Chapter 9: Kissimmee River Restoration and Other Kissimmee Basin Initiatives[1]

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Kissimmee River Phase I Restoration area floodplain when discharge at the S-65A structure is 1,432 cubic feet per second.

Highlights

The chapter reports new results from Kissimmee Basin monitoring studies that were active in Planning Window 2022-2023 (June 1, 2022–May 31, 2023), specifically those conducted under the South Florida Water Management District's Kissimmee River Restoration Evaluation Program and several other projects in the Kissimmee Chain of Lakes. Since 2005, this chapter has reported results of numerous monitoring studies being conducted in the Kissimmee River and floodplain in the Lower Kissimmee Basin and the Headwaters Lakes (Lakes Kissimmee, Cypress, and Hatchineha) as part of the Kissimmee River Restoration Evaluation Program by the South Florida Water Management District and in other lakes in the Upper Kissimmee Basin by the South Florida Water Management District and partner agencies. Results are reported as new data and analyses become available for a given planning window.

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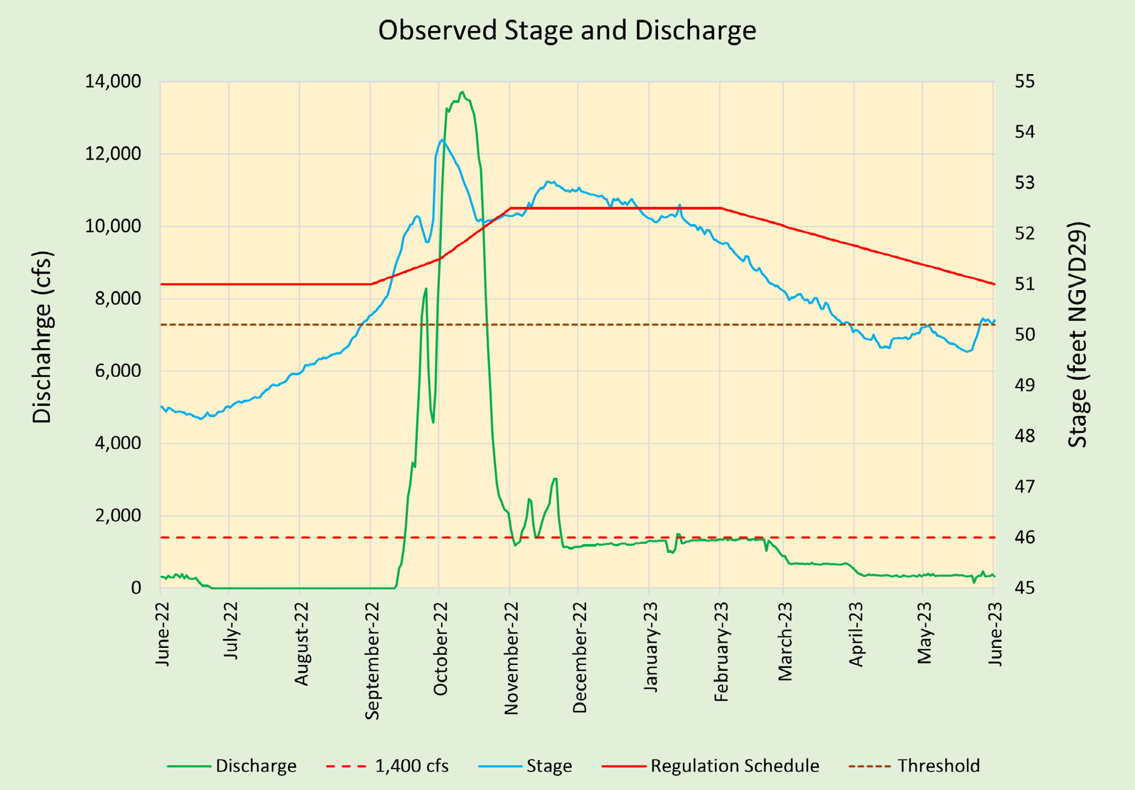
While it may not be possible to fully meet hydrologic targets for the Kissimmee River Restoration Project prior to implementation of the Headwaters Revitalization Schedule, performance can be improved now by implementation of discharge plans that use 1,400 cubic feet per second (cfs) as a minimum discharge when Headwaters Lakes (Lakes Kissimmee, Cypress, and Hatchineha) stage is above a specified threshold (IS-14-50.0 discharge plan). The 2022 wet season marked the seventh implementation of a variation of the IS-14-50.0 discharge plan since the 2015 wet season. Implementation of the plan in Planning Window 2023 resulted in a single 144-day period with bankfull discharge or greater, the longest duration of bankfull discharge since reestablishment of flow in 2001 (see figure on the next page). Rainfall, especially in association with Hurricanes Ian (late September 2022) and Nicole (early November 2022), extended the event well into the 2022-2023 dry season.



Observed stage (blue line) and discharge (green line) in the Headwaters Lakes and S-65 during June 2022–May 2023.

SUMMARY

The chapter reports new results from Kissimmee Basin monitoring studies that were active in Planning Window 2022-2023 (PW2023; June 1, 2022–May 31, 2023), specifically those conducted under the South Florida Water Management District's (SFWMD's or District's) Kissimmee River Restoration Evaluation Program (KRREP) and several projects in the Kissimmee Chain of Lakes (KCOL). Since 2005, this chapter has reported results of numerous monitoring studies being conducted in the Kissimmee River and floodplain in the Lower Kissimmee Basin (LKB) and the Headwaters Lakes (Lakes Kissimmee, Cypress, and Hatchineha) as part of the KRREP by SFWMD and in other lakes in the Upper Kissimmee Basin (UKB) by SFWMD and partner agencies. Results are reported as new data and analyses become available for a given water year. Brief abstracts of study findings are presented in this section; for results and other details such as study methods, refer to the corresponding subsections later in the chapter.

The chapter also summarizes Kissimmee Basin hydrologic conditions and water management in PW2023, as well as construction and management activities and the status of various other projects throughout the Kissimmee Basin. The Kissimmee River Restoration Project (KRRP) entered the twenty-second year of an Interim Period of restoration evaluation that began with completion of the first phase of construction and is expected to continue for five years after the Headwaters Revitalization Schedule (HRS) is fully implemented. Construction and backfilling for the project were completed in July 2021 and the few remaining lands for acquisition are expected to be acquired in 2024. The HRS will be implemented in phases over several years starting in 2024.

BASIN-LEVEL RAINFALL, DISCHARGE, AND LAKE STAGE

To be consistent with Chapter 2A of this volume, rainfall is reported for Water Year 2023 (WY2023; May 1, 2022–April 30, 2023). The Kissimmee Basin experienced above average rainfall in WY2023. Rainfall totals of 54.0 inches over the UKB and 50.0 inches over the LKB were 3.1 and 1.3 inches above their long-term averages, respectively. Despite slightly above average annual rainfall, much of the year was below average punctuated with periods of above average rainfall especially from Hurricanes Ian and Nicole. Despite overall drier conditions, operation of the S-65 water control structure was complex due to periods of heavy rainfall and efforts to balance multiple and sometimes competing objectives. The IS-14-50.0 discharge plan, which specifies 1,400-cubic feet per second (cfs) discharge at the S-65/S-65A water control structures while stage in the Headwater Lakes is above 50 feet (ft) National Geodetic Vertical Datum of 1929 (NGVD29), was recommended for implementation in the 2022 wet season, although it was not followed exactly. This water management did not result in a duration of floodplain inundation for the Kissimmee River comparable to the reference period, although it produced a single 144-day period with bankfull discharge or greater that extended well into the dry season, a highly desirable feature of reference period inundation events. Stage in the Headwaters Lakes was at or above the regulation schedule from mid-September 2022 to late January 2023; dry conditions, outflow to the Kissimmee River, and discontinuation of inflow from Lakes Tohopekaliga and Gentry resulted in a decline of stage in the Headwaters Lakes below 50 ft NGVD29 in early April 2023. Over the dry season, requests to moderate lake recession rates were implemented in Lake Tohopekaliga and East Lake Tohopekaliga to benefit fish and wildlife.

LOWER KISSIMMEE BASIN

KRRP Status

July 2021 marked the completion of KRRP construction after nearly 22 miles of C-38 Canal backfilling, removal of two water control structures, installation of the S-69 weir, and numerous additional construction efforts. This milestone sets the stage for gradual implementation of the new HRS stage regulation schedule for the S-65 water control structure. Following finalization of the last remaining land acquisitions in 2024, HRS will be incrementally implemented in several phases currently projected to start in early 2024. The phased increments will allow successively higher stages in the Headwaters Lakes until approximately 2026, when the HRS is currently projected to be fully implemented. The objective of the HRS is to provide sufficient water storage to reestablish historical (pre-channelization) flow patterns to the Kissimmee River. The higher stages allowed by the schedule are also expected to improve littoral zone habitat in the Headwaters Lakes.

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 in PW2023. A single floodplain inundation event met the depth criterion of at least 1 ft for Expectation 3; however, it lasted only 54 days, far shorter than the Expectation 3 210-day duration criterion, which has never been met in the Interim Period (2001–2023). The inundation event ended with a recession that had a rate of 0.82 ft per 30 days, thus meeting both recession criteria for Expectation 4 in PW2023. However, the percentage of events meeting this criterion over the entire Interim Period is only about half of the Expectation 4 target. While it may not be possible to fully meet these targets prior to HRS implementation, performance can be improved now by implementation of discharge plans that use 1,400 cfs as a minimum discharge when Headwaters Lakes stage is above a specified threshold.

KRREP Dissolved Oxygen

Concentrations of daytime dissolved oxygen (DO) in the river channel of the Kissimmee River Phase I project area continued to be higher on average in PW2023 than prior to construction of the project. Two of the four provisional expectation components used to evaluate DO response were met in PW2023. Mean daily DO concentrations met both the wet season (June–October) target range and the dry season (November–May) target range in PW2023. The third metric, annual frequency of mean daily DO concentration > 1.0 milligram per liter (mg/L) was 93%, which did not meet the provisional target of 98%. The fourth metric, annual frequency of mean daily DO concentration > 2.0 mg/L, was 82% and did not meet the provisional target of 95%. A notable sag started in September when DO concentrations declined below 2.0 mg/L, and remained there for 59 days except for a few short periods totaling 9 days in which DO rose above 2.0 mg/L. During this period, DO reached anoxic levels (daily mean < 1.0 mg/L) on 27 days. Dead fish were observed on the Kissimmee River in the boat ramp basin of the Kissimmee River Shores community in September during this sag event. An expanded network of 19 floodplain sonde stations collected continuous DO data during the 2022 wet season. This data, along with additional continuous water quality parameters from two river sondes installed in 2022, are providing new insights into the DO dynamics of the river and floodplain.

KRREP Floodplain Vegetation

A vegetation map of the Phase I construction area, based on 2020 aerial imagery, has been completed and compared to previous maps dating back to 1952. While total wetland plant coverage remained steady in the Phase I floodplain area between 2015 and 2020, broadleaf and buttonbush marsh coverage in the area declined, and invasive wet shrub coverage increased. Wet prairie cover has remained steady but has become dominated by exotic wet prairie grasses, most notably para grass (*Urocloa mutica*) and West Indian marsh grass (*Hymenachne amplexicaulis*). District personnel have been testing management techniques to try to control these invasions, and it is hoped the combination of these techniques and upcoming changes in water regime that are part of the HRS will begin to limit these invasive species.

KRREP Floodplain Vegetation Management

In the past year, herbicide applications and biocontrol agents were used to control invasive plants in the Kissimmee River floodplain. Post-treatment monitoring data are being collected to guide future management actions to control these invasive species. Two prescribed burns were conducted within the KRRP area, covering a total of 524 acres (ac) in the No Name Slough and Bluff Hammock areas. A critical emerging issue for recovery of the Kissimmee River floodplain is invasion and establishment of exotic grasses, especially West Indian marsh grass, which do not provide quality habitat and are displacing native plant species. KRREP has received new funding and is adaptively implementing long-term management programs and research to address these invasions.

KRREP Fish Studies

Winter centrarchid abundance, measured as catch per unit effort (CPUE), increased by 60% in Phase I due mostly to an increase in bluegill sunfish *(Lepomis macrochirus*) and other sunfish (*Lepomis* spp.). In Phase IV, the abundance of largemouth bass (LMB; *Micropterus salmoides*) increased during winter but a decline in sunfish resulted in an overall reduction in centrarchid abundance. The mean winter biomass catch rate, measured as biomass per unit effort (BPUE), increased in both construction phases, with LMB accounting for more than 70% of the total centrarchid biomass. Limiting or preventing access to floodplain habitat during spawning season likely has negative impacts on the river's centrarchid community. LMB commonly spawn during January–April (dry season), a period during which the floodplain has only been inundated three of the past eight years. Bluegill and other sunfish can spawn during both the dry and wet season (summer) and that extended spawning season may help them recover to some extent from the impacts of anoxic events more rapidly than LMB.

KRREP Wading Bird Abundance

Mean monthly wading bird abundance within restored portions of the river during the 2021-2022 dry season was 100.3 ± 21.9 birds per square kilometer (birds/km^2), bringing the three-year (PW2021–PW2023) running average to 54.0 ± 11.5 birds/km^2, significantly greater than the restoration expectation of 30.6 birds/km^2. Five of the six surveys completed (83%) in the 2021-2023 dry season recorded $\geq$ 30.6 birds/km^2, just below the restoration expectation of at least 85%.

KRREP Waterfowl Abundance

Waterfowl abundance during the 2022-2023 dry season was 22.6 ± 10.0 ducks per square kilometer (ducks/km^2), bringing the three-year (PW2021-PW2023) running average to 14.0 ± 4.4 ducks/km^2, not significantly greater than the restoration target of 3.9 ducks/km^2. Since 2001, annual duck abundance has ranged from 42.0 ± 11.2 to 1.3 ± 1.3 ducks/km^2. Four out of five monthly surveys during winter 2022-2023 were above the restoration target of 3.9 ducks/km^2, bringing the seasonal average above the 80% restoration target. This dry season did not meet the secondary restoration expectation that species richness will be $\geq$ 11 (three-year species total).

UPPER KISSIMMEE BASIN

KRREP Lake Vegetation Monitoring

The District completed the fifth 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 sampling to collect fish community data (fall 2021) and LMB population data (spring 2021). Community data showed a decline in gamefish on Lake Kissimmee since 2017, coinciding with Hurricane Irma. Annual relative abundance of juvenile LMB on Lake Kissimmee have also been very low following trends in submerged aquatic vegetation (SAV).

Snail Kites

Snail kite nesting effort was below average on the KCOL in 2021, which was attributed to kites shifting to better nesting conditions in Lake Okeechobee and southern impoundments. Nesting success on East Lake Tohopekaliga may have been affected by large stage reversals due to unseasonable rainfall in early spring. Statewide nesting effort was much higher than the past two years.

Alligators

FWC alligator monitoring showed very high populations on Lakes Tohopekaliga, Kissimmee, and Hatchineha for the 2021 sampling period compared to the start of sampling in the 1990s. Populations have been stable, with slight increases over the last few years. East Lake Tohopekaliga has a very small alligator population (106 estimated individuals in 2021) 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

SFWMD continued 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 Southern 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 KRREP evaluations includes analyses of newly available data from studies of hydrology, DO, vegetation management, fish, wading birds, waterfowl, and lake vegetation. This subset of restoration evaluation studies assesses the level of response of critical ecosystem components to physical restoration under Interim Period (pre-project completion) hydrologic conditions based on new data and analyses that have not been reported in previous *South Florida Environmental Report* (SFER) *– Volume I* chapters. Results from these studies provide information for sound water management decision making as the recovery of the ecosystem progresses and will help evaluate project success and guide water management decisions.

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, these regions 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 the KRREP. See Koebel and Bousquin (2014) for more details regarding environmental losses in the LKB because of earlier channelization of the river.

This chapter is an update to Chapter 9 of the *2023 South Florida Environmental Report* (SFER) – *Volume I* (Koebel et al. 2023). Its purpose is to report new results from Kissimmee Basin monitoring studies that were active in PW2023, specifically those conducted under SFWMD's KRREP and several projects in the KCOL. The chapter also summarizes Kissimmee Basin hydrologic conditions and water management in PW2023, as well as construction and management activities and the status of various other projects throughout the Kissimmee Basin.

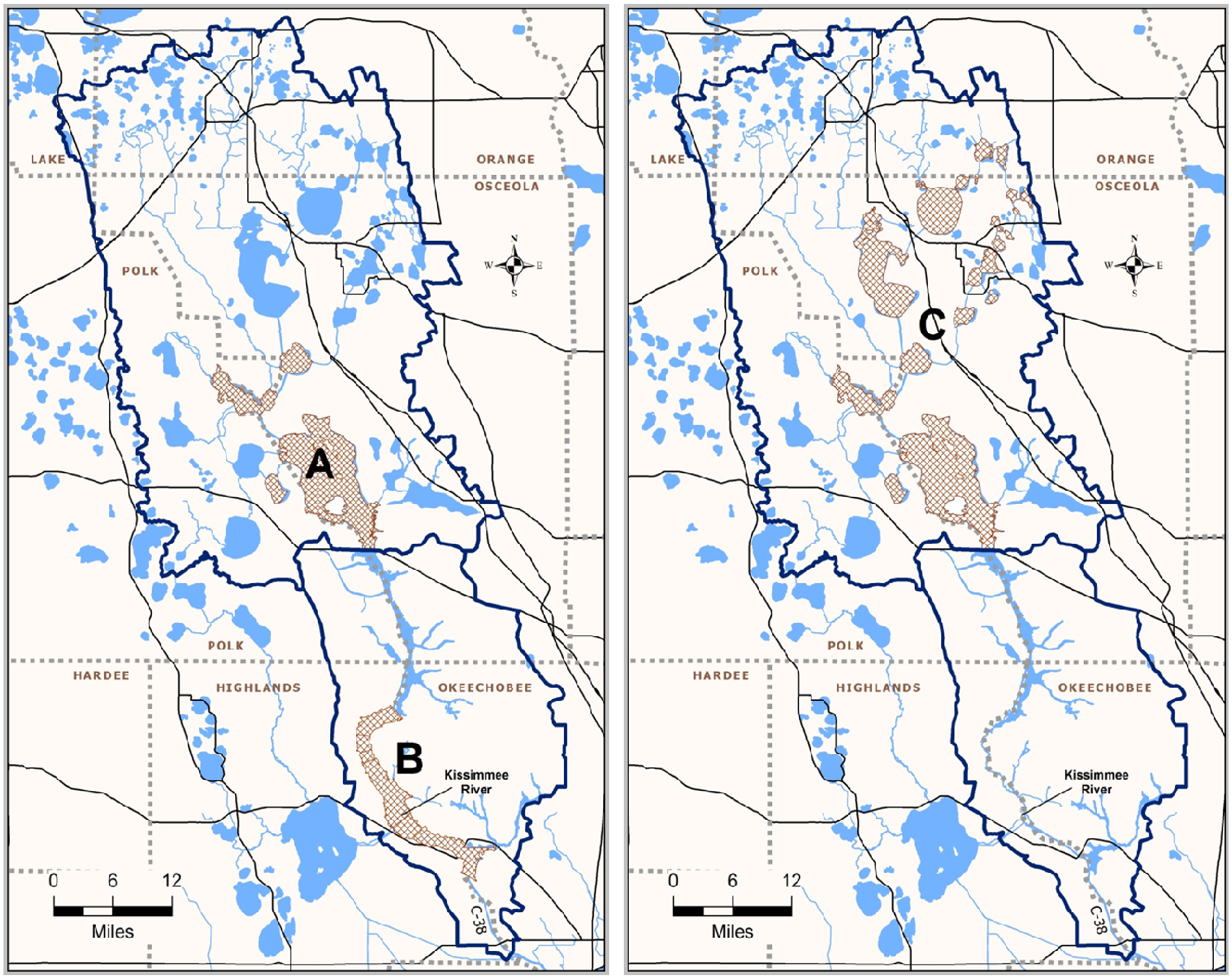


Figure 9-1. Geographic scopes (colored, hatched areas on maps) of major initiatives in the Kissimmee Basin including the (A) Headwaters Lakes components of the KRRP, (B) KRRP, and (C) KCOL and Kissimmee Upper Basin Monitoring and Assessment Project.

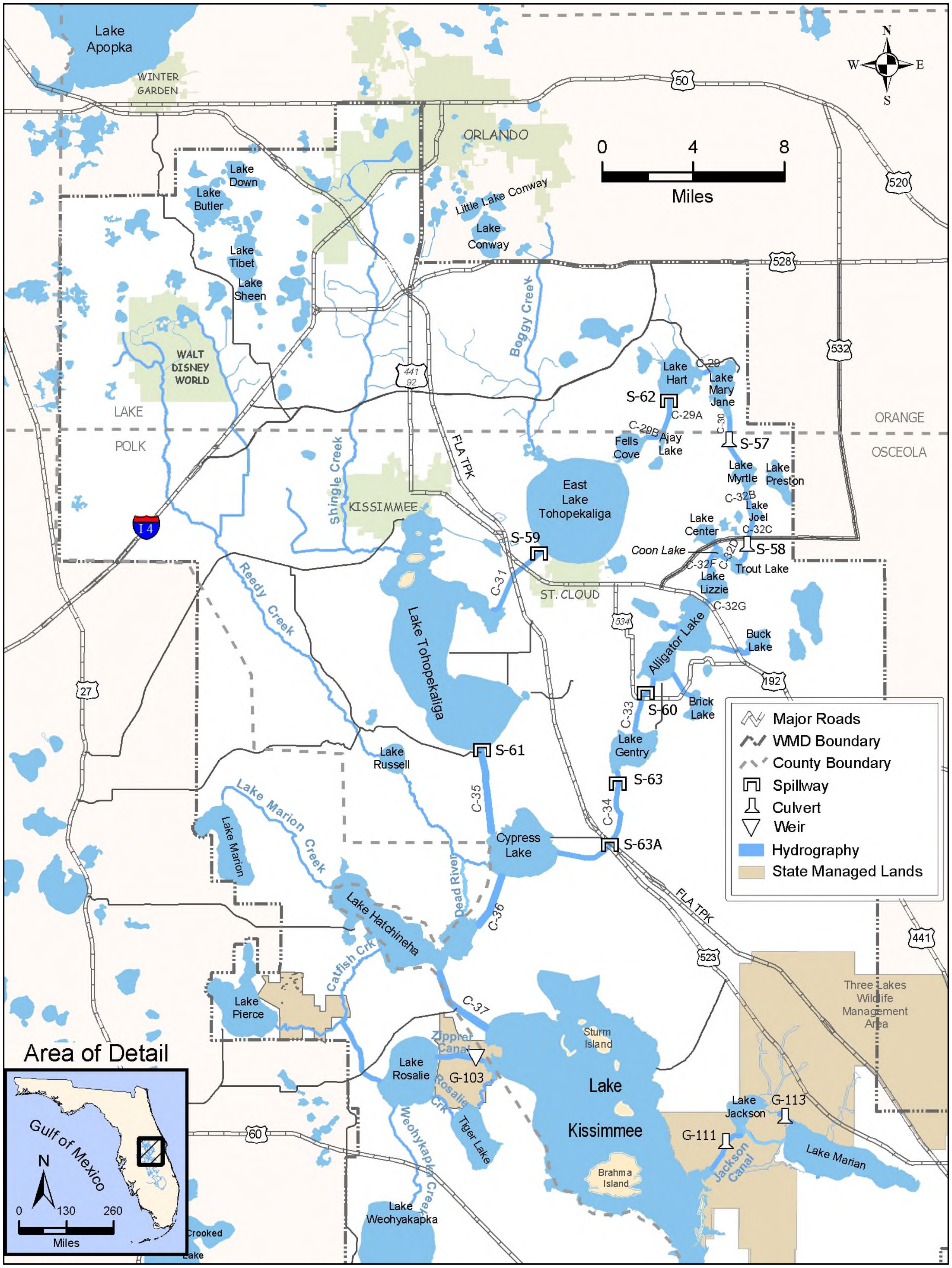
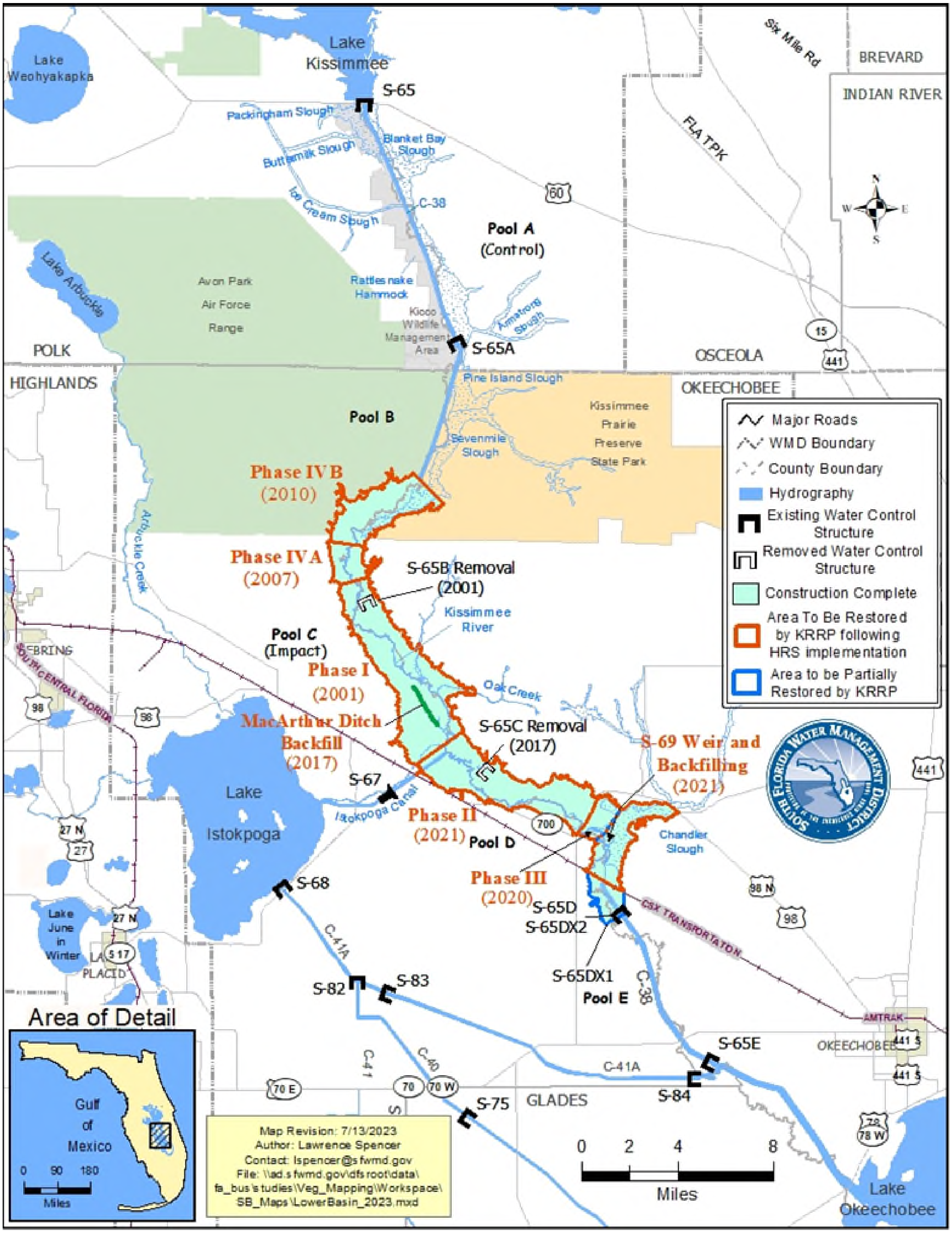


Figure 9-2. Map showing the major features of the Upper Kissimmee Basin (UKB). (Note: WMD –Water Management District.)



Map Revision: 7/13/2023
Author: Lawrence Spencer
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Figure 9-3. Map showing the major features of the Lower Kissimmee Basin (LKB) with completion dates of construction phases and other construction work. (Note: WMD –Water Management District).

KISSIMMEE RIVER RESTORATION PROJECT UPDATE

KRRP construction was completed in July 2021 and this milestone sets the stage for gradual implementation of a new stage regulation schedule, called the Headwaters Revitalization Schedule (HRS), for the S-65 water control structure and the Headwaters Lakes. The first regulation schedule increase toward HRS, called Increment 1, will be implemented in 2024, with the full HRS expected to be in place by 2026. The HRS will allow lake water levels to rise up to 1.5 ft higher than the current S-65 Interim Schedule to increase the water storage capacity of Lakes Kissimmee, Hatchineha, Cypress, and Tiger by approximately 100,000 acre-feet (ac-ft), which will allow storage of sufficient water to more closely approximate the historic flows needed for restoration of the downstream Kissimmee River and its floodplain wetlands; the HRS is also expected to improve littoral zone conditions in the Headwaters Lakes due to the higher water levels it allows. All lands 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 land acquisitions will be finalized in early 2024.

Construction components for the entire KRRP in the LKB include (1) acquiring 65,603 ac of land in the LKB and 36,612 ac of land in the UKB, (2) backfilling approximately 22 miles of the C-38 Canal (over one-third of the canal's length) from the lower end of Pool D north to the middle of the former Pool B, (3) reconnecting the original river channel across backfilled sections of the canal, (4) recarving sections of river channel destroyed during C-38 Canal construction, (5) removing the S-65B and S-65C water control structures and associated tieback levees, and (6) acquiring land and modifying portions of the river's Headwaters Lakes to allow the additional storage volume needed to meet the hydrologic criteria for restoration of the Kissimmee River. The material used for backfilling is that which was dredged during construction of the C-38 Canal. Composed primarily of sand and coarse shell, this spoil material was deposited in large mounds adjacent to the canal.

Reconstruction of the river–floodplain's physical template was implemented in four construction phases (**Figure 9-2**), scheduled for completion in 2021 (**Table 9-1**). 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 after some weather-related setbacks, was completed in 2021. The S-69 weir that will serve as the terminus of the backfilled sections of canal was also completed in 2021.

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

Construction Sequence	Name of Construction Phase	Timeline	Backfilled Canal (miles)	River Channel Recon-structed (miles)	Connector Channels (miles)	River Channel to Receive Reestablished Flow (miles)	Total Area (ac)	Wetland Gained (ac)	Location and Other Notes
1	Reach 1 (Phase I) Project Area	1999–2001 (complete)	7.5	2.9	1.0	13.9	9,506	5,792	Most of Pool C, small section of lower Pool B
2	Reach 4A (Phase IVA) Project Area	2006–2007 (complete)	1.8	0	0	3.9	1,352	512	Upstream of Phase I in Pool B to Weir #1
3	Reach 4B (Phase IVB) Project Area	2008–2010 (complete)	3.9	4.4	0.2	5.9	4,184	1,406	Upstream of Phase IVA in Pool B (upper limit near location of Weir #3)
4	Reaches 2 and 3 (Phases II & III) and S-69 Weir Project Areas	2015–2021 (complete)	8.5	3.7	0.2	16.4	9,921	4,688	Downstream of Phase I (lower Pool C and Pool D south to the CSX Railroad bridge)
	Restoration Project Totals		**21.7**	**11.0**	**1.4**	**40.1**	**24,963**	**12,398**	

CONSTRUCTION STATUS

All backfilling and other mandated construction work for the KRRP was completed by July 2021 and was announced in a ribbon-cutting ceremony at the river on July 29, 2021. The two final contracts completed in 2021 were Reach 2 Backfilling and the S-69 weir. **Table 9-2** provides brief descriptions of these final construction activities. A complete list of contracts can be found in Koebel et al. (2017). In late September/early October, extremely high discharges from Hurricane Ian rainfall resulted in damage to the newly constructed S-69 weir structure. Repair work, including concrete repair, erosion repair, and installation of riprap for the S-69 weir was completed by June 2023 (**Figure 9-4**).

During the final phases of construction repair work in Reach 2 and 3, SFWMD staff discovered two areas of concern that were left out of the original KRREP construction plans. The first area of concern is a hidden berm on the downstream side of highway US98 that runs parallel to the highway, which restricted sheet flow on the floodplain as water flows downstream through the previously constructed culverts under highway US98. A contract was awarded in 2022 to remove this berm and work was completed in May 2023. The second area of concern is a berm and ditch further downstream of the highway US98 bridge in the Reach 3 construction area. This berm runs north to south along the western edge of the floodplain, restricting floodplain expansion and potentially conveying water directly into the nearby residential boat basin in the Hidden Acres community. A contract was awarded in 2022 to degrade portions of the berm and plug sections of the ditch that parallels the berm. Both contracts were completed by June 2023.

Table 9-2. Final KRRP construction activities.
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	Projected or Actual End Date	Cost
10	Reach 2 Backfilling – New channels dredged, 6.5 miles of the C-38 Canal backfilled, and the S-65C structure removed.	Completed	January 2017	July 2021	$26.1 million
	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.	Completed	November 2018	July 2021	$15–$25 million

Note: Dates and costs do not include repair costs for erosion damages in Reach 2 and 3 Backfilling caused by Hurricane Irma.

Figure 9-4. S-69 weir erosion repair and riprap installation post Hurricane Ian high discharges. (Photo by Brent Anderson in March 2023.)

KISSIMMEE BASIN HYDROLOGIC CONDITIONS AND WATER MANAGEMENT IN PLANNING WINDOW 2022-2023

This section describes hydrologic conditions in the UKB and LKB and their relationship to water management activities in Planning Window 2022-2023 (PW2023; June 1, 2022–May 31, 2023). The planning window is used in this section and the following *Lower Kissimmee Basin – Kissimmee River Restoration Evaluation Program* 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. Lake regulation schedules in the UKB reach their low pool stages on June 1, coincident with the official beginning of the wet season. This section focuses on the timing and quantity of rainfall in PW2023 in the Kissimmee Basin, environmental recommendations made 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 or from, and water levels in, the Kissimmee River and its floodplain (**Figure 9-3**) within the KRRP footprint. Operation of these structures is intended to advance 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 group with its own regulation schedule (for an example see **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 2021 will be followed by phased implementation of the HRS, currently projected to last from 2024 to 2025. Full implementation of the HRS, projected for 2026, is expected to provide additional water storage for discharge to the Kissimmee River and its floodplain. However, even during phased implementation, coordinated and flexible water management for the remainder of the Interim Period can realize ecological benefits for the KRRP before full implementation of the HRS.

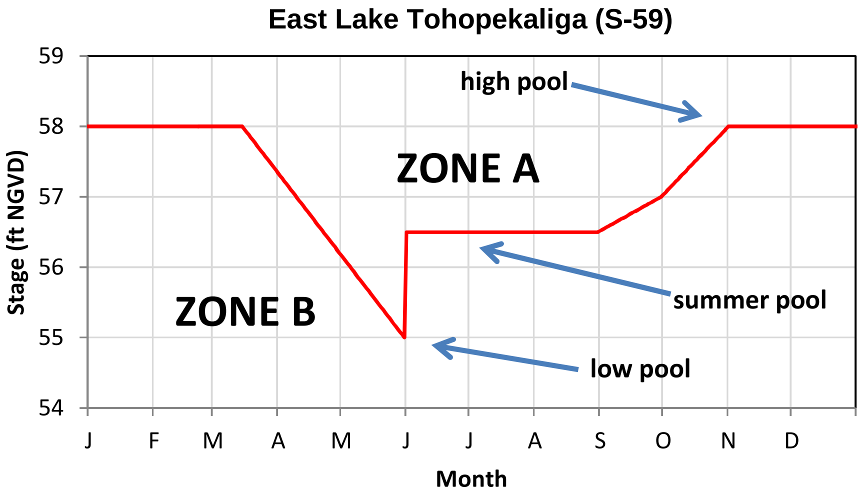


Figure 9-5. The regulation schedule for East Lake Tohopekaliga is an example of regulation schedules for lakes in the UKB. The diagram shows the regulation line (red) that separates Zone A (above the line) from Zone B (below the line). When lake stage is in Zone A, releases are mandatory for flood control; when stage is in Zone B, releases are discretionary for environmental purposes. All lakes in the KCOL have a similar schedule with seasonally varying stage and Zones A and B.

Via structures 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 inflow, rainfall, and runoff into the lakes offsets the volume of water released. Thus, discharge operations at S-65 and S-65A affect both stage in the Headwaters Lakes and flow to and stage in the Kissimmee River. Releases made 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) also raise stages in the Headwaters Lakes. Operation of structures for lake groups north of the Headwaters Lakes indirectly affect water management operations for the KRRP because they affect stage in the Headwaters Lakes; but northern lake groups are generally not operated to raise stage in the Headwaters Lakes for the purpose of meeting flow targets to the Kissimmee River.

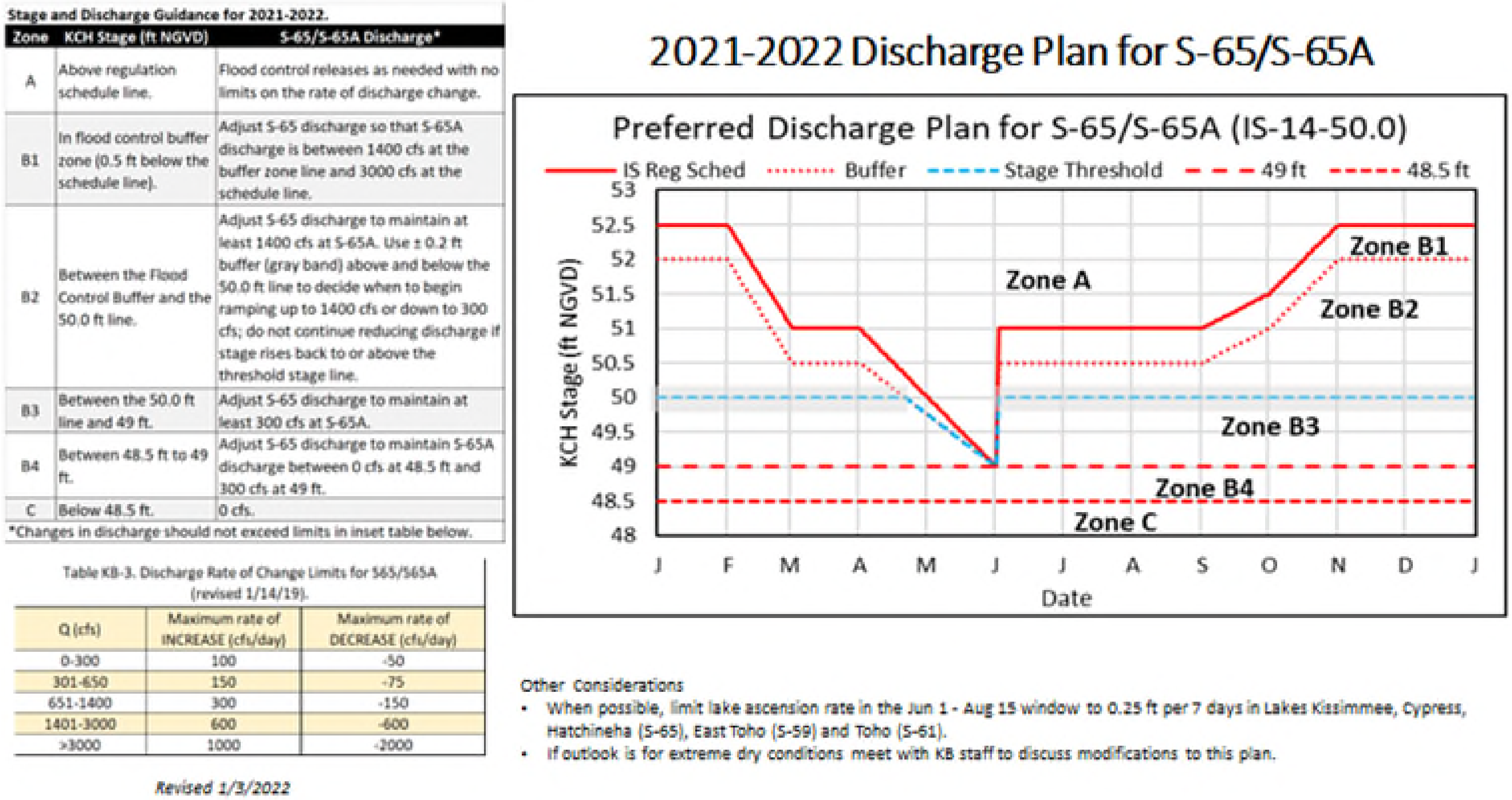
One challenge in the management of flow to the Kissimmee River is the limited storage in Pool A, the reach of the C-38 Canal between S-65 and S-65A. This is due to the narrowness of Pool A (only 250 ft wide) and the limited range of headwater stage fluctuation that is currently allowed at S-65A (46.3–47.5 ft NGVD29). Consequently, direct rainfall and local basin runoff from even relatively small but localized rainfall events can cause water levels in Pool A to rise rapidly, which can necessitate a reduction in the inflow from S-65 or a rapid increase in the outflow at S-65A, or both, to control rising water levels in Pool A. Increases in S-65A discharge must therefore often exceed the recommended maximum rate of change for discharge increases for KRREP, and similarly for rates of decrease. Because S-65A is the primary source of flow to the KRRP, these constraints to its operation can have major consequences for restoration. If a rapid increase in discharge from S-65A occurs, it results in a rapid rise in water levels in the Kissimmee River; when this happens after a period of low discharge and dry floodplain conditions, the resulting high rate of depth increase and floodplain inundation can result in a steep DO sag to low levels due to reduced photosynthesis and increased biochemical oxygen demand (BOD), which can cause a fish kill. This lack of storage in Pool A will continue to pose a challenge for water management now that construction for KRRP is completed.

In addition to other divergent demands in managing water operations for 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 depends on other factors affecting water management decisions, including endangered snail kite (*Rostrhamus sociabilis plumbeus*) nesting activity in the KCOL and Kissimmee River, concerns about water levels or flows in downstream ecosystems (Lake Okeechobee and the St. Lucie and Caloosahatchee estuaries), navigation and resident concerns in the LKB and UKB, and flood control. In addition to the Kissimmee River, three of the UKB lake groups—the Headwaters Lakes, Lake Tohopekaliga, and East Lake Tohopekaliga—are a focus of discretionary environmental water management, which often involves establishing rates of stage decrease in the dry season. In recent years, especially PW2021, river flow rates have been held low to accommodate KRRP construction activities (now complete), which also affected how often and the extent to which the floodplain was inundated.

DISCHARGE PLANS IN INTERIM AND FUTURE OPERATIONS

Several variations of discharge plans under the Interim Schedule have been partially implemented in recent years in efforts to improve the duration and continuity of floodplain inundation in the Kissimmee River during the Interim Period. These plans superimpose discharge specifications linked to stage in the Headwaters Lakes on the pre-established Interim Schedule flood regulation line. These discharge plans are called IS-14-50 (the plan name refers to Interim Schedule – 1,400-cfs minimum discharge while stage is above 50 ft NGVD29 in the Headwaters Lakes). The most recent configuration of IS-14-50 is shown in **Figure 9-6**. See the *2022 Wet Season Water Management Outcomes* subsection below for additional information. The approach has been or will be adapted for future operations under the first increment of HRS and any additional phased increment(s) and is being used in planning for implementation of HRS itself.

Achieving sustained floodplain inundation to replicate pre-channelization conditions is a primary objective of Kissimmee River Restoration, and almost fully depends on discharge from S-65 through S-65A. This is because most of the volume of water passing through the KRRP originates in the UKB, and, due to the slope of the Kissimmee River floodplain, water levels cannot be maintained on the floodplain by the downstream water control structure (previously S-65C, now S-65D) (Anderson 2014) without substantial inflow from the north. Prior to use of the IS-40-50 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 or to minimize flow to the south. The undesirable effect of such operations for the Kissimmee River, clearly visible in stage/discharge hydrographs (e.g., **Figure 9-7**), was sudden inundation of the floodplain followed by rapid termination of the flood event as discharge was reduced below river channel bankfull discharge (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 duration flood event characteristic of the system’s 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, which 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). In the wet season, such “flashy” operations have been a substantial factor in DO declines.



Stage and Discharge Guidance for 2021-2022.

Zone	KCH Stage (ft NGVD)	S-65/S-65A Discharge*
A	Above regulation schedule line.	Flood control releases as needed with no limits on the rate of discharge change.
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; do not continue reducing discharge if stage rises back to or above the threshold stage line.
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.

Table KB-3. Discharge Rate of Change Limits for S65/S65A (revised 1/14/19).

Q (cfs)	Maximum rate of INCREASE (cfs/day)	Maximum rate of DECREASE (cfs/day)
0-300	100	-50
301-650	150	-75
651-1400	300	-150
1401-3000	600	-600
>3000	1000	-2000

Revised 1/3/2022

Other Considerations

- When possible, limit lake ascension rate in the Jun 1 - Aug 15 window to 0.25 ft per 7 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.

Figure 9-6. The IS-14-50.0 discharge plan, which was used starting in wet season 2022. The table insert in the lower left recommends limits on rates of discharge (Q) increase and decrease at the S-65 and S-65A structures. The plan shown uses the Interim Reulation Sched line. The discharge rate of change limits table was modified on January 14, 2019, to allow faster rates of decrease when discharge is greater than 1,400 cfs. (Notes: KB – Kissimmee Basin and Toho – Tohopekaliga. Source: KB-2022-Wet Season Planning Presentation on May 22, 2022.)

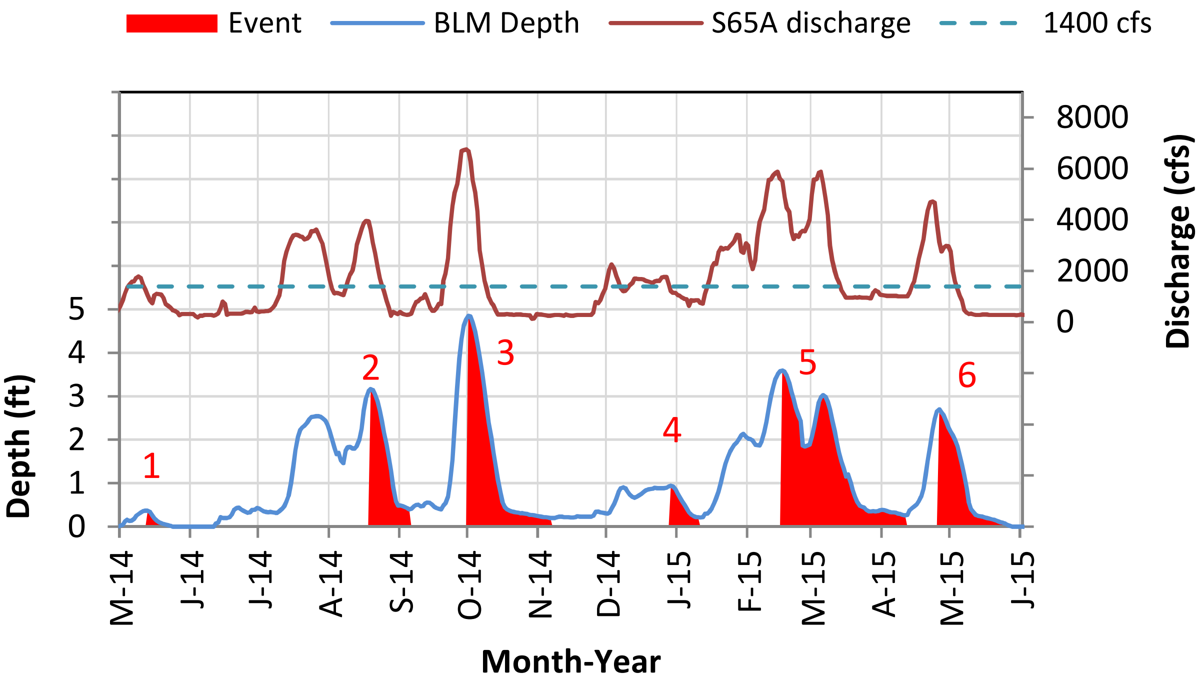


Figure 9-7. An example from PW2015 of unsuitable operations for Kissimmee River restoration. In this case, large, rapid increases in S-65A flood control levels of discharge driven by the regulation line in the Headwaters Lakes were followed by rapid reductions in discharge to maintain high stage in the 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 rates of change in discharge and the range of discharges used in the discharge plans are conservative relative to the hydrologic needs of restoration, as discussed in Koebel et al. (2019) and previous SFER chapters. The maximum rates of discharge change used in the discharge plans (as shown in **Figure 9-6** lower left and **Tables 9-3** and **9-4**) are known to be high relative to the hydrologic needs of restoration. They were originally defined to be as slow as feasible given operational realities as a recognition of other operational requirements (e.g., flood control) balanced against the need to approximate historic conditions for hydrologic restoration.

The issue of DO sags during summer months in the Kissimmee River, which is thought to be related to the rate of increase in flow and water depth, has highlighted concerns that the current rates of change are too fast. Comparing the currently recommended rates to the pre-regulation system, increases greater than 300 cubic feet per second per day (cfs/d) had an exceedance probability of 2.3%, or 8 days per year (d/y), in the Reference Period and 14.9% (54 days per year) in the Late Interim Period (**Figure 9-8A**); the rate of increase in the discharge plans is typically four to five times higher than occurred on average in the Reference Period. On average, observed rates of increase in the Late Interim Period do not exceed the recommended rates (**Table 9-3**), although harmful exceedances of the preferred rates (which are factors in DO declines) may occur over short, critical periods that are not reflected in averages over a year. For example, rates of increase associated with DO crashes in June 2017 and June 2019 were as fast as 759 and 1,030 cfs/d, respectively, while discharge was less than 1,000 cfs; thus, exceeding the recommended maximum rates of discharge increase. Both periods of increase in discharge were followed by periods of anoxia (DO < 1 mg/L) that lasted at least 10 days. KRREP scientists and water managers are working to find operational solutions to this problem.

Rapid reductions in discharge are linked to the inability to sustain floodplain inundation, a major goal of the restoration project. Discharge decreases of at least 300 cfs/d had a probability of 0.64% (2.3 d/y) during the Reference Period and a probability of 9.63% (35 days per year during the Late Interim Period (**Figure 9-8B**). Discharge was decreased at a rate 2.5 to 3.5 times as fast during the Late Interim Period than in the Reference Period (**Table 9-4**). The combination of faster rates of discharge decreases and a lower minimum discharge shortens floodplain hydroperiods.

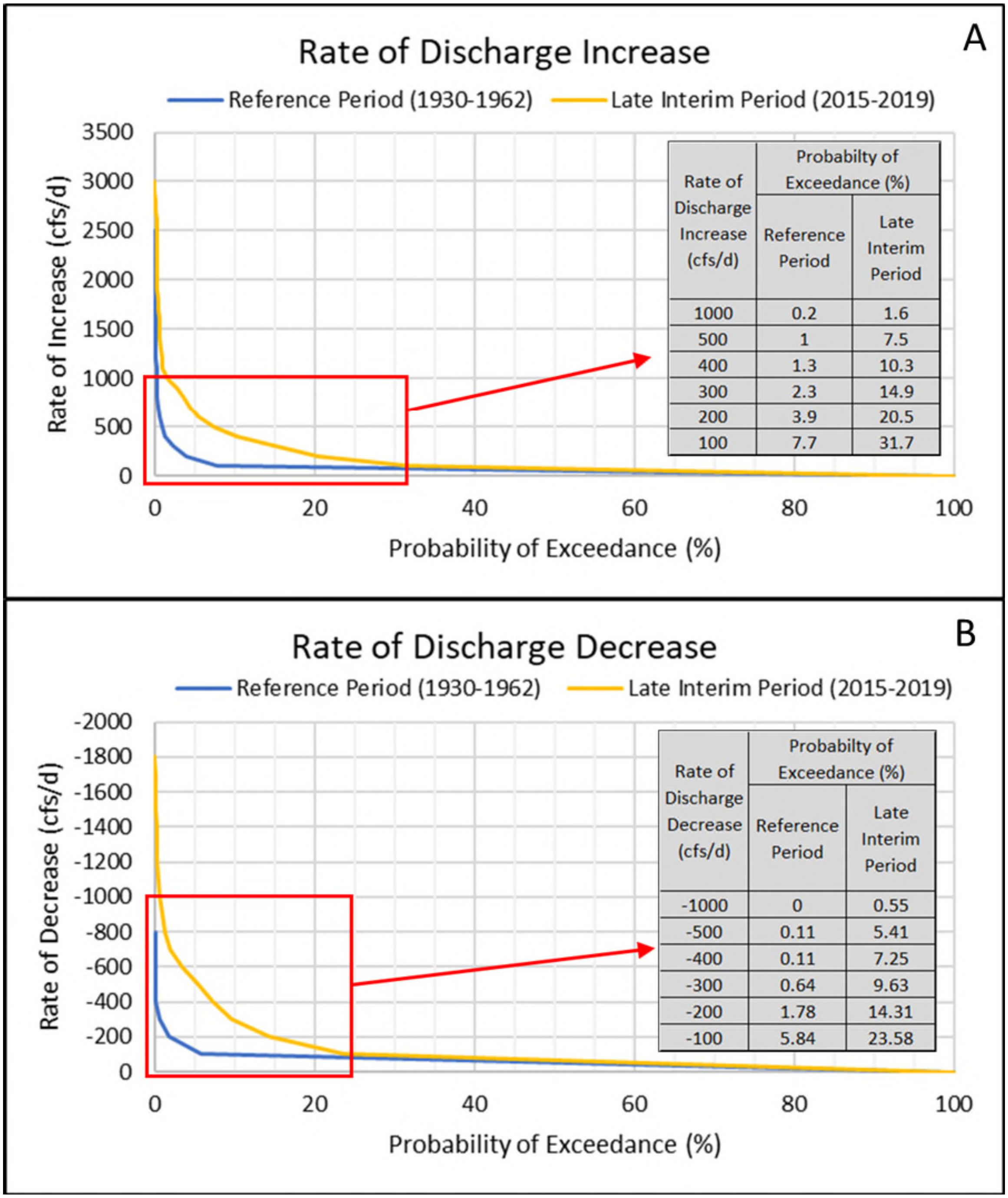
The 1,400-cfs discharge plans are weather-driven in that changes in discharge are linked to changes in stage in the Headwaters Lakes (i.e., discharge is increased only after rainfall has caused lake stage to rise above a threshold and is not reduced unless rainfall is insufficient to keep stage above the threshold). The plans include limits on the rate of discharge increase and decrease. The 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, a similar plan has been incorporated into HRS implementation.

Table 9-3. Comparison of observed rates of discharge increase during the Reference (1930–1962) and Late Interim (2015–2019) periods with the preferred maximum rates of discharge increase in the IS-14-50 discharge plan (**Figure 9-6**, lower left). Discharge was not managed during the Reference Period.

Discharge Rate of Change Limits for S-65/S-65A (revised 7/13/18)		Percent of Days at or Below the Maximum Rate of Increase		Mean Rate of Discharge Increase (cfs/d)	
Discharge (cfs)	Maximum Rate of Increase (cfs/d)	Reference	Late Interim	Reference	Late Interim
0–300	50	97	96	14	10
301–650	75	99	82	16	35
651–1,400	150	99	83	28	76
1,401–3,000	300	97	71	72	196
> 3,000	1000	98	93	210	429

Table 9-4. Comparison of observed rates of discharge decrease during the Reference (1930–1962) and Late Interim (2015–2019) periods with the preferred maximum rates of discharge increase in the IS-14-50 discharge plan (**Figure 9-6**, lower left). Discharge was not managed during the Reference Period.

Discharge Rate of Change Limits for S-65/S-65A (revised 7/13/18)		Percent of Days at or Below the Maximum Rate of Decrease		Mean Rate of Discharge Decrease (cfs/d)	
Discharge (cfs)	Maximum Rate of Decrease (cfs/d)	Reference	Late Interim	Reference	Late Interim
0–300	-50	98	96	-13	-10
301–650	-75	100	88	-13	-32
651–1,400	-150	100	89	-21	-58
1,401–3,000	-600	100	78	-52	-185
> 3,000	-2000	100	97	-135	-347



Rate of Discharge Increase (cfs/d)	Probabilty of Exceedance (%)	
	Reference Period	Late Interim Period
1000	0.2	1.6
500	1	7.5
400	1.3	10.3
300	2.3	14.9
200	3.9	20.5
100	7.7	31.7

Rate of Discharge Decrease (cfs/d)	Probabilty of Exceedance (%)	
	Reference Period	Late Interim Period
-1000	0	0.55
-500	0.11	5.41
-400	0.11	7.25
-300	0.64	9.63
-200	1.78	14.31
-100	5.84	23.58

Figure 9-8. Exceedance curves for rate of (A) increase and (B) decrease in discharge in the Reference (1930–1962) and Late Interim (2015–2019) periods.

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 9-9**). The section follows the conventions of SFWMD and USACE water managers by reporting hydrologic variables in English units—inches for rainfall, ft NGVD29 for stage and depth, and cfs for discharge.

Hydrology in the KRRP Phase I floodplain is complex; its dynamics were characterized for PW2022 using the metric "Mean depth at floodplain broadleaf marsh sites" (referred to as "BLM Depth"). BLM is a vegetation type with very long hydroperiod requirements (see the *Hydroperiod Evaluation (Expectation 3) in PW2022 and the Interim Period* subsection of the *Lower Kissimmee Basin – Kissimmee River Restoration Evaluation Program* section below). It was the dominant wetland plant community on the floodplain prior to channelization and is expected to expand 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 of five historically BLM sites 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 (DEM).

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 complete and historic hydrology is reestablished (see *Hydrology* subsection of the *Lower Kissimmee Basin – Kissimmee River Restoration Evaluation Program* section later in 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 *Lower Kissimmee Basin – Kissimmee River Restoration Evaluation Program* section later in this chapter.

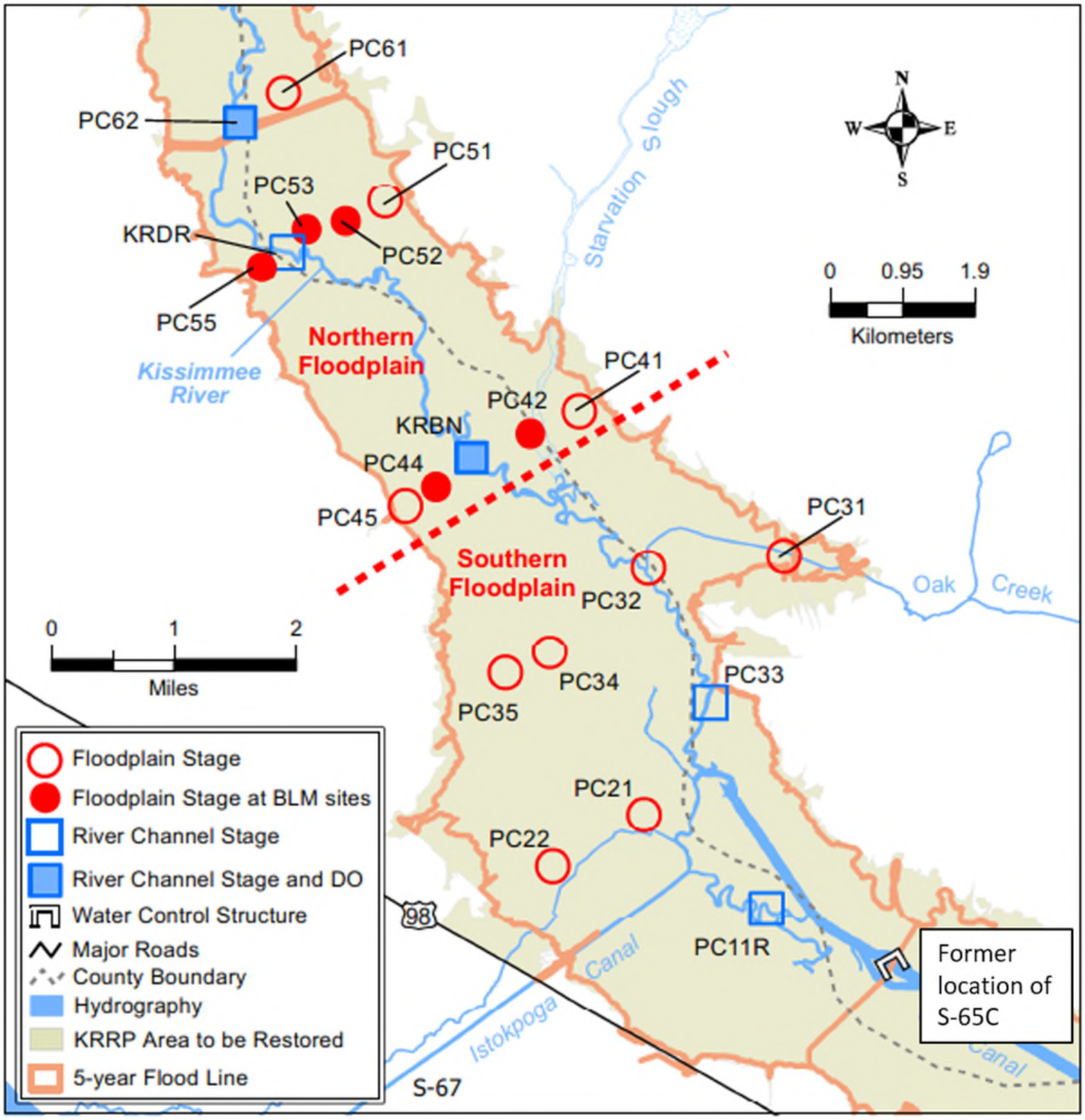


Figure 9-9. Locations of hydrologic monitoring sites in Pool C used to guide operations and evaluate restoration expectations.

RAINFALL

Rainfall totals for PW2023 were slightly above average with 55 inches (108% of the long-term average) and 47 inches (106% of average) for the UKB and LKB, respectively. The slightly above average rainfall was due to rainfall associated with Hurricane Ian, which resulted in September totals that were 3 and 2.5 times the long-term average for the UKB and LKB, respectively (**Figure 9-10**). Only four months (September, November, April, and May) exceeded average rainfall in either the UKB or LKB; the rest were at or below average. In the UKB, rainfall totals were 38.5 inches (118% of average) in the wet season and 16.2 inches (89% of average) in the dry season; in the LKB, rainfall totaled 35.7 inches (112% of average) in the wet season and 15.6 inches (95% of average) in the dry season.

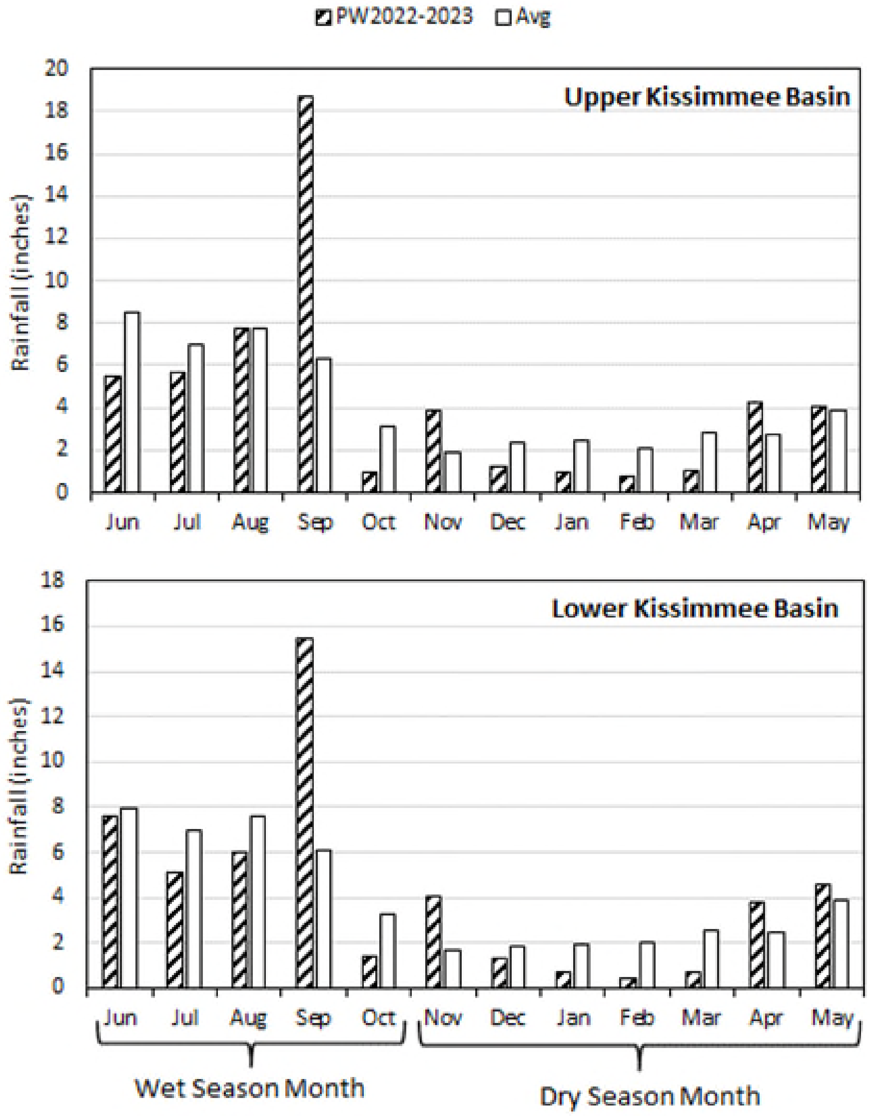


Figure 9-10. Monthly rainfall for PW2023 and average (Avg) rainfall (1991–2020) in the UKB (top panel) and the LKB (bottom panel).

OPERATIONAL REQUESTS AND OUTCOMES

Seasonal Operational Planning

KRREP scientists collect input from partner agencies—SFWMD and USACE for the KRRP; and 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 in the Kissimmee Basin. Throughout development and implementation of the recommendations, KRREP scientists work closely with SFWMD's water managers to implement the 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 volumes of water originating in the UKB that are released to Lake Okeechobee via the Kissimmee River and C-38 Canal. These analyses can 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.

2022 Wet Season Water Management Recommendations

- Use the IS-14-50 discharge plan through the 2022 wet season. The discharge rate of change limits for S-65/S-65A may be adjusted for individual events after consultation with KRREP staff.
- To the extent possible, attempt to control the ascension rate in East Lake Tohopekaliga, Lake Tohopekaliga, and the Headwaters Lakes to be less than 0.5 ft/14 days (d) during the June 1–August 15 window.

2022 Wet Season Water Management Outcomes

IS-14-50.0 Discharge Plan

The IS-14-50 discharge plan for S-65/S-65A was recommended for use in the 2022 wet season (**Figure 9-6**). At the beginning of the wet season, minimal releases of 300 cfs were made at S-65A to the Kissimmee River because of low stage in the Headwaters Lakes (**Figure 9-11B**). With below average rainfall in the UKB (**Figure 9-10**, top panel) and continued stage decline below 48.5 ft NGVD29 in the Headwaters Lakes, discharge at S-65 was reduced to 0 cfs on June 22, 2023, so that S-65A discharge was entirely dependent on runoff from the Pool A basin and remained at low levels until late August, when the first of four events through early November occurred in which where S-65A discharge was increased.

The first event resulted in an increase in S-65A discharge briefly to 1,100 cfs before a reduction to < 100 cfs; the increased discharge was needed to provide flood control in Pool A in response to > 6 inches of rainfall over the Pool A basin during an 11-day period (August 18–28, 2023). The second event began in mid-September and discharge was increased at S-65 and S-65A to 8,000 cfs for flood control in the Headwaters Lakes as stage rose above the regulation schedule (**Figure 9-11B**). As discharge was being decreased after the second event, S-65A discharge was again increased in the third event in response to rainfall from Hurricane Ian (September 28, 2022). In the third event, stage in the Headwaters Lakes peaked above the regulation line at 54.22 ft NGVD29 on October 3, 2022, and was above 54 ft NGVD29 (the maximum December elevation in the upcoming HRS) for 7 days. S-65A discharge (including flow through the auxiliary weirs and culverts and the lock) peaked at 11,946 cfs on October 11, 2022. As discharge was decreasing from the third increase, it was increased for the fourth event, which involved flood control releases to control rising stage in the Headwaters Lakes caused by rainfall from Hurricane Nicole (November 10, 2022). Stage in the Headwaters Lakes rose to 53.0 ft NGVD29; S-65A discharge was increased to 3,500 cfs. As stage in the Headwaters Lakes returned to the regulation schedule, discharge was

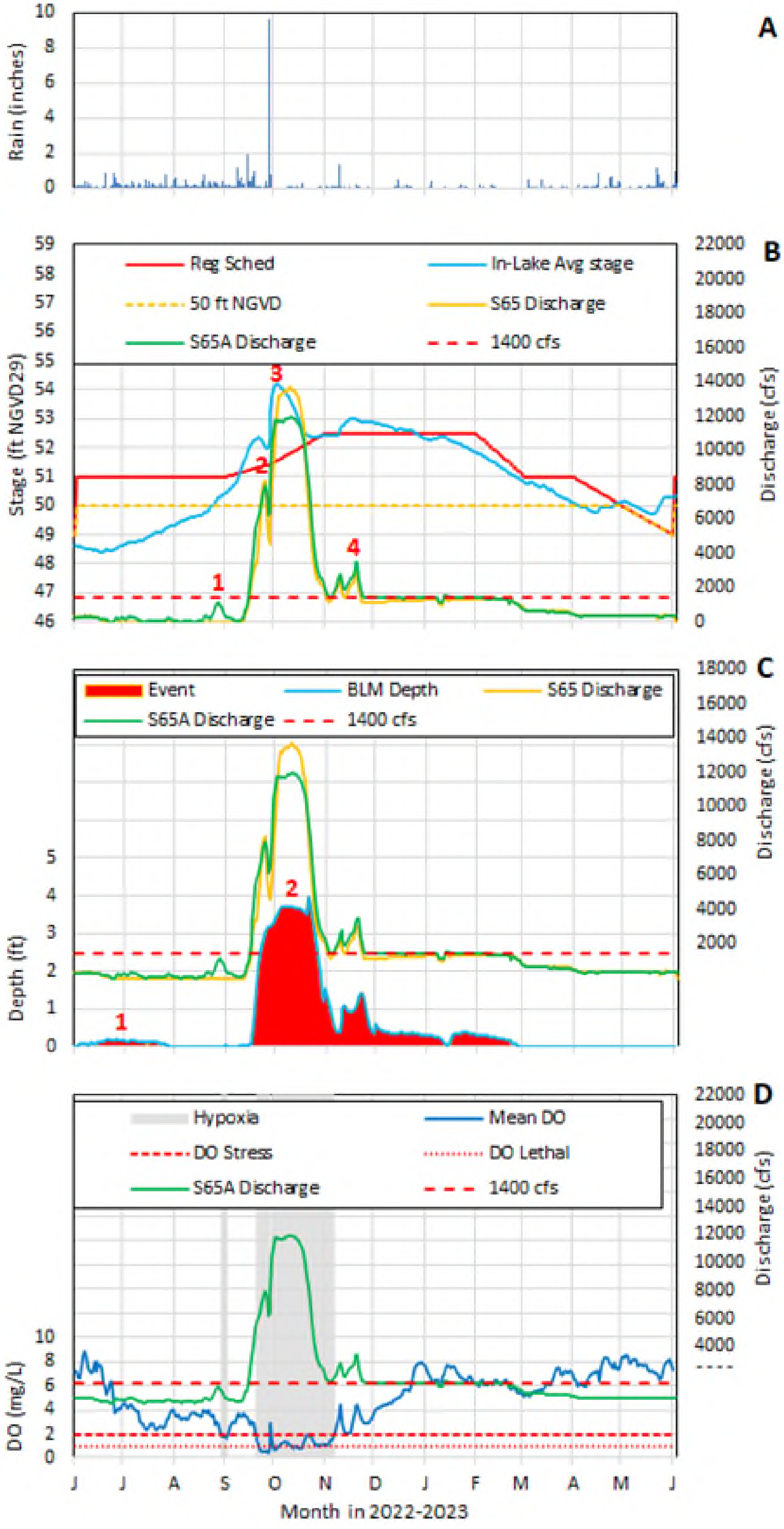


Figure 9-11. (A) Basin rainfall in the Headwaters Lakes, (B) regulation (Reg) schedule, lake stage (In-Lake Avg stage), and discharge from the Headwaters Lakes; (C) BLM Depth at five stations (PC52, PC55, PC53, PC44, and PC42) in the northern floodplain where BLM occurred pre-channelization and is expected 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 PC62, PC33, KRBN, PD62R, PD42R, and discharge at S-65A during PW2022. Red numbers identify four discharge increases in Panel B and two floodplain inundation events in Panel C that are described in the text. See **Figure 9-9** above for locations of hydrologic monitoring sites and the *Hydrology* subsection of the *Lower Kissimmee Basin – Kissimmee River Restoration Evaluation Program* section for more information.

reduced to 1,400 cfs and held at that level, per the discharge plan, well into the dry season (February 5, 2023), when discharge was reduced well-below bankfull. The first increase in discharge did not result in floodplain inundation; the second, third, and fourth discharge in-creases resulted in a single, continuous period of flood-plain inundation.

Implementation of the IS-14-50 discharge plan during the 2022 wet season resulted in a single period of S-65A discharge equaling or exceeding the bankfull discharge of 1,400 cfs for 144 days (September 15, 2022–February 5, 2023). While the 144-day period of bankfull discharge was shorter than was typical in the Reference Period, it did extend well into the dry season, which is an important aspect of Reference Period hydrology that Kissimmee River Restoration seeks to restore. The long period of bankfull discharge benefitted from the volume and timing of rainfall especially that associated with Hurricanes Ian and Nicole.

Wet Season Floodplain Inundation

Two floodplain inundation events (BLM Depth > 0.1 ft) occurred in the 2022 wet season (**Figure 9-11C**). The first lasted for 37 days (June 15, 2022–July 21, 2023), never exceeded 0.2 ft, and resulted from lower basin rainfall and runoff alone as S-65A discharge was < 350 cfs during this time period. The second lasted for 158 days (September 17, 2022–February 21, 2023) and was the result of the second, third, and fourth discharge increases described above. BLM Depth varied over this event with a maximum of 3.97 ft on October 21, 2022, and was at least 1 ft for 68 days (September 19–November 25, 2022) except for 7 days when it decreased as low as 0.4 ft when discharge was being reduced to 1,400 cfs in early November.

Wet Season Dissolved Oxygen

Dissolved oxygen (DO) declined below 2 mg/L in two events during the 2022 wet season (**Figure 9-11D**). The first was minor and was associated with the first increase in discharge to 1,100 cfs in late August; DO went below 2 mg/L for 4 days but did not go below 1.53 mg/L. The second event was more severe with anoxic (DO < 1 mg/L) conditions lasting for 18 days (October 1–18, 2022) during which DO was as low as 0.74 mg/L. Further details are provided in the *Dissolved Oxygen* and *Impact of the 2022 Anoxic Events and Other Environmental Conditions on Centrarchid Fish in the Kissimmee River* subsections in the *Lower Kissimmee Basin – Kissimmee River Restoration Evaluation Program* section later in this chapter.

Ascension Rates in the Kissimmee Chain of Lakes

Stage ascension rates were calculated daily for the June 1–August 15, 2022, window as the difference between current stage and stage 14 days prior for East Lake Tohopekaliga, Lake Tohopekaliga, and the Headwaters Lakes. Ascension rates were also calculated for the Kissimmee River using average stage for five river channel stations in the Phase I area (PC62, KRDR02, KRBN, PC33, and PC11). Stage ascension rates exceeded the preferred rate of 0.5 ft/14 d on 0 days in East Lake Tohopekaliga, 9 days in Lake Tohopekaliga, 0 days in the Headwaters Lakes, and 11 days in the Kissimmee River (**Figure 9-12**).

Most exceedances occurred later in the 2022 wet season as rainfall increased. Such exceedances were to be expected given the rainfall because previous analyses have shown that attempts to control early wet season ascension rates can—and often will—be overwhelmed by rainfall, and ascension rates exceeding 0.5 ft/14 d occurred frequently prior to regulation (Koebel et al. 2016).

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 rates in those lakes so that they did not greatly exceed the preferred maximum ascension rate (**Figures 9-12**). These releases were small and infrequent due to dry conditions early in the wet season; their effect on the ascension rate in the Headwaters Lakes was small, unlike past years when much larger releases could result in larger effects.

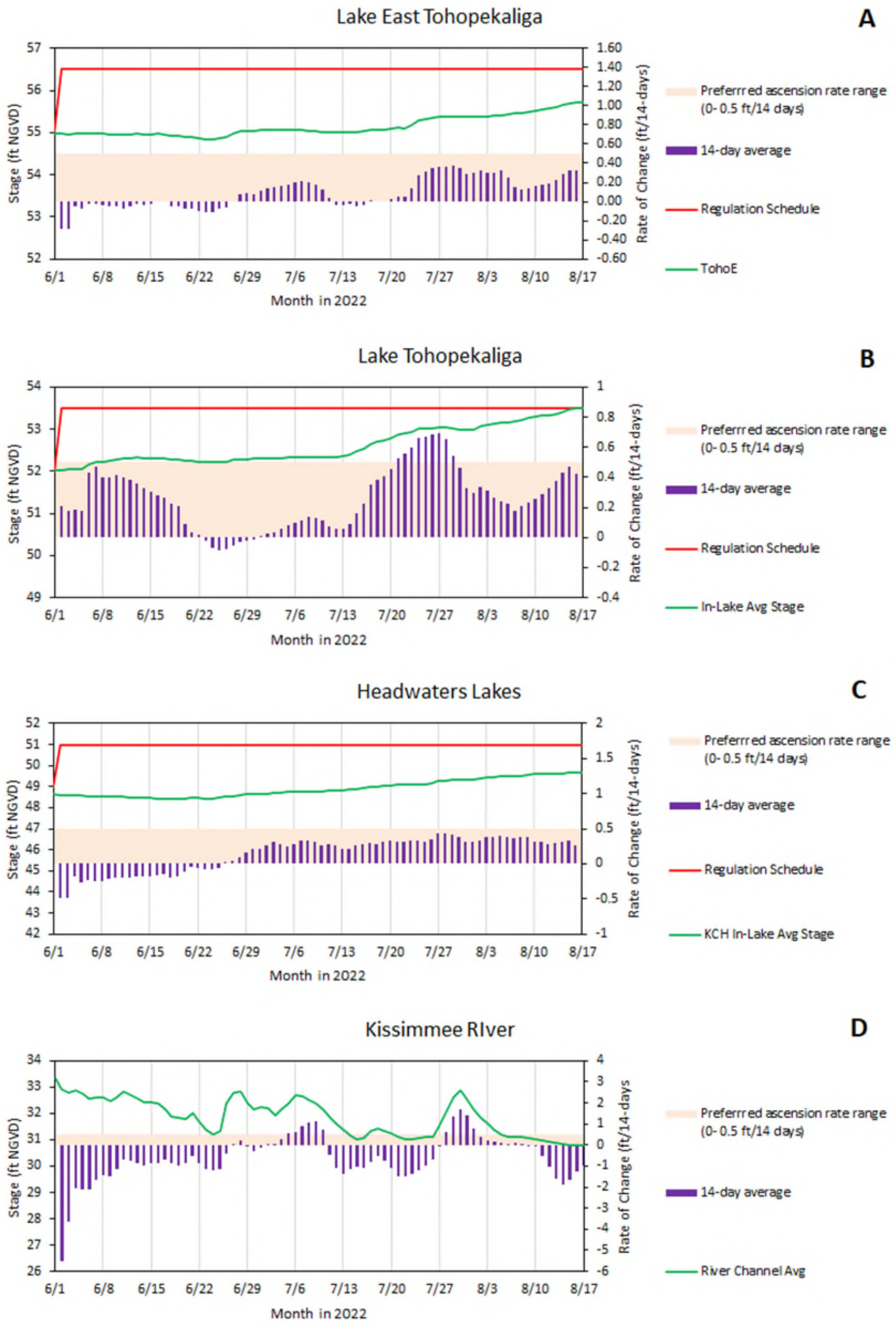


Figure 9-12. Ascension rates in (A) East Lake Tohopekaliga, (B) Lake Tohopekaliga, (C) the Headwaters Lakes, and (D) the Kissimmee River during the 2022 wet season.

2022-2023 Dry Season Water Management Recommendations

- Reduce stage in East Lake Tohopekaliga to 57.5 ft NGVD29 and in Lake Tohopekaliga to 54.5 ft NGVD29 by January 14, 2022, in preparation for managed stage recessions for snail kite nesting season. Begin managed stage recessions for snail kite nesting season in East Lake Tohopekaliga and Lake Tohopekaliga on January 15, 2022. Maintain stage recessions in East Lake Tohopekaliga, Lake Tohopekaliga, and the Headwaters Lakes to stay below the preferred maximum rate of 0.18 ft/7 d through June 1.
- Adjust discharge at S-65/S-65A using the discharge rate of change limits in the IS-14-50 discharge plan. The discharge rate of change limits for S-65/S-65A may be adjusted for individual events after consultation with KRREP staff.

2022-2023 Dry Season Water Management Outcomes

Lake Stage Recessions

In preparation for managed stage recessions for snail kite nesting season, stages in East Lake Tohopekaliga and Lake Tohopekaliga were lowered to 57.5 NGVD29 and 54.5 ft NGVD29, respectively by January 14, 2023, per request from USFWS and FWC. In East Lake Tohopekaliga and Lake Tohopekaliga, stage recessions began on January 15, 2022, as requested by USFWS and FWC, with the lake stages at 57.5 and 54.5 ft NGVD29, respectively; both recessions ended on June 1, 2021, at approximately the low pool of the regulation schedules (**Figures 9-13**). Managed recessions were steady in both lakes with recession rates less than the preferred maximum of 0.18 ft/7 d for 88% of the time in East Lake Tohopekaliga and 87% in Lake Tohopekaliga. Both lakes had minor stage reversals (< 0.2 ft).

IS-14-50.0 in the Dry Season and Recession in the Headwaters Lakes

USACE approved a temporary deviation on March 10, 2023, to the regulation schedule in the Headwaters Lakes. The deviation lowered the regulation schedule from 52.5 ft NGVD29 on February 28, 2023, to 51 ft NGVD29 instead of 49 ft NGVD29 on June 1, 2023. The purpose of the deviation was to increase the probability that S-65A discharge would remain at 1,000 cfs to facilitate repairs to the restoration project.

In the 2022-2023 dry season, recessions in the Headwaters Lakes were managed with the IS-14-50.0 discharge plan rather than a fixed recession line like East Lake Tohopekaliga and Lake Tohopekaliga. Following the discharge plan produced a steady recession in the Headwaters Lakes over most of the dry season (**Figure 9-13C**). Recession rates were less than the preferred maximum of 0.18 ft/7 d for 51% of the time and most exceedances were small.

In the Kissimmee River, reductions in S-65A discharge resulted in high recession rates in late February and again in late March (**Figure 9-13D**). Recession rates were up to 1.5 ft/7 d, well above the preferred maximum of 0.18 ft/7 d used in the lakes. Once discharge was reduced to 300 cfs, stage was steady in the river channel for the remainder of the dry season.

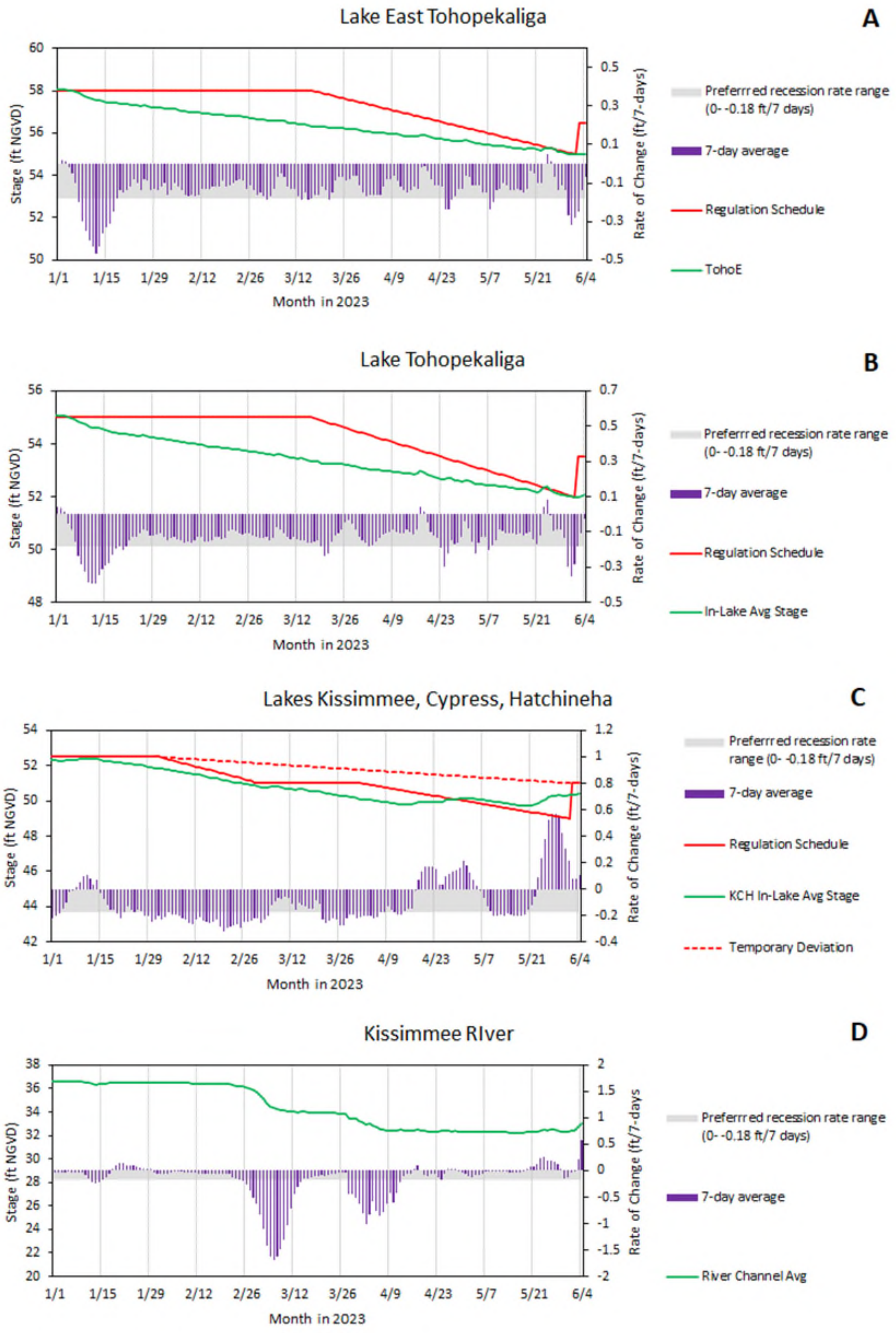


Figure 9-13. Stage and recession rates during the 2021-2022 dry season in (A) East Lake Tohopekaliga, (B) Lake Tohopekaliga, (C) the Headwaters Lakes, and (D) the Kissimmee River.

Dry Season Floodplain Inundation

The wet season 158-day Kissimmee River floodplain inundation event (BLM Depth > 0.1 ft) described above extended into the dry season and ended February 21, 2023 (**Figure 9-11C**). No additional inundation events occurred during the 2022-2023 dry season.

Snail kites nested on the Kissimmee River floodplain of the lower Phase II/III area during the 2022-2023 dry season. Six nests were observed beginning in March 2023. One nest successfully fledged at least one offspring. One factor that likely contributed to the success of this nest was its proximity to the S-65D water control structure and the decision to not lower the headwater stage, which helped maintain sufficient depth at the nest to deter predators.

A key goal for the restoration project is to reestablish a single period of floodplain inundation that begins in the wet season and continues well into dry season, like what happened in PW2023, although for a longer duration. During the Interim Period, it has been much more common to have a floodplain inundation event that begins and ends in the wet season, followed by isolated periods of inundation during the dry season such as occurred in the 2021-2022 dry season. Such brief periods of inundation are likely of little value and may be harmful. For example, as this inundation event was ending, the endangered snail kite established 13 nests in the Kissimmee River floodplain by May 26, 2022, some of which were in the same general area where kites had nested previously during the 2018 wet season (Koebel et al. 2020). Within three weeks, more than two-thirds of the nests had failed, possibly due to the lack of water depth to serve as a barrier to terrestrial predators. Such brief periods of inundation, especially near the beginning of the wet season, may provide a false signal of an early start to the wet season and a longer period of inundation and induce many fish and birds to waste energy on spawning or nesting behaviors with low probability of success.

Summary of PW2022 Water Management Operations

The 2022 wet season marked the seventh implementation of a variation of the IS-14-50.0 discharge plan since the 2015 wet season. Implementation of the plan in PW2023 resulted in a single 144-day period with bankfull discharge or greater, the longest duration of bankfull discharge (**Table 9-5**) since reestablishment of flow in 2001. Rainfall, especially in association with Hurricanes Ian (late September 2022) and Nicole (early November 2022), extended the event well into the 2022-2023 dry season.

The IS-14-50 discharge plan was not strictly followed in the 2022 wet season because of other considerations (e.g., perceived effects on downstream systems) and the uncertainty of rainfall. Discharge was not increased earlier in the wet season even though stage was rising in the Headwaters Lakes; it was decreased by 1,400 cfs while stage in the Headwaters Lakes was above 51 ft NGVD29 instead of waiting until stage had declined to the 50 ft NGVD29 threshold for ramping down to 300 cfs in the IS-14-50 discharge plan (**Figure 9-6**).

Strict implementation of the IS-14-50 discharge plan with the temporary construction deviation, which lowered the schedule to 51 ft NGVD on June 1 instead of 49 ft NGVD29, was simulated with a simple spreadsheet tool that uses the observed data and a stage-area table to convert volumes to changes in stage. The simulation shows that period of at least bankfull discharge would have been 167 days (September 15, 2022–February 28, 2023), 23 days longer than occurred in the 2022 wet season (**Figure 9-14**).

Previous years have illustrated the difficulties of trying to limit rates of stage ascension and recession in a series of connected water bodies, where efforts to achieve targets upstream can complicate downstream conditions. These difficulties were less apparent in PW2023 because of low rainfall during critical windows for ascension (June–August 15) and recession (February–May). Nonetheless, PW2023 highlights the tradeoffs and complexity of such operations, both among the lakes and between the lakes and the Kissimmee River. For example, holding water in the Headwaters Lakes resulted in much more variable ascension rates in the Kissimmee River (**Figure 9-12D**) and extremely high recession rates for prolonged periods (**Figure 9-13D**).

Table 9-5. 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; however, 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
2019	IS-14-50.0	Produced a single wet season floodplain inundation event (Event 2). Flood control in Pool A resulted in an additional, previous event (Event 1).	1 2	2 49
2020	IS-14-50.0	Produced a single wet season floodplain inundation event. Event duration would have been longer if the limit for construction had not delayed implementation of the plan and if discharge had not been reduced to 300 cfs while the lake stage was more than 2 ft above the threshold stage.	1	106
2021	IS-14-50.0	Produced a single wet season floodplain inundation event. Event duration would have been longer if the limit for construction had not delayed implementation of the plan.	1	96
2022	IS-14-50.0	Produced a single wet season floodplain inundation event of 144 days. Strictly following the IS-14-50 discharge plan and not decreasing discharge until stage in the Headwaters Lakes decreased to 50.0 ft NGVD29 would have extended the event duration by 23 days.	1	144

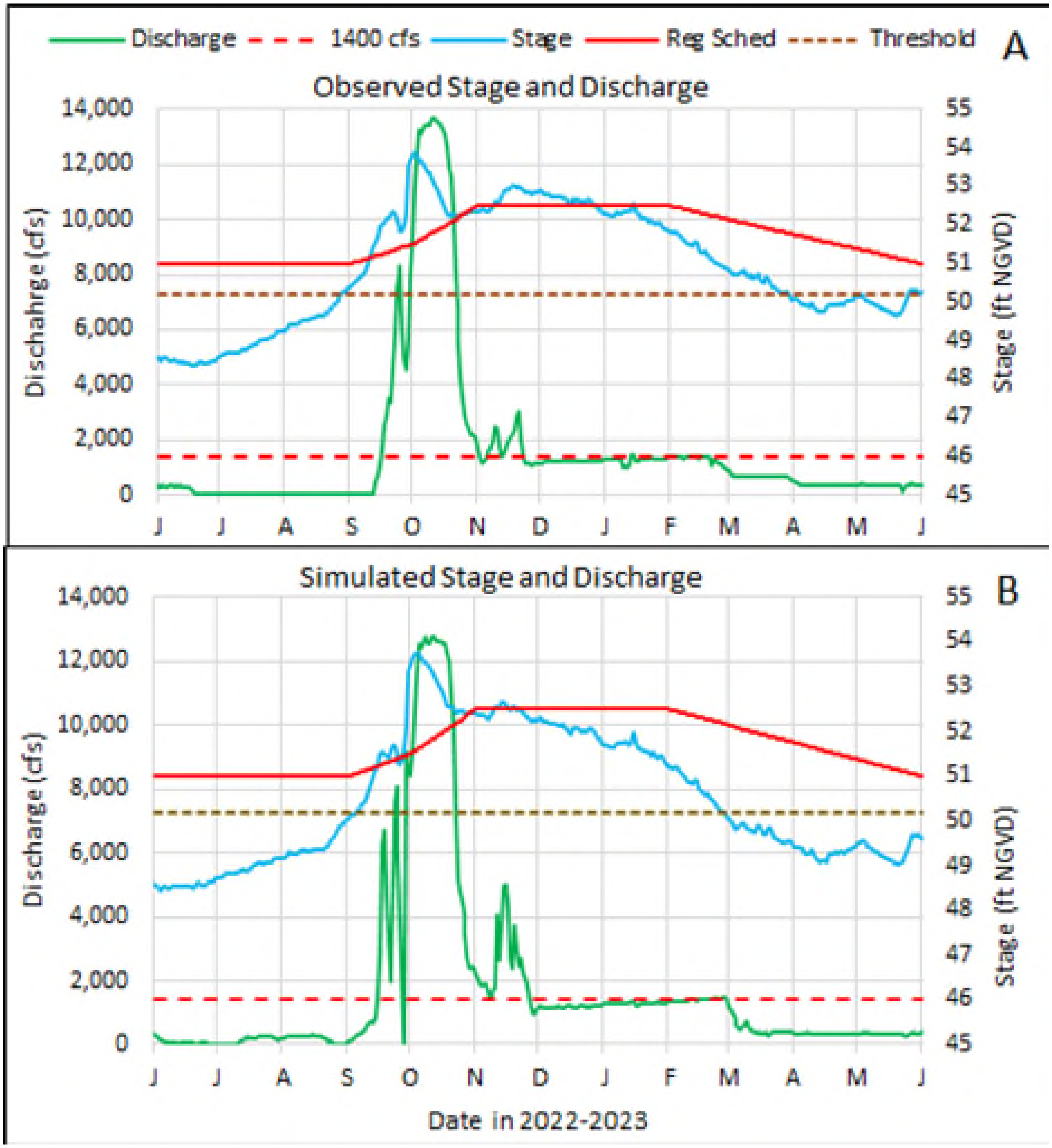


Figure 9-14. Comparison of (A) observed and (B) simulated stage (blue line) and discharge (green line) in the Headwaters Lakes and at S-65 during June 2022–May 2023. The regulation schedule (Reg Sched) incorporates the temporary deviation for February–May 2023. Actual operations (observed values) resulted in one event of discharge greater than 1,400 cfs for 144 days (September 15, 2022–February 5, 2023). Simulation of operations that maintained discharge at 1,400 cfs when stage was above 50.0 ft NGVD20 resulted in a single event for 167 days (September 15, 2022–February 28, 2023). Interim Regulation Schedule (IS), threshold at 50 ft for increasing discharge above 1,400 cfs, and 1,400 cfs lines are provided for reference.

Rapid changes in discharge from the Headwaters Lakes will continue to cause rapid changes in flow and stage in the Kissimmee River; rapid increases in discharge can cause DO declines, while rapid decreases can strand aquatic organisms on the floodplain. These interactions illustrate the strong potential for operational tradeoffs among the lakes in the UKB (including the Headwaters Lakes) and the Kissimmee River, which can complicate implementation of lake stage target requests, including both preferred ascension and recession rates, while attempting to accomplish authorized restoration goals.

A key ecological driver of the Kissimmee River prior to channelization was a single, continuous floodplain inundation event in most years that typically began late in the wet season, continued well into the dry season, and extended throughout the year in some years. These long periods of floodplain inundation provided important foraging habitat for wading birds and waterfowl and nursery areas for important native fish in the breeding season and were necessary to meet the hydroperiod requirements of the dominant wetland vegetation type (BLM) of the Kissimmee River floodplain. Managing for single, continuous floodplain inundation events continues to be a focus of efforts to make releases for 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.

NEW KRREP SHORT-TERM OPERATIONS PROJECTION (STOP) MODEL

A new model called the Short-Term Operations Projection (STOP) Model has been developed by KRREP staff and is being presented for peer review in Appendix 9-1. The model is used to support operational decision making by allowing rapid simulations of the effects of potential operational and rainfall scenarios on water levels in several KCOL lakes and the Kissimmee River over a timescale of several weeks to several months. The objective of the review is to evaluate the design, implementation, and application of the STOP Model to help improve its overall quality and reliability.

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 PW2022 are updated in this section. New results from studies of floodplain hydrology, DO, invasive vegetation, fish, wading birds, and waterfowl 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 9-6** provides a directory of KRREP monitoring study updates that have been presented in the SFER since 2008[4]; updates were also provided in the 2005, 2006, and 2007 SFERs[5].

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[4] Bousquin et al. 2008, 2009; Jones et al. 2010, 2011, 2012, 2013, 2014; Cheek et al. 2015; Koebel et al. 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023.

[5] Williams et al. 2005, 2006, 2007.

Table 9-6. Directory of KRREP Phase I restoration response monitoring study updates in the 2008–2023 SFERs. [a, b]

KRREP Monitoring Study or Project	Expectation Number	Beginning Page Number for Each Subsection in 2007–2023 SFERs ─ Volume I																
		2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Beginning page number for KRREP Section:		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	9-25	9-27	9-31
Hydrology																		
Stage-discharge relationships	None																	
Continuous river channel flow	1		**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		**11-41**	**11-32**	**11-33**	**9-21**	**9-24**	**9-24**	**9-30**	**9-37**	**9-38**	**9-37**	**9-37**	**9-25**	**9-28**	**9-30**	**9-33**	**9-34**
Stage recession rate	4	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**	**9-29**	**9-31**	**9-34**	**9-35**
Flow velocity	5			**11-35**	**11-37**	**9-24**												
BLM indicator	None		11-43						9-33	9-37					**9-28**			
Geomorphology																		
Riverbed deposits	6				**11-70**													
Sandbar formation	7				**11-70**													
Channel monitoring	None		11-54		11-68													
Sediment transport	None				11-71													
Floodplain processes	None				11-72													
Dissolved Oxygen	8	**11-28**	**11-45**	**11-36**	**11-38**		**9-27**	**9-30**	**9-36**	**9-45**	**9-47**	**9-45**	**9-45**	**9-32**	**9-35**	**9-37**	**9-41**	**9-41**
River Channel Metabolism	None	11-35																
Phosphorus	None	11-32	11-51	11-43	11-43	9-25	9-31	9-34	9-40	9-50								
Turbidity	9																	
Periphyton	None																	
River Channel Vegetation																		
Width of littoral vegetation beds	10		**11-59**															
River channel plant community structure	11		**11-59**															
Floodplain Vegetation																		
Areal coverage of floodplain wetlands	12	**11-35**			**11-47**			**9-42**	**9-50**				**9-55**		**9-49**			9-51
Areal coverage of broadleaf marsh	13	**11-35**			**11-47**			**9-43**	**9-51**				**9-56**		9-49			9-51
Areal coverage of wet prairie	14	**11-35**			**11-47**			**9-43**	**9-51**				**9-56**		9-49			9-54

Table 9-5. Continued.

KRREP Monitoring Study or Project	Expectation Number	Beginning Page Number of Subsection in 2007–2023 SFERs ─ Volume I																
		2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Invertebrates																		
Macroinvertebrate drift composition	15																	
Snag invertebrate community structure	16		11-62															
Aquatic invertebrate community structure in BLM	17																	
Benthic invertebrate community structure	18		11-62															
Native and nonnative bivalves	None				11-52													
Non-native apple snails	None														9-52			
Fish																		
Impact of hypoxic events on LMB and bluegill	None												9-58		9-55	9-53	9-62	9-61
Herpetofauna																		
Floodplain reptiles and amphibians	19							Response data will be collected after implementation of the HRS.										
Floodplain amphibian reproduction and development	20							Response data will be collected after implementation of the HRS										
Fish Communities																		
Small fishes in floodplain marshes	21																	
River channel fish community structure	22		**11-66**			**9-29**												
Mercury in fish	None		11-20															
Floodplain fish community composition	23																	
Birds																		
Wading bird abundance	24	**11-44**	**11-72**	**11-50**		**9-36**	**9-41**	**9-53**	**9-57**	**9-51**	**9-55**	**9-57**	**9-60**	**9-38**	**9-62**	**9-62**	**9-75**	**9-72**
Waterfowl	25		**11-73**	**11-52**		**9-37**	**9-42**	**9-55**	**9-59**	**9-54**	**9-57**	**9-59**	**9-64**	**9-42**	**9-66**	**9-66**	**9-78**	**9-76**
Shore birds	None																	
Wading bird nesting	None	11-40	11-72	11-47		9-33	9-38	9-47	9-53	9-56	9-51	9-53	9-66	9-46	9-70	9-71		
Wading bird and waterfowl prey availability	None											9-62		**9-46**				
Threatened and Endangered Species	None														9-84	9-77		

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

b. Reporting on the KRREP began in the 2005 SFER – Volume I.

HYDROLOGY

This section evaluates metrics for Expectations 3 (hydroperiod) and 4 (recession events) in PW2023 and provides an overall assessment of progress toward meeting the expectations during the post-Phase I construction Interim Period (PW2002–PW2023). The reference conditions used to develop these expectations and the effect of channelization on BLM Depth (mean depth at floodplain BLM sites) and recession events were summarized in a previous *Hydrologic Conditions* 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 PW2023 and the Interim Period

> ***Expectat*ion 3 (Hydroperiod Requirements for BLM)**
>
> *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 BLM Depth ≥ 1 ft for a minimum of 210 consecutive days.*
>
> *Component B: 40% of water years will have BLM Depth ≥ 1 ft for 210 consecutive days in the August–February window.*

PW2023 had one event with BLM Depth ≥ 1 ft (**Figure 9-15**). The event had a maximum BLM Depth of 3.95 ft and lasted 68 days (September 19–November 25, 2022) and was associated with implementation of the IS-14-50.0 discharge plan. The 68 day period was approximately the median duration of BLM Depth ≥ 1 ft in the Interim Period (**Figure 9-16**) and was far shorter than the desired duration of 210 days, and thus did not meet the criterion of BLM Depth ≥ 1 ft for 210 days for the water year (Component A) or the August–February window (Component B).

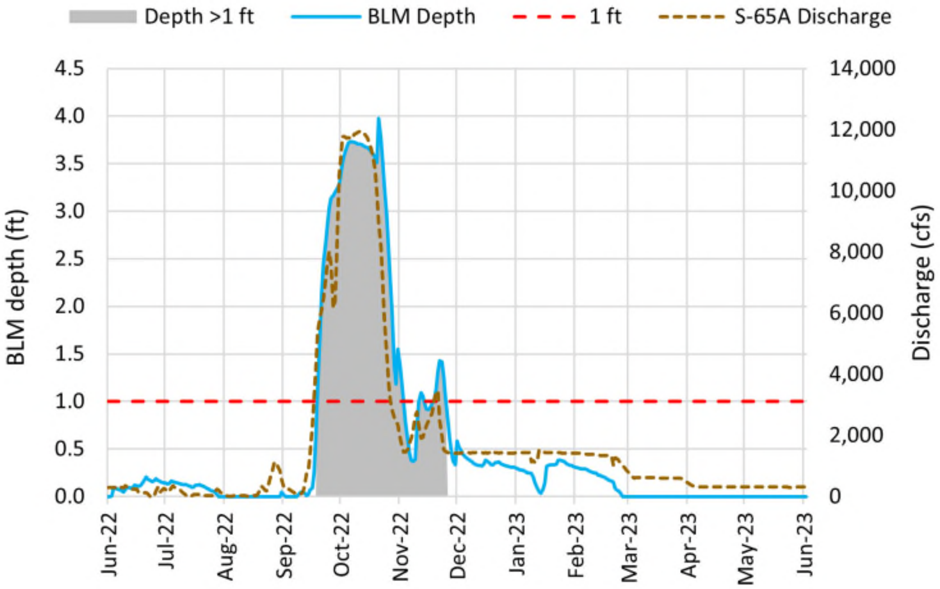


Figure 9-15. BLM Depth and S-65A discharge during PW2023. Gray shading indicates intervals of time when BLM Depth was at least 1 ft. BLM Depth is the average of mean depth at five stage recorders in the northern Phase I area floodplain.

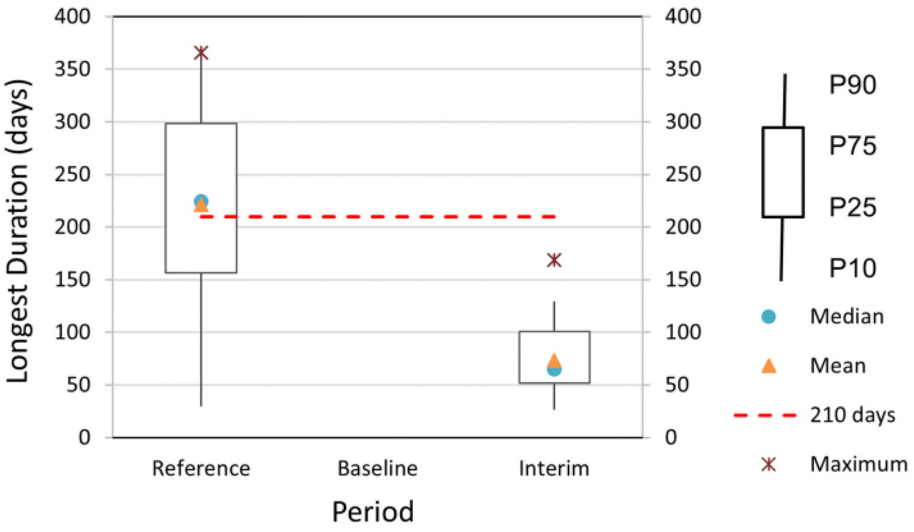


Figure 9-16. Longest duration (consecutive days) with BLM Depth ≥ 1 ft in the Kissimmee River floodplain for 32 Reference Period years, 28 Baseline Period years, and 22 Interim Period years. No events occurred in the Baseline Period. The dashed red line indicates the 210-day criterion (target for 59% years) for the expectation. The box plots show the 90th, 75th, 25th and 10th percentiles.

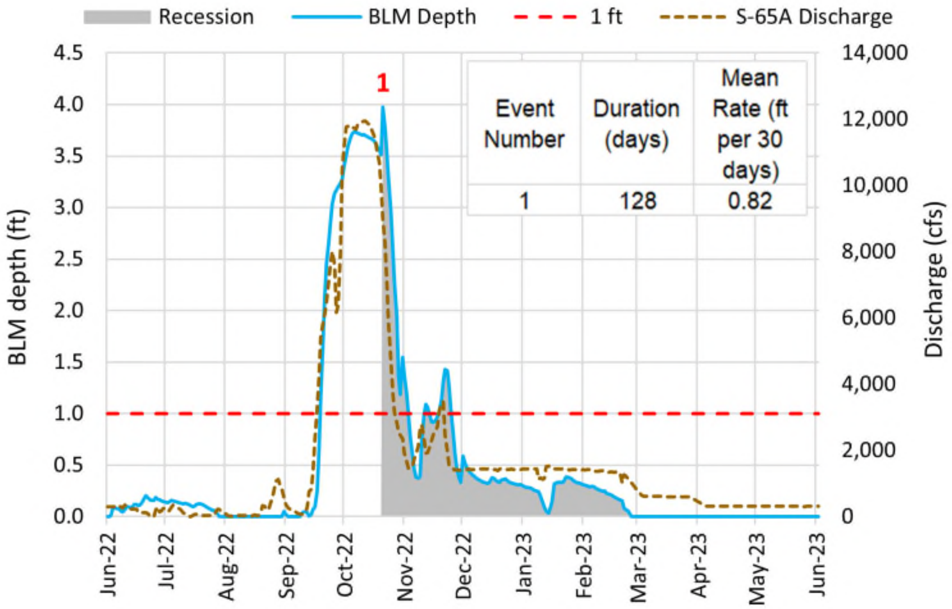
None of the events in the Interim Period (2001–present) have met the 210-day criterion (Component A) or the more restrictive criterion for the August–February window (Component B). Over the entire Interim Period, the longest duration event to date was only 169 consecutive days (range 13 to 169 days with a mean of 73 days), far short of the 210-day criterion, and barely exceeds the 25th percentile of years in the Reference Period (**Figure 9-16**). 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 Expectation 3 criterion for either the planning window (Component A) or the seasonal window (Component B). To have met the 210-consecutive day criterion for Component A in PW2006, 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 9-16**). To meet the criterion during the August–February window (Component B), a second gap of 28 days also would have had to have been disregarded.

Recession Events (Expectation 4) in PW2023 and 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: at least 72% of recession events will have a mean recession rate < 1 ft/30 d.*
> - *Component B: 100% of recession events will have a mean recession rate < 2 ft/30 d.*

PW2023 had one recession event (**Figure 9-17**) that resulted from the second floodplain inundation event described in the *Kissimmee Basin Hydrologic Conditions and Water Management in Planning Window 2022-2023* section earlier in this chapter. The recession event began in October when BLM Depth crested at 3.97 ft and then declined to 0 ft over 128 days for an average recession rate of 0.82 ft/30 d. It occurred during implementation of the IS-14-50.0 discharge plan but the peak in BLM Depth was associated with increased discharge to provide flood control in the Headwaters Lakes following Hurricane

Ian. BLM Depth declined to 0 ft after S-65A discharge was reduced to the minimum level (300 cfs) to hold water in the Headwaters Lakes.



Event Number	Duration (days)	Mean Rate (ft per 30 days)
1	128	0.82

Figure 9-17. BLM Depth and S-65A discharge during PW2023. The recession event is indicated by gray shading and identified by the red number 1. Duration and mean recession rate for each event are shown in the inset table. BLM Depth is the average of mean depth at five stage recorders in the northern Phase I area floodplain.

Because the single recession event in PW2023 had a recession rate less than 1 ft per 30 days, the season can be considered a success. The single recession event in PW2023 brings the Interim Period total to 44 recession events, or an average of two events per year.

The slower recession rate observed in PW2023 compared to previous years was the result, in part, of adhering to slower reductions in S-65A discharge than the maximum rates recommended in the IS-14-50.0 discharge plan, as discussed in *the Kissimmee Basin Hydrologic Conditions and Water Management in Planning Window 2022-2023* section earlier in this chapter. This suggests that modification to IS-14-50.0 and future discharge plans to use slower rates of reduction should be considered.

Over the entire Interim Period, mean recession rates for recession events ranged from 0.14 to 5.13 ft/30 d, with a mean rate over all events of 1.69 ft (± 0.18 standard error or SE)/30 d (**Figure 9-18**). The duration of recession events ranged from 10 to 203 days and averaged 71 days (± 8 SE). Recession rates were < 1 ft/30 d for 36% of the recession events and < 2 ft/30 d for 70% of events; both values are well below their respective targets of 71% for Component A and 100% for Component B. As a result, Interim Period values to date for the two recession rate components did not meet the expectation targets (**Figure 9-19**). More than a third of Interim Period recession events were faster than any that occurred in the Reference Period on which the targets were based.

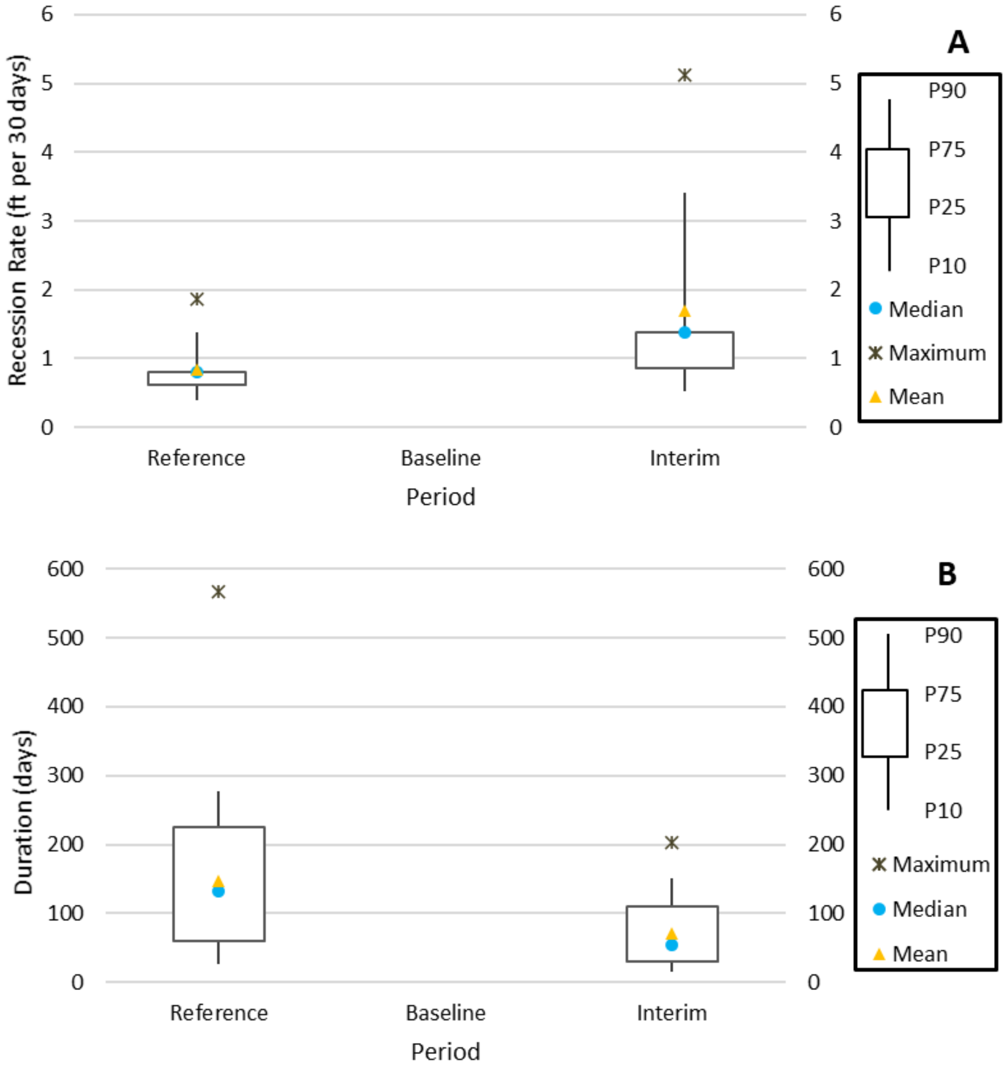


Figure 9-18. (A) Recession rates and (B) event duration for recession events during the Reference Period (PW1931–PW1962) and the Interim Period (PW2002–PW2023) in the Kissimmee River floodplain. No recession events occurred in the Baseline Period (PW1972–PW1999).

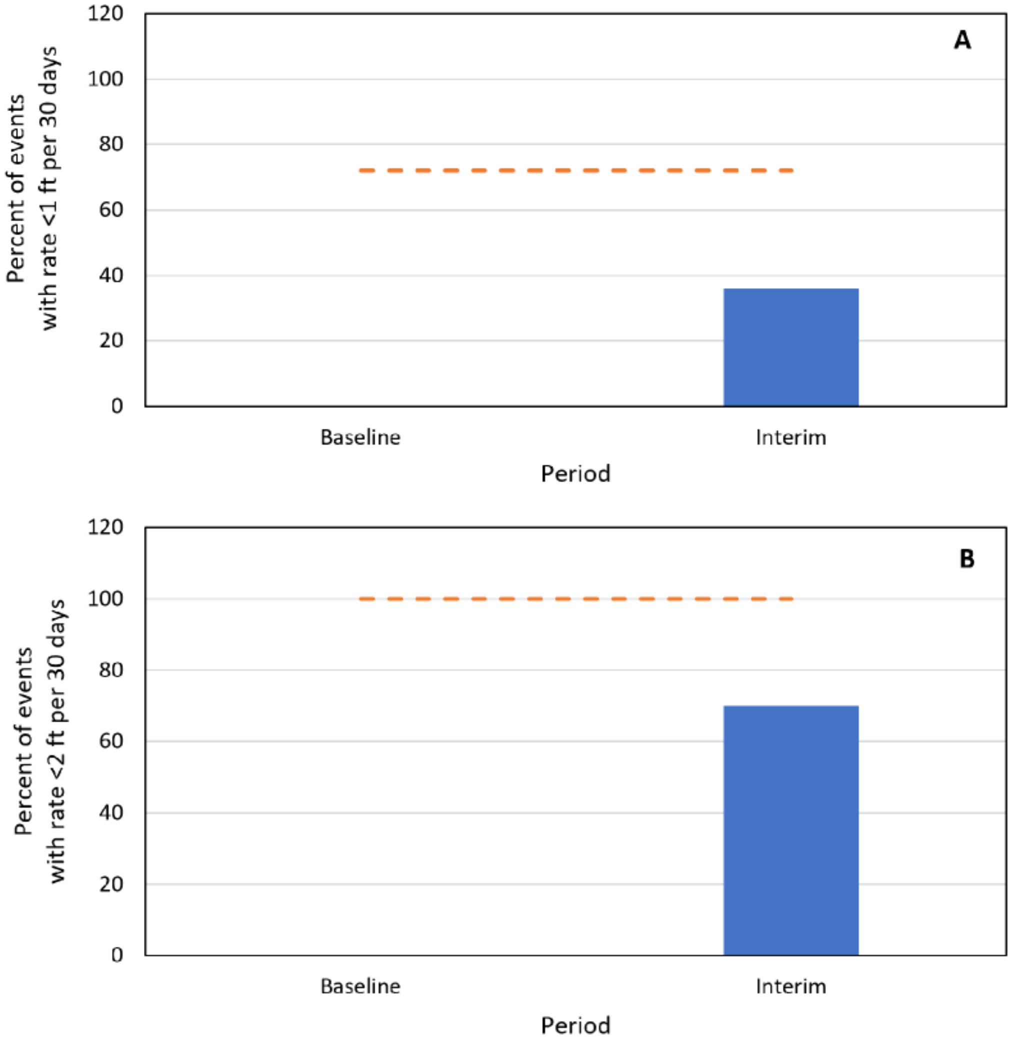


Figure 9-19. Comparison of the percentage of Kissimmee River floodplain recession events having rates (A) < 1 ft/30 d (Component A) and (B) < 2 ft/30 d (Component B) during the Baseline (PW1972–PW1999) and Interim (PW2002–PW2023) periods. The dashed red lines are target percentages based on frequency of events during the pre-channelization Reference Period (PW1932–PW1962). Reductions to low discharge result in disjoined floodplain inundation events with periods of drying.

Discussion of the Hydrologic Expectations in the Interim Period

Reestablishment of flow in the Kissimmee River channel by backfilling the C-38 Canal has allowed water levels to fluctuate in response to variable flow, providing intervals of floodplain inundation and recession during the Interim Period (Anderson 2014). While this is an improvement over the stabilized water levels of the channelized Baseline Period, we have not yet reestablished in even one year the single, long period of floodplain inundation followed by a slow stage recession that typified most years of the pre-channelization Reference Period. Evaluation of the hydrologic expectations shows that even the longest period of inundation with BLM Depth $\geq$ 1 ft in the Interim Period is only about the 25th percentile of pre-channelization events; it follows then that recessions are currently too rapid. The slower (< 1 ft/30 d) recession rate observed in PW2023 indicates that meeting the recession rate expectation in the future will likely depend, in part, on slowing maximum discharge rates of decrease to ~50 cfs/d, at least when between bankfull and minimum discharges.

Excessively fast floodplain stage recession rates have adverse implications for the success of KRRP. A slow stage 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 stage 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, are largely due to structure operations that impose unnatural demands on the system, disrupting the continuity and duration of flood pulses, with the consequence of pronounced intervals of dry conditions that are unsuitable for the floodplain's long hydroperiod marshes (Spencer and Bousquin 2014). If continued, such operations will prevent recovery of the Kissimmee River and floodplain.

Also characteristic of the Interim Period overall are extreme and rapid rises in Kissimmee River floodplain stage (stage reversals) due to rapid increases in discharge at the S-65 and S-65A structures for flood control (e.g., **Figures 9-7** and **9-17**). For example, during PW2019, large discharge increases for flood control twice interrupted floodplain recessions (Koebel et al. 2020). These reversals were a potential threat to snail kites that were nesting on the floodplain at the time. Such flood control releases can result when lake stage is held at or near the regulation schedule line to maintain high lake stage, so that even minor rainfall events can trigger flood control releases. They are not a consequence of the 1,400-cfs discharge plan, which attempts to keep lake stage well below the regulation line (0.5 ft). Large and rapid increases in discharge have been identified as a problem for restoration of the Kissimmee River (Cheek et al. 2014). In addition to the threat to snail kite nesting, 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). As the 2021-2022 dry season demonstrated, moderate increases in discharge that create favorable conditions (e.g., water depths) on the floodplain for snail kite nesting can pose a problem if conditions cannot be sustained for a sufficient time for eggs to hatch and young to fledge.

Relationship of Hydroperiod and Recession Events to Discharge

BLM depth is influenced, to a small extent, by direct rainfall and associated runoff from within the LKB but sustaining prolonged periods of inundation almost completely depends on inflow discharge through S-65 and 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 restoration expectations and 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 dependent on appropriate water management.

Recommendations to use versions of 1,400-cfs discharge plans to address the hydroperiod and recession expectations for the improvement of hydrologic conditions as required by KRRP's source documentation

(USACE 1991, 1996) have been made for every wet season beginning in 2015. Similar discharge plans are being applied to the future HRS and the interim phased increments that will lead to it; how well these plans improve hydrologic performance before or after the HRS is implemented will be strongly influenced by how consistently they are implemented.

Implementation of discharge plans during the 2015, 2017, 2018, 2019, 2020, 2021, and 2022 wet seasons resulted in a single floodplain inundation event during each wet season, with BLM hydroperiods of 76, 63, 63, 67, 101, 54, and 68 days, respectively. The approach used in the plans of holding discharge at 1,400 cfs during these events has in all cases 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 to the extent possible across all years, regardless of rainfall conditions, to ensure capitalization on years with enough rainfall to provide both prolonged floodplain inundation and periods of higher stage in the Headwaters Lakes by using these balanced discharge plans.

Implementation of the discharge plans indicates a promising direction for Kissimmee Basin adaptive management to achieve a balance between stage goals in the Headwaters Lakes and S-65 discharge goals for the river, to achieve benefits over time in both systems without harming either. In the same years, 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 periods of implementation.

SFWMD will continue to evaluate, refine, and implement similar discharge plans in future years both during phased implementation of HRS and after full HRS implementation. The discharge plans are examples of hydrologically- and ecologically-balanced operations designed to link discharge for the KRRP to rainfall via linkage to upstream lake stage to achieve mutually beneficial operations for these two inextricably connected parts of the Kissimmee Basin ecosystem. For the Interim Period, the plan does not attempt to fully meet the KRRP expectations for hydroperiod and recession events, although implementations of 1,400-cfs discharge plans have demonstrated that substantial improvements in performance for the hydrologic expectations can be made if they are implemented consistently, even without the additional storage that will be provided by HRS. Such operations will better approximate both the natural relationship between lake stages and flow to the river 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, 2018, 2019, 2020, 2021, and 2022 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, implementation of the discharge plan in the 2022 wet season resulted in floodplain inundation that extended into the dry season and allowed snail kites to nest in the floodplain and successfully fledge young (see the *Dry Season Floodplain Inundation* subsection in *Kissimmee Basin Hydrologic Conditions and Water Management in Planning Window 2022-2023* section earlier in this chapter).

Extension of discharge plans through the dry season will help address another issue identified in previous years: rapid changes in discharge to manipulate stage in the Headwaters Lakes can result in harmful depth fluctuations in the Kissimmee River and floodplain. For example, current KRREP operational guidelines allow maximum rates of discharge decrease and increase that are often relaxed in consideration of other operational needs; however, the specified maximum rates of change are much faster than occurred in the Reference Period, as was demonstrated in the *Kissimmee Basin Hydrologic Conditions and Water Management in Planning Window 2022–2023* section earlier in this chapter. Other examples include 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); precisely following dry season stage recession lines by controlling all stage reversals in these lakes; creating 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, and directly impacting wading bird foraging and nesting and fish breeding, among other negative impacts on other components of the ecosystem. Further, operating for similar dry season stages year after year in the Headwaters Lakes could reduce inter-annual variability, which is widely viewed as a desirable characteristic of healthy lakes (Perrin et al. 1982, USFWS 1994, Hill et al. 1998, Keddy and Fraser 2000).

Summary

The performance of hydrologic Expectations 3 (hydroperiod) and 4 (recession events) in PW2023 was influenced by the implementation of the IS-14-50.0 in the 2022 wet season. Outcomes were also affected by below-average rainfall early in wet season followed by rainfall from Hurricane Ian in late September and Hurricane Nicole in early November, which extended floodplain inundation into the dry season and operations to slow recession (as described in the *Kissimmee Basin Hydrologic Conditions and Water Management in Planning Window 2022-2023* section earlier in this chapter).

Expectation 3

The targets for Expectation 3 (hydroperiod) were not met in PW2023 nor in any year of the Interim Period thus far (PW2002–PW2023). Performance for Expectation 3 (hydroperiod) can be improved by consistently 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 met in PW2023; however, the percentage of events meeting the targets during the Interim Period thus far (PW2002–PW2023) is only about half the target in Expectation 4. Performance for Expectation 4 (recession events) can be improved by slowing the rate of recession in the Kissimmee River, and especially by eliminating the practice of decreasing discharge to low levels to hold the Headwaters Lakes at high stages for extended periods.

Use of discharge plans such as the one implemented in PW2023 can improve hydrologic conditions for Expectations 3 (hydroperiod) and 4 (recession events) and create conditions for the reestablishment of historic hydrology to initiate recovery of the biotic components of the river/floodplain ecosystem.

DISSOLVED OXYGEN

Dissolved oxygen (DO) directly affects aquatic life through oxygen 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 the KRREP expectations for evaluation of the status and success of the KRRP (Colangelo and Jones 2005).

DO in the Kissimmee River is a function of the balance between primary production, reaeration, and respiration (Chen 2019), which are influenced by many factors including temperature, rainfall, water depth, floodplain interactions, and discharge at water control structure S-65A (Chen et al. 2016).

Calculations in this report for expectation evaluation and control/impact comparisons are made for PW2023 (June 1, 2022–May 31, 2023); please note this might affect direct comparisons to information presented in some previous SFERs, which used the water year (May 1–April 30).

Evaluation of Expectation 8

New Provisional Expectation 8 Components

To better capture the diurnal patterns of DO levels, we have developed new provisional expectation components starting with 2023 SFER based on new continuous data from reference streams. These new expectations are evaluated with continuous data being collected from the Kissimmee River channel. For details on the methods of their development please see the *Development of New Expectation 8 Components* subsection in Koebel et al. (2023).

> ***Provisional Expectation 8***
>
> *[a] Mean daily concentration of DO in the Kissimmee River channel will increase from < 1.0 to 2.0 mg/L to 2.5 to 6.0 mg/L during the wet season (June–October).*
>
> *[b] Mean daily concentration of DO in the Kissimmee River channel will increase from 2 to 4 mg/L to 4.5 to 7.5 mg/L during the dry season (November–May).*
>
> *[c] Mean daily concentration of DO in the Kissimmee River channel will exceed 1.0 mg/L more than 98% of the time annually.*
>
> *[d] Mean daily concentration of DO in the Kissimmee River channel will exceed 2.0 mg/L more than 95% of the time annually.*

Methods

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

Based on analyses of reference and baseline data, restoration of the Kissimmee River was expected to improve DO concentrations in the river channel primarily by reintroducing flow, which reduces the amount of organic matter compared to that which 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, continuous 30-minute DO data were collected from five nearby free-flowing blackwater streams (Arbuckle, Josephine, Fisheating, Catfish, and Marion creeks) and used to estimate reference (pre-channelization) conditions for the Kissimmee River (**Table 9-7**). Data were collected from 2015 to 2016, and additional data collection has been ongoing since 2021. Note this is an updated methodology for establishing the expectation targets (reference data) compared to previous evaluations of Phase I DO response. To learn more about the previous methodology, which was based on daytime grab samples to establish reference conditions, see Koebel et al. (2022). For Baseline (channelized) Period data, 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 10:00 am and 2:00 pm from PW1996 to PW1999. Expectation 8 Components [a], [b], [c], and [d] were updated in last year's chapter based on these reference and Baseline Period data (Koebel et al. 2023).

Table 9-7. Reference, Baseline, and Post-construction periods DO sampling for performance evaluation of the KRRP.

Period	Sampling Type and Frequency	Depth	Dates Collected	Location	Purpose
Reference (represents the pre-channelized condition)	Sonde; continuous	0.5–1.0 meters (m)	2015–2016 2021–present	Reference nearby free-flowing blackwater streams	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 and Phase II/III areas	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	Control/impact comparisons

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 used to establish Reference and Baseline DO conditions. Grab samples used for comparing control and impact areas were collected monthly from sampling stations KREA91, KREA92, and KREA97 in Pool A and KREA93, KREA94, and KREA98 in the Phase I area between 10:00 am and 2:00 pm. Prior to the 2023 SFER, these grab samples were also used for evaluating Components [a], [b], and [c], but going forward, continuous data will be used to better capture the range of diurnal variation in DO levels. For the previous methodologies, please see Koebel et al. (2022).

For statistical evaluation of a restoration effect on DO, the difference between the impact area (Phase I, where flow was reestablished in 2001) and control area (Pool A, which was not altered by restoration construction) means (ICd) 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 significance level (α) = 0.05.

For evaluation of all Expectation 8 components during the Interim Period, continuous monitoring of daily mean DO (based on 24 hours of data collected at 30-minute intervals) at stations KRBN, PC33, and PC62 in Phase I and PD62 and PD42 in Phase II/III was conducted using stationary DO sondes in the river channel (**Figure 9-20**). Phase II/III sonde data was added to this evaluation in the 2023 SFER as construction was finished on this phase with the completion of the canal backfilling and construction of the S-69 weir in summer 2021. Data from all these stations are also used to provide technical guidance for adaptive management of discharge at water control structures S-65 and S-65A.

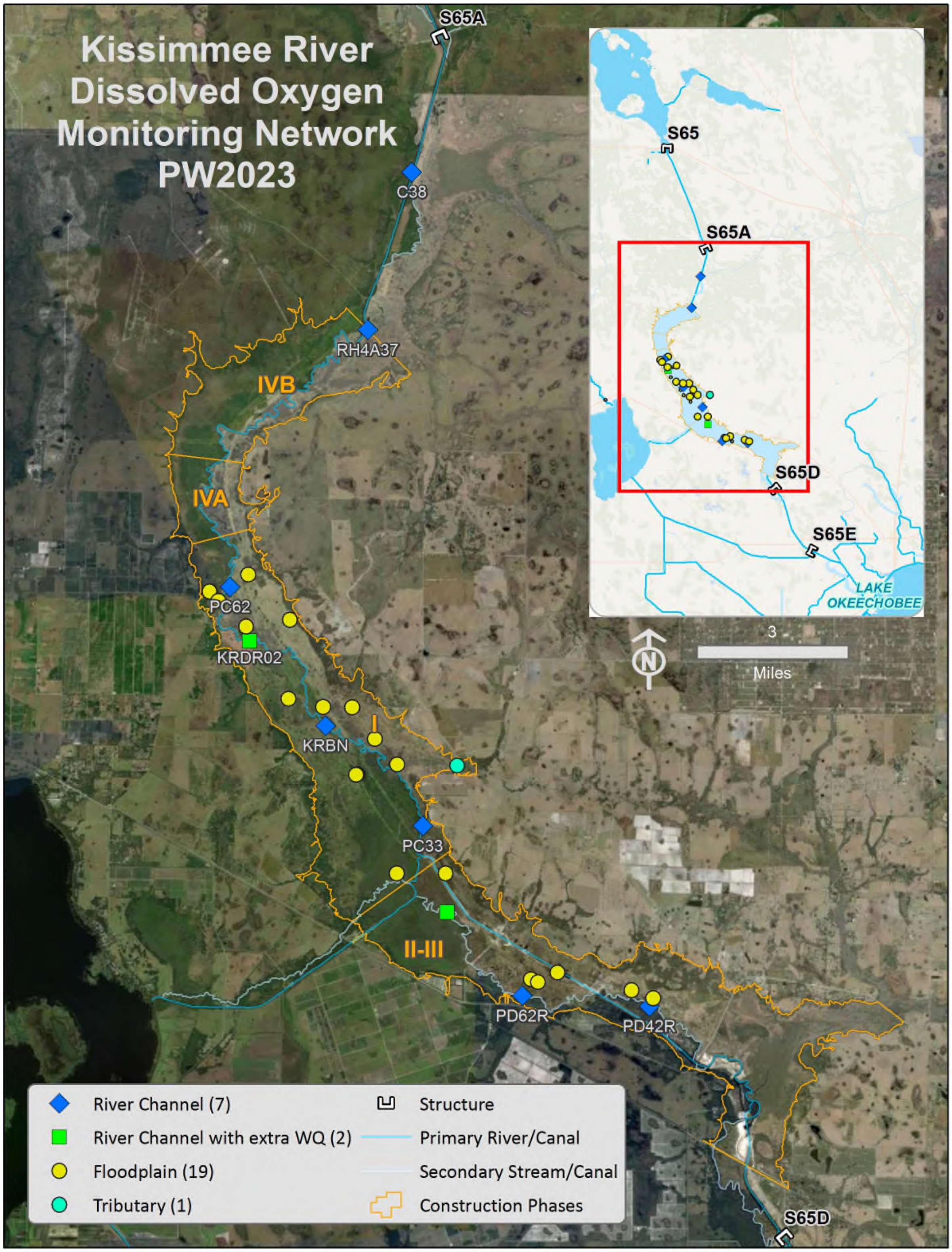


Figure 9-20. Sampling plan as deployed for PW2023. The legend indicates sonde location type (River Channel, Floodplain, or Tributary) and number of sondes. Floodplain sites are seasonal deployments to coincide with the wet season and floodplain inundation. River channel with extra water quality (WQ) indicates two locations where extra continuous water quality parameters are collected including chlorophyll and fluorescent dissolved organic matter.

Results

Evaluation of Expectation 8: Post-Construction DO from PW2002 to PW2023

Since completion of Phase I construction (PW2002–PW2023), mean daytime DO in the Phase I impact area has averaged 2.84 ± 0.10 mg/L (1 SE) during the wet season and 6.62 ± 0.07 mg/L during the dry season (**Figure 9-21**). By comparison, post-construction DO in the control area (Pool A) was significantly lower at 2.01 ± 0.11 and 3.79 ± 0.10 mg/L during the wet and dry seasons, respectively (probability factor [p] < 0.01). Mean annual daytime DO has been significantly higher in the Phase I area (5.03 ± 0.16 mg/L) than in Pool A (3.01 ± 0.19 mg/L) for the 22 planning windows following completion of Phase I construction (p < 0.01) (**Figure 9-22**).

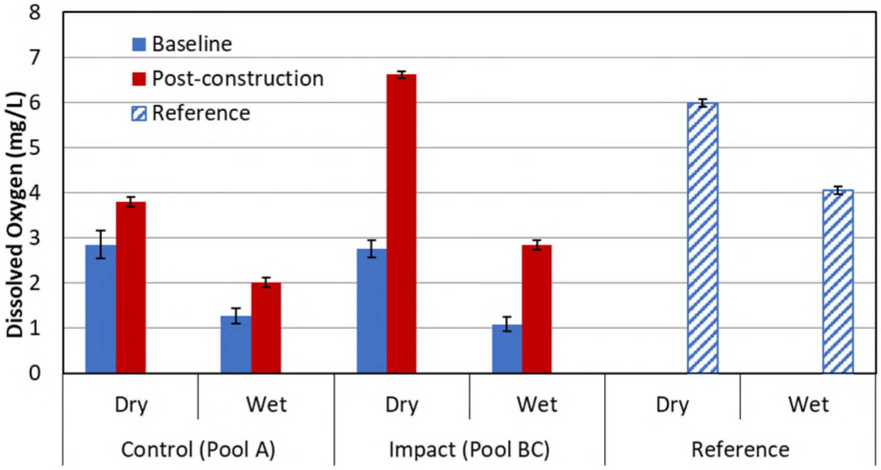


Figure 9-21. Daytime DO concentrations (mean ± SE) in reference streams for period of record PW1973–PW1999 and control and impact areas in wet and dry seasons during the Baseline (PW1997–PW1999) and Post-Phase I Construction (PW2002–PW2023) periods. Impact areas in Phase I have had reestablished flow since construction was completed in 2001. Control areas in Pool A have not been altered by KRRP construction activities and therefore, remain non-flowing.

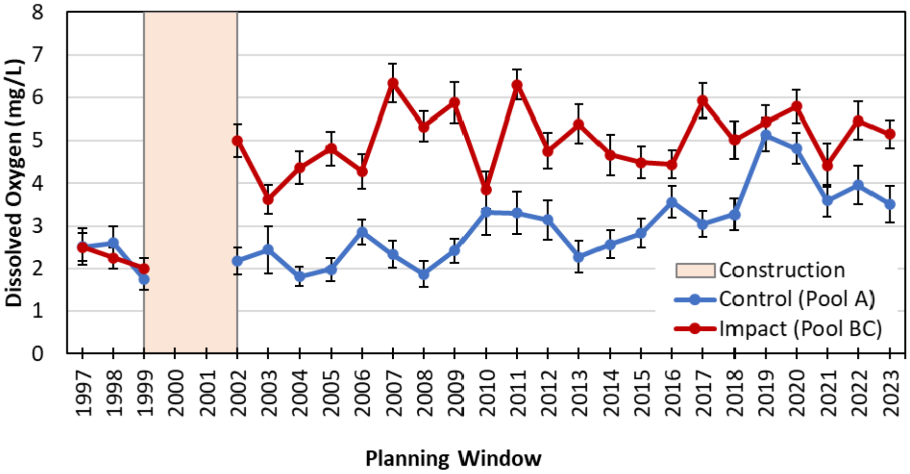


Figure 9-22. Daytime DO concentrations (mean ± SE) of sampling stations KREA91, KREA92, and KREA97 in the Pool A control area and sampling stations KREA93, KREA94, and KREA98 in the Phase I impact area of the Kissimmee River for each planning window during the baseline (PW1997−PW1999) and post-Phase I construction periods (PW2002−PW2023).

A comparison of Baseline and Post-Phase I construction data indicated that overall, DO greatly improved in the Phase I impact area during the Post-Phase I Construction period compared to the control area. The ICd for DO was significantly higher (t-test) for the Post-Construction period (2.01 ± 0.15 mg/L) than for the Baseline period (-0.18 ± 0.19 mg/L; $p < 0.01$).

In PW2023, two of the four provisional expectation components were met in the combined Phase I and Phase II/III area (**Table 9-8**). When averaged separately, Phase II/III DO levels were somewhat higher than those in Phase I during the wet season (3.5 mg/L compared to 2.9 mg/L) but were similar during the dry season. The component evaluations for the combined Phase I and Phase II/III areas are discussed here, while the values for each area averaged separately are summarized in **Table 9-8**. Mean daily DO concentration in the wet season in the combined Phase I and Phase II/III area was 3.1 mg/L, meeting the Component [a] target of 2.5 to 6 mg/L. Mean daily DO concentration in the dry season was 6.0 mg/L, meeting Component [b], which requires 4.5 to 7.5 mg/L. The percentage of time during PW2023 that mean daily DO concentrations were > 1 mg/L was only 93%, thus not meeting its Component [c] target of > 98%. The percentage of time that mean daily DO concentrations were > 2 mg/L in the river channel in PW2023 was 85%, not meeting the Component [d] target of > 95% of the time.

Table 9-8. Restoration expectation component metrics and PW2023 values for DO.

Expectation Components	Phase I PW2023 Value	Metric Achieved in Phase I in PW2023	Phase II/III PW2023 Value	Metric Achieved in Phase II/III in PW2023	Phase I & Phase II/III PW2023 Value	Metric Achieved in Phase I & Phase II/III in PW2023
[a] Mean daily DO of 2.5 to 6.0 mg/L during the wet season (June–October).	2.9	Yes	3.5	Yes	3.1	Yes
[b] Mean daily DO of 4.5 to 7.5 mg/L during the dry season (November–May).	6.0	Yes	5.9	Yes	6.0	Yes
[c] Mean daily channel DO will be > 1 mg/L more than 98% of the time annually.	94%	No	89%	No	93%	No
[d] Mean daily channel DO will be > 2 mg/L more than 95% of the time annually.	84%	No	85%	No	85%	No

Development of New Expectation 8 Components

Previously, evaluation of Components [a], [b], and [c] of Expectation 8 used DO measurements from monthly grab samples that are exclusively collected during the daytime, when DO is the highest. This was done to match the methods of the reference data on which the DO expectation was originally based. However, continuous 30-minute interval DO data are now available in the river channel from multiple deployed sondes, which better capture daily fluctuations in DO due to varying rates of photosynthesis and respiration. These continuous data can also capture changes in DO levels that occur during the month-long period between grab samples. To improve evaluations, we are developing new mean daily DO targets for all Expectation 8 components, and are changing Components [a], [b], and [c] to use mean daily DO concentrations instead of mean daytime DO concentrations. This will enable DO to be evaluated more stringently using a full year of continuous 30-minute data. These specific target values are still provisional and will be updated as needed as more data is gathered from reference streams. For more details on the specifics of how these new expectations were calculated, please see Koebel et al. (2023). To see the effect of these changes on past evaluations, the results of using the original expectation components and the water year period was compared to using the provisional expectation components and the planning window period (**Table 9-9**). Phase II/III data were excluded from the provisional components in this table to provide a more accurate comparison.

Table 9-9. Comparison of evaluation of DO Expectation 8 previous and provisional expectation components

Previous Expectation Components	**Reference**	**WY 2004**	**WY 2005**	**WY 2006**	**WY 2007**	**WY 2008**	**WY 2009**	**WY 2010**	**WY 2011**	**WY 2012**	**WY 2013**	**WY 2014**	**WY 2015**	**WY 2016**	**WY 2017**	**WY 2018**	**WY 2019**	**WY 2020**	**WY 2021**	**WY 2022**	**WY 2023**	**Total Years Met**
[a] Mean Daytime DO of 3 – 6 mg/L during the wet season (Jun–Oct).	**2.4 - 6.0**	3.3	3.0	2.9	3.1	3.2	3.3	2.5	na*	2.5	3.7	2.8	3.9	2.7	3.4	2.4	3.1	3.5	1.0	2.9	3.8	**11**
[b] Mean Daytime DO of 5 – 7 mg/L during the dry season (Nov–May).	**3.7 - 7.4**	6.1	6.0	5.9	6.2	6.4	6.6	6.2	na	7.0	7.3	7.1	4.9	5.9	7.3	7.1	7.0	7.4	7.1	7.2	6.2	**18**
[c] Mean Daytime DO concentrations within 1 m of the channel bottom will be >1 mg/L more than 50 percent of the time annually.	**na**	>50%	>50%	>50%	>50%	>50%	>50%	97%	na	96%	na	na	92%	92%	100%	83%	100%	96%	78%	87%	100%	**17**
[d] Mean Daily channel DO at 0.5 to 1.0 m depth will be >2 mg/L more than 90 percent of the time annually.	**> 90 %**	85%	80%	70%	87%	81%	80%	84%	na	78%	82%	79%	81%	95%	82%	78%	95%	84%	65%	83%	84%	**2**
All Expectation Components achieved?		No	No	No	No	No	No	No	na	No	No	No	No	No	No	No	Yes	No	No	No	No	**1**

Provisional Expectation Components	**Reference**	**PW 2004**	**PW 2005**	**PW 2006**	**PW 2007**	**PW 2008**	**PW 2009**	**PW 2010**	**PW 2011**	**PW 2012**	**PW 2013**	**PW 2014**	**PW 2015**	**PW 2016**	**PW 2017**	**PW 2018**	**PW 2019**	**PW 2020**	**PW 2021**	**PW 2022**	**PW 2023**	**Total Years Met**
[a] Mean Daily DO of 2.5 – 6.0 mg/L during the wet season (Jun–Oct).	**2.7 - 5.7**	2.9	2.7	2.2	na	na	na	na	na	2.5	2.8	2.4	2.7	3.7	3.1	2.2	3.1	3.6	1.2	3.0	2.9	**11**
[b] Mean Daily DO of 4.5 – 7.5 mg/L during the dry season (Nov–May).	**4.6 - 7.5**	5.9	6.1	5.1	na	na	na	na	na	5.9	7.4	7.0	6.1	5.5	7.8	6.8	6.6	7.5	7.0	7.0	6.0	**15**
[c] Mean Daily channel DO will be >1 mg/L more than 98 percent of the time annually.	**97.9%**	97%	88%	93%	na	na	na	na	na	93%	92%	92%	93%	87%	94%	92%	100%	91%	75%	92%	94%	**1**
[d] Mean Daily channel DO will be >2 mg/L more than 95 percent of the time annually.	**95.5%**	92%	83%	78%	na	na	na	na	na	82%	83%	81%	82%	83%	85%	78%	96%	86%	65%	84%	84%	**1**
All Expectation Components achieved?		No	No	No	na	na	na	na	na	No	No	No	No	No	No	No	Yes	No	No	No	No	**1**

*Green cells met expectation components, orange cells did not; 'na' means there was not sufficient data to accurately assess the expectation component that year

Planning Window 2023 Hypoxia Events

The 2023 wet season began with a markedly dry period during which flow to the river from S-65A was kept at 300 cfs or less. During this period, average daily river channel DO levels (measured at PC62, KRBN, PC33, PD62R, and PD42R; **Figure 9-20**) remained in the 3.0–4.0 mg/L range. On August 30, 2022, average river DO levels dropped to hypoxic levels of less than 2 mg/L (DO sag); at 1.6 mg/L which was 0.4 mg/L lower than the day prior (**Figure 9-23**). This sag event lasted 5 days until DO levels again rose above 2 mg/L on September 4. This brief sag coincided with a significant amount of local rain over several days along with a modest increase in discharge of 1,125 cfs to the river from S-65A. Another more severe DO sag followed on September 20 after the river basin received four days of intense rain and S-65A discharge was increased to over 5,000 cfs, inundating a large amount of the floodplain. This sag event lasted until November 17, with Hurricane Ian in late September and Hurricane Nicole in early November resulting in large amounts of rainfall and substantial increases in S-65A discharge (**Figure 9-23**). This event had a total of 50 days of DO levels below 2 mg/L with 27 of those days reaching anoxic levels (daily average under 1 mg/L). Within this event there were also 9 days that DO levels rose above 2 mg/L, but never went higher than 4.5 mg/L. Potential causes of the DO sags are likely be a combination of factors associated with a presence of a higher volume of water in the system, including rapidly increased water depth, disruption of aquatic photosynthesis, mobilization of nutrients on the newly inundated Kissimmee River floodplain, and reduced light availability in the water column. Dead fish were observed on the Kissimmee River in the boat ramp basin of the Kissimmee River Shores community in late September near the beginning of the second sag event described above. See the *Fish Studies* subsection below for more information about the effects of these events on the native centrarchid population.

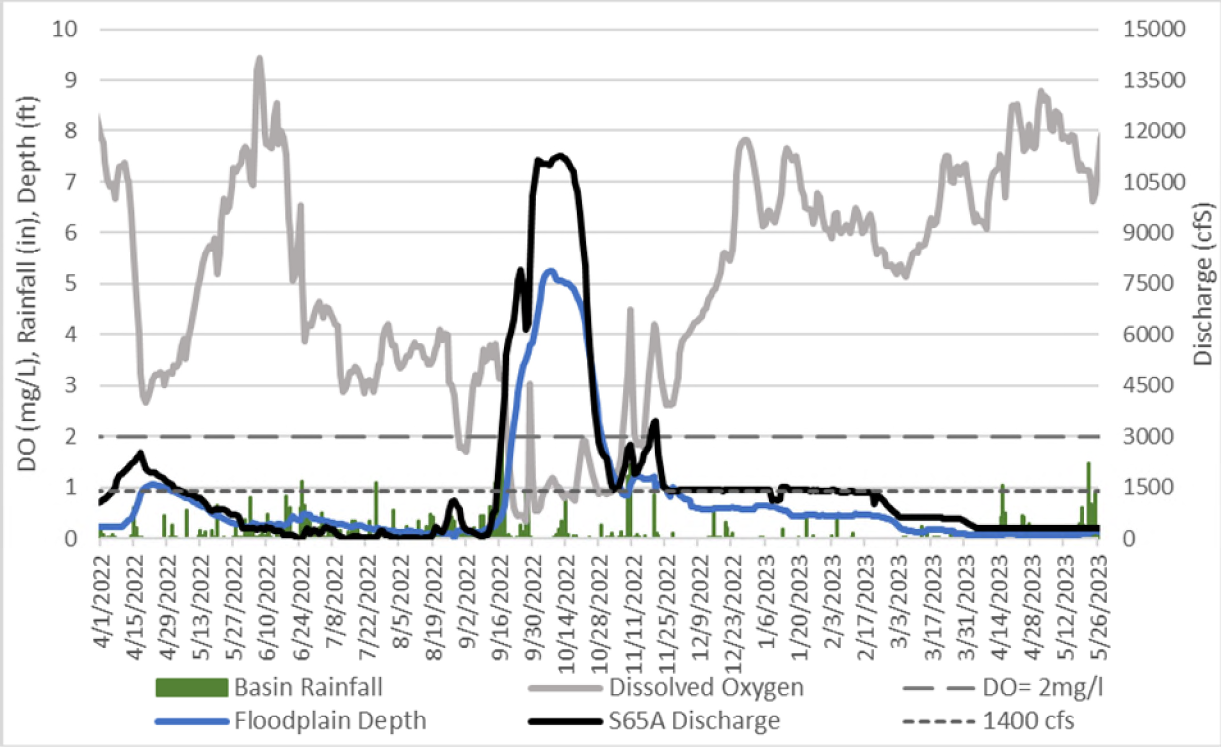


Figure 9-23. Average DO concentrations at sampling stations PC62, KRBN, PC33, PD62R, and PD42R in the Kissimmee River channel of the Phases I and II/III, estimated average floodplain depth for Phase I in feet, rainfall in inches for the Kissimmee River Basin, and daily discharge from S-65A during PW2023. Lines at 1,400 cfs (estimated flow when river is over bank) and DO at 2 mg/L (level at which sportfish are negatively impacted) lines are provided for reference.

Recent Research Findings on Kissimmee River DO Dynamics

Floodplain DO and Expanded River Channel Monitoring

A primary hypothesis about the cause of DO sags in the river and floodplain is mobilization of accumulated organic matter and the associated biochemical oxygen demand (BOD) that occurs as the floodplain is inundated by rain and/or high flow events and becomes hydrologically connected to the river (Cheek et al. 2015). This mobilized organic matter may cause an increase in decomposition that could result in the consumption of DO by respiration outpacing the addition of DO by photosynthesis and diffusion from the atmosphere. Even during periods of low (within-bank) flow, organic matter may be transported directly to the river channel in floodplain runoff and could potentially cause increased BOD once there.

To further explore DO dynamics and associated sag events within the river channel and floodplain, an enhanced network of floodplain DO recorders was deployed for continuous floodplain monitoring starting in the PW2022 wet season (**Figure 9-20**). This expansion is intended to increase the spatial extent of DO data collection on the floodplain and included 19 stations installed in the PW2023 wet season. This monitoring will be ongoing, but specific locations may change to address evolving research priorities. Additionally, in PW2022 recorders were deployed in the river channel upstream and downstream of Phase I and in the C-38 Canal north of the project area. Two of the sites in the river channel are collecting additional water quality parameters including turbidity, chlorophyll, and fluorescent dissolved organic matter (fDOM) near the north end of the Phase I area and just downstream of its south end. Grab samples are also being collected at these two river sites to validate their continuous data and create relationships between fDOM data and the more widely used parameter of total organic carbon (TOC). Both fDOM and TOC are measures of the amount of the amount of organic matter in the river, which may reduce DO levels through increased respiration in the process described above.

Preliminary Floodplain DO Observations and Results

Prior to the PW2023 wet season, a total of 19 DO sites were deployed in the Kissimmee River floodplain (**Figure 9-20**). The PW2023 wet season started with an unusually dry period during which the floodplain was never significantly inundated and DO data could only be gathered from a few floodplain sites. The floodplain remained mostly dry until significant rain and increases in discharge from S-65A in mid-September quickly inundated a large portion of its area. At the end of September, Hurricane Ian caused extreme rainfall and discharges to the river resulting in the entire floodplain becoming inundated with several feet of water until discharge to the river was reduced at the end of October. Much of the floodplain remained inundated to some degree until flows from S-65A were further reduced below 1,400 cfs in February (**Figure 9-23**). During the September and October deep flooding period, most of the floodplain sites recorded DO levels cycling between lows of 0.0 to 1.0 mg/L at night to peaks of 1.0 to 2.0 mg/L during the day (**Figure 9-24**). While these DO levels are relatively low, they were higher than those seen at most sites during the PW2022 wet season when 11 of the 21 floodplain sites rarely recorded DO levels above 0 mg/L and 5 sites only occasionally rose above 0 mg/L (Koebel et al. 2023). Relatively higher DO levels being measured this wet season could be a result of the floodplain water being deep enough to reduce emergent and floating vegetation that would typically shade out a shallower floodplain. Reduced shading could have led to greater growth of aquatic primary producers, which would increase DO concentrations.

After this deep inundation period, there were 11 sites in the PW2023 wet season that saw notable diel fluctuations in DO starting in November, with some cycling between 0.0 mg/L at night and peaking at 8.0mg/L during the day (**Figure 9-24**). The DO levels at these sites tended to increase as the floodplain remained inundated in many places through February. During this time, average river DO values also increased from 2 mg/L in early November to over 6 mg/L by mid-December. This data importantly shows that conditions in the floodplain and river can improve over time while the floodplain continues to be inundated. Throughout the entire floodplain inundation period, average river DO levels closely matched those seen in many floodplain sites, likely indicating a strong hydrologic connection between the river and the floodplain (**Figure 9-24**). Investigations and floodplain DO sampling will continue in upcoming wet seasons and results will be presented in future SFERs.

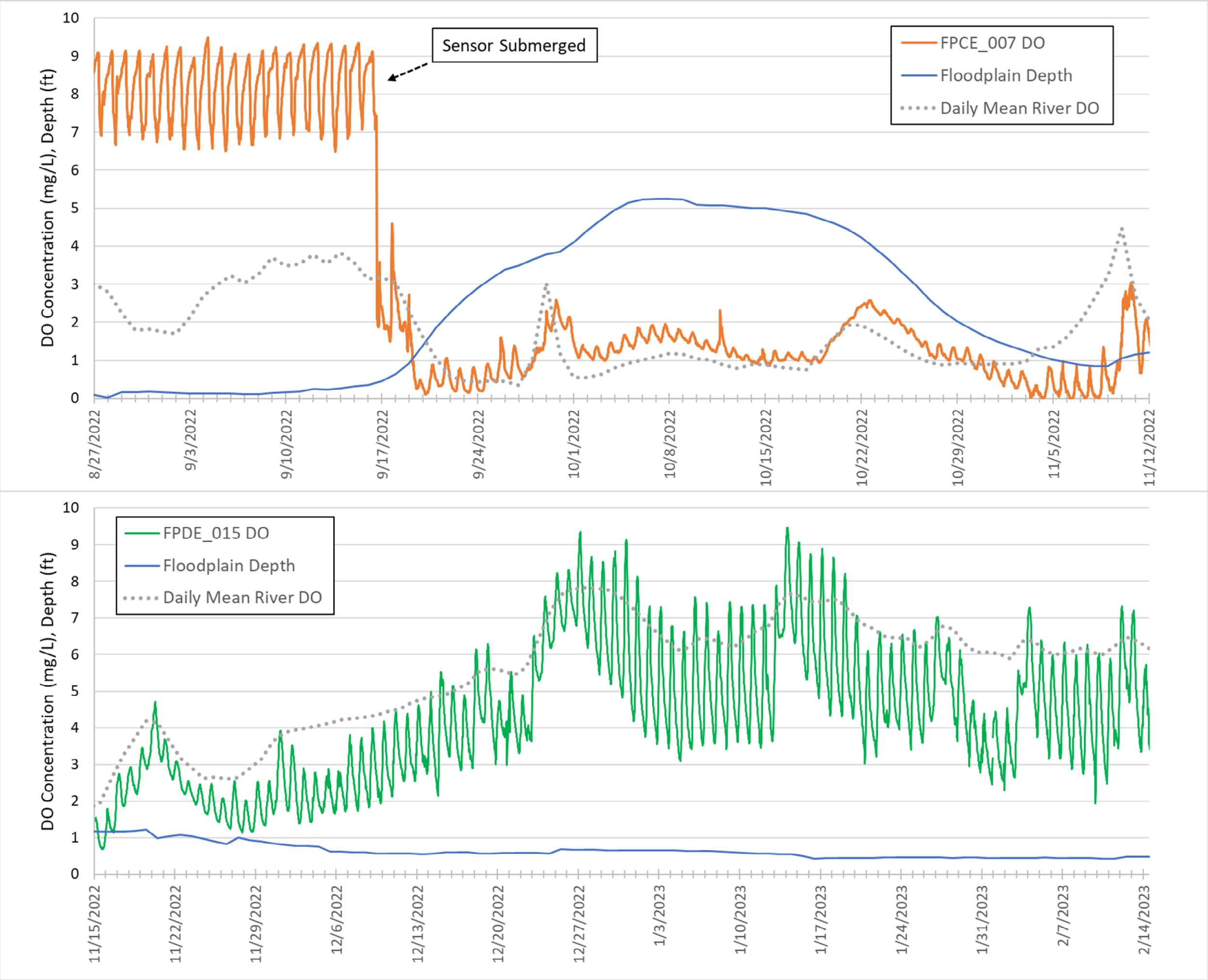


Figure 9-24. DO at selected floodplain sites and daily mean river DO during the PW2023 floodplain inundation period between September 2022 and February 2023. Arrow points to when sonde became submerged and switched from readings of ambient air to DO concentrations in the water. The top plot of FPCE_007 demonstrates the rapid decline to low DO that then stays between 0 and 2 mg/L as was seen at most floodplain sites. The bottom plot of FPDE_015 shows the late season pattern seen at most sites of more significant diel fluctuations in DO.

FLOODPLAIN VEGETATION

KRREP scientists developed expectations predicting coverage of wetland vegetation communities on the restored Kissimmee River floodplain (Carnal 2005a, b, c) based on historical areal coverage using data from the 1952–1954 pre-channelization vegetation map (**Figure 9-25**, map a; derived from Pierce et al. 1982). The expectations for overall wetland area and two dominant vegetation types, broadleaf marsh and wet prairie, are enumerated in the subsections below. These expectations refer to the entire project area and predict full response only after HRS is implemented. Because the project is not complete at this writing, the expected values are compared with results for the Phase I area only.

A vegetation map based on 2020 aerial imagery of the Kissimmee River floodplain was completed in 2022 covering the Phase I construction area (**Figure 9-25**, map g). To evaluate interim (pre-project completion) responses of floodplain vegetation, the 2020 map was compared with previous maps (**Figure 9-25,** maps a–f) of floodplain vegetation from six time periods: 1952 (pre-channelization), 1974 (3 years following completion of channelization), 2003 (2 years following completion of Phase I), 2008 (7 years following completion of Phase I), 2011 (10 years following completions of Phase I), and 2015 (14 years after completion of Phase I).

Plant Community Coverage (Expectations 12, 13, and 14)

> ***Expectation 12***
>
> *Wetland plant communities will cover > 80% of the area of the floodplain restored in Phases I–IV (Anderson et al. 2005).*

After increasing to the expected areal coverage by 2008, total wetland plant community coverage in the Phase I floodplain has remained above that threshold varying slightly between 82 and 84% coverage. Wetland coverage showed a slight decrease to 3,171 hectares or ha (82%) in 2020 (**Table 9-10**), which is not viewed as a significant change.

> ***Expectation 13***
>
> *Broadleaf marsh (BLM) will cover at least 50% of the restored floodplain in Pools B, C, and D (Anderson et al. 2005).*

Broadleaf and buttonbush marsh vegetation decreased in the latest period to about 330 ha (9%) of Phase I floodplain area, down from 639 ha (17%) in 2015 (**Table 9-10**). One hectare is equivalent to approximately 2.5 ac. Broadleaf and buttonbush marsh vegetation is a long-hydroperiod marsh vegetation type that, prior to channelization, was characteristic of lower elevations of the floodplain that were inundated for up to 7 months of the year. In the 2020 map, broadleaf and buttonbush marsh vegetation continues to occupy an area well below its expected coverage level on the Phase I floodplain (50%), and it showed a marked reduction over the previous map. Inability to achieve suitably prolonged periods of floodplain inundation under the current regulation schedule is a dominant factor in the failure of BLM to recover, but pressure from invasive plant species, including the wetland shrubs Carolina willow (*Salix caroliniana*) and primrose willow (*Ludwigia peruviana*); as well as invasive grasses such as West Indian marsh grass (*Hymenachne amplexicaulis*), also may be competing directly in BLM areas, as their occurrence adjacent to these areas appears to have increased over the period (L. Spencer, SFWMD, personal observation).

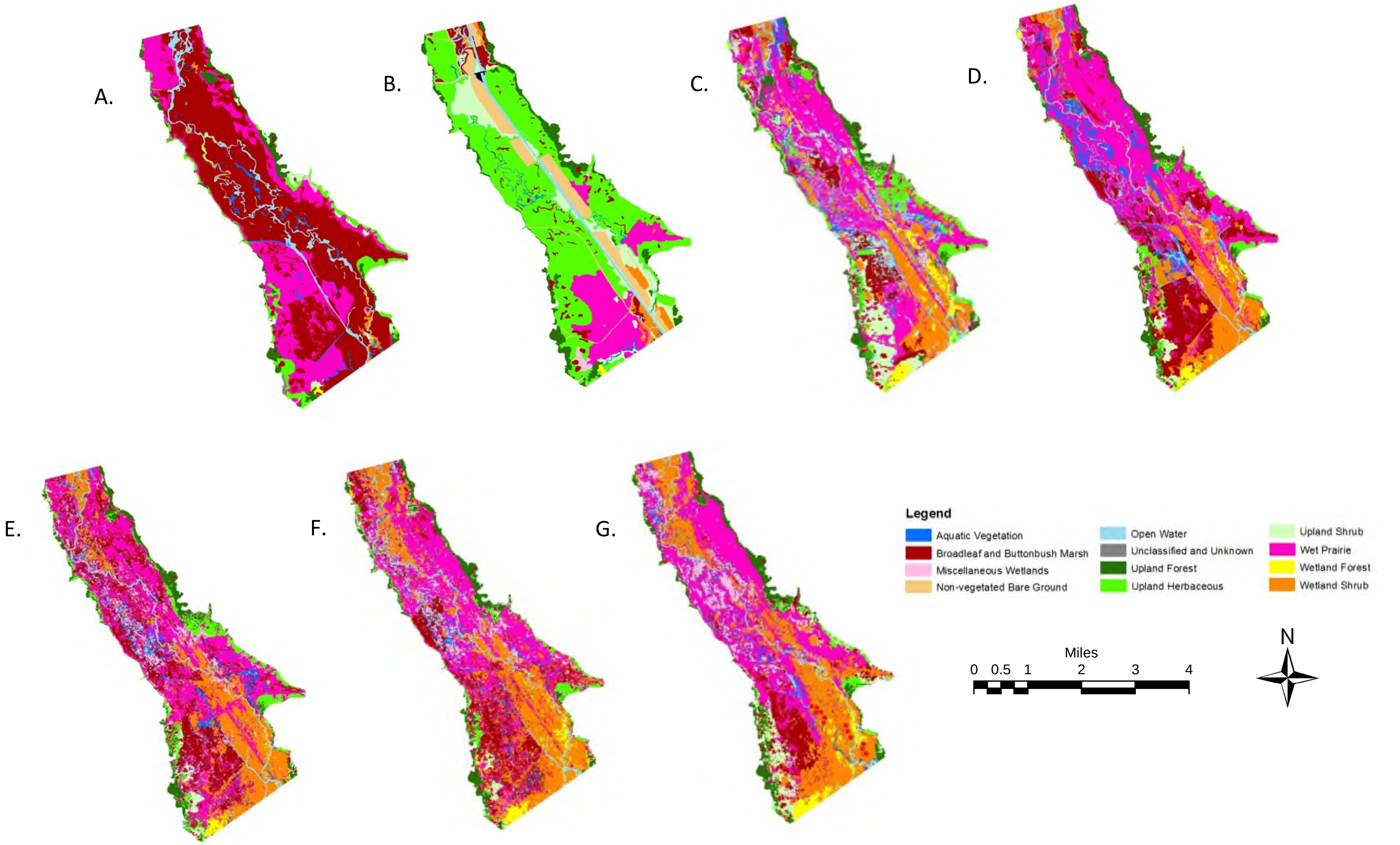


Figure 9-25. Vegetation maps of the Phase I construction area from seven time periods in the history of the Kissimmee River: (A) 1952–1954, (B) 1974, (C) 2003, (D) 2008, (E) 2011, (F) 2015, and (G) 2020.

Table 9-10. Sum of area in hectares (and percent area) of vegetation types within the Phase I restoration area over seven time periods.

Plant Community	Area (ha) and Percent Area by Time Period						
	1952	**1974**	**2003**	**2008**	**2011**	**2015**	**2020**
Broadleaf (including Buttonbush) Marsh	1,913	175	304	658	793	639	330
	49.7%	4.6%	7.9%	17.1%	20.6%	16.6%	8.6%
Wet Prairie	1,186	525	1,270	1,513	1,167	1,136	1,239
	30.8%	13.6%	33.0%	39.3%	30.3%	29.5%	32.2%
Wetland Shrub	36	104	637	706	734	1,002	1,088
	0.9%	2.7%	16.6%	18.3%	19.1%	26.0%	28.3%
Other Wetland	82	68	341	331	508	470	514
	2.1%	1.8%	-8.9%	8.6%	13.2%	12.2%	13.4%
Aquatics	61	36	136	241	173	109	120
	1.6%	0.9%	3.5%	6.3%	4.5%	2.8%	3.1%
Miscellaneous Wetlands	9	26	76	25	298	264	276
	0.2%	0.7%	2.0%	0.6%	7.8%	6.9%	7.2%
Wet Forest	12	6	129	65	37	97	118
	0.3%	0.1%	3.3%	1.7%	0.9%	2.5%	3.1%
Total Wetlands	**3,216**	**872**	**2,553**	**3,208**	**3,201**	**3,247**	**3,171**
	83.6%	**22.7%**	**66.4%**	**83.4%**	**83.2%**	**84.4%**	**82.4%**
Other Classes	631	2,975	1,294	639	646	600	676
	16.4%	77.3%	33.7%	16.6%	16.9%	15.6%	17.6%
Total Area	**3,847**	**3,847**	**3,847**	**3,847**	**3,847**	**3,847**	**3,847**

> ***Expectation 14***
>
> *Wet Prairie communities will cover at least 17% of the floodplain restored by Phases I–IV of the restoration project (Anderson et al. 2005).*

Wet prairie vegetation increased in 2020 to about 1,240 ha (32%) from 1,136 ha (30%) in 2015 (**Table 9-10**). That wet prairie has higher coverage than occurred historically is primarily due to the shorter hydroperiods in the current system, which prevent BLM from occupying its historic range. A relatively new and notable issue is the expansion of exotic wetland grasses, including para grass (*Urocloa mutica*) and West Indian marsh grass in wet prairie areas, which occupy areas that were dominated by BLM and native wet prairie grasses in the historic system. Wetland Shrub coverage increased about 2% between 2015 and 2020 (from 1,140 ha [30%] to 1,239 ha [32%]). Wetland shrub coverage has increased in every floodplain vegetation map produced since restoration construction began in 2001, mostly because of expansion of *S. caroliniana* populations, especially within the northern to central parts of the Phase I area (**Figure 9-25, map g** and **Table 9-10**). This expansion may be due to natural expansion of the established populations of mature willows within this area. As it did in the 2011 and 2015 maps, the invasive *L. peruviana* dominates the central floodplain in the southern portion of the Phase I area, closest to the former S-65C water control structure (**Figure 9-25, map g** and **Table 9-10**). Relatively stable water levels associated with the structure may have allowed this invader to out-compete native species in this area. This structure was removed in 2017. Once HRS is implemented, conditions may not be as favorable for *L. peruviana*, and native vegetation may return to this area (Spencer and Bousquin 2014).

To help reverse these expansions of invasive species using adaptive management, SFWMD personnel have been testing vegetation management techniques in some parts of the floodplain, including herbicide and fire used in different combinations to test their efficacy. So far, such treatments have been promising, but measurable reductions of invasive species over the long term will require further testing and application of an integrated approach. Beneficial changes in the coverage of invasive species may also be accelerated as the HRS is implemented. Although near-continuous flow has been maintained in the river channel and the floodplain has been inundated intermittently in the 19 years that have elapsed between completion of Phase I and the 2020 imagery, historical hydroperiods may not be closely approximated until after the HRS is implemented. The changes in hydrology that will follow implementation of HRS are expected to drive further changes in the coverage of vegetation types and these conditions should favor BLM vegetation in lower elevations of the floodplain.

FLOODPLAIN VEGETATION MANAGEMENT ISSUES AND ACTIVITIES

During the Interim Period of the KRRP (the period since 2001 when Phase I construction was completed through present), several significant vegetation management issues have arisen that require adaptive management action. The primary vegetation management issues within the KRRP are as follows:

- Invasion of floodplain wet prairie and BLM habitat by exotic grasses listed on the *2019 FLEPPC's* (Florida Exotic Pest Plant Council's) *List of Invasive Plant Species* (FLEPPC 2019). These are primarily West Indian marsh grass (Category I), para grass (Category II), and limpo grass (*Hemarthria altissima*; Category I), all of which are displacing native species.
- Invasion of former spoil areas, the backfilled C-38 Canal, and other disturbed soils by the native Carolina willow and the exotic Peruvian primrosewillow.
- Invasion of wet prairie and former BLM habitat by wax myrtle (*Myrica cerifera*) and other facultative shrubs. For more information on facultative plants, see Rule 62-340.450, Florida Administrative Code (F.A.C.) and https://floridadep.gov/water/submerged-lands-environmental-resources-coordination/content/wetland-delineation-vegetative.

The long-term management goal for the KRRP is to rely primarily on hydrologic change and prescribed fire to reestablish and maintain pre-channelization floodplain marshes, using herbicide and mechanical treatments only if necessary to achieve restoration goals. No single management tool is used in isolation and each management unit is evaluated individually to determine the combination and sequence of management actions that 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 primarily on hydrologic change and prescribed fire:

- Hydrologic change through implementation of HRS is expected to begin in 2026. Expected changes include longer hydroperiods, greater stage amplitude, slower rates of stage change, and a more natural seasonality in discharge to the river from the 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 and are being evaluated for efficacy.
- 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 SFWMD 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*), water hyacinth planthopper (*Megamelus scutellaris*), and water hyacinth weevils (*Neochetina* spp.). See Chapter 7 of this volume for more information on biocontrol agents used on SFWMD lands.
- In PW2023, two prescribed burns were conducted, and herbicide application and biocontrol agents were used to continue to address the vegetation management issues described above. In addition, experimental plots were established to better inform future efforts.

Prescribed Fire

The District is using prescribed fire as a management tool to help reach the goal of restoring ecological integrity within the KRRP area. It is hoped that well timed prescribed burns in the lightning season (late spring and early summer) will help reduce coverage of exotic grasses and invasive shrubs by direct consumption and enhancing 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.

In PW2023, two prescribed burns within the KRRP area totaling 524 ac were conducted mostly in the adjacent uplands near the floodplain in Phase I (**Figure 9-26**). On July 7, 2022, 299 ac had applied fire conducted in No Name Slough with an additional 225 ac in Bluff Hammock conducted on February 22, 2023. Conditions were not suitable for burns within the floodplain at that time. Areas that were treated with herbicides will be burned when conditions are favorable for maximum invasive control.

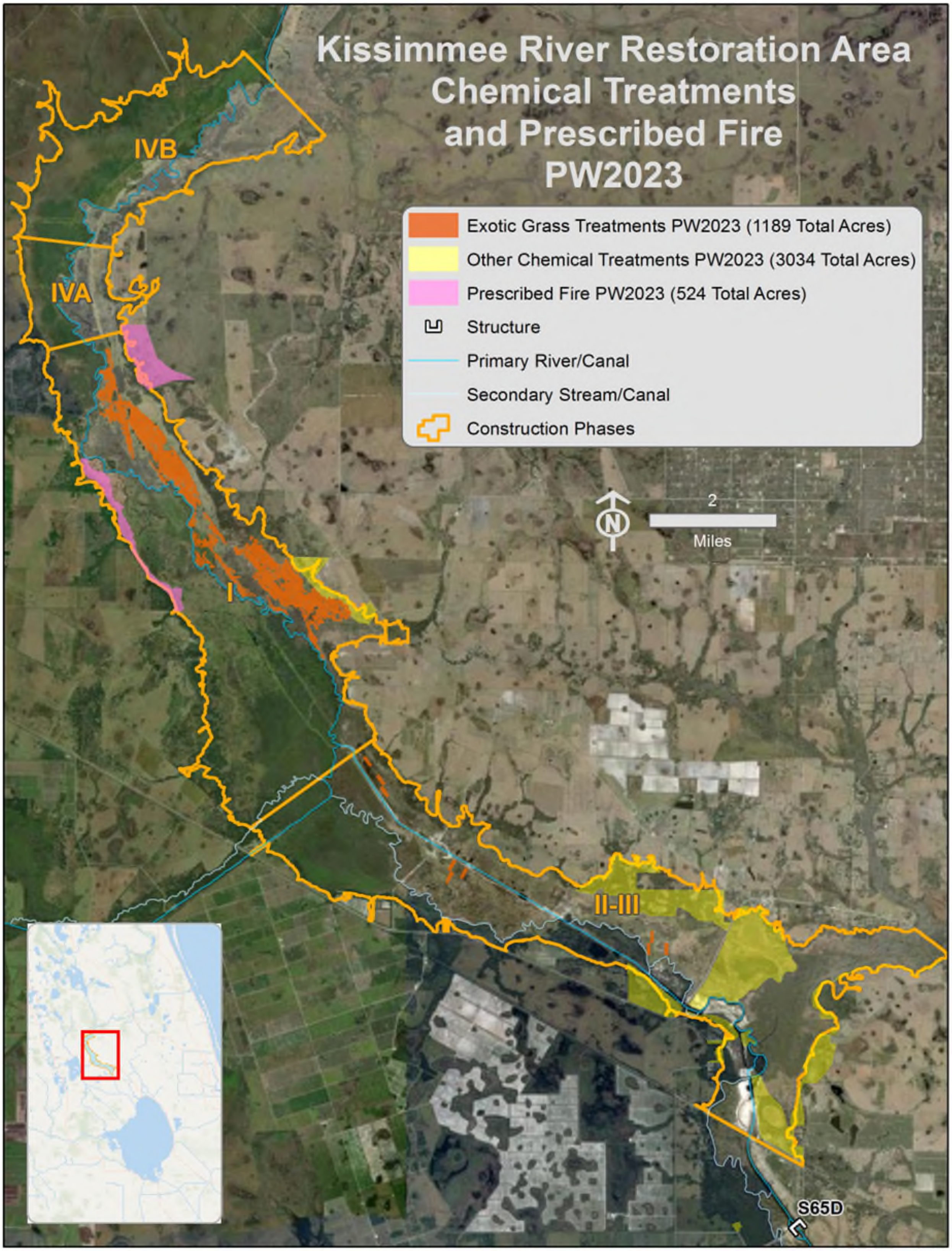


Figure 9-26. Map of locations of prescribed fire and chemical treatments within the KRRP area and directly adjacent District lands

Fire effects on vegetation are being monitored by SFWMD using permanent photo-monitoring points (examples can found in Chapter 9 of the 2022 SFER – Volume I; Koebel et al. 2022), aerial photography, and vegetation plots. Ground photo monitoring points and vegetation plots are monitored at 3-, 6-, 12-, and 24-months post-burn. Longer-term monitoring of vegetation will be conducted via aerial photo interpretation approximately every 3 to 5 years. Vegetation plots consist of a 3-meter radius circular plot centered on a permanent photo point where each species is identified and assigned a Daubenmire cover class (Daubenmire 1959). These data are used to estimate vegetation height, species richness, composition, diversity, and coverage of native versus exotic vegetation before and after management actions such as prescribed burns. The results of this monitoring will be used to assess the effects of fire on floodplain vegetation and help 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.

Herbicide Treatments

Herbicide treatments are costly, and funding is oftentimes inadequate to effectively address the invasive vegetation management issues occurring within the KRRP area. Planning and funding for invasive vegetation management within the KRRP area was not considered when the project was first initiated decades ago; thus, aggressive expansion of invasive grasses and shrubs has remained uncontrolled (**Figure 9-27**). Continued and enhanced interagency cooperation, coordination, and funding is vital to the long-term outcome of the KRRP. District funding for a long-term program of control and experimentation to find suitable methods began in PW2023, as detailed below.

West Indian Marsh Grass Treatments

The primary vegetation management issue to be addressed during the remainder of the Interim Period and into the 5-Year Post-Construction Restoration Evaluation Period is the invasion of floodplain wet prairie and BLM habitat by several exotic grasses listed on the *FLEPPC's 2019 List of Invasive Plant Species*: primarily paragrass (Category II), limpo grass (Category I), and West Indian marsh grass (Category I) (FLEPPC 2019). While a combination of glyphosate and imazapyr is effective at killing invasive exotic grasses such as paragrass and torpedograss in Florida (Enloe et al. 2020), as well as West Indian marsh grass in Australia (Cooperative Research Center for Australian Weed Management 2003), we do not have comprehensive information about its effect on West Indian marsh grass in Florida (Sellers et al. 2008, Quincy and Enloe 2020).

In 2022, a vegetation map was created by KRREP scientists detailing the extent of exotics within the Phase I footprint (**Figure 9-27**). Additional details concerning vegetation mapping is provided earlier in this section. In PW2023, aerial and ground reconnaissance confirmed that these infestations are still present, and the exotics vegetation map was used a basis for initial treatments of 1,189 ac of monotypic paragrass and West Indian marsh grass stands within Phase I (**Figure 9-26**). While this will help open areas for native communities to expand and provide important habitat for native wildlife and fisheries, further research is also necessary to optimize future efforts in controlling exotic infestations on the floodplain.

In PW2023, SFWMD is funding a contract with University of Florida to (1) address when the best time is to apply herbicide to these species in south-central Florida (wet season versus dry season) and (2) determine which infestation density and treatment combination provides the most rapid recovery of desirable native wetland species. Twenty-four herbicide plots, approximately 7 ac each with 12 treatment and 12 control plots, have been established by SFWMD prior to the start of monitoring. The contractor has established 10 permanent study quadrats with field markers in each treatment plots for a total of 240 quadrats (**Figure 9-28**). Vegetation will be monitored within each permanent survey quadrat before

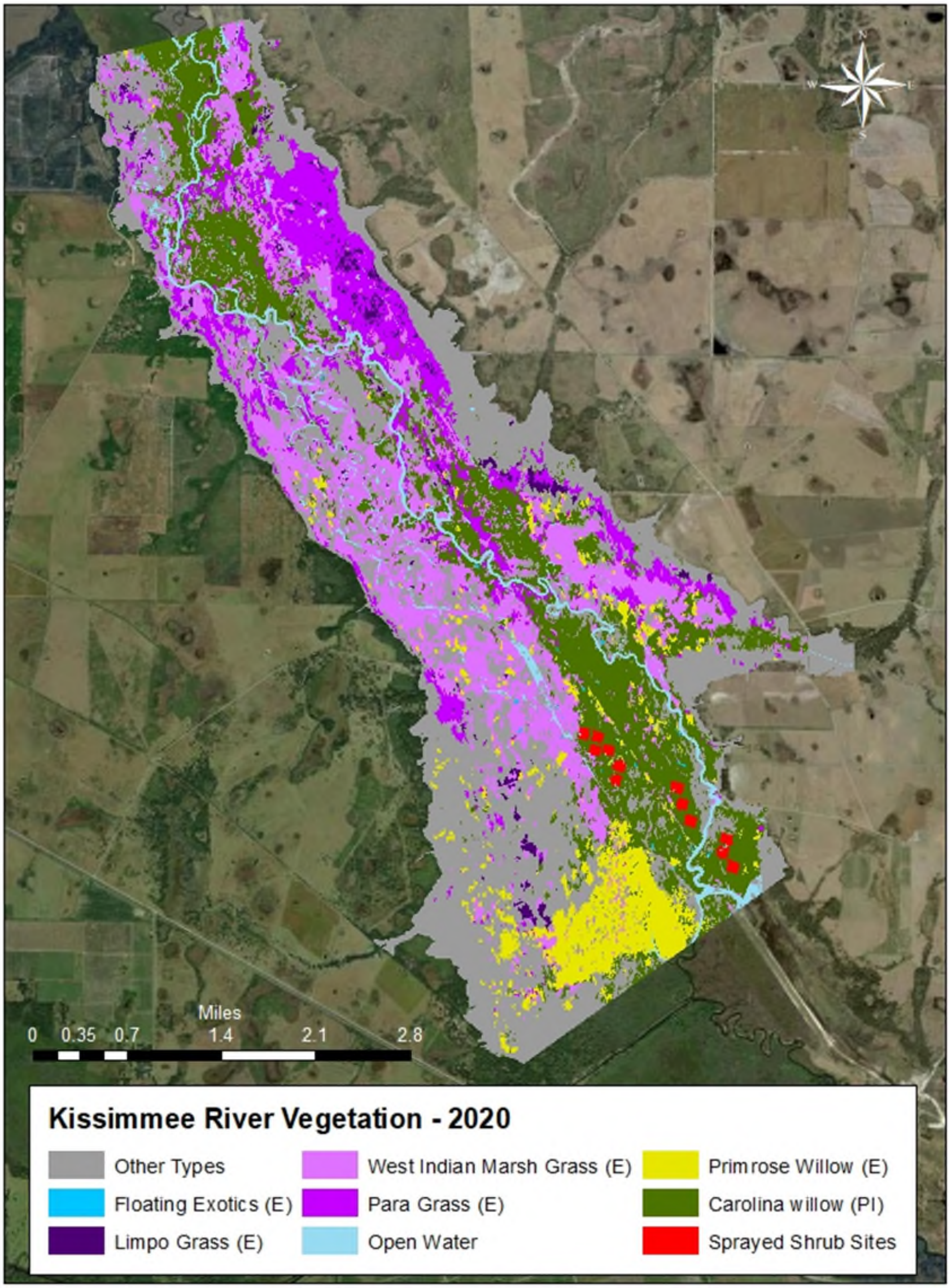


Figure 9-27. Vegetation map of Kissimmee River floodplain Phase I area showing exotic or potentially invasive map classes. (Note: E = Exotic invasive class and PI = Potentially Invasive class.

each herbicide treatment, wet season (sample size [n] = 120 quadrats) versus dry season (n = 120 quadrats), and at 1, 3, 6, 9, and 12 months following each treatment. Field sampling will be staggered based on the initial dry season and wet season treatment dates. This will provide estimates of percent cover to statistically compare the herbicide treatment efficacy of (1) wet versus dry season and (2) exotic monoculture versus mixed vegetative communities. Initial dry season treatments were completed April 2023; wet season treatments and initial monitoring will be conducted in PW2024.

Knowledge of how West Indian marsh grass responds to treatment on the floodplain under different conditions will aid in developing optimal control strategies and improving treatment efficacy. Validation of these approaches and herbicides as viable tools for control of West Indian marsh grass will be of value to land managers at SFWMD as well as numerous stakeholders including other public and private land managers and farmers. This study will directly impact the decisions for operational herbicide treatments on the Kissimmee River in upcoming years to help achieve long-term management goals. Detailed methods and results will be presented in a future SFER once the project is complete.

Carolina Willow Treatments

The expansion of the native shrub Carolina willow in the Kissimmee River floodplain has resulted in replacement of herbaceous wetland communities and has become a hindrance in the restoration of these natural communities. State agencies, water management districts, and conservation groups that manage natural areas have experienced similar encroachment of Carolina willow elsewhere, and although there has been research into the management of this species in wetlands, no previous research has been conducted in the Kissimmee River floodplain where hydrologic conditions and restoration efforts are unique. To determine the best management practices to reduce Carolina willow populations while promoting desired native plant community recovery and establishment, experimental trials were developed and implemented in Pool B/C north of the Istokpoga Canal, and east of Hickory Hammock Wildlife Management Area. The experimental herbicide trials were designed to evaluate the efficacy and non-target impacts of three herbicide treatments that target Carolina willow. Preliminary results showed that all treatments under saturated conditions were successful, based on visual determination of defoliation and mortality of Carolina willow upwards of 90%. Additional details of experimental treatments and plots can be found in Chapter 9 of the 2022 SFER – Volume I (Koebel et al. 2022). Research is ongoing and additional results will be forthcoming in a future SFER chapter.

Upland Species Treatments

Herbicide applications targeting Old World climbing fern (*Lygodium microphyllum*), Brazilian pepper (*Schinus terebinthifolia*), tropical soda apple (*Solanum* sp.), strawberry guava (*Psidium cattleianum*), and other SFWMD priority invasive species were conducted within the floodplain but mostly in associated uplands during PW2023 (**Figure 9-26**). The total area of these treatments was approximately 3,034 ac. For a more comprehensive summary of SFWMD herbicide treatments along the Kissimmee River, refer to Chapter 7 of this volume.

Biocontrol

To combat Old World climbing fern, populations of the brown lygodium moth (*Neomusotima conspurcatalis*) and eriophyid (*Floracarus perrepae)* mites have been introduced in general locations near Chandler Slough. Additional introductions and monitoring are ongoing. The United States Department of Agriculture monitors moth introduction sites at other locations outside of the LKB.

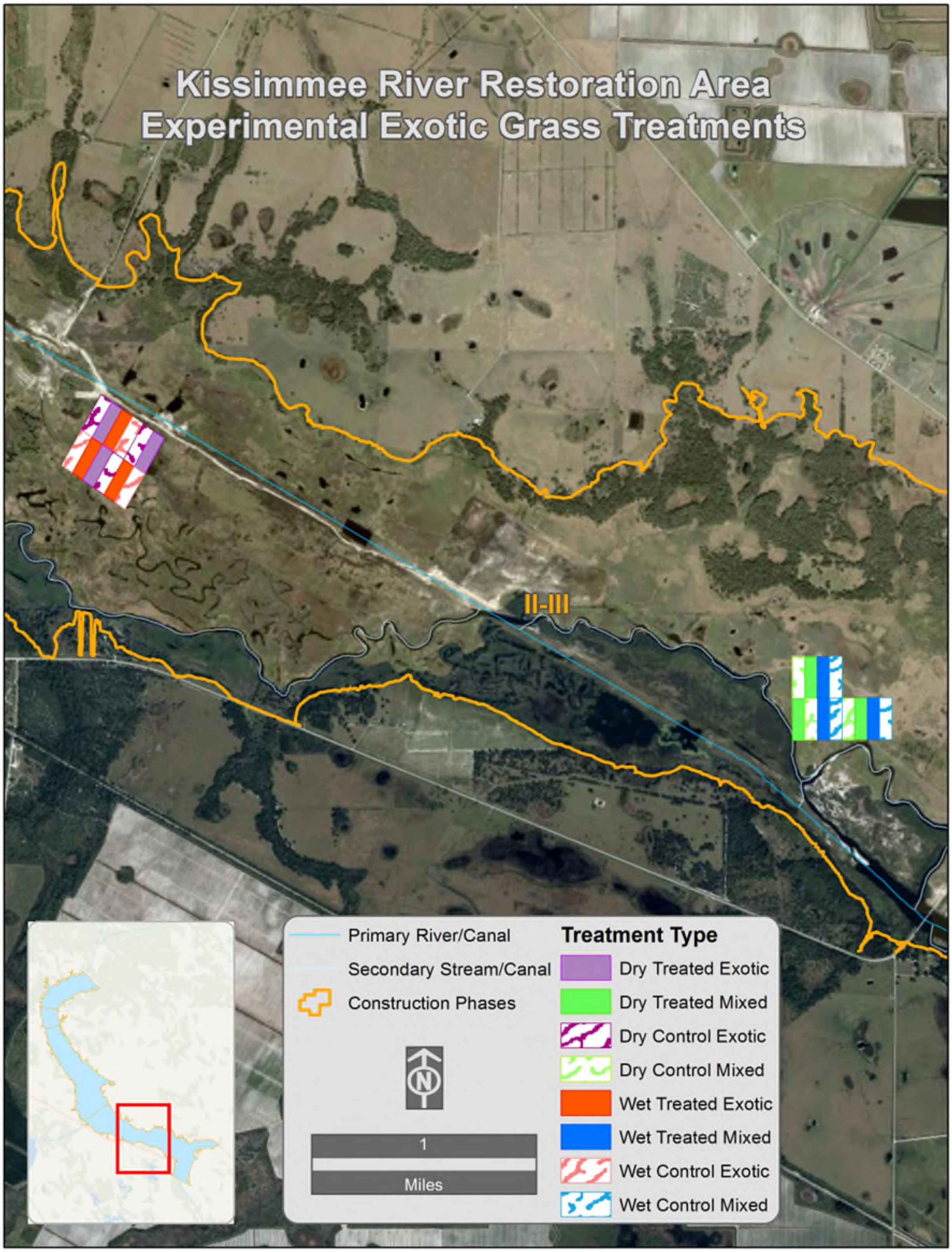


Figure 9-28. Location map and experimental plots for the invasive exotics grass study that commenced in PW2023. Dry treated exotic and dry treated mixed were sprayed in April 2023. Wet treated exotic and wet treated mixed will be sprayed during PW2024.

FISH STUDIES – IMPACT OF 2022 ANOXIC EVENTS AND OTHER ENVIRONMENTAL CONDITIONS ON CENTRARCHID FISH IN THE KISSIMMEE RIVER

Estimates of centrarchid abundance, measured as catch per unit effort (CPUE), during spring 2022 were 70 fish per hour (fish/hr) and 200 fish/hr in Phase I and Phase IV, respectively. Largemouth bass (LMB; (*Micropterus salmoides*)) comprised 42% of the total centrarchid catch in Phase I, a number well above the nine-year average of 18%. In Phase IV, bluegill sunfish (*Lepomis macrochirus*) and LMB accounted for 54 and 19% of the total centrarchid catch, respectively, and their relative abundance was within 2% of the nine-year average. Age-0 LMB were not collected in spring 2021 but they accounted for 82 and 64% of the LMB catch in Phase I and Phase IV, respectively, during spring 2022. Anoxic events during summer 2022 were followed by nearly a 70% decline in winter centrarchid abundance. The decline in centrarchid abundance included a 98% reduction in LMB in Phase I and a 91% reduction in Phase IV. The large decline in LMB abundance also contributed to a significant decline in winter centrarchid biomass that exceeded 80%.

In addition to requiring an adequate concentration of DO to survive, preferably > 2 mg/L, centrarchids in the Kissimmee River use floodplain habitat for both reproduction and foraging/feeding activity. Water management that limits or prevents access to floodplain habitat during spawning season is likely another factor that negatively impacts the river's centrarchid community. LMB commonly spawn during January–April (dry season), a period when inundation depths on connected floodplain have exceeded 1 ft for at least one month only during 2015 and 2016 and again for about two weeks in 2019. Bluegill and other sunfish can spawn during both the dry and wet season (summer), and that extended spawning season may help them recover to some extent from the impacts of anoxic events more rapidly than LMB.

Introduction

In the Kissimmee River, fish, especially gamefish, can experience physiological stress when the concentration of dissolved oxygen (DO) is hypoxic (DO = 1.0 to 1.9 mg/L), and may die when DO is <1 mg/L (anoxia) (Furse et al. 1996). Since Phase I and Phase IV of construction for the Kissimmee River Restoration Project (KRRP) were completed in 2001 and 2009, respectively, DO concentrations in the river have generally improved (see the *Dissolved Oxygen* update earlier in this section), but prolonged periods of anoxic conditions do continue to occur in the summer wet season. In 2014, KRREP began a new study to quantify fish populations in the river channel and monitor their response to restoration construction, water management, and DO conditions.

Centrarchids (sunfish) are an important group of freshwater gamefish. The most common centrarchids found in the Kissimmee River include bluegill sunfish, LMB, black crappie (*Pomoxis nigromaculatus*), redear sunfish (*Lepomis microlophus)*, spotted sunfish (*Lepomis punctatus*), and warmouth (*Lepomis gulosus*). Like many fish, these species experience substantial challenges when exposed to prolonged periods of anoxic conditions, but sunfish are especially sensitive to low DO. For this update, spring samples were collected May 31–June 9, 2022, at the beginning of the wet season, and winter (dry season) samples were collected January 5–January 10, 2023. DO concentrations were favorable (> 5 mg/L) for centrarchid fish during both sampling events, although periods of both hypoxic and anoxic conditions occurred during the 2022 wet season (summer) (**Figure 9-29**). Of 56 days below 2 mg/L, 25 days were anoxic (< 1 mg/L, and potentially lethal to centrarchids). The impacts past anoxic events had on the river's centrarchid community have been reported previously (Koebel et al. 2018, 2020, 2021, 2022). To evaluate the effects the most recent anoxic events had on the river's fishery, we compared fish abundance and biomass data collected during spring 2022 (prior to the anoxic events) with the sample means collected during the winter season (following the anoxic events). We focused analyses on the entire centrarchid community; however, bluegill sunfish is the most common centrarchid species observed in the river and when combined with LMB, these two species often account for most of the total centrarchid catch (abundance) and biomass.

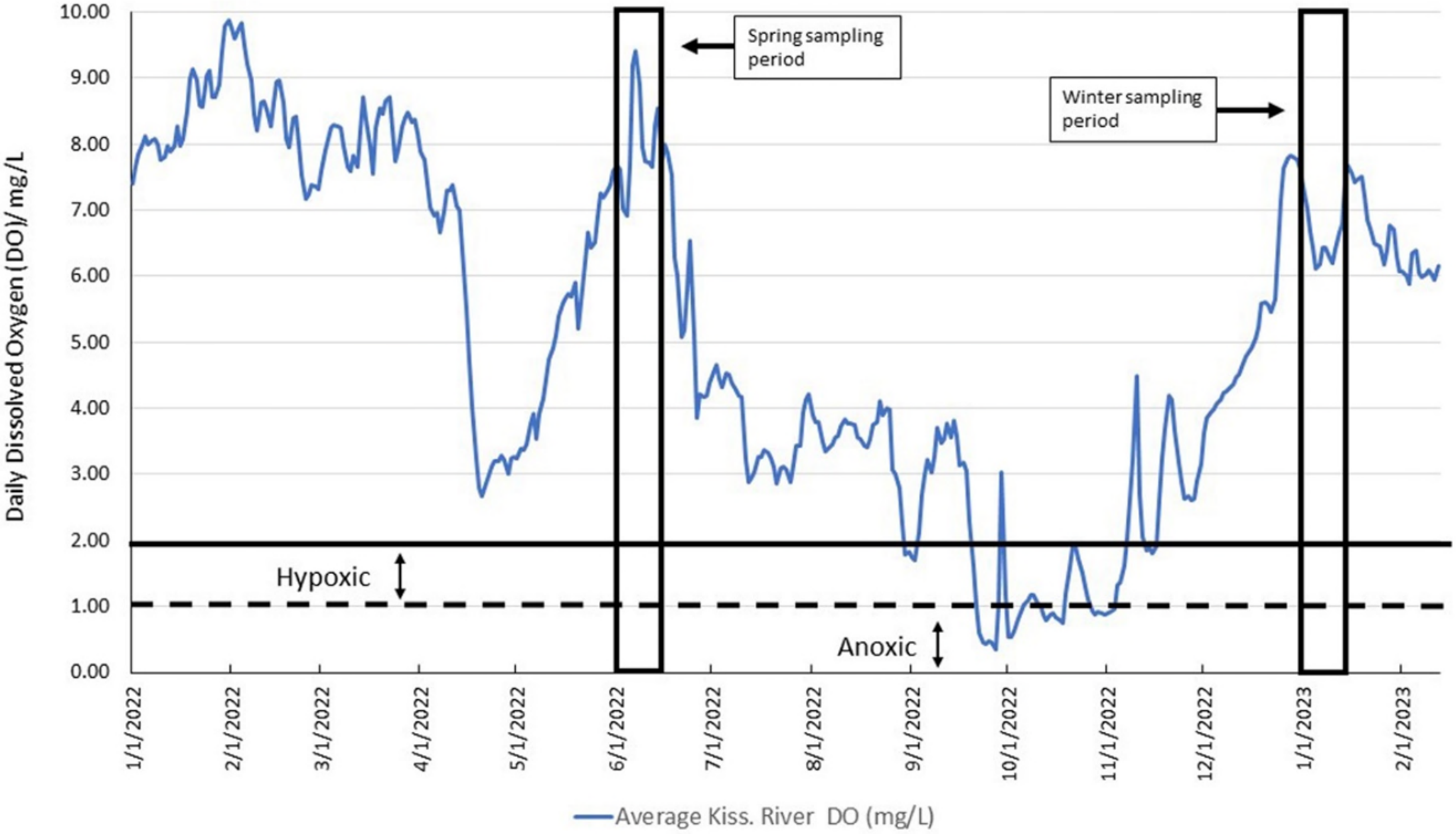


Figure 9-29. Daily DO concentrations (blue line) in sections of the Kissimmee River with reestablished flow, January 1, 2022–February 28, 2023, including the spring and winter sampling events in PW2023. Black rectangular boxes indicate the period of fish sampling and the corresponding DO at the time of sampling. DO concentrations < 1 mg/L are considered anoxic and will likely result in fish death.

Methods

Beginning in 2014, fish were sampled annually by electrofishing in spring (May to June) during a period of within-bank flow (< 1,400 cfs). Electrofishing CPUE, (measured as the number of fish/hr) and biomass per unit effort (BPUE), measured as kilogram per hour (kg/hr) data were used to estimate the abundance and biomass of fish in the Kissimmee River, respectively. Winter sampling (December–January) was added in 2017 and summer sampling was conducted in 2017 and 2019 following previous harmful anoxic events. Fish were sampled along randomly selected transects in the Phase I (n = 12) and Phase IV (n = 10) restoration areas at low speed using a double-boom electrofishing boat. Each transect followed a 150-meter (m) segment of river shoreline and was sampled for approximately 15 minutes (900 seconds). The exact sampling duration of each transect was used to calculate the number (CPUE) and biomass (BPUE) rate per unit effort (time) for all species. Captured fish were collected, identified, measured to the nearest millimeter of total length (TL), weighed to the nearest gram, and released alive.

Results and Discussion

Fish Abundance

Catch rates for centrarchids during spring 2022 averaged 70 fish/hr and 200 fish/hr in Phase I and Phase IV, respectively (**Figure 9-30**). In Phase I, LMB comprised 42% of the total centrarchid catch. This was well above the nine-year average of 18%. Bluegill, commonly the most abundant species, accounted for 31% of the catch followed collectively by other centrarchids (27%) that included black crappie, redear sunfish, spotted sunfish, and warmouth (**Figure 9-31**). In Phase IV, abundance of the three centrarchid groups were all within 2% of their nine-year averages. Bluegill accounted for 54% of the total catch followed by other centrarchids (27%) and LMB (19%) (**Figure 9-31**).

Catch rates for LMB in Phase I (30 fish/hr) and Phase IV (38 fish/hr) were 3.6- and 5.6-fold greater in 2022 when compared to spring 2021. The increase in LMB abundance was mostly due to large increases in the abundance of age-0 fish. In 2021, no age-0 LMB were collected but in 2022 they accounted for 82% (n = 74) of the total LMB catch in Phase I and 64% (n = 61) of the catch in Phase IV (**Figure 9-32**). Summer anoxic events were followed by nearly a 70% decline in centrarchid abundance. The decline included a 98% and 91% reduction in LMB abundance in Phase I (0.3 fish/hr) and Phase IV (3.6 fish/hr), respectively. This suggests that few if any of the age-0 LMB observed during the spring sample survived 2022.

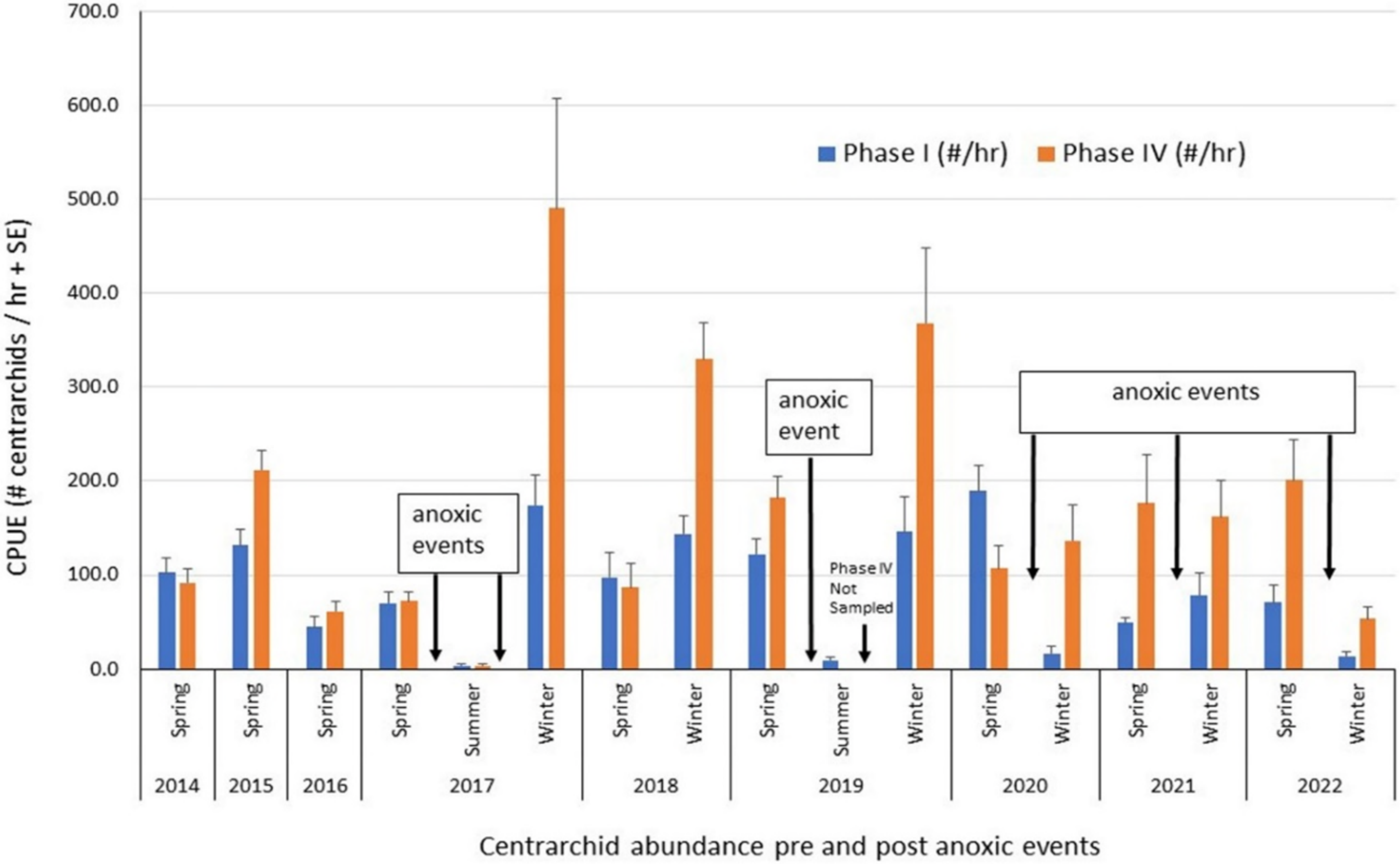


Figure 9-30. Mean abundance reported as catch per unit effort (CPUE, # fish/hr) of all centrarchid species collected in Phase I (blue bars) and Phase IV (orange bars) during spring 2014–winter 2022. The 2022 winter sampling occurred in January 2023. Anoxic events totaling 25 days or more occurred during summer 2015 and 2016, which are not shown on the graph, and in 2017, 2019, 2020, 2021, and 2022.

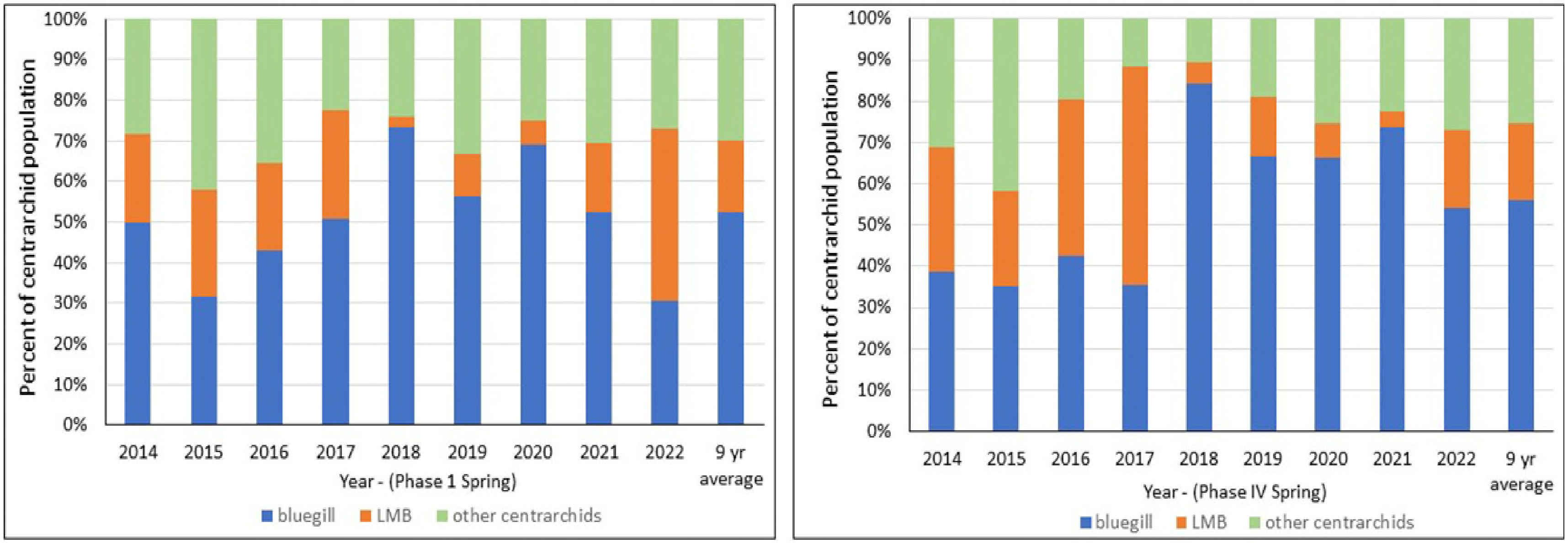


Figure 9-31. Percent of the total centrarchid catch comprised of bluegill sunfish (blue bars), largemouth bass (LMB) (orange bars), and other centrarchids (green bars). Sampling was conducted during spring of each year in Phase I (left panel) and Phase IV (right panel).

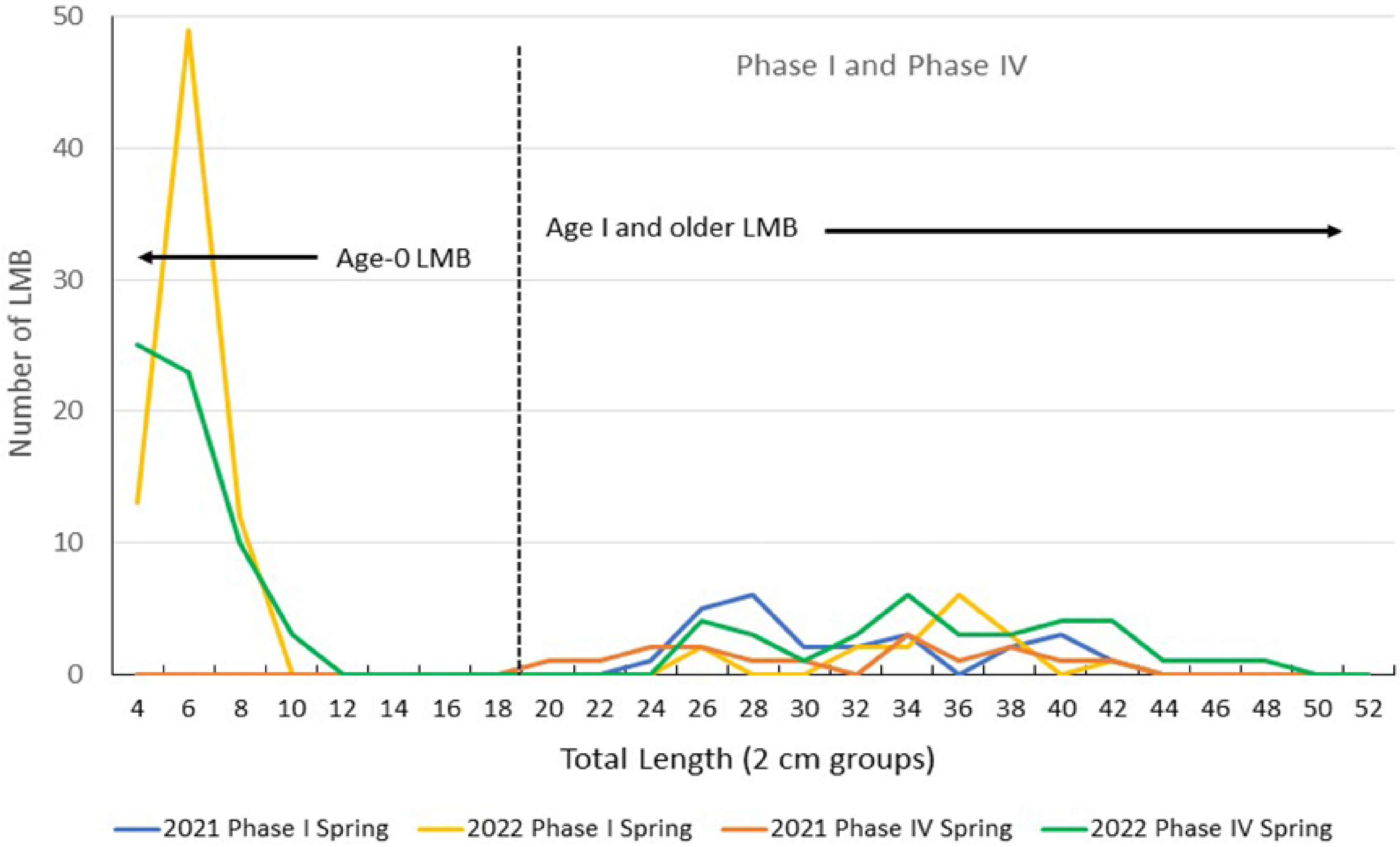


Figure 9-32. Number of largemouth bass (LMB) collected by size class (2-centimeter groups) during the spring and winter seasons in 2021 and 2022. The vertical line represents the approximate separation of age-0 LMB from age-1 and older LMB based on fish total length.

Fish Biomass

Centrarchid biomass in spring 2022 averaged 5.5 and 14.4 kg/hr in Phases I and IV, respectively. During winter, biomass was reduced to 0.4 kg/hr in Phase I (93% decrease) and 2.4 kg/hr in Phase IV (83% decrease) (**Figure 9-33**). The large decline in centrarchid biomass was significant in both areas of the river (Phase I ANOVA F= 10.5, $p < 0.05$, Phase IV ANOVA F = 9.2, $p < 0.05$) (**Figure 9-34**) and comparable with biomass observed in 2017, 2019, and 2020.

LMB accounted for about 70% of total spring centrarchid biomass in Phases I and IV. Much of the uniform decline in centrarchid biomass that occurred across both phases of the river by winter 2022 resulted from large reductions in LMB biomass. Only one LMB was collected in Phase I during the winter sample and biomass was reduced by greater than 99%. In Phase IV, LMB biomass was reduced 90%, from 10.4 kg/hr to 1 kg/hr (**Figure 9-35**). Total biomass of the other centrarchid species declined by 79% in Phase I and 65% in Phase IV.

Similar declines in winter LMB biomass were also observed in 2017, 2019, and 2020 following summer anoxic events, but not in 2021. During 2021, the abundance of LMB declined in Phase I between spring and winter; however, the average biomass of individual LMB increased from 498 grams (g) to 1.02 kg. The increase in individual biomass offset the reduction in abundance and resulted in a net increase in winter biomass. In Phase IV, winter abundance of LMB increased by 65% in 2021 and the average biomass of individual LMB increased from 503 to 742 g. It is likely that some of the larger adult LMB observed during winter 2021 migrated into the study area from areas outside of Phases I or IV as they were preparing to spawn (Koebel et al. 2023). The relatively large number of age-0 LMB observed during spring 2022 suggest some of the spawning effort was successful. We are uncertain why larger adult LMB did not appear to migrate into the study during the winter season in 2022 or in other years as previously discussed. However, the movements of LMB can be influenced by environmental conditions that include having access to desirable inundated floodplain habitat during spawning season.

In addition to requiring an adequate concentration of DO to survive, preferably 2 mg/L or greater, many fish species found in the Kissimmee River use floodplain habitat for both reproduction and foraging/feeding. LMB and bluegill and other sunfish depend on shallow floodplain areas for spawning because they prefer to build their nests in relatively shallow, open areas with sandy substrate. Water management that limits or prevents access to floodplain habitat during spawning season is likely another factor impacting the river's centrarchid community. LMB in the region commonly spawn during the winter (December–April) when water temperature is between 15 degrees Celsius (°C) and 25 °C (Rogers and Allen 2009). Although the river typically has adequate DO for LMB spawning, which was estimated at > 5 mg/L by Lee et al. (1980), during the winter season, inundation depths on the connected floodplain have exceeded 1 ft for at least one month during spawning season only in 2015 and 2016 and for about two weeks in 2019 (**Figure 9-36**). Bluegill and other sunfish can spawn during both the dry (spring) and wet (summer) seasons when the floodplain tends to be inundated. This extended spawning season may help them recover from the impacts of anoxic events more rapidly than LMB.

It will be difficult for the river's fishery to show long-term improvement until DO conditions improve and proper floodplain inundation depths and frequencies that allow access to floodplain habitat during the breeding season are established. In 2020, the river was anoxic or hypoxic for 121 days. Conditions improved somewhat in 2021 and 2022 when the occurrence of these events was reduced to 64 and 56 days, respectively. SFWMD and its partners continue to work to reduce the severity and duration of hypoxic/anoxic events and to improve hydrologic conditions in the river and on the floodplain to the extent possible.

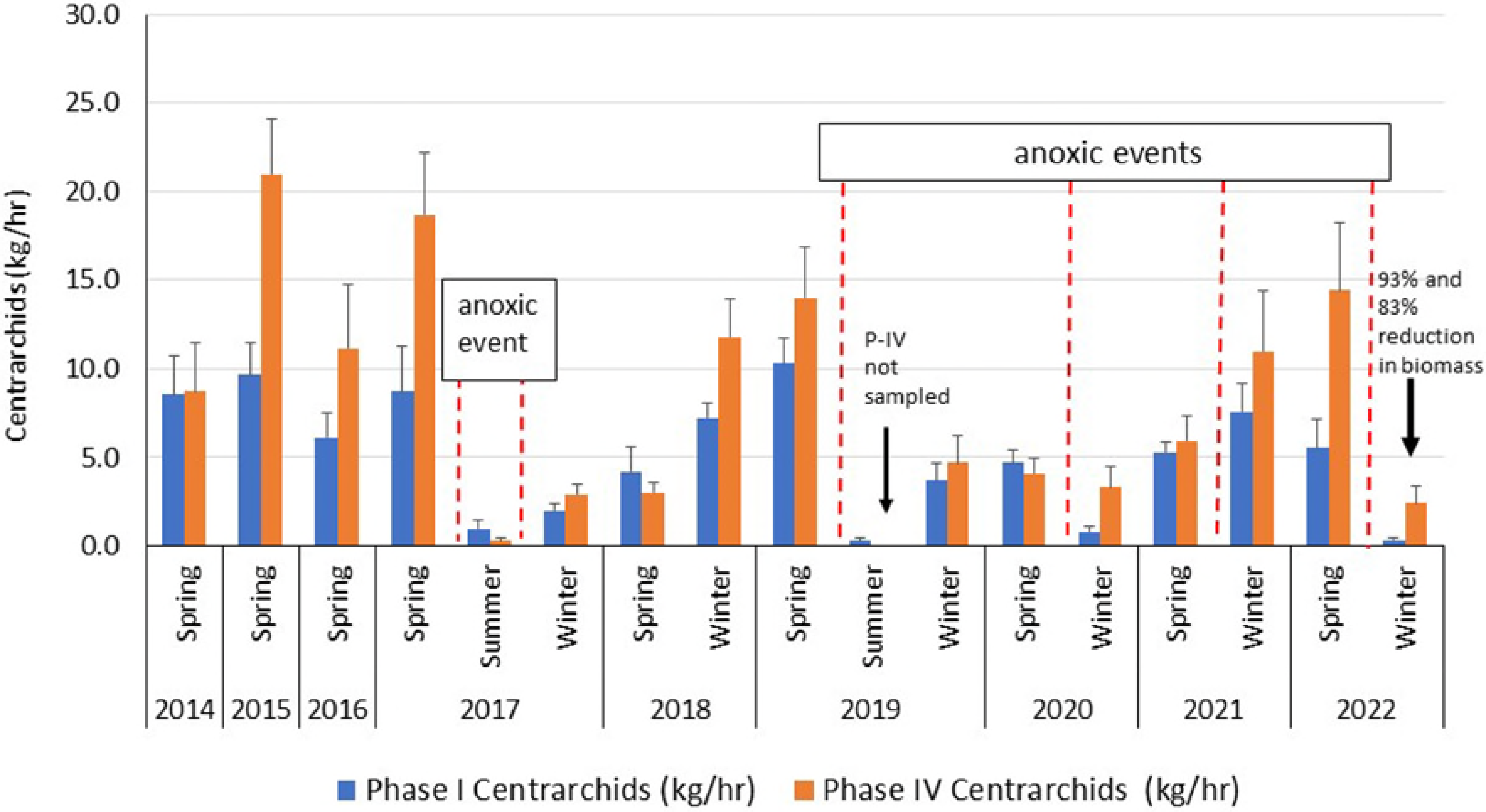


Figure 9-33. Mean centrarchid biomass (kg/hour ± S.E.) collected in Phase I (blue bars) and Phase IV (orange bars) during spring 2014–winter 2022. Anoxic events of 25 days or more occurred during summer 2015 and 2016, which are not shown on the graph, and in 2017, 2019, 2020, 2021, and 2022.

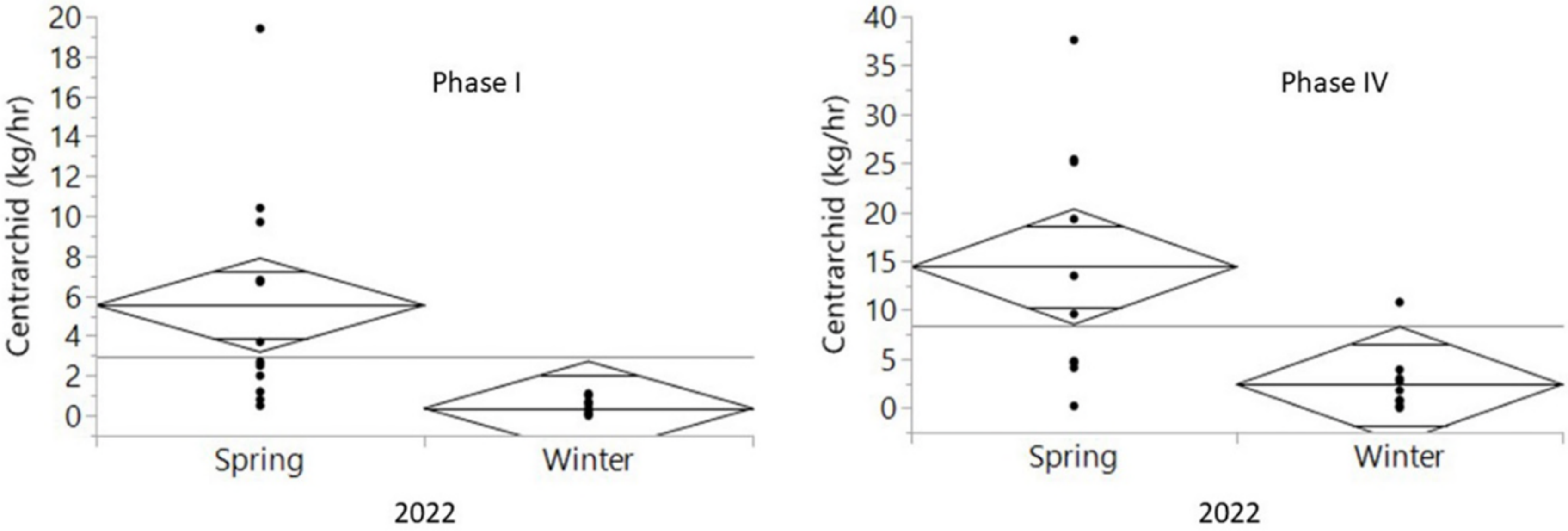


Figure 9-34. Mean centrarchid biomass (center line inside each triangle) by season in Phase I (left panel) and Phase IV (right panel). Vertical points show biomass values for individual sampling locations. Note the graphs have different y-axis scales.

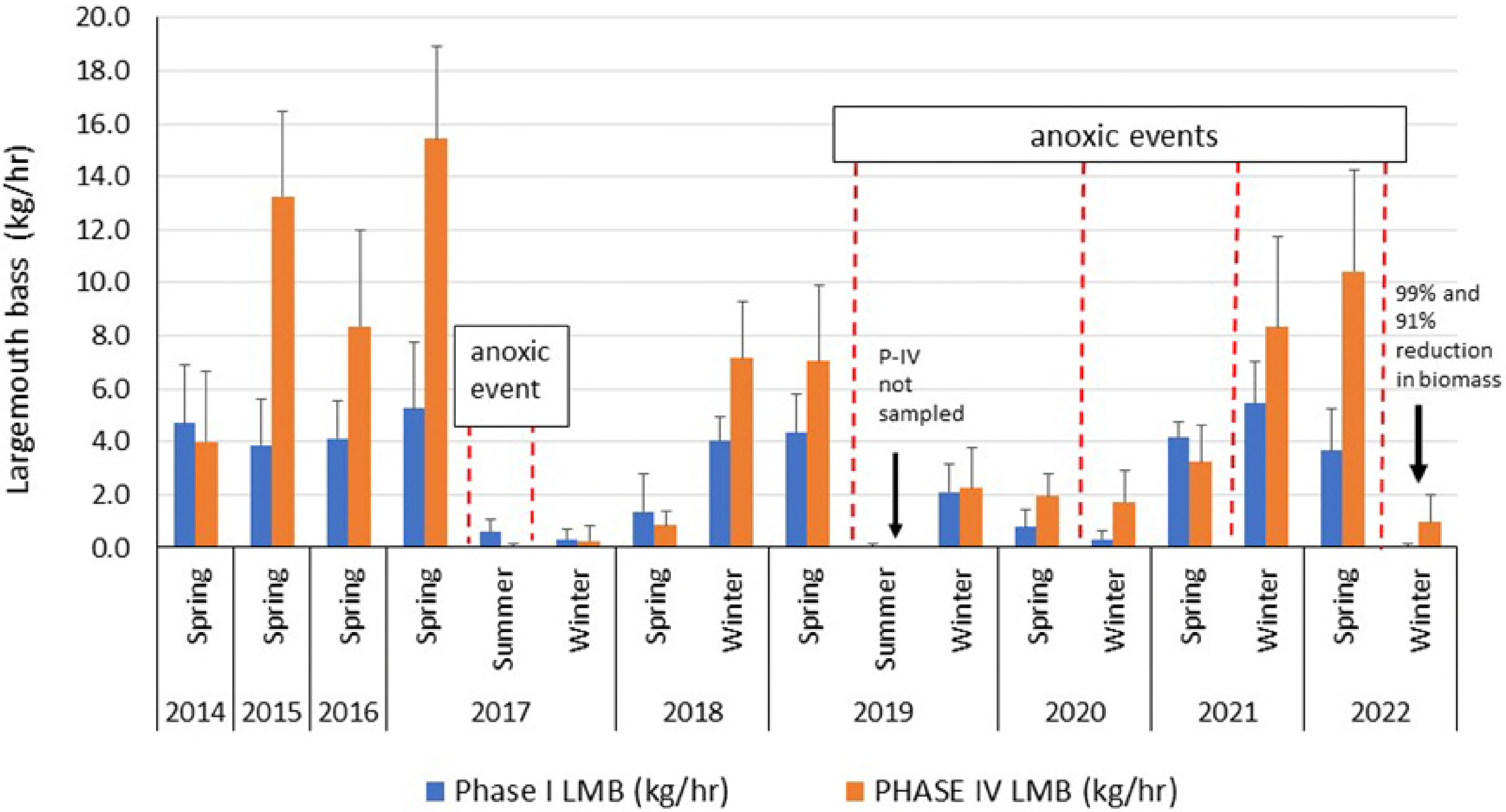


Figure 9-35. LMB biomass (kg/hr ± S.E.) collected in Phase I (blue bars) and Phase IV (orange bars) during spring 2014–winter 2022. Anoxic events of 25 days or more occurred during summer 2015 and 2016, which are not shown on the graph, and in 2017, 2019, 2020, 2021, and 2022.

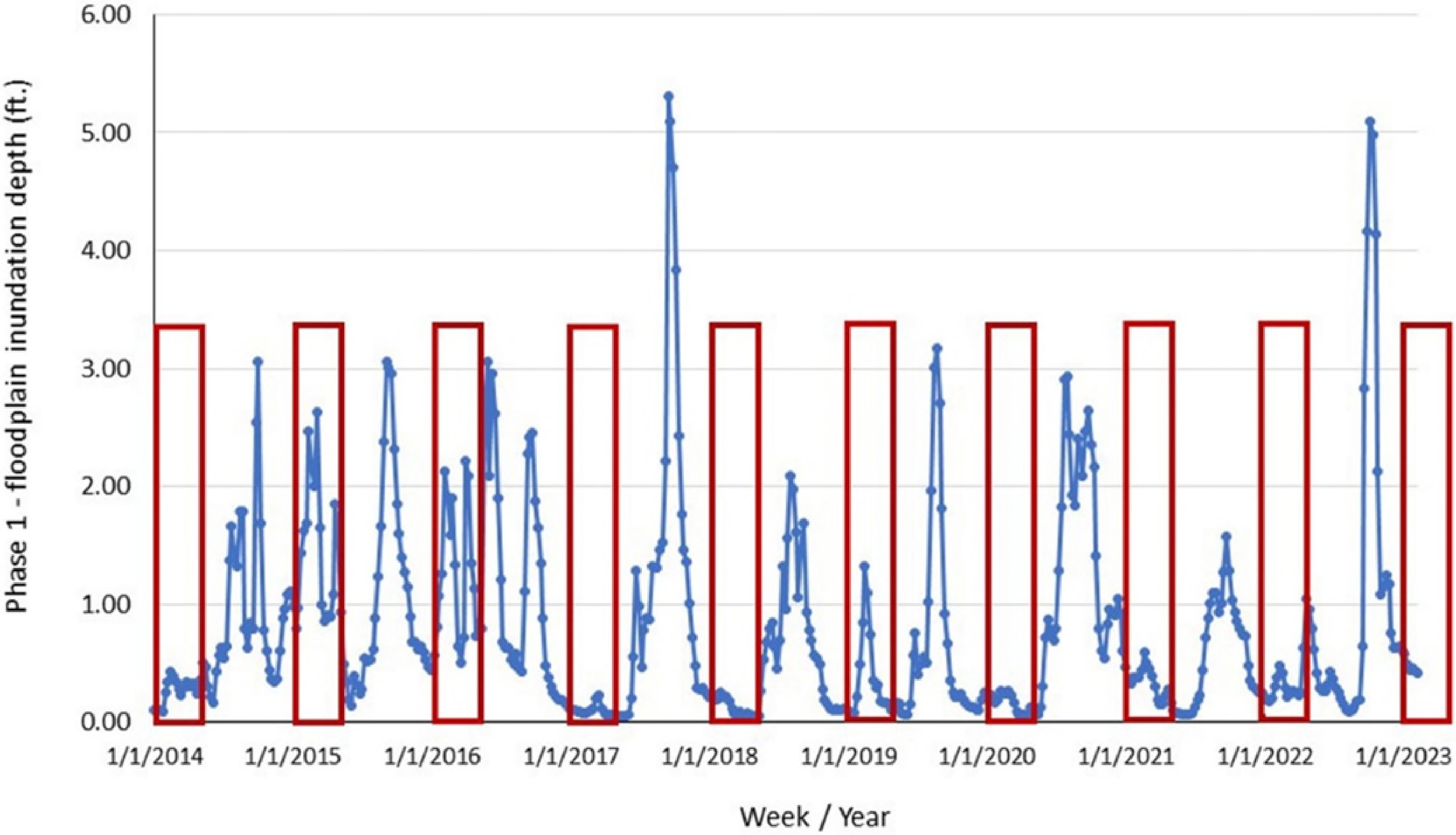


Figure 9-36. Hydrograph (blue line) showing the weekly average inundation depth of the floodplain in Phase I (January 2014–January 2023). Red boxes represent the approximate spawning season of LMB. Inundation depth on the floodplain exceeded 1 ft for at least one month only in 2015 and 2016 and for two weeks in 2019.

WADING BIRDS AND WATERFOWL

Birds are integral to the Kissimmee River ecosystem and highly valued by the public. While quantitative pre-channelization data are sparse, available data and anecdotal accounts suggest 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 support such an assemblage once again. 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 2022-2023 dry season within PW2023 and compare recent data to the KRREP avian restoration expectation targets. Statistical significance was evaluated at $\alpha = 0.05$.

Wading Bird Abundance

> ***Expectation 24***
>
> *[a] 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 or birds/km^2 (3-year running average) and
>
> *[b] at least 85% of the monthly surveys will have ≥ 30.6* 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 2002–2021 = 39.0 ± 3.0 birds/km^2; (**Figures 9-37** and **9-38**). The long-term annual three-year running mean (2002–2023) is 41.4 ± 3.2 birds/km^2, significantly greater than the restoration expectation of 30.6 birds/km^2 (t-test, $p < 0.002$, Williams and Melvin 2005b). Annual three-year running means have been significantly greater than the restoration expectation of 30.6 birds/km^2 in only 6 of the past 19 years of the 2002–2022 survey period. These were 2002–2004, 2003–2005, 2004–2006, 2005–2007, 2018–2020, and the current period of 2021–2023.

Mean monthly wading bird abundance within the restored portions of the river during the 2022-2023 dry season was 100.3 ± 21.9 birds/km^2, bringing the three-year (PW2021–PW2023) running average to 54.0 ± 11.5 birds/km^2, significantly greater than the component (a) restoration expectation of 30.6 birds/km^2 (t-test, $p = 0.03$, **Figure 9-37**). Five of six surveys (83%) in the 2022-2023 dry season recorded ≥ 30.6 birds/km^2, just below the restoration expectation of at least 85%. Unfortunately, no data were collected in November (seventh survey) since the flight was not able to be completed.

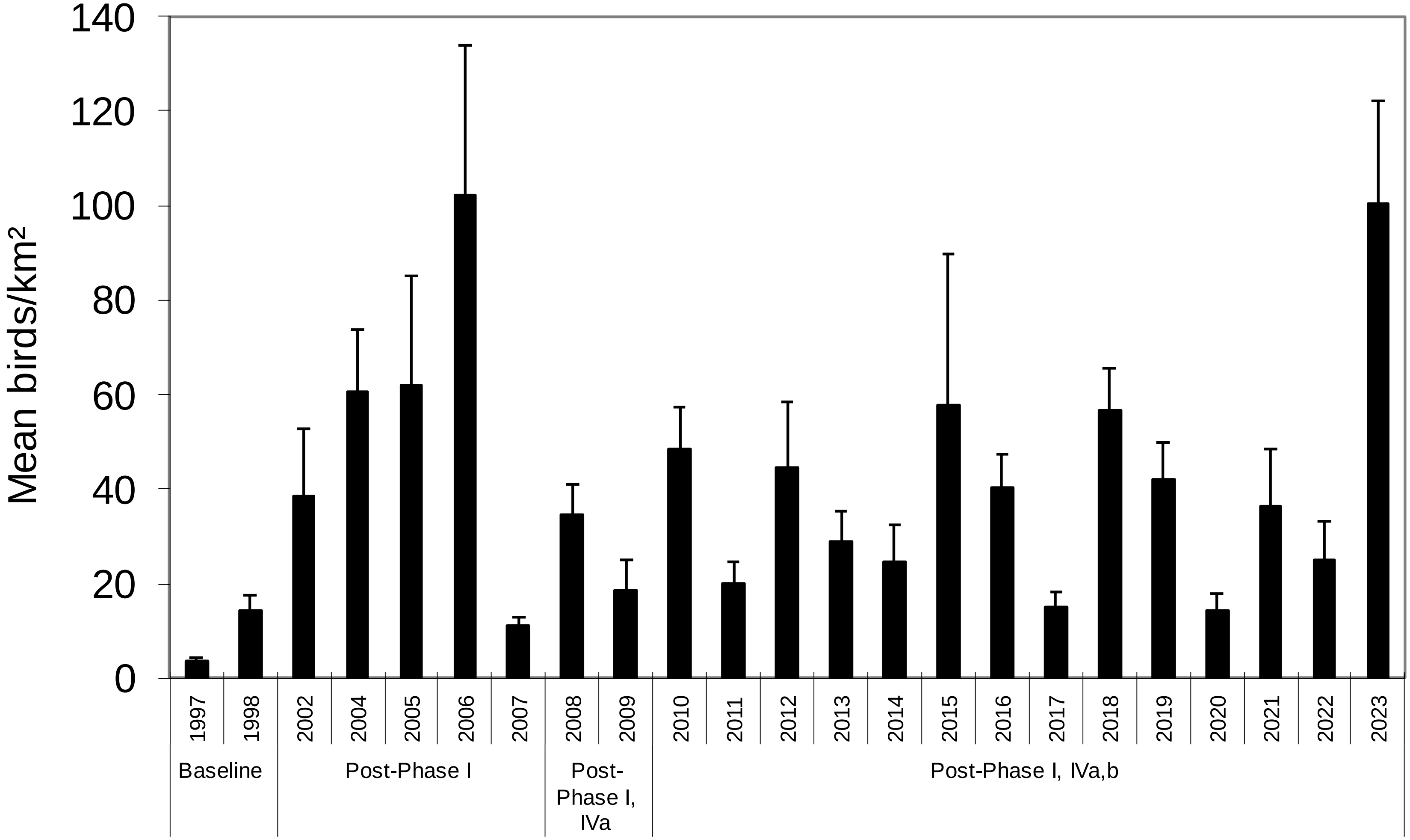


Figure 9-37. Baseline and post-Phases I, IVA, and IVB mean abundance ± SE of long-legged wading birds/km^2, excluding cattle egrets, during the dry season (December–May) within the 100-year flood line of the Kissimmee River.

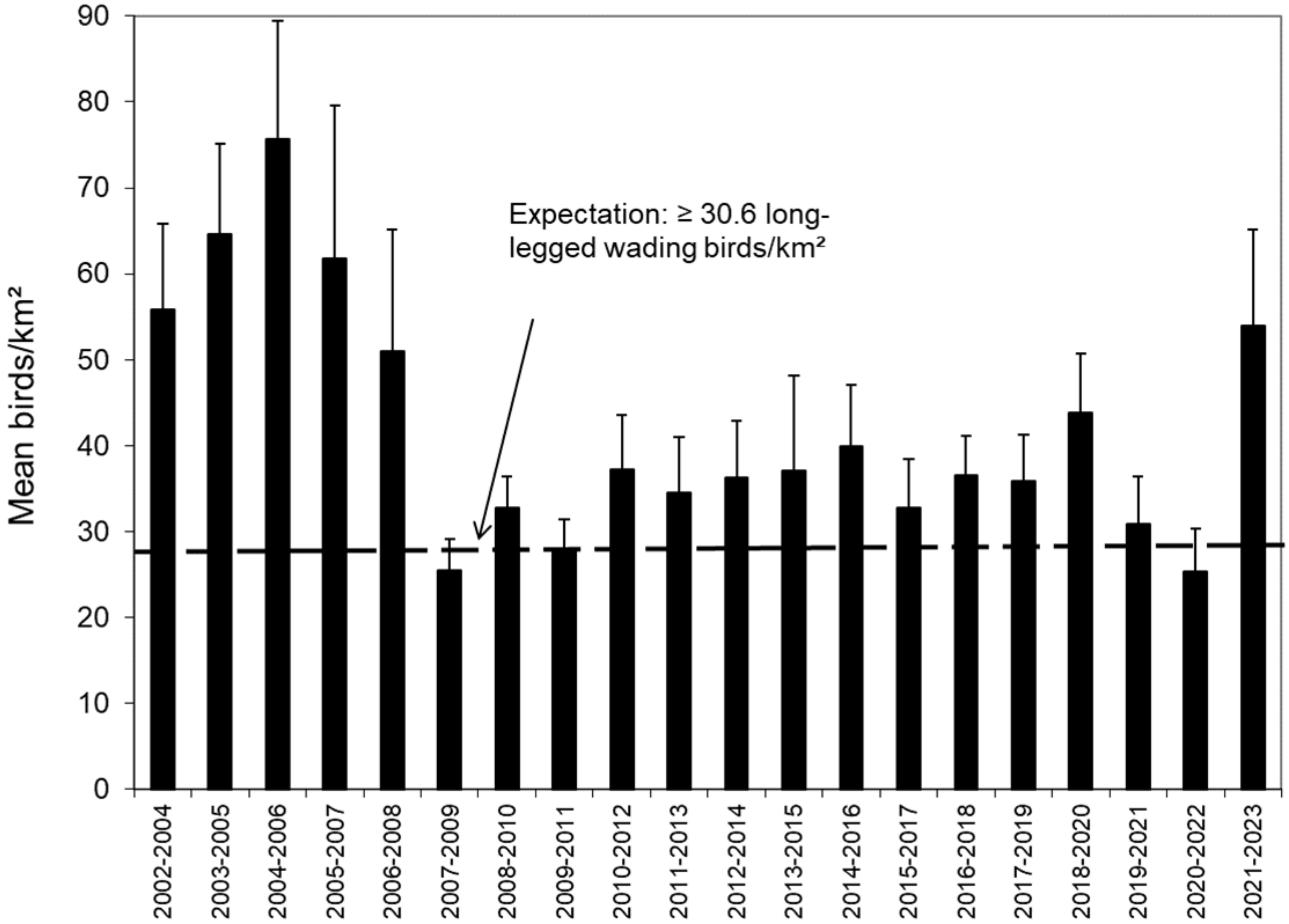


Figure 9-38. Post-restoration abundance as three-year running averages ± SE of long-legged wading, excluding cattle egrets, during the dry season (December–May) within the Phase I, IVA, and IVB restoration areas of the Kissimmee River.

The 2022-2023 wet season was accentuated with Hurricane Ian in late September and Hurricane Nicole in early November, which produced most of the rainfall (116 and 106% in Upper and Lower Kissimmee Basins for the wet season, respectively) and substantial increases in S-65A discharge. This was then followed by below average rainfall during the dry season (69 and 71% in Upper and Lower Kissimmee Basins, respectively). Well above average numbers of wading birds were observed during most of the season following a steady recession of water levels on the floodplain after high inundation the previous wet season that led to optimal foraging conditions. Water levels continued to decline through the May survey, by which time wading bird numbers had declined by approximately 90% from their peak in March, with floodplain water depths averaging approximately 0.1 ft (**Figure 9-39**). During the May survey, very few pools of standing water remained, which likely had already been depleted of prey. However, bird numbers remained above average for most prior dry season surveys, as water levels did not see any ecologically significant reversals (water level increases) of > 0.25 ft on the floodplain (**Figure 9-39**). Without such reversals during the dry season and a sustained wet season, a steady dry down will typically increase prey availability for wading birds by concentrating prey items into shallower depths within an overall smaller surface area of inundation, although under some circumstances prolonged foraging can result in prey depletion.

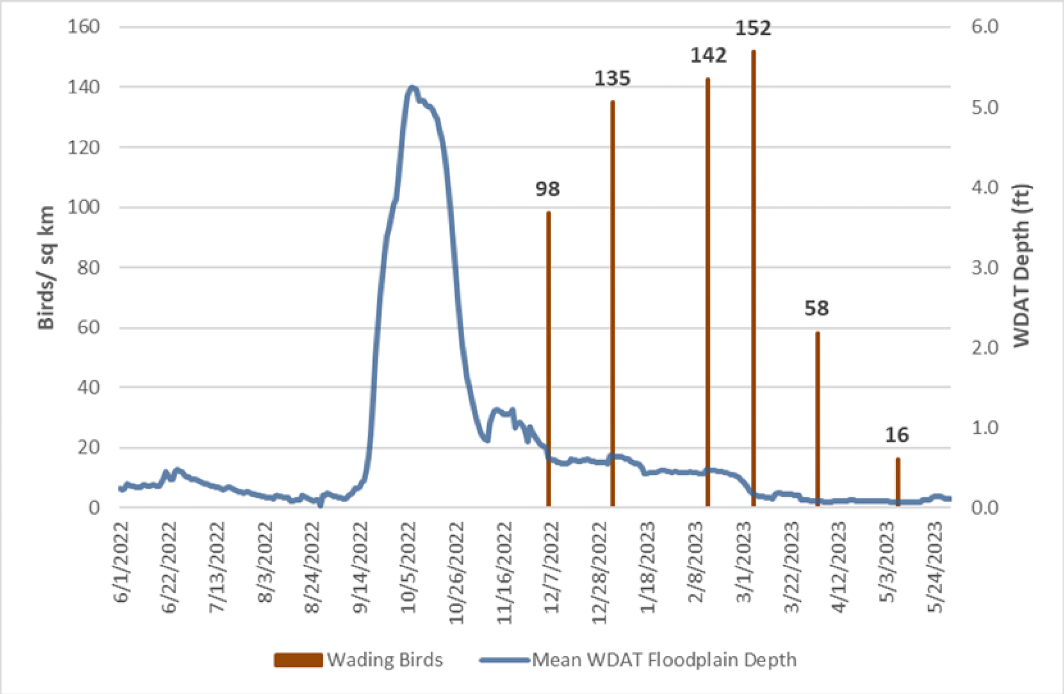


Figure 9-39. Wading bird abundance versus mean floodplain depth in the KRRP area (Phases I, IVA, and IVB) during the 2022-2023 dry season (December–May, the November survey was unable to be completed in PW2023). Floodplain depth is obtained from the South Florida Water Depth Assessment Tool (WDAT; Godin 2012).

As in previous years, white ibis (*Eudocimus albus*) dominated the surveys numerically with a total of 7,624 birds counted across surveys (65.1%), followed in order of abundance by small white herons (snowy egrets [*Egretta thula*] and juvenile little blue herons [*Egretta caerulea*]; 1,511, 13.5%), great egrets (*Ardea alba*; 1,357, 11.6%), glossy ibis (*Plegadis falcinellus*; 514, 4.4%), great blue herons (*A. herodias*; 198, 1.7%), roseate spoonbills (*Platalea ajaja*; 144, 1.2%), small dark herons (tri-colored herons [*Egretta tricolor*] and adult little blue herons; 171, 1.4%), wood storks (*Mycteria americana* 107, 0.9%), and black-crowned and yellow-crowned night herons (*Nycticorax nycticorax* and *Nyctanassa violacea*, 21, 0.2%).

Waterfowl Abundance and Species Richness

Expectation 25

[a] Winter (November–March abundance of waterfowl within the restored area of the floodplain will be ≥ 3.9 ducks per square kilometer or ducks/km^2 (3-year running average) in at least 80% of the monthly surveys, and

[b] waterfowl species richness will be ≥ 11 (3-year species total).

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/km^2 in the Phase I area during the Baseline Period, well below the restoration expectation of 3.9 ducks/km^2. The long-term mean annual 3-year running average (2002–2023) of waterfowl abundance is 12.3 ± 1.4 birds/km^2, significantly greater than the restoration expectation of 3.9 birds/km^2 (t-test, $p < 0.001$) (**Figure 9-40**). Annual 3-year running means were significantly greater than the restoration expectation of 3.9 birds/km^2 in 14 of the past 19 years of the survey period 2002–2023 (t-test, p-values < 0.05). Periods that were not significantly greater than the target value were 2004–2006, 2005–2007, 2006–2009, 2007–2010, 2019–2021, 2020–2022, and the current period of 2021–2023 (**Figure 9-41**).

Waterfowl abundance during the 2022-2023 dry season was 22.6 ± 10.0 ducks/km^2, bringing the 3-year (PW2021–PW2023) running average to 14.0 ± 4.4 ducks/km^2, significantly greater than the restoration target of 3.9 ducks/km^2 (t-test, p-value = 0.02) (**Figures 9-40** and **9-41**). 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 PW2002–PW2023 = 12.3 ± 1.4 birds/km^2). Four of the five monthly surveys (December, January, March, and April; November was not able to be surveyed) during winter 2022-2023 were above the restoration target of 3.9 ducks/km^2 to bring the seasonal average above the restoration target (**Figure 9-42**). This dry season did not meet the secondary restoration expectations species richness of ≥ 11 (3-year species total).

This year, teal (*Anas* sp.; 1,790, 91.4%) was predominately found in large flocks and dominated numerically, followed by significantly lower numbers of mottled duck (115, 8.0%), black-bellied whistling duck (*Dendrocygna autumnalis*; 30, 1.5%), and ring-necked duck (*Aythya collaris*; 8, 0.4%). The 3-year species total for 2021–2023 was 8 species, below the restoration target for waterfowl species richness of ≥ 11 species (3-year species total). Totals numerically may have been greater if the November survey could have been completed.

The American wigeon (*Mareca americana*), northern pintail (*Anas acuta*), and northern shoveler (*Spatula clypeata*) are other species that were not detected during the baseline surveys but they have been present following restoration construction. However, these species are not regularly observed; therefore, the restoration target for waterfowl species richness (≥ 11 species) has yet to be reached on an annual or cumulative basis. Blue-winged teal and mottled duck remain the two most observed species.

Restoration of the physical characteristics of the Kissimmee River and floodplain, along with improvements in the hydrologic characteristics of inflows under 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 KRRP Area 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.

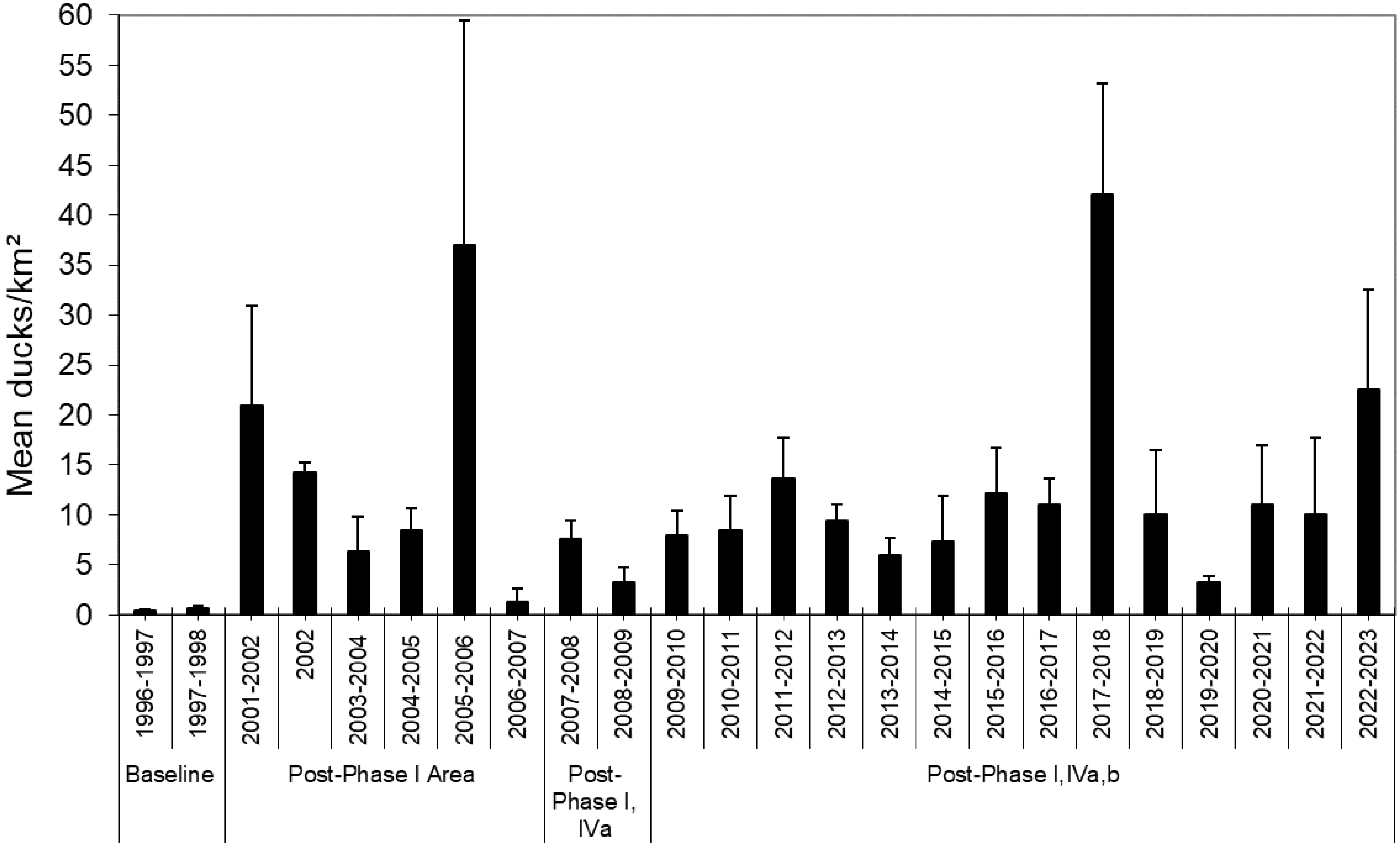


Figure 9-40. Baseline and post-Phases I, IVA, and IVB mean abundance ± SE of waterfowl during winter (November–March) within the 100-year flood line of the Kissimmee River. Baseline abundance was measured in the Phase I area prior to restoration. Measurement of post restoration abundance began approximately nine months following completion of Phase I.

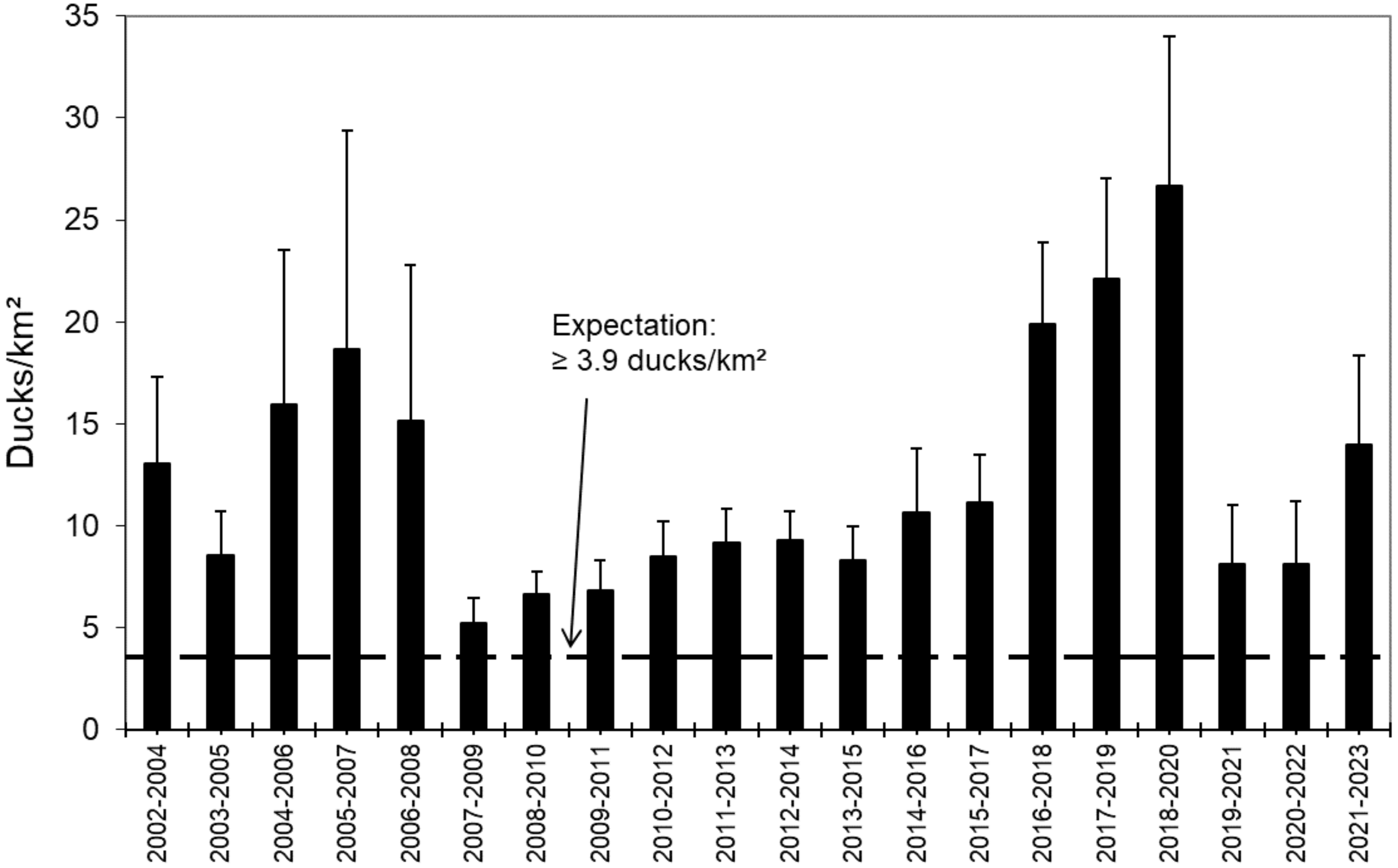


Figure 9-41. Post-restoration abundance as 3-year running averages ± SE of waterfowl (ducks/km^2) during the winter (November–March) within the Phase I, IVA, and IVB restoration areas of the Kissimmee River.

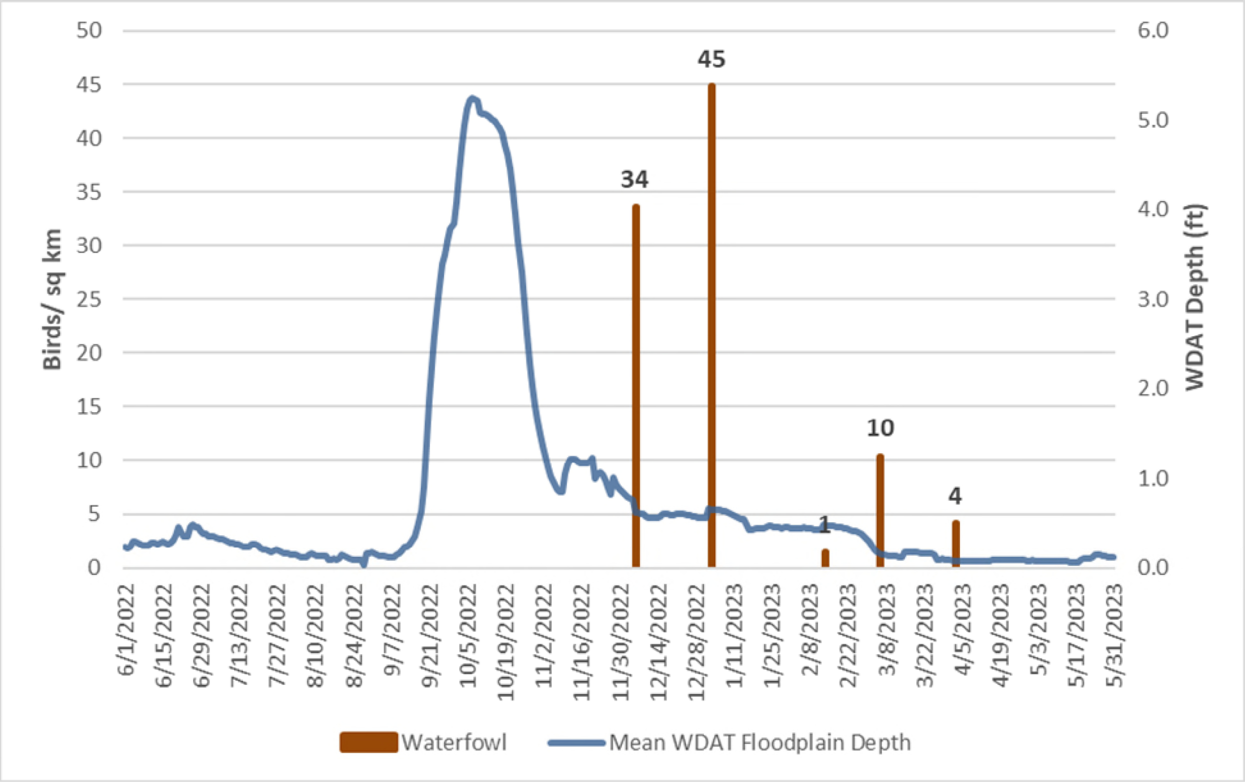


Figure 9-42. Waterfowl abundance versus mean floodplain depth in the KRRP area (Phases I, IVA, and IVB) during the 2022-2023 dry season (December 2022–May 2023, November survey not able to be completed). Source of floodplain depth data is the South Florida Water Depth Assessment Tool (WDAT; Godin 2012).

UPPER KISSIMMEE BASIN

The Kissimmee Chain of Lakes (KCOL) and Upper Kissimmee Basin (UKB) Monitoring and Assessment Project involves data collection, evaluation, and reporting to support SFWMD's mission to manage and protect water resources. The monitoring also contributes to the assessment of the KRRP, which—under HRS—will increase storage in the Headwaters Lakes to improve timing and volume of flow to ensure the ecological and hydrologic success of the KRRP. This portion of UKB monitoring is part of the KRREP, which includes goals for littoral zone improvement in the Headwaters Lakes. 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 KCOL and UKB reporting includes a variety 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 THE UPPER KISSIMMEE BASIN

As the final component of KRRP, the HRS was designed to increase storage in the Headwater Lakes to provide appropriate flow patterns to the restored Kissimmee River and floodplain. KRRP construction was completed in 2021 and agencies are currently evaluating conditions paving the way to adoption of HRS. The increased storage that results due to higher maximum regulatory stages is also expected to improve the quantity and quality of littoral habitat in the Headwater Lakes. The HRS will increase regulatory stages and change the operating schedule for the S-65 structure, which controls discharge from and stage in 3 major water bodies in the KCOL, including Lakes Cypress, Hatchineha, and Kissimmee (USACE 1996), together known as the Headwaters Lakes (**Figure 9-2**).

Fisheries

The KCOL fishery is monitored by FWC via electrofishing and creel (angler) surveys. On the two lakes most important to anglers, Lakes Kissimmee and Tohopekaliga, annual sampling includes electrofishing surveys in the fall (fish community) and spring (LMB), and creel (angler) surveys conducted from January through May. Fall surveys provide community data with number of fish per functional group, which are black crappie, catfish, exotic species, small forage fish, LMB, rough fish, and sunfish. Spring surveys provide an assessment of the size distribution and relative abundance of LMB populations. Creel surveys have been conducted on Lake Kissimmee since 2011 and Lake Tohopekaliga since 2018. In addition, smaller lakes are also periodically sampled in the spring. This report includes results from fall and spring 2022 on Lakes Kissimmee and Tohopekaliga, and spring 2022 on Lakes Cypress and Hatchineha.

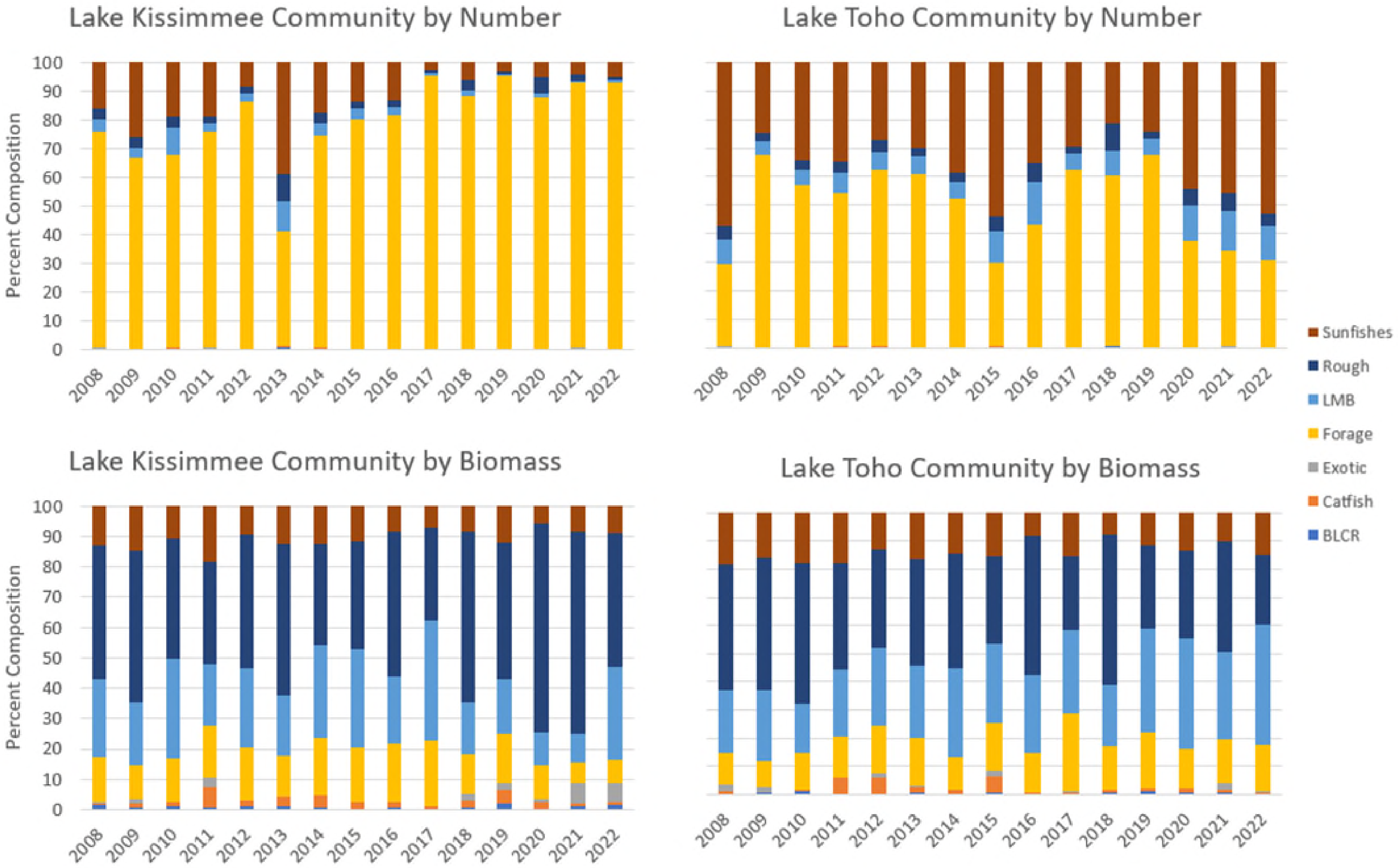
Electrofishing Surveys

Electrofishing surveys use a standardized sampling protocol first implemented in 2006 where random transects near shorelines are sampled for 15 minutes each for LMB samples and 10 minutes each for fish community samples. A total of 25 transects each were sampled on Lakes Kissimmee, Tohopekaliga, and Hatchineha and 19 transects on Lake Cypress.

Lakes Kissimmee and Tohopekaliga

On Lake Tohopekaliga, the fish community has always been numerically dominated by sunfish (i.e., bream) and forage fish, while forage fish are generally the dominant group on Lake Kissimmee (**Figure 9-43**). The forage fish category is comprised of a variety of fish families but is dominated by small-bodied fishes (e.g., minnows [Cyprinidae], live bearers [Poeciliidae], and shad [Cluepeidae]); as the name implies, this group is an important component of lake food webs, sustaining predators and other fish.

The fish community biomass has always been dominated by rough fish, primarily Florida gar (*Lepisosteus platyrhincus*) and bowfin (*Amia calva*) (**Figure 9-43**). These data vary annually, yet appear typical to a complex, Central Florida lake system (Bachmann et al. 1996). Gamefish include the complex of sunfish, LMB, black crappie, and catfishes (channel catfish [*Ictalurus puntatus*] and bullheads [*Ameiurus* spp.]). Additionally, non-native fishes continue to make up small portions of the fish community both by number and biomass. Non-native fish include armored sailfin catfish species (*Pterygoplichtys* spp.), brown hoplo (*Hoplosternum littorale*), blue tilapia (*Oreochromis aureus*), and Mayan cichlid (*Mayaheros urophthalmus*).



Lake Kissimmee Community by Number

Lake Toho Community by Number

Lake Kissimmee Community by Biomass

Lake Toho Community by Biomass

Figure 9-43. Fish community structure by number (total percent of all fish sampled annually; top) and biomass (total percent of all fish sampled annually by weigh, bottom). (Note: BLCR – black crappie, LMB – largemouth bass, and Toho – Tohopekaliga.)

On Lake Kissimmee, overall gamefish composition (by number and/or biomass) are at or near historical low values, particularly sunfish and LMB populations (**Figure 9-43**). Both sunfish and LMB show declines beginning in fall 2017; LMB biomass increased in 2022, which may support results from catch rates discussed below. The LMB average composition (by number) during the 2006–2016 period was 4.47%, which fell to 1.05% during the 2017–2021 period. The sunfish average during the 2006–2016 period was 20.27%, which fell to 4.17% during the 2017–2021 period. In contrast, gamefish and non-gamefish communities on Lake Tohopekaliga appear balanced both in number and in biomass.

Catch rates for adult LMB (> 2 years old) on both lakes were within the range of historical averages since standardized sampling began in 2007 (**Figure 9-44**). However, on Lake Kissimmee, catch rates for age-2+ LMB have been variable since 2017, ranging from 6 to 10 bass per sample, and catch rates for presumed age-1 bass have been consistently low since 2017. There was a slight increase in catch rates of age-1 bass in 2022 to near historical averages, yet it is too early to quantify recruitment to larger sizes. The low recruitment is likely a main cause of the variable catch rates of age-2+ bass. A probable cause of these low recruitment rates is lack of habitat. Coverage of subsurface vegetation (SV) decreased by half from 2015 to 2019 and has remained low since (**Figure 9-45**). Since 2017, SV coverage has decreased by approximately 10%. SV is not the same as SAV; SV can be SAV or emergent aquatic vegetation but excludes floating mat species. SV coverage is estimated by FWC.

Catch rates for age-1 and age-2+ LMB have been variable in Lake Tohopekaliga (**Figure 9-44**) where SV consistently covers > 50% of the lake, which likely promotes high survival of young bass (higher recruitment). Although this level of vegetation can support a robust bass fishery, too much SV for extended periods can cause problems with the bass fishery as well. The abundance of habitat promotes survival of juvenile bass, which in turn creates competition for the lake’s resources. High levels of vegetation have been known to have impacts on overall growth of bass populations and can create a fishery with a high abundance of small bass, limiting the production of larger bass that important to the fishery.

Lakes Cypress and Hatchineha

Lake Cypress had moderate catch rates of LMB (16.5 ± 1.73 bass per transect; mean ± SE). The Lake Cypress bass sample (n = 314) was dominated by presumed age-1 bass (< 230 millimeters) and low catches of large fish (> 409 millimeters; **Figure 9-46**). Lake Cypress has abundant SAV, which likely promotes bass recruitment but may reduce growth to larger sizes, resulting in high abundance of small to medium sized bass (**Figure 9-46**).

Lake Hatchineha LMB catch rates (13.16 ± 8.60 bass per transect) increased from 2020 (7.24 ± 0.998) indicating that the fishery became more stable in 2022. The sample length-frequency was bimodal with the first peak representing presumed age-1 bass (< 23 centimeters TL). Overall size distribution was well represented for Lake Hatchineha, rather than being dominated by 30- to 40-centimeter bass with very few large fish as in 2020. (**Figure 9-46**). Unlike Lakes Cypress and Tohopekaliga, Lake Hatchineha has a moderate level of SV (mean annual coverage is 21%), but a large portion of the vegetation is limited to a single, dense area in the northeastern part of the lake (**Figure 9-45**).

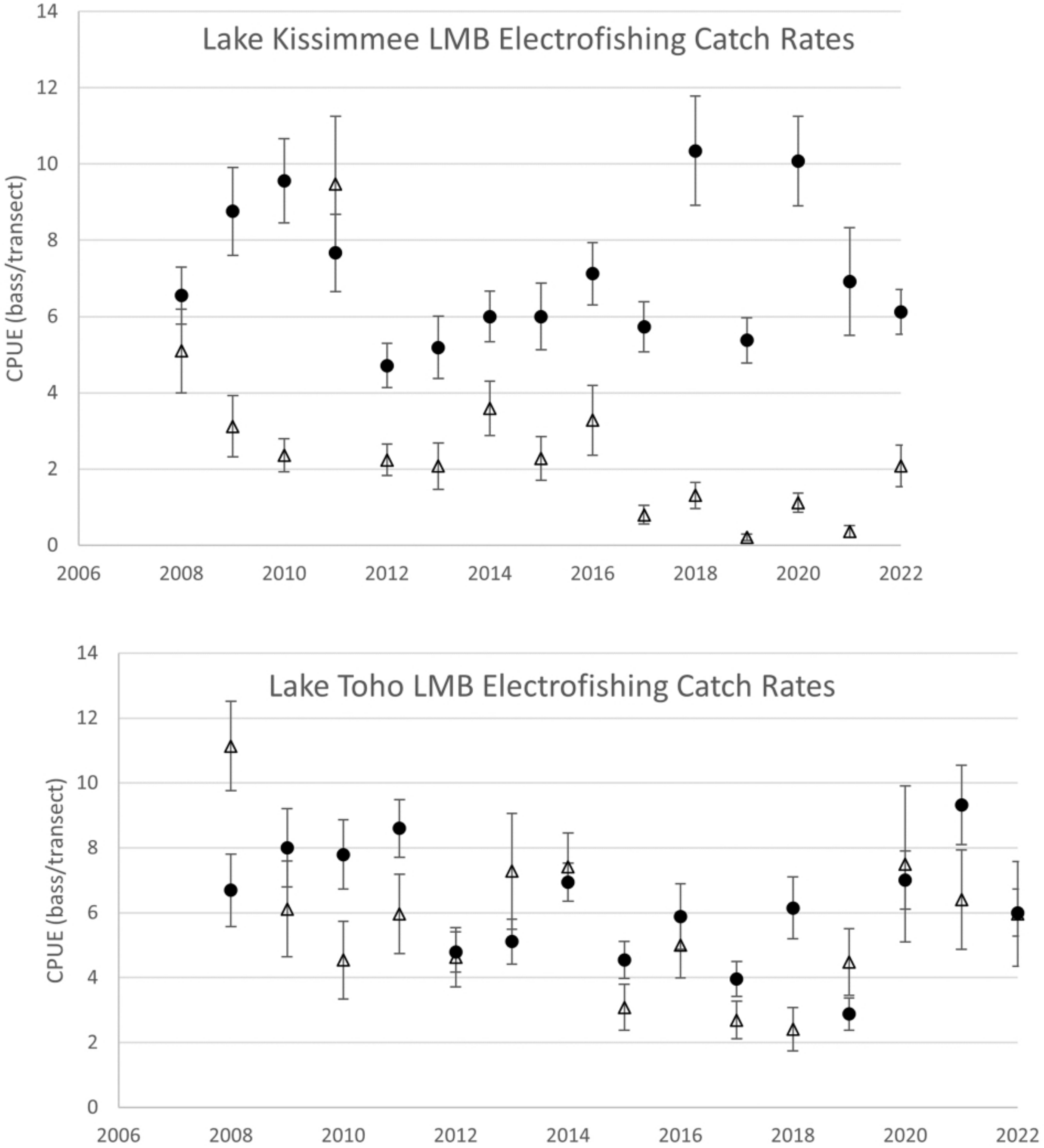


Figure 9-44. Electrofishing catch rates on Lakes Kissimmee and Tohopekaliga or Toho (2008 to 2022). Presumed age-1 bass (< 230 millimeters) are denoted by white triangles and presumed age-2+ bass (≥ 230 millimeters) are denoted by black circles. SE is denoted by error bars for each year.

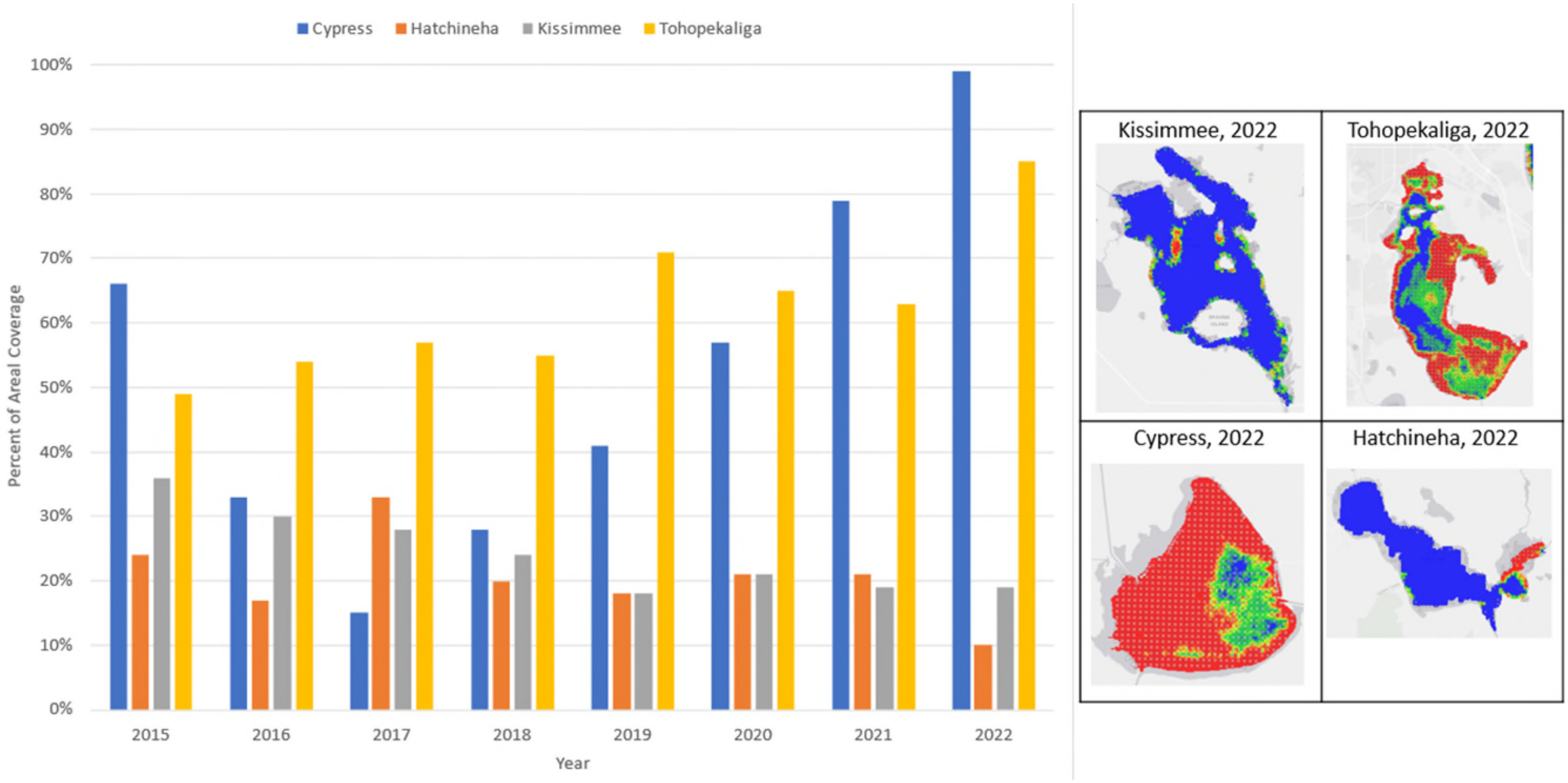
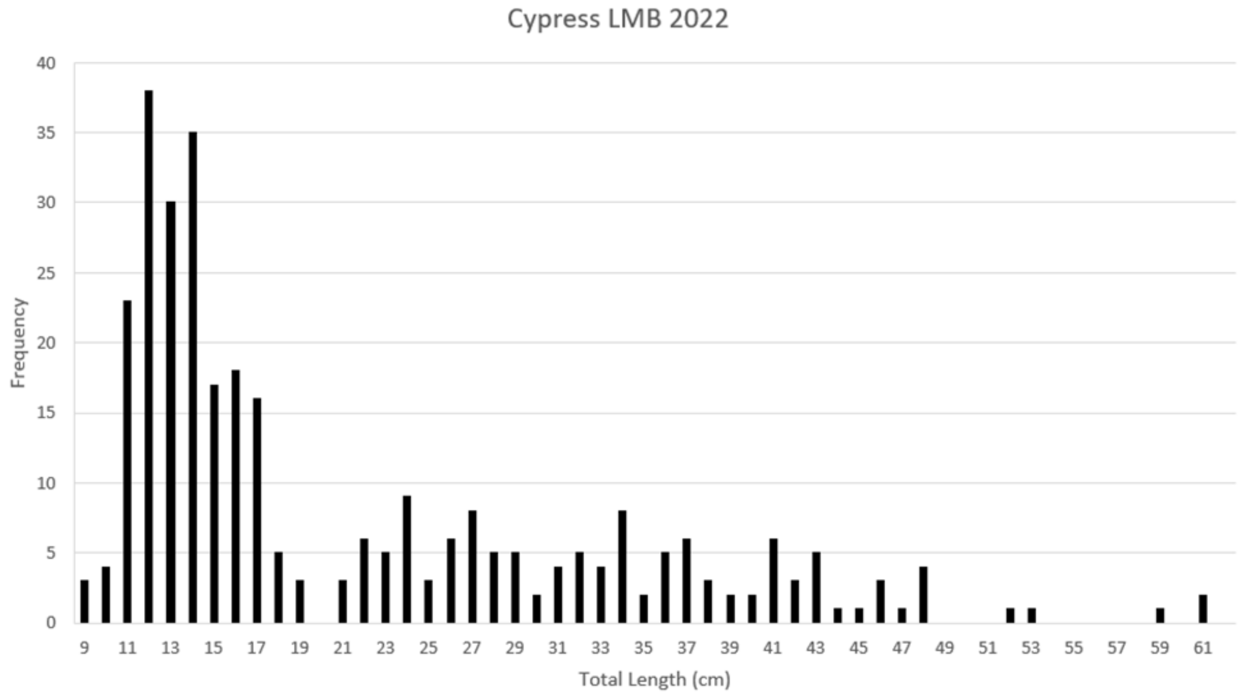


Figure 9-45. Percent areal coverage of SV on Lakes Kissimmee, Tohopekaliga, Cypress, and Hatchineha 2015–2022. Accompanying maps show each lake with SV in red (high density) and green (low density) and open water in blue. Lakes are not shown to scale.



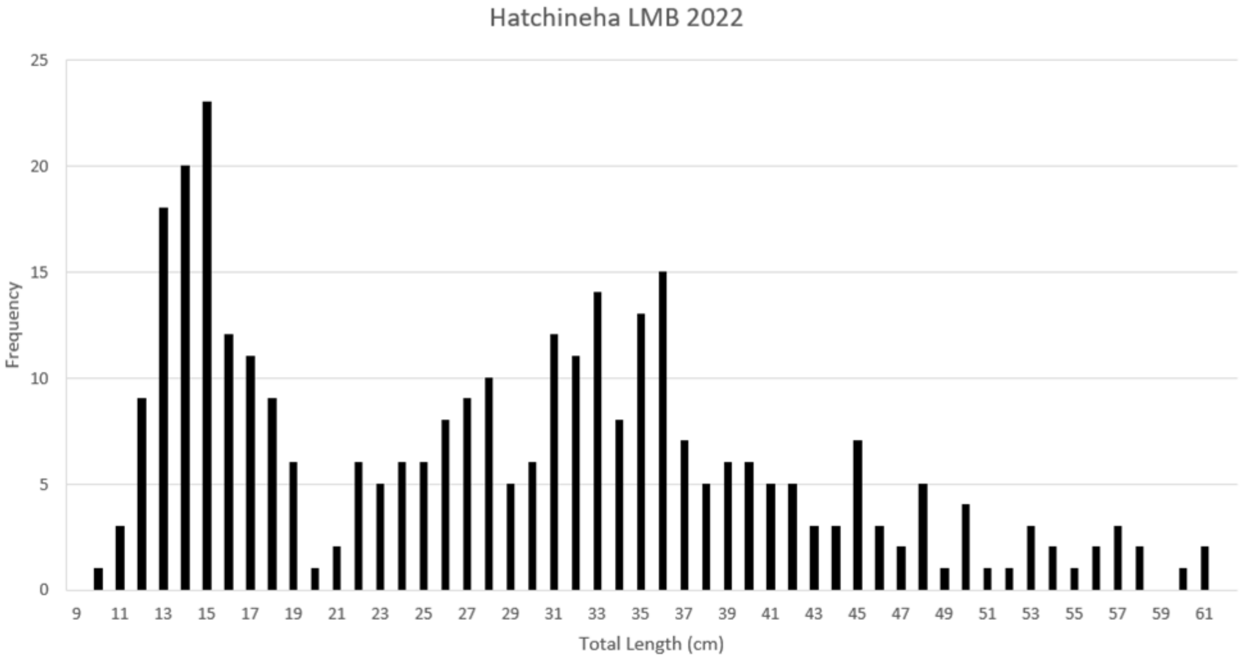


Figure 9-46. Distribution of length of LMB sampled at Lakes Cypress and Hatchineha in spring 2022.

Creel Surveys on Lakes Kissimmee and Tohopekaliga

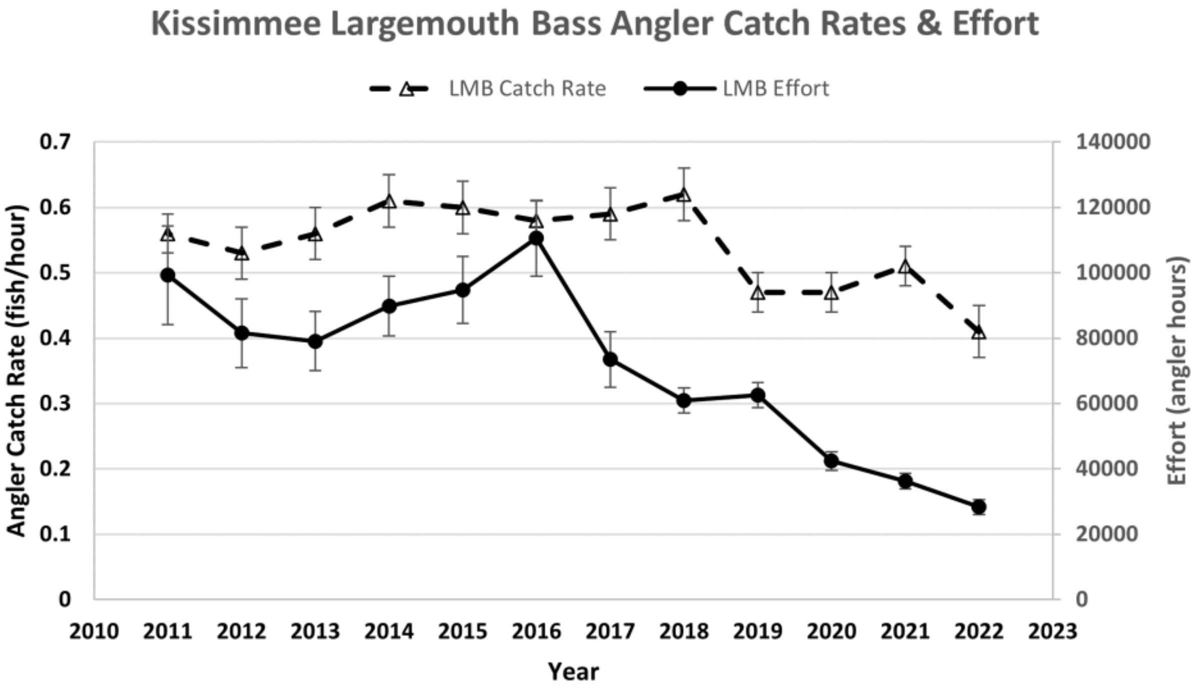
Peak season creel surveys (November–May) have been conducted on Lake Kissimmee since 2011 and Lake Tohopekaliga since 2018. The goal is to estimate angler effort (number of hours spent fishing and for each fish species) and angler catch rates (how many fish caught or harvested per hour or fish/hr). The survey is designed to coincide with the majority of black crappie and LMB spawning seasons, when angler use tends to be highest. In 2022, the lowest estimated total effort was recorded at Lake Kissimmee, 78,242 ± 4,239 hours (mean ± SE). There has been a marked decrease from 2011–2016 (150,000 hours) and from the 2010 high of > 207,000 hours (**Figure 9-47**). Total angler effort on Lake Tohopekaliga, for comparison, has stayed relatively stable in the past four years, ranging from 50,000 to 68,000 hours.

LMB effort on Lake Kissimmee has steadily declined since 2016, declining to a historical low in 2022 (28,384 ± 2,282). Following suit, angler catch rates declined in 2019 and have remained suppressed (**Figure 9-47**). It is unknown why angler effort is decreasing but is likely due to multiple factors including the decrease in catch rates and loss of angler preferred fishing habitats (SAV beds). Although not as drastic as bass, black crappie effort appears to be slowly declining as well. While crappie effort is declining, harvest rates appear to be somewhat stable (although variable). On Lake Tohopekaliga, LMB catch rates have remained high (> 0.8 fish/hr) since 2019 and peaked at 1.04 fish/hr, which represents an above average bass fishery (**Figure 9-48**). In 2022, bass catch rates dipped below 0.8 fish/hr for the first time since 2018 (0.74 ± 0.04 fish/hr), possibly due to the high levels of dense vegetation limiting angler success (Figure 9-**45**). As an indicator of declining lake conditions, this trend is a concern for management agencies and should continue to be monitored. Black crappie effort, meanwhile, is usually low compared to other popular crappie fisheries. Total angler hours for crappie are generally below 3,000 hours but peaked in 2020 with 4,365 hours. Black crappie harvest rates can be high but are also variable ranging from 1.8 to 3.1 fish/hr.

Many of the declines in the Lake Kissimmee fishery occurred after Hurricane Irma, which impacted much of Central Florida in September 2017. The direct and indirect effects have been documented in FWC's long-term monitoring of the lake and in this chapter in the 2022 SFER including plant community losses on Lake Kissimmee, namely decreases in deep-water grasses, floating leaf, and BLM communities (Koebel et al. 2022). Hurricane Irma, and perhaps other unmeasured factors, appear to be having long-term impacts on Lake Kissimmee (see also Chapter 8B of this report for similar effects on Lake Okeechobee). While cause for concern, there are signs that conditions are at least not declining further. Vegetation coverage, bass recruitment, and bass catch rates all declined sharply after the hurricane but have since stabilized. Current rates of LMB recruitment (**Figure 9-44**) suggest that catch rates (both electrofishing and angler) for adult LMB will likely decline over the next few years if improvements in do not occur.

Once recognized nationally as a premier bass fishery, the current state of Lake Kissimmee no longer supports the robust fishery that once existed. FWC is engaging with SFWMD and USACE to seek opportunities for habitat improvement (SAV and deep-water grasses) for bass, specifically through large-scale management actions (i.e., drawdown). Increases in habitat will promote recruitment, which should translate to increased fishing effort.

Lake Tohopekaliga, on the other hand, has consistently high coverage of SV (**Figure 9-45**) that supports LMB recruitment (**Figure 9-44**). However, these high levels of vegetation may be affecting growth and the number of large, quality, and trophy size fish in the population. Angler catch rates for LMB in Lake Tohopekaliga are well above average (**Figure 9-48**) yet bass angling effort has not increased; though effort is affected by many conditions independent of the fishery (economy, travel, COVID, etc.). Other fisheries, like black crappie (and anecdotally bream sunfish) may also benefit from decreased SAV and a better balance of the vegetation community. Overall, the Lake Tohopekaliga fish community composition is well-balanced, with an abundance of forage for sportfish and low levels of non-native fish.



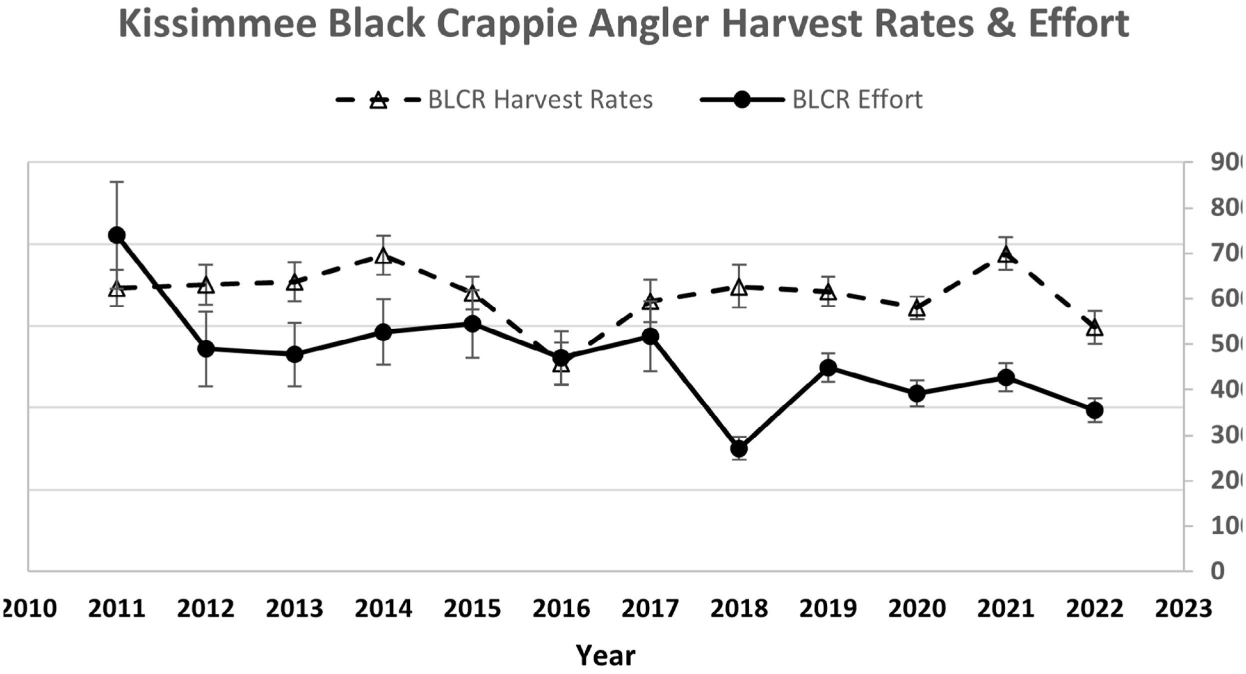


Figure 9-47. LMB (top panel) and black crappie (bottom panel) catch rates and effort for Lake Kissimmee.

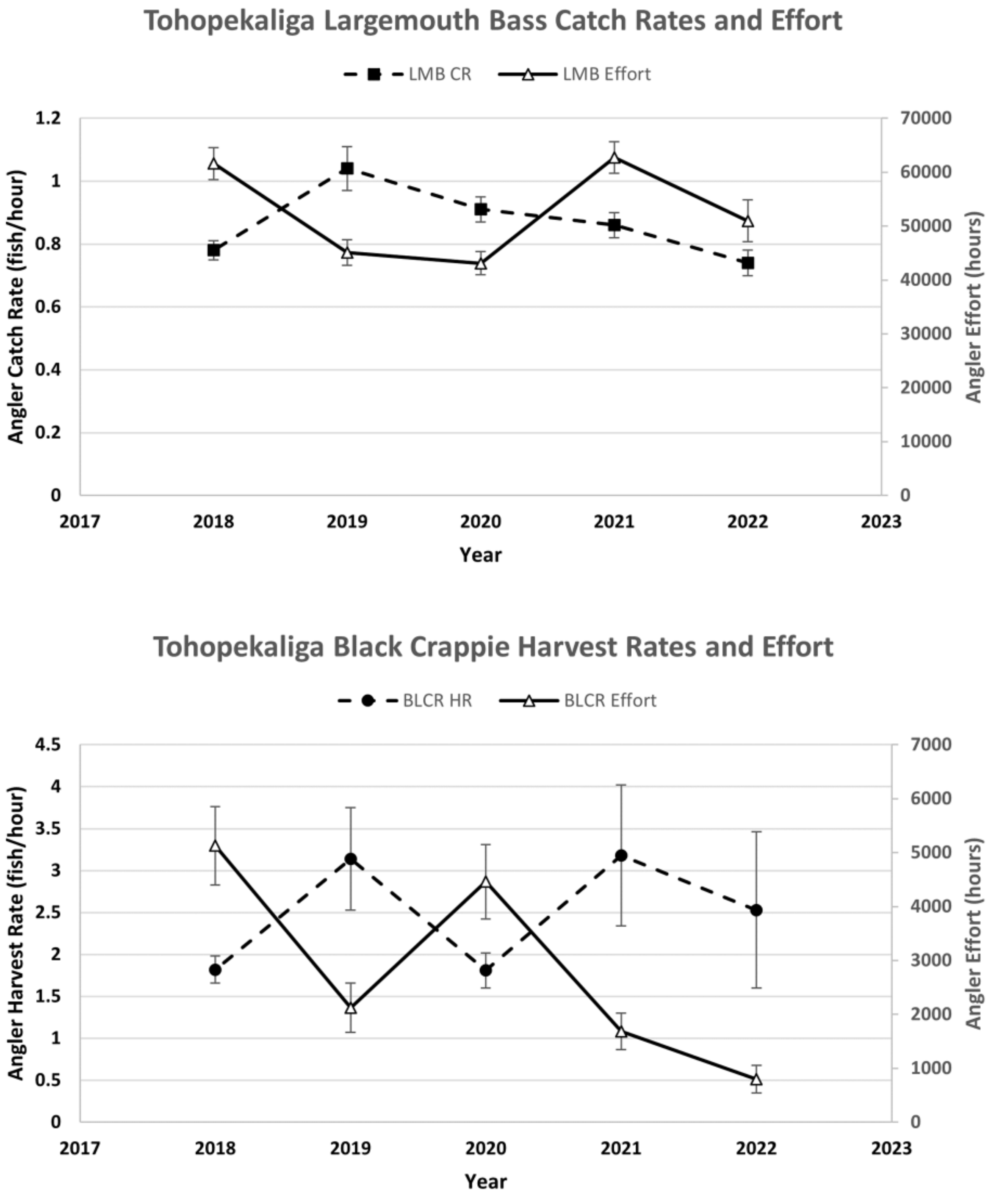


Figure 9-48. LMB (top panel) and black crappie (bottom panel) catch rates and effort for Lake Tohopekaliga.

As on Lake Tohopekaliga, the high amount of SV (**Figure 9-45**) on Lake Cypress appears to promote high LMB recruitment (**Figure 9-46**). Lake Hatchineha generally lacks vegetation (**Figure 9-45**), which probably limits LMB recruitment (**Figure 9-46**). There are no angler surveys at Lake Cypress and Hatchineha, so all catch information is anecdotal from local biologists. Lake Cypress can produce good numbers and size of bass but often the lake receives little fishing pressure of any kind. Lake Hatchineha receives very low effort, probably the lowest per acre than any other lake in the KCOL.

Conclusions

The LMB fishery at Lake Kissimmee has shown significant declining trends since 2017. The overall decrease in habitat (e.g., vegetation) during this time has led to low recruitment of LMB, which in turn leads to lower catches of adult bass by biologists and anglers. There was a slight increase in electrofishing catch rates of juvenile bass, but it is too early to tell if this will lead to long-term increases in LMB abundance. Angling effort and catch rates for LMB have continued to decline following the trends in relative abundance. It is unlikely that Lake Kissimmee will return to its once famed state as a major LMB fishery without major habitat changes. The black crappie angler catch, often overshadowed by the decline in LMB, remains high, yet angler effort appears to be declining for unknown reasons.

Lake Tohopekaliga has had almost directly opposite trends of Lake Kissimmee. Prior to 2017 hurricanes, there was a high coverage of SAV, minimizing some of the habitat impacts. Since then, SAV and other deep-water vegetation has continued to recover and expand throughout the lake. General increases in both juvenile and adult LMB have been attributed by lake managers to increases in habitat. The recent increases in juvenile abundance will likely be seen in the fishery metrics in coming years. Interestingly, the angler catch and effort have not significantly increased with the LMB abundance. There could be many factors for this but one may be that high levels of vegetation make both access and fishing success more difficult for anglers. Lake Tohopekaliga has never been a destination for black crappie anglers and with recent years of high levels of vegetation, these anglers are now almost non-existent.

Snail Kites

Statewide snail kite nesting effort, distribution, and population size are systematically monitored by the University of Florida on an annual basis (see Fletcher et al. 20202 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 record nesting information; including the location, status (incubating, nestlings, failed, or successful, or unknown), 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.

Please note, although the focal snail kite nesting season is March through June, in most years at least some nesting activity occurs outside of this time at multiple areas across the state and does not align with the traditional water year and planning window timeframes. Therefore, this section refers to the 2022 snail kite nesting season, December 2021 through November 2022.

In 2022, survey crews located a total of 444 active nests (i.e., containing eggs or nestlings) throughout the snail kite's Florida range (**Figure 9-49A**). This represents a decrease in nesting effort from 2021 (585nests), but is roughly equal to the 10-year average (432 nests). There were 68 kite nests documented in the KCOL in 2022, well below the 10-year average of 110 nests per year. Nesting in the KCOL made up only 15% of the statewide snail kite nesting effort in 2022 (**Figure 9-49C**), like 2021, and its lowest contribution since at least 2006. This low contribution of nesting effort in the KCOL is mostly attributed to the high nesting effort in Payne's Prairie (48%).

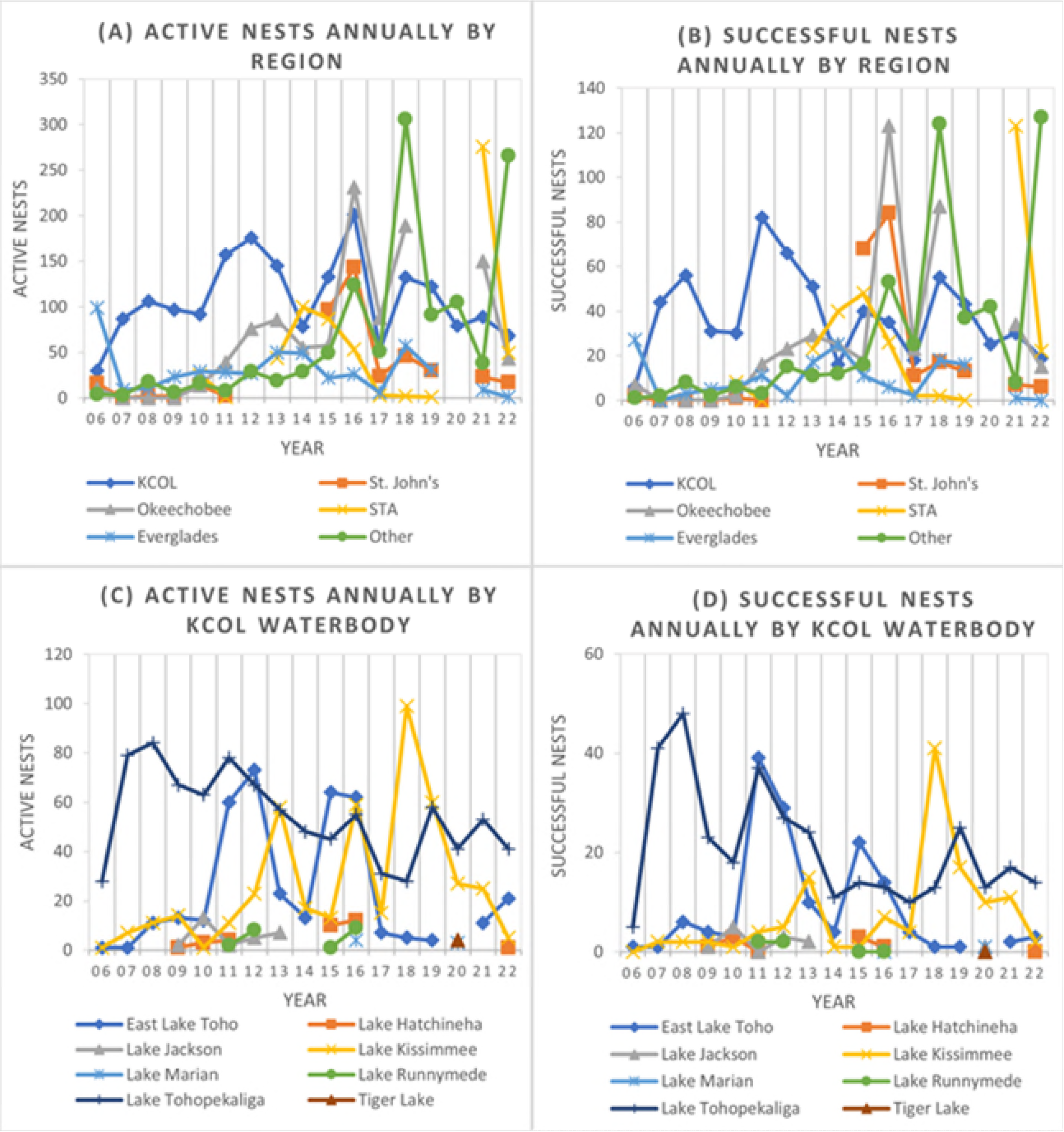


Figure 9-49. (A) Active snail kite nests for each region from 2006 to 2022 and (B) the total number successful for each region. (C) Active snail kite nests for each major water body in the KCOL, and (D) the total number successful from 2006 to 2022 in the KCOL.

Lake Okeechobee had average water levels in 2022 and below average nesting effort after a high effort year in 2021. There was a total of 43 snail kite nests (10% of statewide effort) documented on Lake Okeechobee in 2022 (**Figure 9-49A**). Kites nested in relatively new impoundments in big numbers in 2021 (48%) but effort in impounded wetlands like stormwater treatment areas (STAs) greatly decreased in 2022 (48 to 11%). The C-44 and Lake Hicpochee impoundments each had kite nesting in 2022. Nesting in the Everglades region has been very low or non-existent since 2019. There was only one nest attempt documented in the Everglades region in 2022 in Everglades National Park. In the Other region, kites returned to nest in large numbers in Payne's Prairie (214 nests, 48% of statewide effort). Also in the Other region, kites nested in Hungryland Wildlife Management Area (2 nests), the KRRP area (12 nests), Lake Istokpoga (12 nests), Harn's Marsh (20 nests), and Lake Parker in Polk County (1 nest). There were five kite nests documented along the Withlacoochee River for the first time; unfortunately, none were successful.

Within the KCOL, there were 21 nests located at East Lake Tohopekaliga (5% of the statewide nesting effort), 41 nests located on Lake Tohopekaliga (9% of the statewide nesting effort), one nest (< 0.01% of the statewide effort) at Lake Hatchineha, and five nests (1% of the statewide nesting effort) on Lake Kissimmee in 2022 (**Figure 9-49C**). Of the 68 nests in the KCOL, 19 nests (28%) were observed to be successful (**Figure 9-49D**).

In summary, snail kite nesting was high in Payne's Prairie and low in the KCOL and elsewhere. Nesting effort was below average in the KCOL and the contribution to statewide nesting was at its lowest percentage in recent record. The consistency of nesting in the KCOL supports its importance to the overall kite population in Florida. We also continue to see non-traditional nesting areas play a significant role in statewide snail kite nesting, particularly in 2022 with nearly half of all nests occurring in Payne's Prairie, in contrast to nearly the same percentage last year in impounded wetlands.

Alligators

FWC conducts American alligator (*Alligator* mississippiensis) monitoring studies in many public water bodies throughout the state to estimate relative abundance of their populations (Hutton and Woolhouse 1989). See Koebel et al. (2021) for details on methods and analyses.

Lake Kissimmee

Total alligator population estimates on Lake Kissimmee have continued to stay stable in recent years. The 2022 estimated population was 13,763 alligators, an increase of approximately 179% since population monitoring began in 1991 (**Figure 9-50a**). The estimated number of juvenile (1 to 4 ft) alligators was 8,494 individuals, a 366% increase over the 1991 estimated population. The adult (6 ft and larger) portion of the alligator population also increased and was estimated at 2,575 individuals, a 5% increase since 1991.

Lake Tohopekaliga

Alligator population estimates on Lake Tohopekaliga have continued to stay stable as well. The 2022 estimated population was 6,639, an increase of 166% since population monitoring began in 1994 (**Figure 9-50b**). The estimated number of juvenile (1 to 4 ft) alligators was 4,460 individuals, a 266% increase over the 1994 estimated population. The adult (6 ft and larger) portion of the alligator population also increased and was estimated at 2,291 individuals, a 221% increase over the 1994 estimated population.

East Lake Tohopekaliga

Total alligator population estimates on East Lake Tohopekaliga have remained relatively stable. The 2022 estimated population was 124 alligators, like estimates (increase of 22%) when population monitoring began in 2003. The estimated number of juvenile (1 to 4 ft) alligators was 29 individuals, a 33% decline from the 2003 estimated population. The adult (6 ft and larger) portion of the alligator population was 45 individuals, a 17% decrease from the 2003 estimated population.

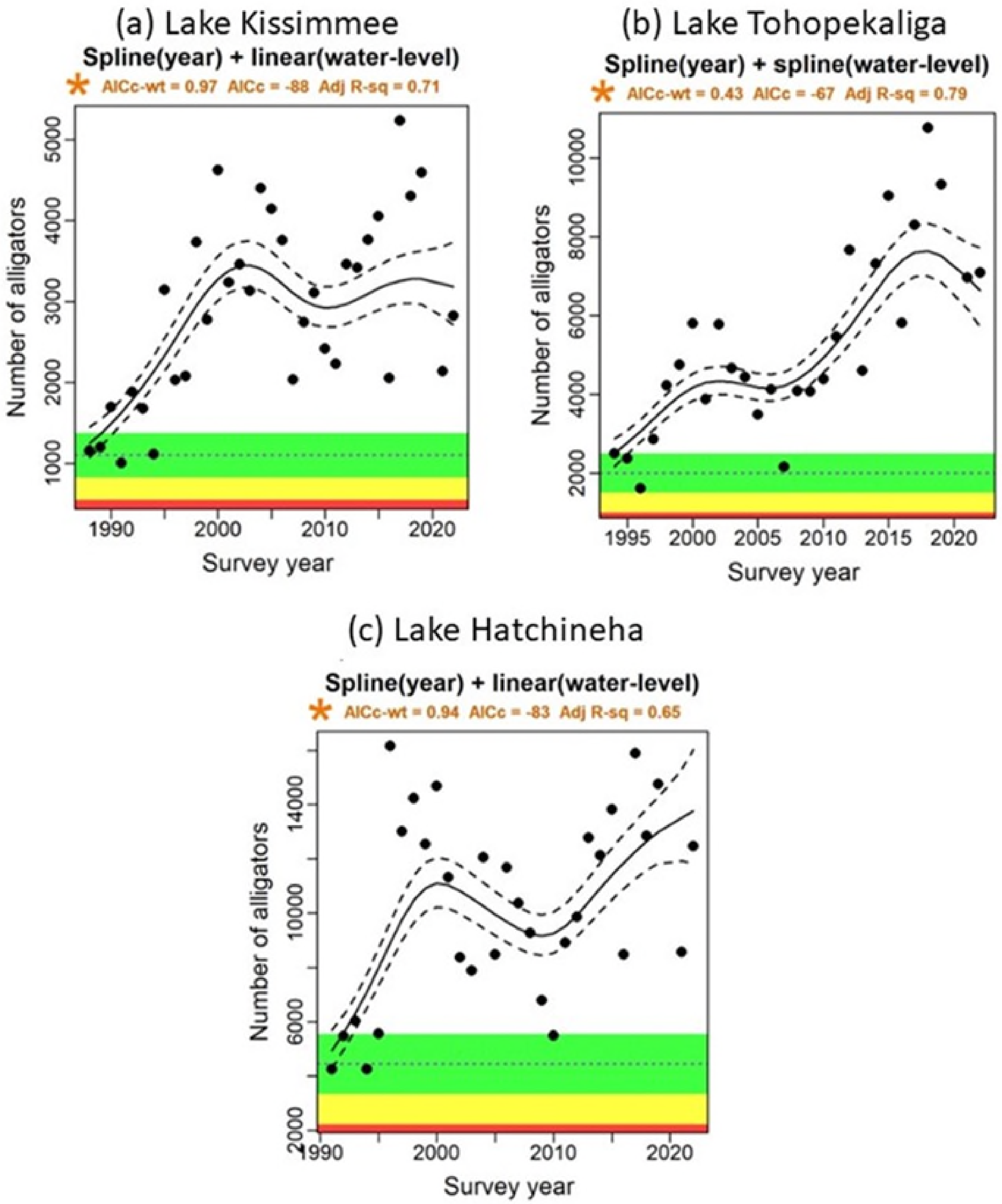


Figure 9-50. Alligator population trends on (a) Lake Kissimmee, (b) Lake Tohopekaliga, and (c) Lake Hatchineha based on night light surveys conducted 1988–2022. Green-shaded area represents ± 25% of the population management target; yellow-shaded area represents 25–50% of the target; and the red-shaded 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.

Lake Hatchineha

Total alligator population estimates on Lake Hatchineha have remained stable to increasing. The 2022 estimated population was 3,186 alligators, a 155% increase since population monitoring began in 1988 (**Figure 9-50c**). The estimated number of juvenile (1 to 4 ft) alligators was 1,503 individuals, a 122% increase since 1988. The adult (6 ft and larger) portion of the alligator population also increased and was estimated at 1,198 individuals, a 177% increase over the 1988 estimated population.

Lake Cypress

The 2022 estimated population on Lake Cypress was 629 alligators, a 43% decrease since population monitoring began in 2000. The estimated number of juvenile (1 to 4 ft) alligators was 182 individuals, while the estimated number of adult (6 ft and larger) alligators was 306 individuals. Those estimates represent a 37 and 43% decrease, respectively, from the 2000 estimated population.

Summary

Decreases in populations between 2005 and 2010 within the largest lakes of KCOL (Lakes Kissimmee, Tohopekaliga, and Hatchineha) are likely due to the severe 2006 drought that lasted from 2006 through 2008. Large decreases in water level can have negative effects on the survival of juvenile alligators.

Alligator populations on the three largest lakes within the KCOL 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 subsequent high recruitment of younger alligators into adult size classes.

Trend analyses for East Lake Tohopekaliga and Lake Cypress indicate declines for juveniles, adults, and total populations. However, all size classes on the lakes remain within the acceptable range of population estimates. The decline of adults might reflect harvesting from recreational and nuisance trappers, while declines in juveniles may suggest a decrease in available habitat for smaller alligators. The removal of dense emergent vegetation and hydrilla (*Hydrilla* spp.) can reduce the amount of available cover and foraging area for juvenile alligators. The drawdown on East Lake Tohopekaliga could have further negative effects on juvenile populations because of the reduction in nesting and foraging habitats, as well as available cover. Continued monitoring should allow us to assess the effects of the drawdown on alligator populations.

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