effort by the District to utilize prescribed fire as a management tool to help reach the goal of restoring ecological integrity within the KRRA, four prescribed burns (~1,415 acres total) were conducted within the 100-year floodline (KRRP project boundary) in 2019. Burns were conducted in No Name Slough (April 4, 2019, ~16 acres), Oak Creek (April 11, 2019, ≈918 acres), Turkey Hammock (May 1, 2019, ≈50 acres), and Starvation Slough (June 24, 2019, ≈431 acres). It is hoped that well timed prescribed burns in the late spring and early summer will help reduce coverage of exotic grasses and invasive shrubs by direct consumption and increasing the competitive advantage of native wet prairie and BLM species. Native wet prairie and BLM species are adapted to lightning season fires just prior to wet season inundation. Lightning season wildfires are one of the historic ecological processes that helped shape the vegetation structure of the river floodplain and its associated fauna.

Fire effects on vegetation are being monitored by the District using permanent photo monitoring points (see **Figures 9-36** and **9-37** as examples), aerial photography, and vegetation plots. Ground photo points and vegetation plots are monitored at 3, 6, 12, and 24 months post-burn, and every 5-years post-burn after that. Longer-term monitoring of vegetation will be conducted via aerial photo interpretation approximately every 3 to 5 years. The results of this monitoring will be used to determine what other vegetation management activities will be required to manage invasive exotic grasses and shrubs within the floodplain. Activities may include hydrological manipulations, herbicide, and mechanical treatments such as roller-chopping and shredding. It is known from other study areas throughout the state that prescribed fire alone will not eliminate or even reduce invasive exotic grasses over the long-term; it needs to be used in conjunction with hydrological management and oftentimes herbicide applications prior to burning.

Figure 9-36. Starvation Slough Prescribed Burn Photo Point 2, pre-burn on April 22, 2019. The trees in the background are the live oak hammock indicating roughly the 100-year floodline, the shrubs behind the graduated PVC pole are mostly native swamp rose-mallow (*Hibiscus grandiflorus*), and the herbaceous species are dominated by the invasive exotic grasses limpo grass and paragrass.

Figure 9-37. Starvation Slough Prescribed Burn Photo Point 2 three days post-burn on June 27, 2019. The oak hammock was not burned, the swamp rose-mallow was scorched aboveground, and the exotic grasses were partially consumed, being slightly reduced in height from approximately 60 cm to 20 cm (see graduated PVC pole in 10-cm increments). The lighter-colored grass laid over is indicative of scorched limpo grass (*Hemarthria altissima*).

Herbicide Treatments

Several herbicide treatments were conducted within the Kissimmee River floodplain during WY2019, two of which were experimental. One experimental treatment of approximately 30 ac of Carolina willow was conducted on the Kissimmee River floodplain, also near Oak Creek, on March 30, 2018. The goal of this treatment was to determine which herbicide(s) provide the optimal balance between effective control of Carolina willow and minimal impacts to non-target native wet prairie and BLM plant species. Both canopy and understory vegetation data were collected for this experiment at 30, 180, and 360 days after treatment and will be collected again at 540 days after treatment. A final summary report of results will be presented in this chapter of next year's SFER. The results of this study will be used to help determine a path forward in reducing the acreage of invasive Carolina willow within the KRRA.

A second experimental treatment of approximately 60 ac of the invasive exotic West Indian marsh grass (*Hymenachne amplexicaulis*) was conducted on November 15, 2018, near Oak Creek. The treatment was part of a research project led by Dr. Stephen Enloe of the University of Florida examining the efficacy and selectivity of the grass-specific herbicides sethoxydim and fluazifop-butyl compared to standard non-selective treatments (e.g., Glyphosate + imazapyr) (Enloe 2017). Post-treatment data has been collected at 60 and 180 days after treatment and will be collected again at 360 days after initial treatment. Results of this study will be presented in a peer reviewed journal article by 2020.

District herbicide treatments targeting Old World climbing fern (*Lygodium microphyllum*), Brazilian pepper (*Schinus terebinthifolia*), tropical soda apple (*Solanum* sp.), strawberry guava (*Psidium cattleianum*) and other District priority invasive species were conducted within the floodplain during WY2019. Most treatments occurred south of current restoration construction in Pool D, within several miles of the S-65D structure, but aerial treatment of lygodium did occur along the entire length of the Kissimmee River. For a more comprehensive summary of District herbicide treatments along the Kissimmee River refer to Chapter 7 (Status of Nonindigenous Species) of this volume.

Herbicide treatments are costly and funding is oftentimes inadequate to effectively address the invasive vegetation management issues occurring within the KRRA. Planning and funding for invasive vegetation management within the KRRA was not considered when the project was first initiated decades ago, thus aggressive expansion of invasive grasses and shrubs has remained uncontrolled. Therefore, continued and enhanced interagency cooperation, coordination, and funding is vital to the long-term outcome of the KRRP.

Biocontrol

Populations of the brown lygodium moth (*Neomusotima conspurcatalis*) were released in three locations on May 16, 2019. Seven thousand moths were released near the Lockett Estate where Highway 98 crosses the Kissimmee River, and 4,500 moths were released approximately 0.75 miles northeast of the Istokpoga Canal boat ramp along the Istokpoga Canal. The United States Department of Agriculture monitors moth introduction sites at other locations outside of the LKB.

UPPER KISSIMMEE BASIN PROJECTS

KISSIMMEE CHAIN OF LAKES AND UPPER KISSIMMEE BASIN MONITORING AND ASSESSMENT PROJECT

The Kissimmee Chain of Lakes (KCOL) and Upper Kissimmee Basin (UKB) Monitoring and Assessment Project involves data collection, evaluation, and reporting to support the District's mission to manage and protect water resources. The monitoring also contributes to the assessment of the Kissimmee River Headwaters Revitalization Project (HRP), which—under the HRS—will increase storage in the Headwaters Lakes (Lakes Kissimmee, Cypress, and Hatchineha) to improve timing and volume of flow to ensure KRRP hydrologic success. Together, these products support management decisions and are used to determine whether management intervention is required or whether the ecosystem is responding as intended to management actions. Key focus areas include the following:

- Data collection and evaluations to define relationships between hydrology and the lake littoral vegetation response to seasonal water level conditions.
- Coordination with agency and environmental stakeholders to ensure non-redundant and complementary data collection and evaluation; to annually report on ecological conditions within the KCOL and UKB; and to facilitate information sharing and identification of emerging issues and concerns.

The scope of this year's UKB Projects section includes an overview of watershed assessment, monitoring, and research results. The results provide an overview of ecological conditions and water quality trends in the UKB by combining data and information from SFWMD's monitoring activities with those of KCOL partner agencies.

MONITORING HEADWATERS REVITALIZATION AND UPPER KISSIMMEE BASIN

The HRP was designed to increase storage in the Headwaters Lakes to provide appropriate flow patterns to the Kissimmee River and floodplain upon completion of KRRP construction. The increased storage that results due to higher maximum regulatory stages are expected to improve the quantity and quality of littoral habitat in the Headwaters Lakes. The HRS will increase regulatory stages and change the operating schedule for S-65, which controls discharge from and stage in the Headwaters Lakes.

Aerial Imagery Classification

The Florida Fish and Wildlife Conservation Commission (FWC) has been producing vegetation community maps from aerial imagery of the major water bodies in the KCOL and Lake Istokpoga since 2005. The monitoring effort was initiated to develop lake management plans using quantifiable habitat targets for a suite of representative wildlife species. Although these maps focus on emergent vegetation within the littoral zone, the management plans target aquatic in-lake habitat, rather than wetland habitats such as marshes that occur at higher elevations along the lake shore. To better assess littoral vegetation conditions and to monitor efficacy of management actions, FWC developed a classification system using vegetation types that were common or representative of specific habitat value for fish and wildlife. The classes were based on an amended version of the Florida Land Use, Cover and Forms Classification System (FLUCCS; FDOT 1999), and contained estimates of plant coverage (sparse, medium, or dense) for each. The full scope of this project was described in Chapter 9 of the 2018 SFER (Koebel et al. 2018).

FWC is making major changes to their mapping methods to reduce costs and produce maps in a shorter timeframe, making use of new image technology and computer-based analysis methods. In March 2016, FWC contracted with two companies to develop a digital procedure in ArcGIS to map emergent vegetation using high resolution (2-m or 10-m pixel size) satellite imagery. Certain KCOL lakes were mapped in early 2016 and early 2017 with the goal of refining the methods, particularly determining the appropriate number of ground-truthing points needed for accuracy assessments. Development of this method is ongoing, details about the finalized procedure and schedules for mapping KCOL lakes will be included in future versions of the SFER.

The primary goal of the newly implemented District vegetation mapping project is to monitor changes in wetland plant communities on the Headwaters Lakes, including Lake Tiger and connecting wetlands, within elevations identified in the 1994 Fish and Wildlife Coordination Act Report (USACE 1996). The target elevations are up to and including 54 ft National Geodetic Vertical Datum of 1929 (NGVD29), which tend to be higher than the areas mapped by FWC and include extensive areas of marsh, but there is overlap. Similar to FWC's current mapping effort, we are researching and developing a digital mapping procedure as an alternative to traditional field survey and manual interpretation methods using very high resolution (1-foot) aerial photography and four new techniques: object-based image analysis, machine learning classifiers, texture analysis, and ensemble analysis (Zhang et al. 2018). As described in Zhang et al. (2018) uncertainty maps are one helpful byproduct of ensemble analysis that identifies areas where analysis has less certainty, enabling more efficient and targeted ground truthing to resolve these errors.

Vegetation Monitoring

Monitoring vegetation within the existing littoral zones and up to future lake regulation elevations is necessary to estimate the effects of the HRS in the Headwaters Lakes on the quantity and quality of littoral habitat and document vegetation changes (USACE 1996). The need for vegetation monitoring was identified in the UKB Monitoring and Assessment Project (initiated in October 2010) to address data gaps and knowledge uncertainties determined during development of the *Kissimmee Chain of Lakes Long-Term Management Plan* (SFWMD et al. 2011). By combining monitoring efforts between these projects, expected improvements from the HRP can be better isolated from other management activities in the UKB, and monitoring efforts can be expanded to include wildlife responses in the future.

Currently, there are two vegetation monitoring studies on the KCOL that will fill these needs. The first is a District project that involves tracking changes in specific plant community types over time and documenting any distributional shifts up or down slope if they occur. The second is an FWC project that involves quantifying specific littoral communities via aerial imagery on a 3- to 5-year rotation in the major KCOL water bodies. Currently, FWC is considering new methods for this project, including use of satellite imagery. Updated methods will be described, and any new results will be presented in future SFERs.

Permanent South Florida Water Management District Monitoring Stations

In 2009, a study was initiated to provide baseline monitoring of littoral zone vegetation on the Headwaters Lakes, which included establishing sampling units and collecting one season of data (Jones et al. 2011). This 2009 study consisted of transects oriented parallel to the lakeshore with groups of 3 to 5 1-m square quadrats established in each vegetation zone present. Vegetation zones were based on FLUCCS codes identified according to dominant species cover. This sampling was not repeated in subsequent years and in early 2015 a new study was initiated when long-term, permanent monitoring stations were established on three of the major water bodies in the KCOL (East Lake Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee). These permanent monitoring stations are sampled annually in August through September. Lake Kissimmee is the only lake that will have a different regulation schedule under the HRS, while Lake Tohopekaliga and East Lake Tohopekaliga will serve as control lakes for comparison. Additional monitoring stations may be added in the future to the other Headwaters Lakes or in the expansive Gardner Cobb Marsh that historically connected the Headwaters Lakes. The current study's permanent monitoring stations include circular plots that are stratified by water depth and community type throughout the littoral zone, as well as belt transects set perpendicular to shore in the upper reaches of the littoral zone.

FISH POPULATION MONITORING

The status of the fishery in the KCOL is monitored on a regular basis by FWC via electrofishing and creel surveys. Electrofishing surveys use a standardized sampling protocol implemented in 2007, where random transects are sampled for 15 minutes each. Electrofishing surveys occur in the fall and spring every 2 to 3 years on the major lakes in the KCOL. Fall surveys provide community data with number of fish per functional group: black crappie (*Pomoxis nigromaculatus*), catfish (Siluriformes), exotic species, small forage fish, largemouth bass (*Micropterus salmoides*), rough fish, sunfish (*Lepomis* spp.), game fish, and nongame fish. Spring surveys provide an assessment of the size distribution and abundance of largemouth bass populations. The most recent summaries were tallied for fall 2017 and spring 2018 on Lakes Kissimmee and Tohopekaliga.

Community

Community data is summarized in **Figure 9-38** to provide a more complete understanding of the diversity and type of fish present in the KCOL. Samples from fall 2017 include 25 species on Lake Kissimmee and 26 species on Lake Tohopekaliga divided into eight functional groups (catfishes, exotics, forage, other, rough, sunfishes, and gamefishes; certain groups are counted twice because the nongame fish category includes all species not included in the gamefishes group). A large majority of the fish population, both number of individuals and number of species, is composed of small native forage fishes, such as topminnows and killifish (*Fundulus* spp.), and shiners (Cyprinids). As the name implies, this group is also an important component of lake food webs, sustaining predators including other fish. FWC cautions against interpreting differences between yearly samples and averages as real indications of increases and decreases in populations, explaining that results are greatly affected by habitat conditions such as water levels or amount of submerged aquatic vegetation, making it hard to directly compare samples. The relative consistency of the Simpson's Diversity index and species richness, coupled with the low number of exotic fish seem to indicate the 2017 sample reflects a more or less stable population.

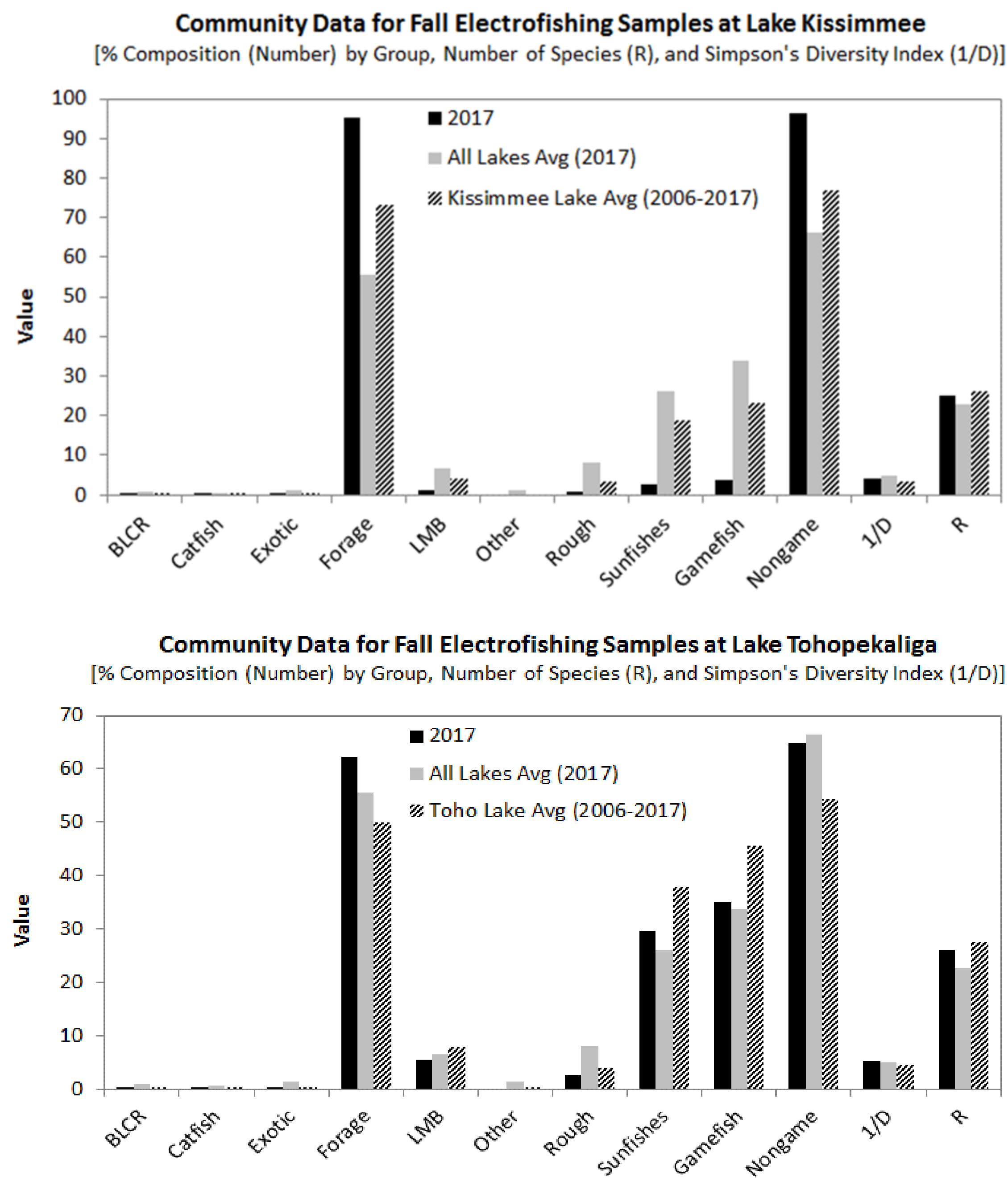


Figure 9-38. Percent composition of fish functional groups, species richness, and Simpson's Diversity, within Lakes Kissimmee (top panel) and Tohopekaliga (bottom panel) during fall 2017. (Note: BLCR – black crappie, LMB – largemouth bass, rough – bowfin, Florida gar, and similar species.

Largemouth Bass Abundance

Catch per unit effort (CPUE) is one metric used to assess the annual abundance of largemouth bass, though catch rates can vary some with density of vegetation, water clarity, inclement weather, or an abundance of small size classes. CPUE was approximately 46.62 and 34.52 bass per hour (bass/hr) on Lakes Kissimmee and Tohopekaliga, respectively, which is up from 2017 when values ranged from 15.3 to 39.0 bass/hr. Last year, FWC reported that differences are likely due to differences in sampling effort, namely inexperienced staff. The 2018 results seem to reflect more normal sampling effort and fish populations.

The annual size distributions generally show a bimodal peak if the population is doing well, with a peak in subadults (< 25 cm) indicating good production of young and a second peak in larger size classes indicating good recruitment of young into the population (**Figure 9-39**). When there are few to no subadults found in a given year, there typically is a subsequent decline in larger size classes within 2 to 3 years after, and the opposite can be found as well. In 2018, the frequency distribution data from Lakes Kissimmee and Tohopekaliga show a bimodal pattern, with a very moderate subadult peak and a higher number of larger adult fish in Lake Kissimmee, and moderate numbers in both size classes in Lake Tohopekaliga.

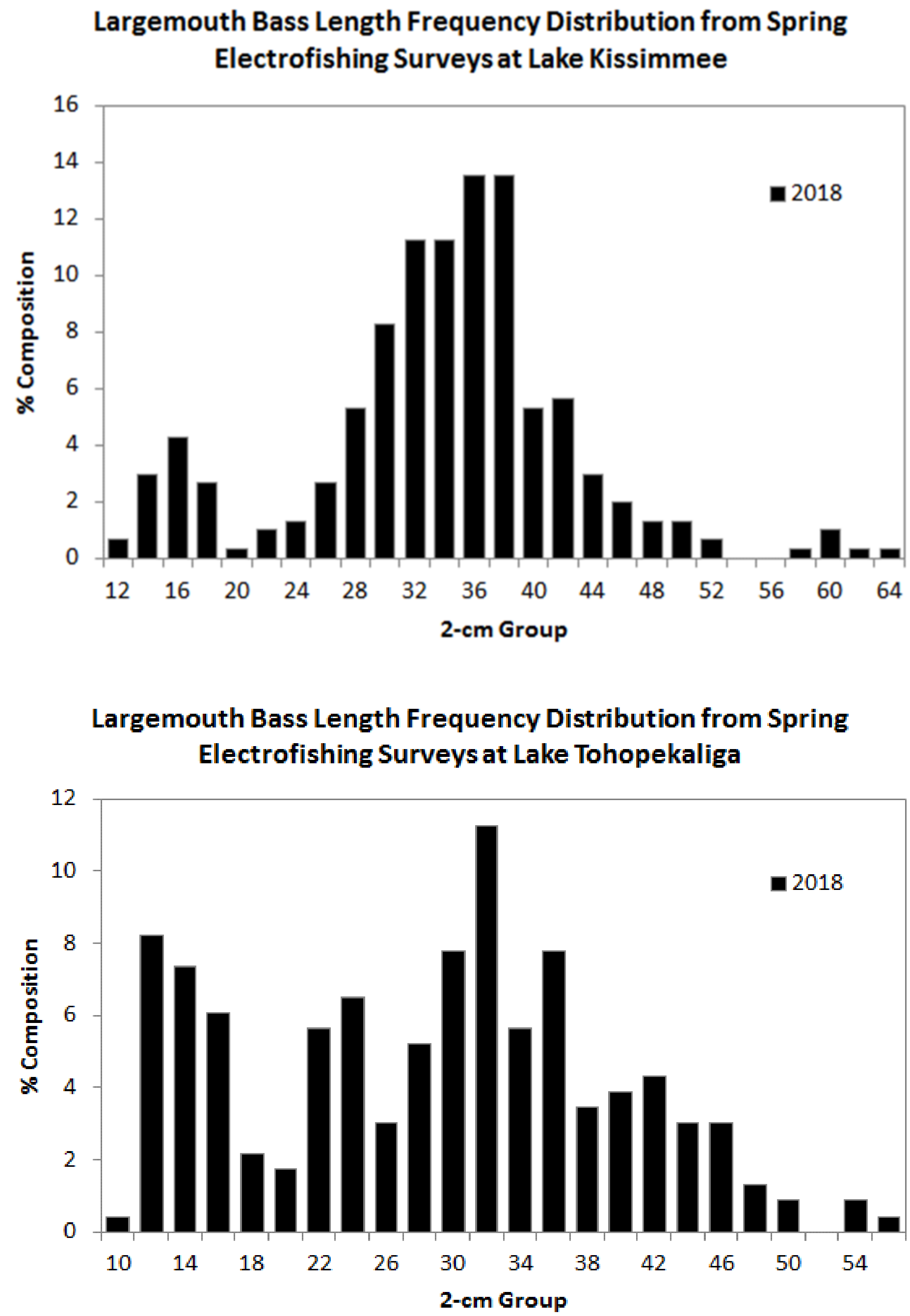


Figure 9-39. Length-frequency distribution for largemouth bass collected by electrofishing at Lakes Kissimmee (top panel; n = 303), and Tohopekaliga (bottom panel; n = 231) during spring 2018. Fish lengths were placed into two-centimeter groups (e.g., 10 cm group = 10.00 through 11.99 cm total length).

STATEWIDE EVERGLADE SNAIL KITE POPULATION MONITORING

Statewide Everglade snail kite (*Rostrhamus sociabilis plumbeus*) nesting effort, distribution, and population size are systematically monitored by the University of Florida on an annual basis (see Fletcher et al. [2018] for details). This monitoring effort covers most wetlands, statewide, in which snail kite breeding activity has been observed within the last decade or more. In the KCOL region, surveyed water bodies include East Lake Tohopekaliga and Lake Runnymede (grouped as East Lake Tohopekaliga); Lake Tohopekaliga; Lake Kissimmee; and Lakes Jackson, Cypress, Hatchineha, and Marian (grouped as Other). Surveys begin in January and crews recorded nesting information; including the location, status (building, incubating, nestlings, failed, or successful), leg bands of parents (if possible), and other important characteristics. Following the first survey in January, each nest is revisited at about 3-week intervals until the nest is no longer active. Alpha-numeric leg bands are put on most nestlings when they are 24 days old for future identification and for estimating population size. The number of snail kites observed in each water body is counted and identified by their alpha-numeric leg bands, if possible.

In 2018, survey crews located a total of 732 active nests (i.e., containing eggs or nestlings) throughout the snail kite's Florida range. This represents a dramatic increase in nesting effort from 2017 (225 active nests) and is the second most active nests statewide (778 active nests in 2016) since at least 2006. Nesting activity showed a bimodal pattern with lots of early nesting in the Rotenberger WMA and Water Conservation Area (WCA) 3A from January to early April, lower nesting activity from late April to early June and high nesting activity from late June through August in Lake Okeechobee and the Kissimmee River floodplain. Nesting in the KCOL only made up 18% of the statewide snail kite nesting in 2018, its lowest contribution since at least 2006. Lake Okeechobee had 189 active nests in 2018, 87 of which were successful. The Everglades had 57 nests, 18 of which were successful. The upper St. John's River basin had 46 active nests, 17 of which were successful.

For the first time since at least 2006, the most snail kite nests were found in the "Other" region. The Other region consists of any wetlands not encompassed by the KCOL, Lake Okeechobee, Everglades Stormwater Treatment Areas (STAs), or Upper St. John's regions. In 2018, the highest levels of nesting were seen in the Rotenberger WMA and Kissimmee River. Prior to 2017, there had only been one snail kite nest recorded in the WMA in 2013 near the border of STA-5. A wildfire burned most of the WMA in May 2017 and higher than normal water levels following an extreme rain event occurred in June 2017. A handful of snail kite nests appeared in the WMA in August 2017 but were destroyed by Hurricane Irma. Snail kites immediately built new nests and continued to nest in the WMA into 2018. After 35 Snail Kite nests were found in the WMA in late 2017, there were 147 snail kite nests found there in 2018, of which 68 nests were successful. There were also 3 nests found at Paynes Prairie Preserve State Park in Alachua County, 100 miles north of the KCOL.

Within the KCOL, there were 28 nests located on Lake Tohopekaliga in 2018, 4% of the statewide nesting effort. Lake Kissimmee had 99 nests (14% of the statewide nesting effort) and East Lake Tohopekaliga had 5 nests (< 1% of the statewide nesting effort). There was no nesting documented on any other KCOL water body (**Figure 9-40C**). Of the 132 nests in the KCOL, 55 nests (42%) were observed to be successful (**Figure 9-40D**).

In summary, despite a near record snail kite nesting year statewide, the KCOL was outperformed by Lake Okeechobee and "Other" areas. However, overall nesting and successful nests were at or above average for the KCOL. This was generally driven by below average nesting in Lake Tohopekaliga and very low nesting for a second consecutive year in East Lake Tohopekaliga. Lake Kissimmee had the most nests in 2018 since at least 2006. Many of these nests occurred on floating islands covered in woody vegetation. These islands may have appeared on Lake Kissimmee due to disturbance from Hurricane Irma in 2017. Apparent success rate on Lake Kissimmee was 46% in 2018, much higher than average for that lake, suggesting the kites benefitted from the security of nesting on floating islands.

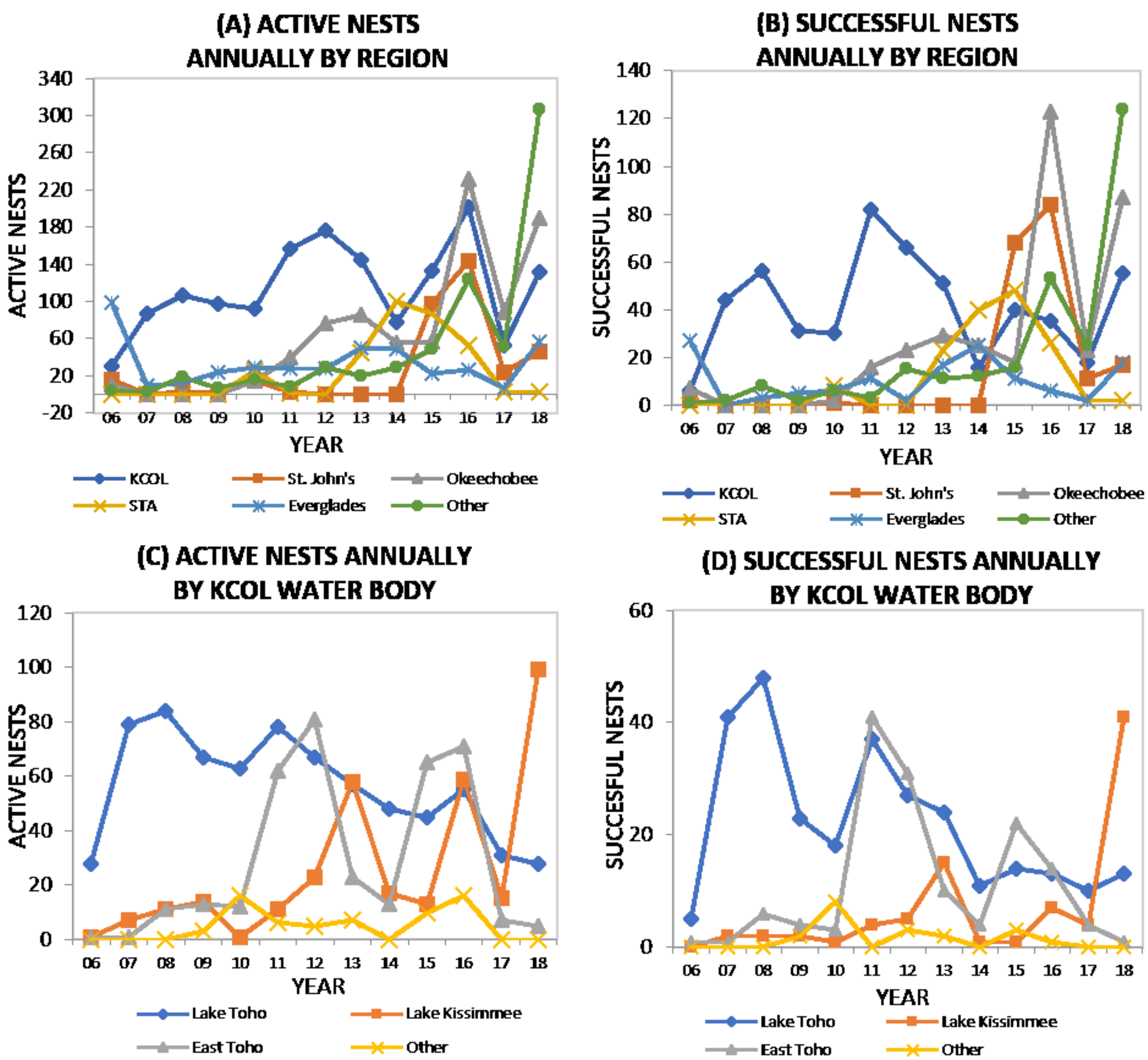


Figure 9-40. (A) Active snail kite nests for each region from 2006 to 2018 and (B) the total number successful; (C) active snail kite nests for each major water body in the KCOL region; and (D) the total number successful from 2006 to 2018. (Note: Toho – Tohopekaliga.)

ALLIGATOR POPULATION MONITORING

FWC conducts American alligator (*Alligator mississippiensis*) monitoring studies in many public water bodies throughout the state to obtain relative abundance of their populations (Hutton and Woolhouse 1989). Alligator activities vary seasonally (Lutterschmidt and Wasko 2006), so night light surveys are conducted from May through mid-June (spring surveys) and July through mid-August (summer surveys) and are analyzed separately. Survey routes are standardized and follow the perimeter of a lake along the open water-shoreline/marsh interface (Woodward and Marion 1978), or middle/centerline of a river/canal section, depending on width. Spotlights (200,000 candlepower) are used to locate alligator eye reflections and sizes are estimated to the nearest 1 ft, if possible. When the exact size cannot be determined, broader size categories (0–2 ft, 2–4 ft, 4–6 ft, ≥ 4 ft, ≥ 6 ft, and ≥ 9 ft) are used, or they are recorded as unknown size.

For trend analysis by year, counts are summed in each size category. Average date, water level, and water temperature within replicates are determined for each year. FWC uses Turnbull's (1976) approach for interval-censored data via the "%ice" SAS macro (So et al. 2010) to allocate counts into size categories. A modified version of this macro is used to produce an overall probability distribution function, describing the estimated proportions of unit-interval lengths for each replicate-unit-year sample. The probability distribution function is summed for specified portions of the alligator size range to produce the cumulative distribution function for each replicate-unit-year. Standard errors and 95% confidence intervals for cumulative distribution function are determined via the macro as well, and these are multiplied by the total number of all alligators counted for each replicate-unit-year sample to estimate the total count, its SE, and confidence limits.

FWC models year trends in the natural logarithms of the estimated counts using the generalized additive modeling package of the R statistical environment (Hastie 2009). Akaike's information criterion (AIC_C) is used to select the best of six models from some combination of year and water level as predictors, modeled as either linear or spline (piecewise) regressions with four knots, or separations (de Boor 2001). The predictors in the six models are (1) linear year effect; (2) four-knot spline for year; (3) linear year and linear water level; (4) linear year and four-knot spline for water level; (5) linear water level and four-knot spline for year; and (6) four-knot spline for year and four-knot spline for water level. A fixed detectability coefficient of 0.14 is applied to survey counts to generate population estimates from the generalized additive modeling analyses (Woodward et al. 1996).

Lake Kissimmee

Total alligator population estimates on Lake Kissimmee have continued to stay strong in recent years. The 2018 estimated population was 13,450 alligators, which is an increase of approximately 182% since population monitoring began in 1991 (**Figure 9-41a**). The estimated number of juvenile (1–4 ft) alligators was 6,825 individuals, which is a 296% increase over the 1991 estimated population. The adult (6 ft and larger) portion of the alligator population also increased and was estimated at 3,802 individuals, a 55% increase since 1991.

Lake Tohopekaliga

Total alligator population estimates on Lake Tohopekaliga have continued to stay strong. The 2017 estimated population was 7,826 alligators, an approximate increase of 181% since population monitoring began in 1994 (**Figure 9-41b**). The estimated number of juvenile (1–4 ft) alligators was 5,137 individuals, a 349% increase over the 1994 estimated population. The adult (6 ft and larger) portion of the alligator population also increased and was estimated at 1,372 individuals, an 85% increase over the 1994 estimated population.

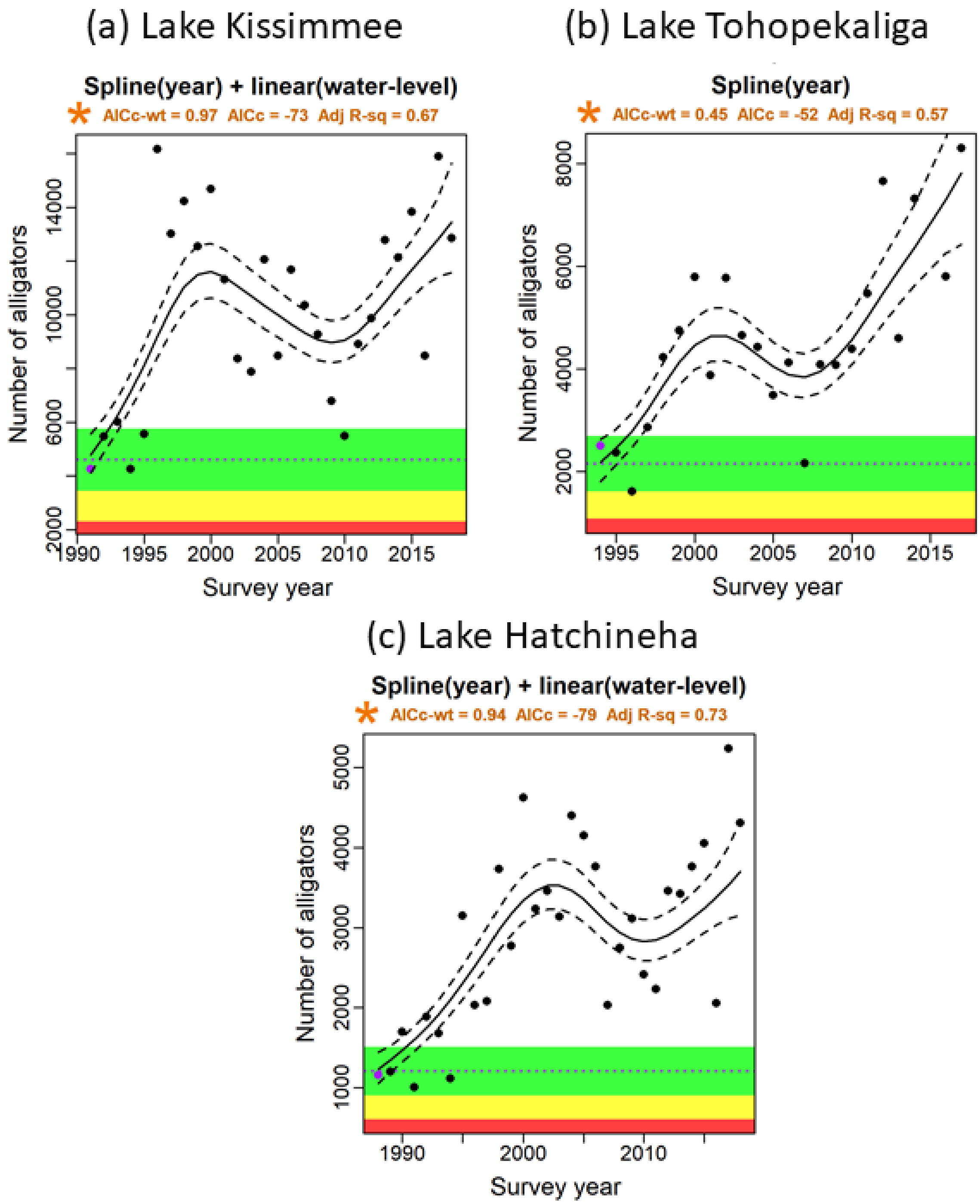


Figure 9-50. Alligator population trends on (a) Lake Kissimmee, (b) Lake Tohopekaliga, and (c) Lake Hatchineha based on night light surveys conducted between 1988 and 2018. Green-shaded area represents ± 25% of the population management target; yellow-shaded area represents 25–50% of the target; and the red-shaded area represents ≤ 50% of the target. Dashed lines represent 70% confidence intervals around the solid trend line. Note that both the x- and y-axes scales vary between figures. (Note: Adj R-sq – adjusted R-squared; AICc – Akaike's information criterion; AICc – Akaike information criterion with a correction for small sample sizes; and AIC_c-wt – Akaike weights.

East Lake Tohopekaliga

The 2018 total alligator population estimate on East Lake Tohopekaliga was 96 alligators. Although this estimate is approximately 21% lower than the 2003 (first year of monitoring) estimate, the variation in survey counts is relatively high and there is no significant trend. The estimated number of juvenile (1 to 4 ft) alligators was 23 individuals, a 51% decline from 45 in 2003. The adult (6 ft and larger) portion of the alligator population was 35 individuals, a 43% decrease from the 2003 estimated population of 64 adults.

Lake Hatchineha

Total alligator population estimates on Lake Hatchineha have remained strong. The 2018 estimated population was 3,702 alligators, an increase of approximately 200% since population monitoring began in 1988 (**Figure 9-49c**). The estimated number of juvenile (1–4 ft) alligators was 1,990 individuals, a 202% increase since 1988. The adult (6 ft and larger) portion of the alligator population also increased and was estimated at 1,055 individuals, a 161% increase over the 1988 estimated population.

Cypress Lake

The 2018 estimated population on Cypress Lake was 687 alligators, a 40% decrease since population monitoring began in 2000. The estimated number of juvenile (1–4 ft) alligators was 127 individuals, while the estimated number of adult alligators was 392 individuals. Those estimates represent a 67% decline and a 10% decrease, respectively, from the 2000 estimated population.

Kissimmee Chain of Lakes Alligator Populations Summary

Alligator populations on the three largest lakes within the KCOL (Kissimmee, Tohopekaliga, and Hatchineha) have shown increases in juvenile, adult, and total populations over the period for which monitoring surveys have been conducted. Increases in the number of juveniles could be an indication of sufficient nesting habitat, favorable nesting conditions, high hatching success, and sufficient habitat for hatchlings and juveniles. Likewise, increases in the number of adults possibly are due to high survival of juveniles and subsequently high recruitment of younger alligators into the adult size classes.

Trend analyses for East Lake Tohopekaliga and Cypress Lake indicate declines for juveniles, adults, and total populations. The decline of adults might reflect the harvest from recreational and nuisance trappers. The declines noted for the juveniles is unclear but might reflect changes in the available habitat for smaller alligators. The removal of dense emergent vegetation and hydrilla can reduce the amount of available cover and foraging area for juvenile alligators. The drawdown scheduled for East Lake Tohopekaliga could have further negative effects on juvenile populations. Preserving selected mature marsh areas around the lake can provide nesting habitat, as well as juvenile cover and forage areas that will support the number of juvenile alligators using the lake.

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