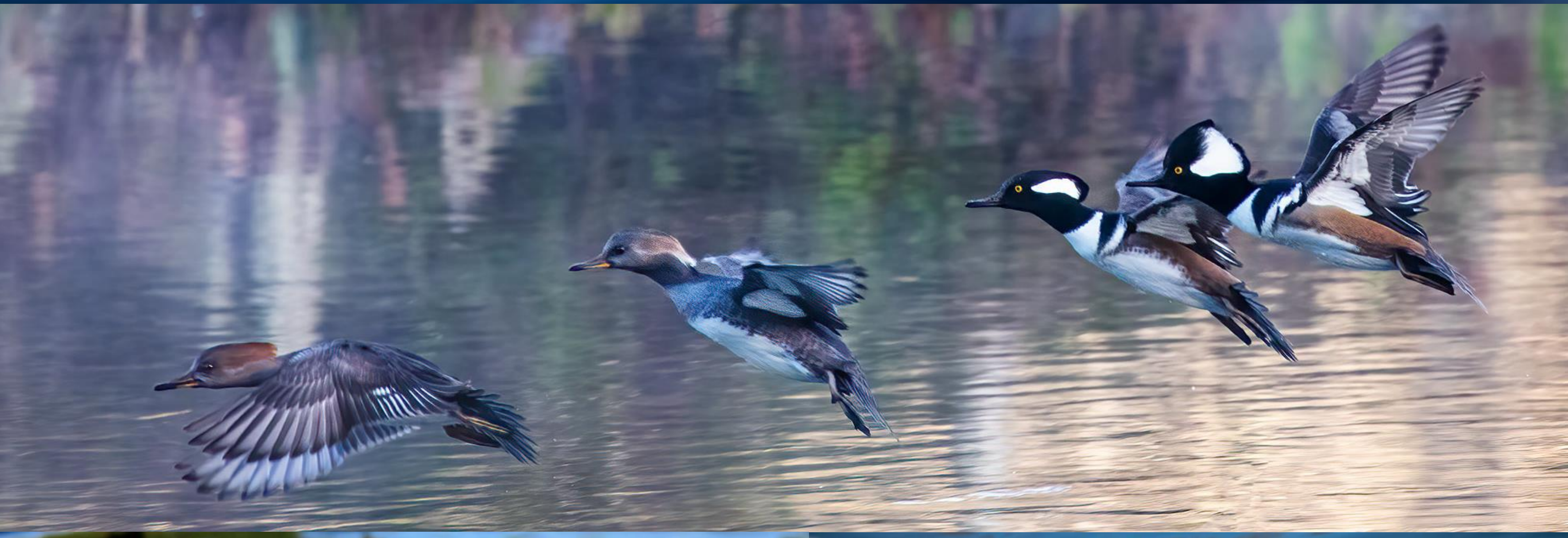



Upper Wakulla River Wildlife Abundance Trends January 2012 – June 2024

August 2025

Robert E. Deyle



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Executive Summary

This report focuses on trends in the abundance of 19 species surveyed by park staff and volunteers from January 2012 through June 2024. This is the period demarcated by the cessation of annual herbicide treatments to control the invasive aquatic plant hydrilla and a substantial decline in nitrogen inflows resulting from a major upgrade to the Tallahassee wastewater treatment facility. It is referred to here as the "post-hydrilla-management period." These trends are analyzed in the context of long-term trends encompassing the full survey record beginning in September 1992. Trend graphs and statistical analyses are included for each of the 19 species, as well as discussions of other factors that may explain the observed patterns.

Two recent perturbations have substantially altered the habitat of the upper Wakulla River for some species, in particular the pied-billed grebe and to a lesser extent the common gallinule: disintegration of the bulrush (*Schoenoplectus californicus*) island beginning in 2016 and massive loss of knotweed (*Polygonum sp.*), which comprises the first zone of emergent plants along the river margins in many places, beginning in May 2021.

The long-term trend in aggregate wildlife abundance, measured as total numbers of individual animals counted per survey for all 19 species over the 31.5 years of this monitoring project, remains significantly negative. However, the passage of time explains less of the observed variation in abundance than it did in the previous analysis with an R-squared of 0.162 as of June 2024 rather than 0.228 as of May 2021.[1] Three species exhibited no statistically significant long-term trend, nine decreased, and six increased. Manatee abundance also has increased, starting in 2003, the first year in which they were surveyed.

The trend in aggregate wildlife abundance for all 19 species during the post-hydrilla management period shifted from a significant decrease for the period 2012 through May 2021 to no significant trend with the analysis extended through June 2024. This reflects large increases in the numbers of hooded mergansers and white ibis in the winter of 2023-2024 associated with a dramatic decline in pied-billed grebes with which they compete for crayfish, their principal food source.

[1] R-squared, referred to as the coefficient of determination, measures the explanatory power of a regression model. The R-squared value of 0.162 indicates that the passage of time during the period November 1992 through June 2024 explains 16.2 percent of the observed variation in total animal abundance.

Three species exhibited significant decreasing trends during the post-hydrilla-management period through June 2024: American coot, cooter turtle, and pied-billed grebe. Ten species experienced significant increases: green heron, tricolored heron, great egret, little blue heron, American alligator, double-crested cormorant, yellow-crowned night heron, cattle egret, white ibis, and hooded merganser. The remaining six species exhibited no significant trend: snowy egret, great blue heron, osprey, anhinga, manatee, and common gallinule.

Notable changes since May 2021 (Deyle, 2022) include the following:

- Analysis was suspended for four species that are now rarely observed: blue-winged teal, limpkin, purple gallinule, and wood duck.
- American alligator abundance declined some although the post-hydrilla-management trend remains positive.
- The rate of decline in American coot numbers increased.
- The trend in anhinga abundance shifted from positive to not significant, reflecting a decrease in counts per survey. Since 2021, anhinga have been increasingly observed eating crayfish rather than fish.
- The trend for the common gallinule shifted from weakly negative to not significant. Monthly means were lower in June 2024 than May 2020 prior to the dramatic loss of knotweed habitat.
- Cooter turtle abundance changed from no significant trend to negative; more prolonged dark water conditions may have been a factor, but available weekly visibility data do not indicate that has been the case.
- The double-crested cormorant maximum count trebled in 2023 from 30 to 90. It has been on an upswing since 2018, presumably because of the nesting colony down river. Similar to the anhinga, since 2021 cormorants have been increasingly observed eating crayfish rather than fish.
- The abundance trend for the great blue heron is no longer significant; it had been weakly negative.
- The upward trend in hooded merganser counts continued. The rate of change increased as did the R-squared measure of the explanatory power of the trend, from 0.096 to 0.206.
- The trend for the little blue heron shifted from not significant to weakly positive.
- Manatee abundance changed from a decreasing trend to no significant trend reflecting higher counts between May 2021 and June 2024. The previous high single day count of 34 was exceeded on eight occasions with a maximum of 56.
- Osprey counts per survey changed from a decreasing trend to no significant trend reflecting a levelling off with just one active nest on the upper river.
- The pied-billed grebe population which had appeared to have achieved a new equilibrium is now in significant decline due to habitat loss from the disintegration of the bulrush island and the loss of knotweed.
- White ibis annual means increased in 2022 and 2023. Annual abundance has shifted from no significant trend to an increase.
- The yellow-crowned night heron trend has continued to be positive while annual means have been on a strong upward path since 2020.

The upper Wakulla River ecosystem appears to have shifted from a food web based primarily on submerged aquatic vegetation (SAV) to a more detrital-based food web. Species that feed primarily or substantially on crayfish, which are detrital feeders, i.e. hooded merganser, yellow-crowned night-heron, and white ibis, continue to exhibit stable or increasing trends. The exception is the pied-billed grebe which has declined precipitously with the disintegration of the bulrush island and the extensive loss of knotweed habitat. Counts of hooded mergansers and white ibis exhibit statistically significant negative relationships with those of pied-billed grebes, while annual means of yellow-crowned night herons have been on a strong upward path since 2020. These species appear to have taken advantage of the grebe decline.

Common gallinule and American coot, which feed predominantly on SAV, continue to decline (coots) or have levelled off after declining (gallinule). Those species that depend more heavily on medium to large fish also appear to have reached new, lower carrying capacities: osprey (a single nesting pair), great blue heron (no nesting), and anhinga (only a couple active nests).

<u>Introduction</u>

Park staff and volunteers have monitored the abundance of 35 species of animals along the 2-mile river boat tour route in Wakulla Springs State Park over 31.5 years (monthly by park staff from September 1992 through October 2012 and weekly by volunteers since November 2012).[2] This report analyzes data for 19 of those species excluding several that occur in very small numbers.[3] It extends the analysis prepared by Deyle in 2022 by analyzing additional data collected from June 2021 through June 2024.

The report focuses on trends from January 2012 through June 2024. This is the period demarcated by the cessation in annual herbicide treatments to control the invasive aquatic plant hydrilla and a substantial decline in nitrogen inflows resulting from a major upgrade to the Tallahassee wastewater treatment facility. It is referred to here as the "post-hydrilla-management period." These trends are analyzed in the context of long-term trends encompassing the full survey record beginning in September 1992. Trend graphs and statistical analyses are included for each of the 19 species, as well as discussions of other factors that may explain the observed patterns.

The 2022 report analyzes trends during three periods defined by several significant perturbations to the upper Wakulla River ecosystem: 1992-2000; 2000-2012; and 2012-2021.

- <u>Hydrilla Invasion (1992-2000)</u>: This nine-year period encompasses the time prior to and during the invasion of the exotic plant, *Hydrilla verticillata,* and the first three years of efforts to control it by mechanical removal. Hydrilla roots in the sediments, grows to and spreads over the surface, forming mats that shade out most of the native submerged aquatic vegetation (SAV) and interfere with tour boat operation. The abrasive stems with their whorled leaves also pose a nuisance to swimmers.

  Hydrilla was first observed near the boat dock in April 1997. By December of that year, it had spread downriver to the first turn, approximately one quarter mile past the boat dock. During 1998 it invaded the spring basin, the swimming area, and the area behind the spring. In 1998, the state park initiated efforts to remove hydrilla by hand pulling and applied the aquatic plant herbicide Aquathol in granular form in the swimming area. The herbicide proved ineffective. Despite removing some 260,000 kg during that year, the hydrilla continued to spread down river. Intensive mechanical harvesting was implemented along with hand pulling in 1999 and 2000 to clear the

[2] Many thanks to the volunteers who spent portions of their Saturday mornings monitoring wildlife during the two years since the last analysis of monitoring data: Doug Alderson, Connie Bersok, Shukun Fang, Melissa Forehand, Kim Forehand-van der Linde, Liesel Hamilton, Lisa Lazarus, Lynette Norr, and Nico Wienders, and to park biologist, Patty Wilbur, for supporting this continuing initiative, tracking down squirrely data, and providing personal observations to supplement the raw numbers. Special thanks to Bob Thompson who organized and managed the volunteer monitoring initiative until his "retirement" in 2018, for his encouragement and support and for driving the boat after the COVID pandemic led to uncoupling the survey from the regular river tours. Thanks also to park volunteer coordinator, Jackie Turner, for her support in coordinating the monitoring program following Bob Thompson's retirement as volunteer monitoring program manager. I am solely accountable for the final product, subject to Patty Wilbur's review and approval.

[3] See Appendix A: Copy of Current Survey Form. Species counted but not analyzed here because of very low counts include Florida softshell turtle, snake (any), American bittern, least bittern, wood duck, blue-winged teal, lesser scaup, bufflehead, red-shouldered hawk, bald eagle, purple gallinule, limpkin, spotted sandpiper, barred owl, and kingfisher. We dropped the American wigeon and black-crowned night-heron from the survey in 2018 and added the bufflehead. The last wigeon counted was in December 2014, while bufflehead have been routinely listed as "another species observed" in the comment section.

swimming area and boat tour routes. Nevertheless, the hydrilla continued to expand downriver past the first turn and began to occupy large areas in the middle and on the west side of the river. It also infested the spring to a depth of 60 feet obscuring features on the glass bottom boat tour. In 2000 the hydrilla spread further, going beyond the tour boat turnaround one mile from the boat dock and continuing another mile down the river.

- <u>Hydrilla Management (2000-2012)</u>: This 13-year period comprises the time when the park intensified efforts to remove the hydrilla. Mechanical harvesting supplemented by hand pulling continued through 2001 but with no success in stemming the invasion and "unacceptable . . . by-catch of juvenile fish and macroinvertebrates" (Van Dyke, 2019, p. 1). In 2002, the state park resorted to treating the upper river by applying liquid Aquathol across the spring basin.[4] This continued for most of the ensuing 11 years.

  The initial treatment succeeded in killing back the stems of 70 to 80 percent of the hydrilla (Van Dyke, 2019). However, several of the native SAV species also succumbed and recovered to differing degrees after each treatment. The rapid hydrilla die-off led to a surge of dead plants that scoured the bottom sediments of the upper river and likely caused additional loss of native SAV. The hydrilla recovered to some extent each year, necessitating regular treatments. Native SAV species also recovered, some more readily than others, resulting in changes to the species composition of the SAV community. Algae[5] recovered most quickly and began to dominate some areas of the upper river. During this time, manatee began to graze the hydrilla in increasing numbers. Manatee were first observed in the park in 1997 and appeared periodically in small numbers until 2003. Also, during this time, total nitrogen discharges from Tallahassee wastewater management facilities to the aquifer that feeds Wakulla Spring began to decline culminating in a 73 percent drop between 2011 and 2012 as major improvements to the T.P. Smith wastewater treatment plant went online (see Appendix B, Figure B-1). These changes were reflected in a decline in nitrate-nitrogen levels at the spring, which levelled off at about 0.41 mg/L in 2014 (see Figure B-2).

- <u>Post Hydrilla Management (2012-2024)</u>: This 13-year period is defined by three change factors that occurred in 2012:

  - cessation of herbicide treatment of hydrilla: the last treatment was in May 2012;
  - substantial reduction in nitrate-nitrogen loading to the spring following completion of the upgrades to the Tallahassee wastewater treatment plant in November 2012; and
  - the November 2012 shift from monthly wildlife surveying by staff to weekly surveying by volunteers.

  The cessation of Aquathol treatment should have ended the cycle of SAV injury and recovery as well as any toxic effects on animal species. The substantial reduction in nitrate-nitrogen inflow to the spring may have contributed to the apparent inability of the hydrilla to recover from heavy manatee grazing. The shift to weekly wildlife monitoring likely resulted in a more robust data base, reducing the influence of factors that vary from one survey date to another including air temperature, precipitation, water depth, cloud cover, visibility depth, surveyor aptitude, distractions during the boat tour, etc.

[4] Aquathol is a brand name for endothall, a pesticide registered for use in aquatic ecosystems by the Florida Fish and Wildlife Commission (UF IFAS, 2019). While considered "safe," it is not risk free and does have documented deleterious effects on an array of aquatic organisms (Pesticide Action Network, 2019).

[5] The term "algae" as used here also includes the so-called "blue-green algae," which actually are bacteria (cyanobacteria) that lack a nucleus. The dominant "algae" that formed dense mats during this period include the cyanobacterium *Lyngbya*, the green alga *Spirogyra*, and the yellow-green alga *Vaucheria*.

This report uses two approaches to analyze long-term wildlife abundance:

- animal counts for each survey for September 1992 through June 2024 for statistical analysis of trends and
- annual mean or annual seasonal monthly mean animal counts for 1994-2023 for visual analysis of patterns.[6]

The counts per survey approach offers the greatest statistical power for testing the significance of apparent trends,.[7] However, the high variance among individual surveys makes it difficult to visually detect temporal patterns. Therefore, the analyses of aggregate wildlife abundance and individual species in Appendix C include graphs of annual mean or annual seasonal monthly mean animal counts. Where species abundance is strongly seasonal, i.e. individuals are entirely absent or nearly so for several months, statistical trend analysis is conducted only for the months when the species is predominantly present. Table 1 lists the different seasonal abundance patterns exhibited by the monitored species.

Table 1. Wakulla Wildlife Seasonal Abundance Patterns

Abundance Pattern	Species
Year-round breeder (YB)	American alligator, anhinga, common gallinule,* cooter turtle, green heron, pied-billed grebe,* yellow-crowned night-heron
Year-round occasional breeder (YOB)	Double-crested cormorant,** great blue heron, great egret,** little blue heron**
Year-round non-breeder (YNB)	Snowy egret, tricolored heron
Winter migrant (WM)	American coot, hooded merganser
Summer breeder (SB)	Cattle egret,** osprey
Winter peak non-breeder (WP)	Manatee, white ibis

*Year-round breeding populations, probably supplemented by winter migrants.
**These species often nest in colonies downriver from the tour boat survey route and occasionally along the tour boat route as well.

The next sections present trend analyses for aggregate wildlife abundance and individual species abundance plus trends for the post-hydrilla-management analysis periods. These are followed by a summary of findings. Detailed results for aggregate wildlife abundance and each species are presented in Appendix C. Those include graphs of monthly means, counts per survey, and annual mean counts per survey over the entire period of record for each species and graphs of counts per survey for the post-hydrilla management period. Trend lines and associated statistics (model fit: prob(F); model explanatory

[6] Annual means were calculated for each month and then averaged for the year beginning in 1994 because of incomplete data in 1992 and 1993. Annual seasonal monthly means were calculated for the months when an individual species is most commonly observed, e.g. the months in residence for winter migrants.

[7] Larger numbers of observations (N) provide greater statistical power in ordinary least squares regression, i.e. they decrease the likelihood of concluding that no relationship exists when in fact one does. Regression analyses of counts per survey data, where the number of observations is 500+ for most species, offer greater statistical power than the analyses of long-term annual means employed in the 2017 report which were for 20 years, i.e. N=20. The results from means analyses are conservative, i.e. more likely to understate than overstate apparently significant trends. Note, however, that the explanatory power (R^2) of animal count trends is generally lower than that of trends based on annual means. Reducing the data to annual means removes much of the variance among individual observations thereby "smoothing" the data and increasing the power of time as a predictor of abundance.

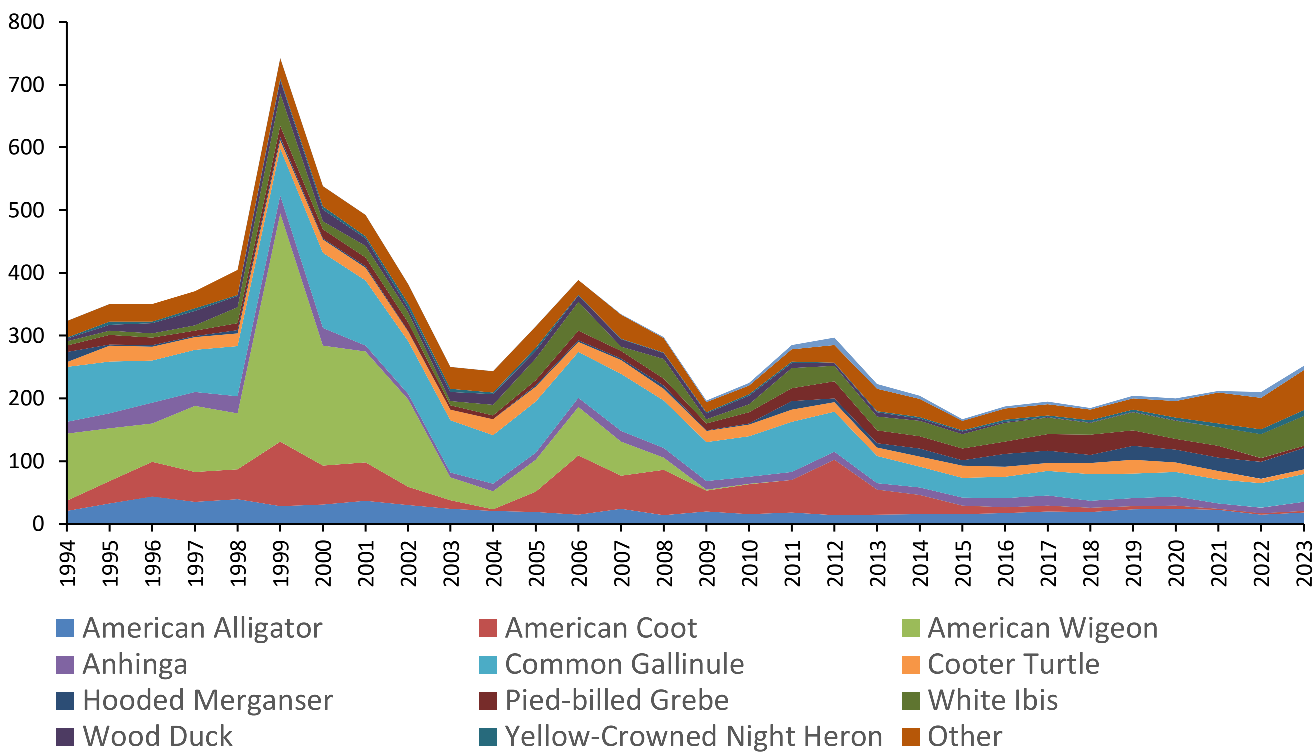
power: R-squared or R^2; and slope) are included in counts-per-survey plots where simple ordinary least-squares regression analysis yields a linear model significant at the 95% level or better (prob(F) $\leq$ 0.05).[8]

Aggregate Wildlife Abundance Trends

Changes in the aggregate numbers of individual animals counted per survey can serve as an indicator of shifts in the relative biological productivity of the upper river ecosystem. In previous analyses of the survey data, we have analyzed the total numbers counted per survey for all 24 species analyzed. However, aggregate trends revealed by these means may be confounded by variables outside the Wakulla River ecosystem for species that are not year-round residents. For example, the abundance of winter migrants will reflect both the carrying capacity of the Wakulla River and factors that influence summer breeding success as well as migration timing and destination. As detailed in Appendix C, research has revealed that some species are not migrating as far south as in the past, likely because of changing climate. Other species, such as white ibis, migrate regionally, nesting elsewhere during the summer and returning to the river in fall and winter.

Figure 1 illustrates variation over the period of record in the relative numbers of the most prevalent monitored animal species. The figure reveals a shift in dominant species from the 1999 peak to the post-hydrilla-management period beginning in 2012. Two winter migrants, American coot (red) and American wigeon (light green), along with the common gallinule (light blue), dominated total species counts in 1999. By 2023, the most prevalent species included white ibis (dark green), common gallinule, and hooded merganser (dark blue). Figure 1 shows the disappearance of wigeon from the upper Wakulla River. Meanwhile American coot, American alligator (medium blue), and common gallinule have decreased, and hooded merganser and white ibis have increased. Pied-billed grebes (dark red) had been on the rise but decreased after 2022.

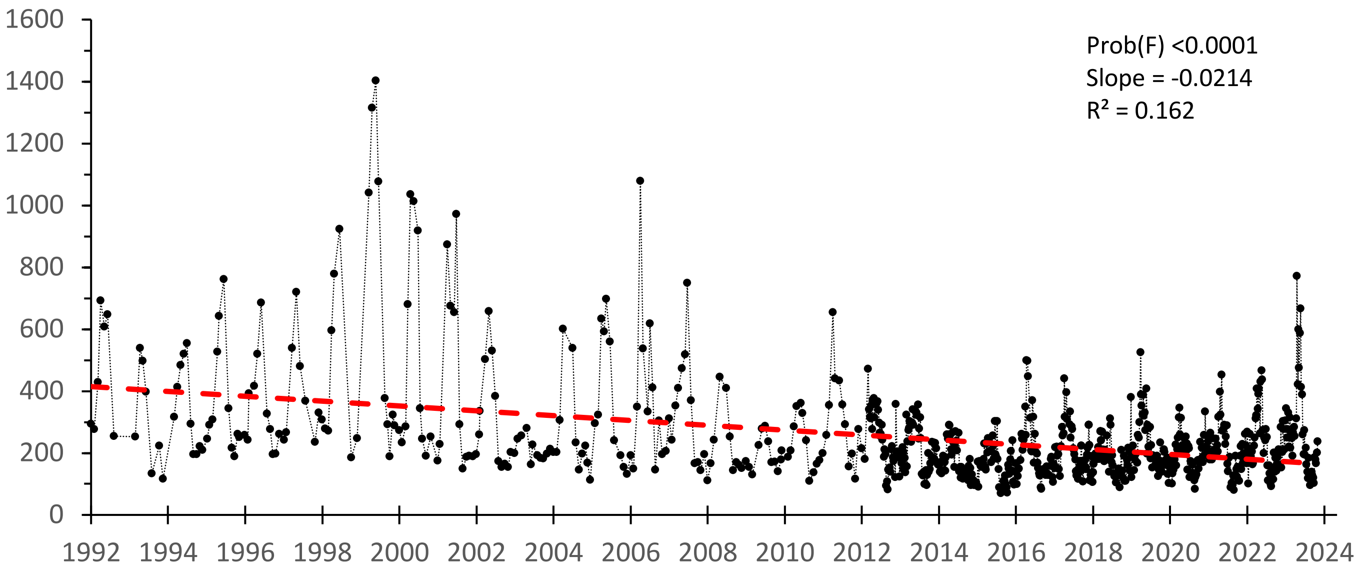
Figure 1. Total Annual Mean Animal Counts for Most Prevalent Species 1994-2023



[8] See Appendix C for descriptions of these statistics.

Figure 2 reveals a statistically significant decline in aggregate wildlife abundance for the period of record. Total animal counts per survey for all 24 species on the upper Wakulla River exhibit a significant (better than 99.99% level) decreasing abundance trend of -0.0214 animals counted per day or 7.8 counts per year over the period of record, 9/1/92 – 6/30/24. Survey date explains 16.2% of the observed variation in counts per survey.

Figure 2. Total Counts per Survey 24 Species, 1992 - June 2024



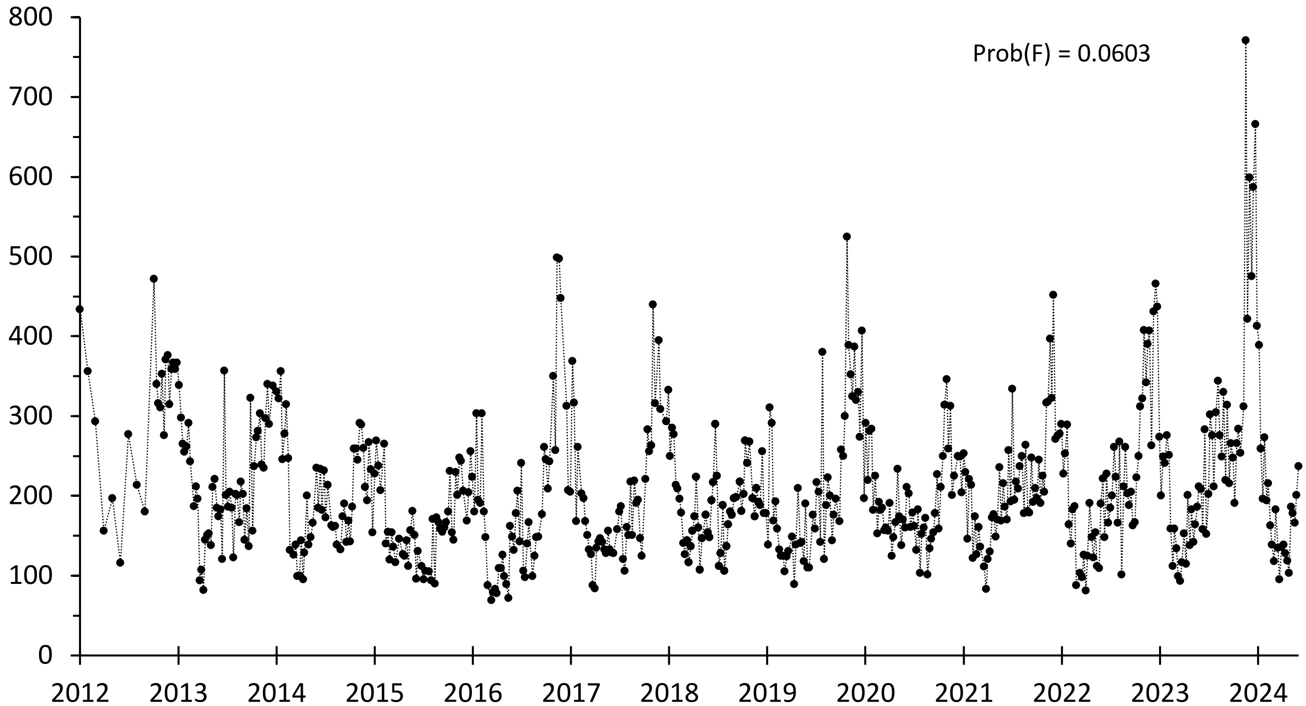
As shown in Figure 3, regression analysis reveals no significant trend in aggregate wildlife abundance during the post-hydrilla management period, January 2012 through June 2024: Prob(F) = 0.0603. This finding differs from that of the previous analysis through May 2021 where the trend was significantly negative at the 99.86% level. This change reflects the very high abundance counts in December 2023 and January 2024 which were due primarily to very large numbers of winter migrant hooded mergansers (see Appendix C).

These results, as depicted in Figure 1, suggest an increase in the overall biological productivity of the upper Wakulla River ecosystem accompanying the hydrilla invasion (1992-2000), likely fueled in part by high levels of nitrate-nitrogen[9] and enhanced floating aquatic vegetation habitat that probably favored the American wigeon, American coot, common gallinule, and other species that fed on the aquatic organisms supported by the hydrilla habitat.

This was followed by a steep decline during the early years of intensive hydrilla management (2000-2004) consistent with by-catch losses from mechanical harvesting and drastic changes in the native SAV community that began with the hydrilla invasion and have been manifest in the aftermath of the herbicide treatments in the post-hydrilla management period (2012-2024). *Sagittaria kurziana* (spring tape grass), which had been the dominant native SAV species, proved to be very sensitive to the herbicide, while the other submerged aquatic grass, *Vallisneria americana* (American eelgrass), was able to recover more quickly. Large areas of the bottom sediments were colonized by algae during the annual fluxes in SAV accompanying the herbicide treatments (Savery, 2005), but extensive areas of the main channel were reduced to bare sediments and shells due to the scouring that followed the initial hydrilla die back (Van Dyke, 2019).

[9] Nitrate-nitrite and total nitrogen data from the spring indicate that levels increased in the mid-1980s, were fairly constant through the 1990s, and began to decrease in 2001 (Gilbert, 2012).

Figure 3. Total Counts per Survey 24 Species, 2012 - June 2024



As shown in Table 2, quarterly SAV sampling since 2013 suggests a fairly stable SAV community with no significant changes in the mean percent cover for algae, bare sediment, hydrilla, or *Vallisneria*. Only *Sagittaria* has exhibited a statistically significant increase (see Figure 4).

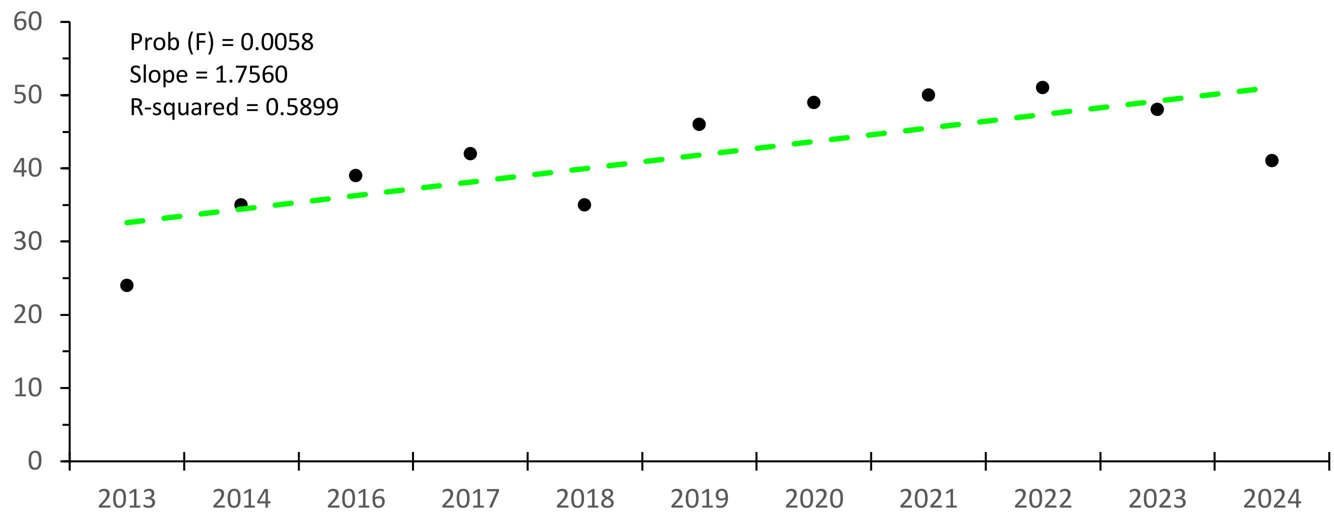
Table 2. SAV Trends April 2013 – June 2024

Cover Type	Mean Percent Cover	Trend*
Sagittaria kurziana	32	increasing
Algae	30	none
Bare sediment	24	none
Hydrilla verticillata	8	none
Vallisneria americana	2	none

*Significant at 95% level or better

The post-hydrilla-management wildlife abundance trend shifted from modestly negative measured from 2012 through May 2021 (slope = -0.117) to no significant trend with the analysis extended through June 2024. This suggests an emerging dynamic equilibrium defined by the carrying capacity of the altered food web. The trend shift, however, was mostly due to very large counts of hooded mergansers, as high as 370, in December 2023 and January 2024. This was not replicated in 2024-2025 when the maximum count for these months was 202.

Figure 4. Mean Percent Cover Sagittaria kurziana April/May/June 2013-2024



<u>Species Abundance Trends for Post-Hydrilla-Management Period</u>

Table 3 and Figure 5 present species abundance trends, based on animal counts per survey, for the post-hydrilla-management period (January 2012 through June 2024). These are represented as annual rates of change based on the slopes of the regression models for each species. Table 3 also presents trends previously reported by Deyle (2022) for the period 2012 through May 2021.

Trend significance is classified as follows:

> Increasing Abundance: linear regression model is statistically significant at the 95% level (prob(F) ≤ 0.05) and slope is positive.
>
> Decreasing Abundance: linear regression model is statistically significant and slope is negative.
>
> No Significant Trend: linear regression model is not statistically significant (prob(F) > 0.05).

Table 3 lists species in order of increasing abundance based on slope. R-squared statistics (R^2) are included for assessing the strength of the trends. Cells highlighted in green report statistically significant positive rates of change. Those in red are significantly negative, while those in yellow are not significant. Figure 5 uses the same color scheme.

Three species exhibited significant decreasing trends during the post-hydrilla-management period through June 2024: American coot, cooter turtle, and pied-billed grebe. Ten species experienced significant increases: green heron, tricolored heron, great egret, little blue heron, American alligator, double-crested cormorant, yellow-crowned night heron, white ibis, hooded merganser, and cattle egret,. The remaining six species exhibited no significant trend: snowy egret, great blue heron, osprey, anhinga, manatee, and common gallinule.

As shown in Table 3, the most substantial changes in these trends with the analysis extended to June 2024 include the following:

- the shifts from no significant rate of change to a significant negative rate of change for the cooter and pied-billed grebe;
- shifts from a negative rate of change to no significant change for the great blue heron, osprey, manatee, and common gallinule;
- the shift for the anhinga from a positive rate of change to no significant change; and
- shifts for the little blue heron and white ibis from no significant change to positive rates of change.

Table 3. Species Abundance Rates of Change: 2012 through May 2021 and June 2024

	2012 - May 2021		2012 - June 2024	
Species	**Slope**	**R^2**	**Slope**	**R^2**
American coot****	-0.0304	0.604	-0.0208	0.565
Pied-billed grebe	0.0005	0.001	-0.0042	0.138
Cooter turtle	-0.0003	0.000	-0.0019	0.035
Snowy egret	0.0000	0.001	0.0000	0.003
Great blue heron	-0.0002	0.011	0.0000	0.002
Osprey***	-0.0003	0.057	0.0000	0.003
Green heron	0.0002	0.028	0.0001	0.024
Anhinga	0.0080	0.019	0.0001	0.001
Tricolored heron	0.0002	0.041	0.0002	0.033
Manatee	-0.0015	0.066	0.0003	0.003
Great egret	0.0004	0.052	0.0003	0.054
Little blue heron	<0.0001	0.001	0.0004	0.023
Common gallinule	-0.0015	0.010	0.0004	0.001
American alligator	0.0033	0.118	0.0012	0.026
Double-crested cormorant	0.0017	0.124	0.0038	0.209
Yellow-crowned night heron	0.0010	0.111	0.0017	0.286
Cattle egret**	0.0055	0.241	0.0039	0.169
White ibis	0.0024	0.007	0.0049	0.034
Hooded merganser*	0.0149	0.096	0.0231	0.206

* Counts per Survey Post-Hydrilla Management (Nov-Mar 2012-13 - 2023-24)
** Counts per Survey After Nesting Colony Relocation (May-Aug 2015 - 2023)
*** Counts per Survey Post-Hydrilla Management (Feb-Jul 2012 - 2023)
**** Counts per Survey Post-Hydrilla Management (Nov-Feb 2012-13 - 2023-24)

As displayed in Figure 5, the American coot and pied-billed grebe experienced the most rapid rates of decline, followed by the cooter turtle. The hooded merganser exhibited the most rapid rate of increase followed by the white ibis, cattle egret, double-crested cormorant, and yellow-crowned night heron. The following paragraphs examine each species in turn.

Winter counts per survey of the predominantly herbivorous **American coot** (The Cornell Lab of Ornithology, 2019) have varied substantially yielding a significant long-term negative trend over the period of record (see Appendix C). As shown in Figure 6, the coot has experienced a steep decline since 2012. However, none of the recent ecosystem disturbances at Wakulla Spring appear to have been responsible. The long-term decline is consistent with documented decreases in breeding populations in most of the areas from which it probably migrates in the Midwest and eastern North America (Sauer et al., 2017; 2020) and a northward shifting of its winter range (La Sorte and Thompson, 2007).

The **pied-billed grebe** is a year-round breeding resident whose numbers are augmented by winter migrants from September through March. Despite a significant long-term trend of increasing abundance over the period of record (see Appendix C), the grebe's abundance levelled off during the post-hydrilla management period from 2012 through May 2021 (see Table 3). However, ecosystem perturbations since then led to a precipitous decline beginning in April 2022 changing that trend to significantly negative (see Figure 7).

Figure 5. Species Abundance Rates of Change: 2012 through June 2024

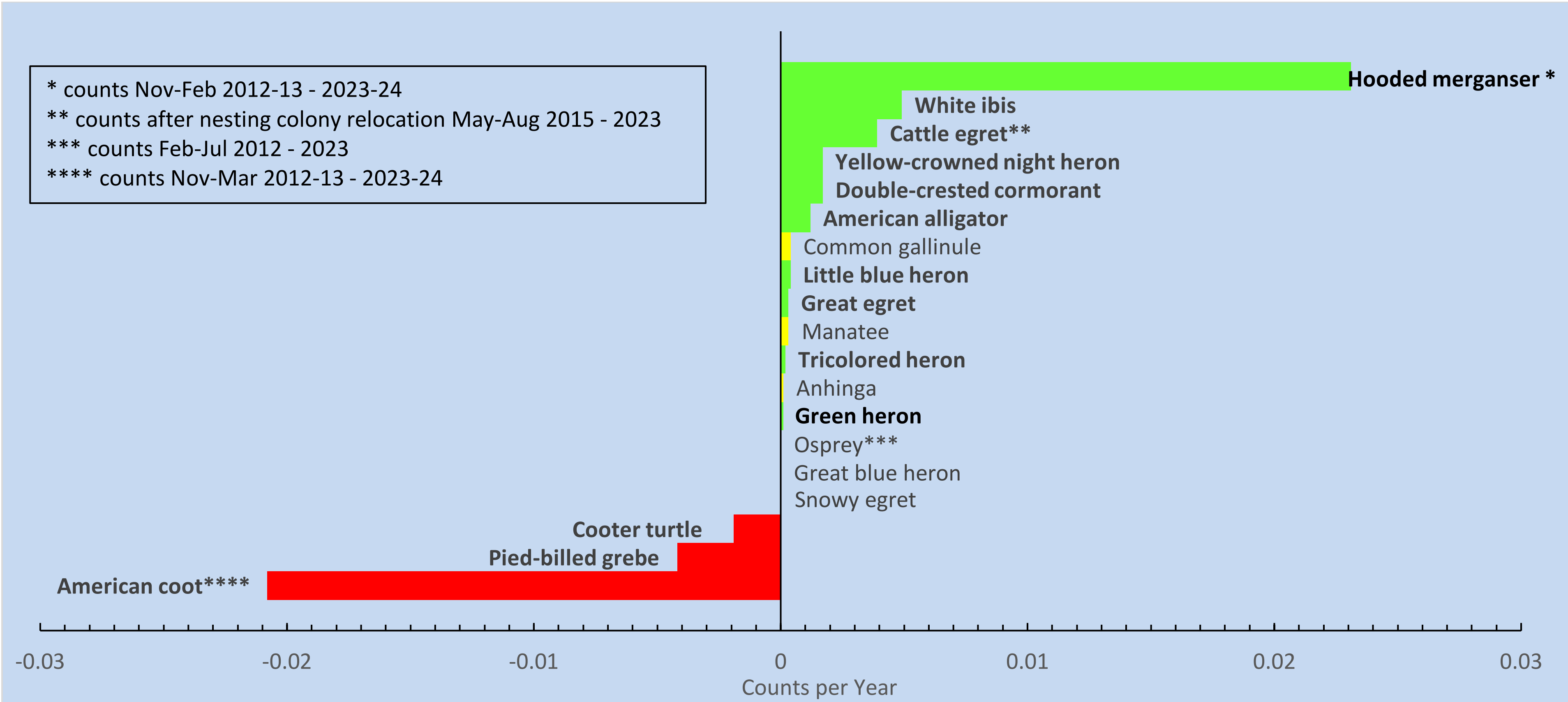


Figure 6. American Coot Winter Counts per Survey (Nov-Feb 2012-13 - 2023-24)

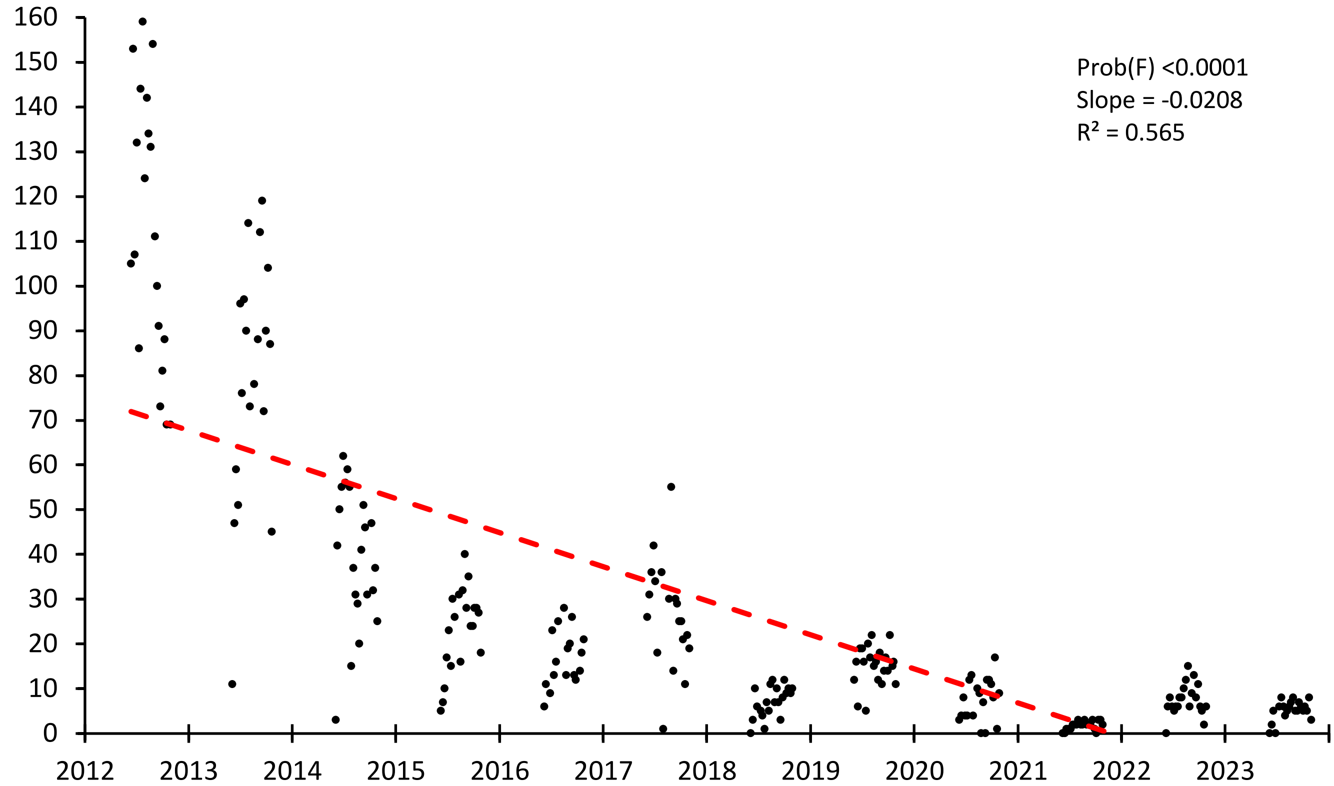
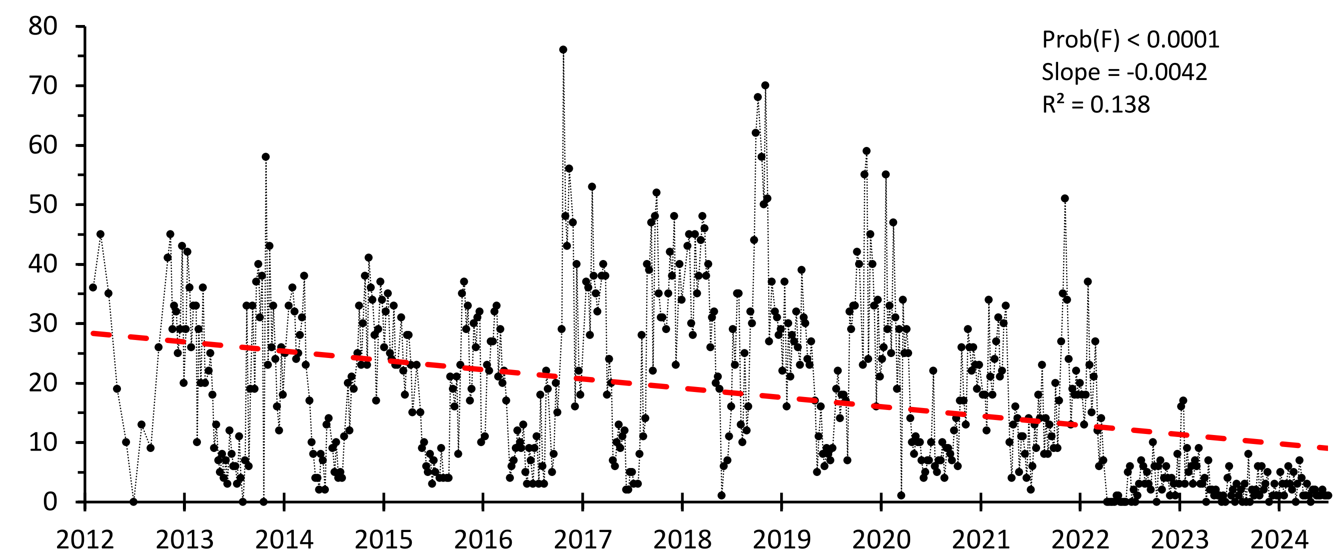


Figure 7. Pied-billed Grebe Counts per Survey (2012 – June 2024)



Two ecosystem changes have substantially reduced pied-billed grebe habitat: (1) disintegration of the so-called "bulrush island" at the tour boat turn around and (2) a dramatic loss of riparian emergent vegetation.

The bulrush island was created in part from dredge spoil when previous owner Edward Ball had the turnaround channel created for his new river boats in the mid 1960s. It was dominated by California bulrush (*Schoenoplectus californicus*) with outer zones of knotweed, also known as smartweed

(*Polygonum sp.*), water hemlock (*Cicuta maculatum*), and pickerel weed (*Pontederia chordata*), plus some cattails (*Typha spp.*) on the higher ground at the down-river end of the island. The knotweed provides important cover and nesting habitat for pied-billed grebe and common gallinule. The island began to break apart between 2016 and 2018 as the bulrushes began to die off (see Figures 8 and 9). The disintegration began with areas of open water in the interior of the island. As it progressed these areas broke through completely. By 2024 it had been reduced to a series of smaller islands (see Figure 10). No cause has been determined. However, the advent of periodic salinity spikes in the spring discharge (Northwest Florida Water Management District, 2021, p. 49) may have played a role as the California bulrush has a limited salinity tolerance (Neill, 2007).

Figure 8. Bulrush Island February 2016

Source: Google Earth.

Figure 9. Bulrush Island October 2018

Source: Google Earth

Figure 10. Bulrush Island April 2024

Source: Google Earth

The die-off of the three species of emergent riparian vegetation began in May 2021. Knotweed was most seriously affected (see Figure 11). Park staff and volunteers found evidence of distress to those species along the entire three miles of the river within the park as well as downstream of the park boundary but not in other nearby streams. By September 2021 the surviving plants began to bounce back, but by that time the river had lost about 20,000 square feet (0.4 acre) of emergent marsh habitat along the upper mile (personal observation). Algae moved in to colonize the exposed sediments while other submerged aquatic species colonized portions of a few sites: white water lily (*Nymphaea odorata*), red ludwigia (*Ludwigia repens*), and parrot feather (*Myriophyllum aquaticum*). A second, less extensive die-off occurred the following spring. No cause was ever identified.

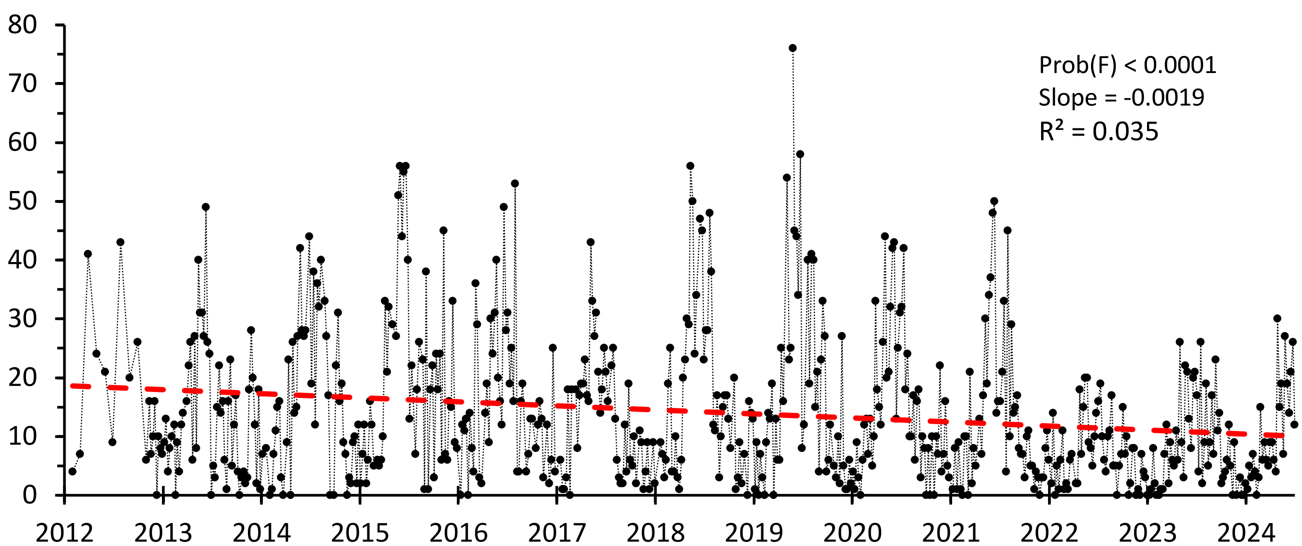
Figure 11. Dying Knotweed May 2021

Photo by Bob Thompson.

Cooter turtles, which include both the Suwannee cooter (*Pseudemys concinna suwanniensis*) and the coastal plain cooter (*Pseudemys floridana floridana*), have exhibited a long-term decline in abundance (see Appendix C). The post-hydrilla management trend was not significant for the period through May 2021, but shifted to significantly negative after extending the data through June 2024 (see Table 3). Cooters are year-round breeders that primarily eat submerged aquatic vegetation, especially *Vallisneria spp.*, *Naias spp.*, *Sagittaria kurziana*, and *Ceratophyllum demersum* (Krysko et al., 2019). These are all taxa that were affected by the Aquathol treatment of the hydrilla. Quarterly SAV surveys begun in 2013 have recorded almost no *Naias spp.* in the upper river along the tour route. *Sagittaria kurziana* was very sensitive to the herbicide and likely does not occur at the same densities in the main river channel now given the broad expanses of bare sediment. However, it is now the most prevalent SAV species. *Vallisneria americana* was more resistant to the herbicide but is now the least prevalent of the species included in the quarterly survey (see Table 2). *Ceratophyllum demersum* was a relatively minor component of the river SAV community and is now virtually absent.

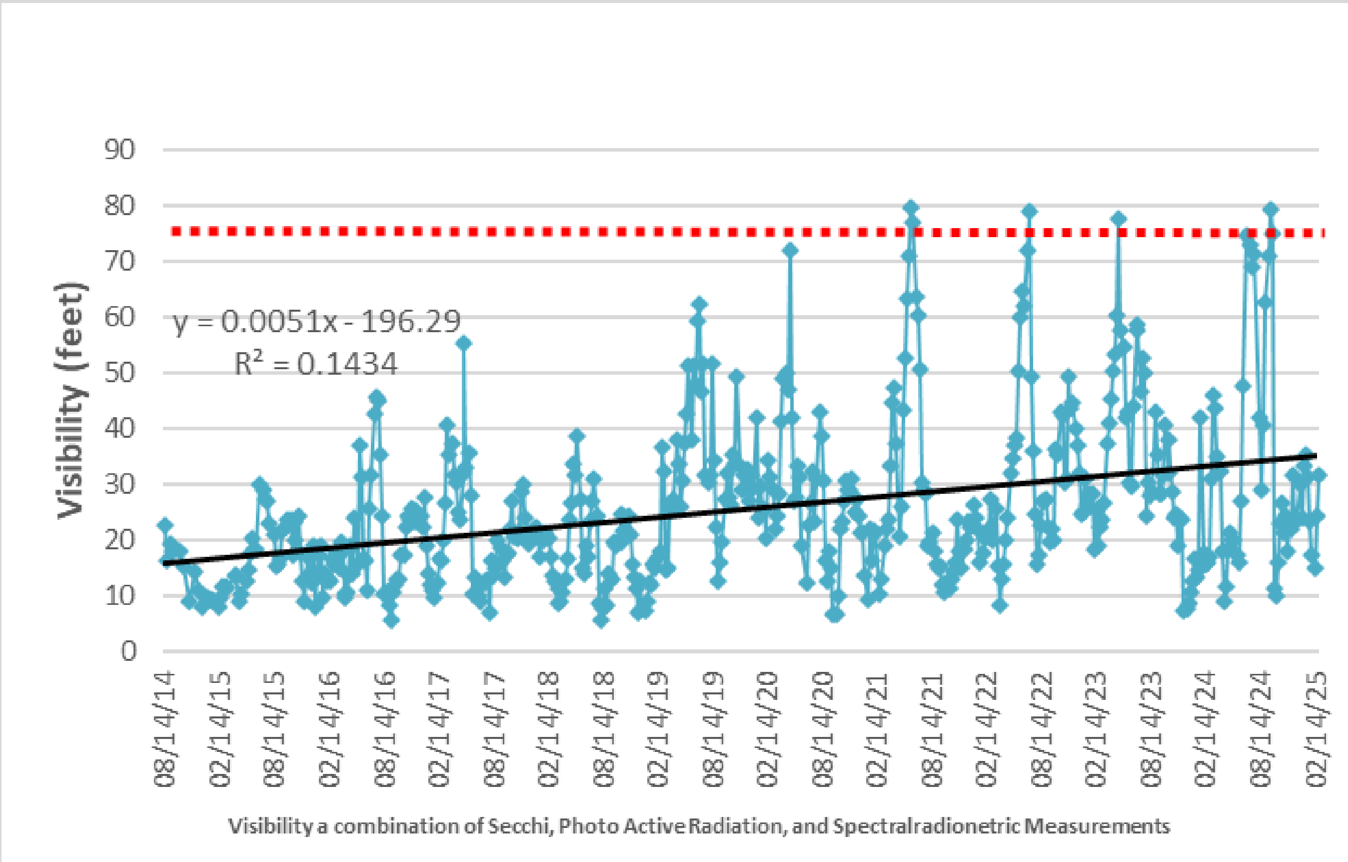
Cooter survey counts vary substantially (see Figure 12). This likely reflects the effects of air temperature and cloud cover on basking behavior, the effects of varying river stage elevation on available basking sites, and the effects of varying water visibility depth on observing turtles in the water. Multivariate analysis of data for the period November 10, 2012, through May 29, 2021, conducted by Deyle (2022), indicated that cooter turtles, like the American alligator, are more abundant when river stage is lower (more basking sites), air temperature is warmer, and the weather is clear or has some clouds. The recent shift to a negative trend does not appear to coincide with increased frequency of dark water conditions (see Figure 13).

Figure 12. Cooter Turtle Counts per Survey (2012 – June 2024)



Three of the four species with the greatest significant rates of change depicted in Figure 5 are major consumers of crayfish: **hooded merganser**, **white ibis**, and **yellow-crowned night heron**. As shown in Table 3, the hooded merganser and yellow-crowned night heron demonstrated significant positive trends from January 2012 through both May 2021 and June 2024. The white ibis trend shifted from non-significant through May 2021 to significant through June 2024. The cattle egret and double-crested cormorant differ in that both breed in a multi-species colony located in the second mile of the river downstream of the spring.

Figure 13. Wakulla Spring Visibility Depth (August 2014 – February 2025)



Source: McGlynn Laboratories, Inc.

The **hooded merganser** is a winter migrant with a varied diet that includes "small fish, aquatic insects, crustaceans (especially crayfish), amphibians, vegetation, and mollusks" (The Cornel Lab of Ornithology, 2019). On the upper Wakulla River, they are almost exclusively observed eating crayfish (personal observation). As shown in Figure 14, the merganser experienced a significant increase in counts per survey during the post-hydrilla management period, continuing its long-term trend since 1992. The long-term increasing trend is consistent with increases in summer breeding populations throughout the eastern Canadian provinces and in the Midwest, New England, and Mid-Atlantic states between 1993 and 2019 (Sauer et al., 2020) as well as in eastern North America between 2005 and 2015 (Sauer et al., 2017). The increasing trend also is consistent with a southward trend in the centers of abundance and occurrence of wintering populations between 1975 and 2004 (La Sorte and Thompson, 2007).

The **white ibis** has experienced a long-term increasing trend in abundance (see Appendix C). As noted above, the trend during the post-hydrilla management period shifted from not significant to significantly positive with extension of the analysis from May 2021 to June 2024 (see Figure 15). They eat primarily insects and crustaceans, especially crayfish (Wikipedia, 2019).

Ibis migrate regionally and their site allegiance can be low for both breeding and roosting habitat (Heath et al., 2009). During summer months (April - June), counts are low on the upper Wakulla River, often comprising mostly immature birds (personal observation), while adults are presumably nesting in colonies elsewhere. Adults and immatures congregate in much larger numbers during the non-breeding season starting in July and peaking from October through February (see Appendix C).

Figure 14. Hooded Merganser Winter Counts per Survey (Nov-Feb 2012-13 - 2023-24)

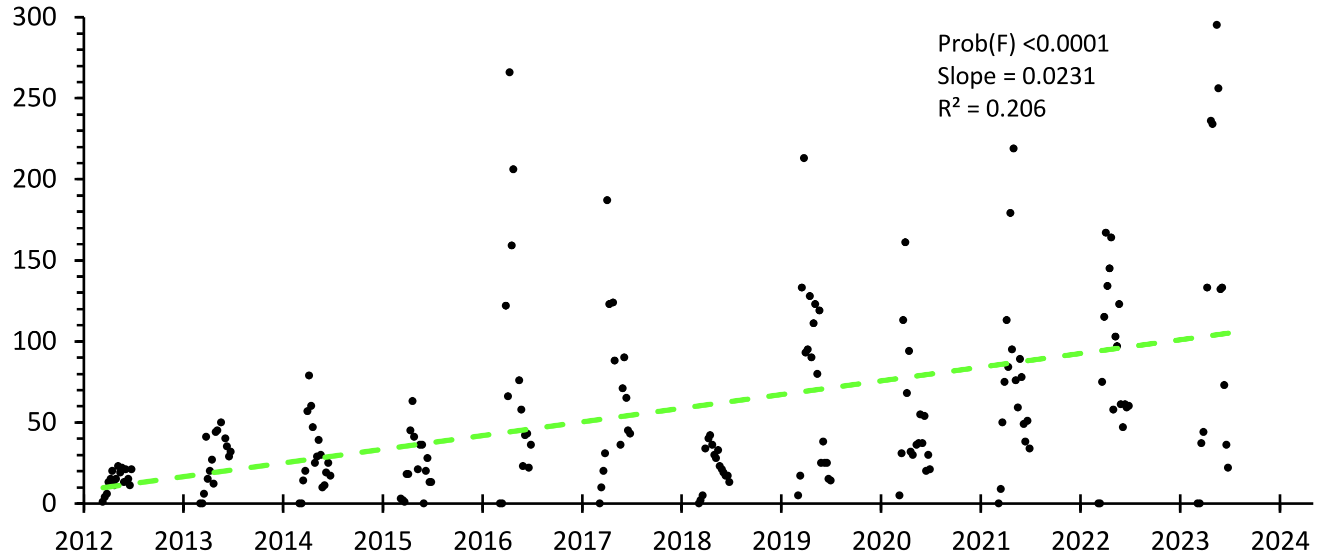
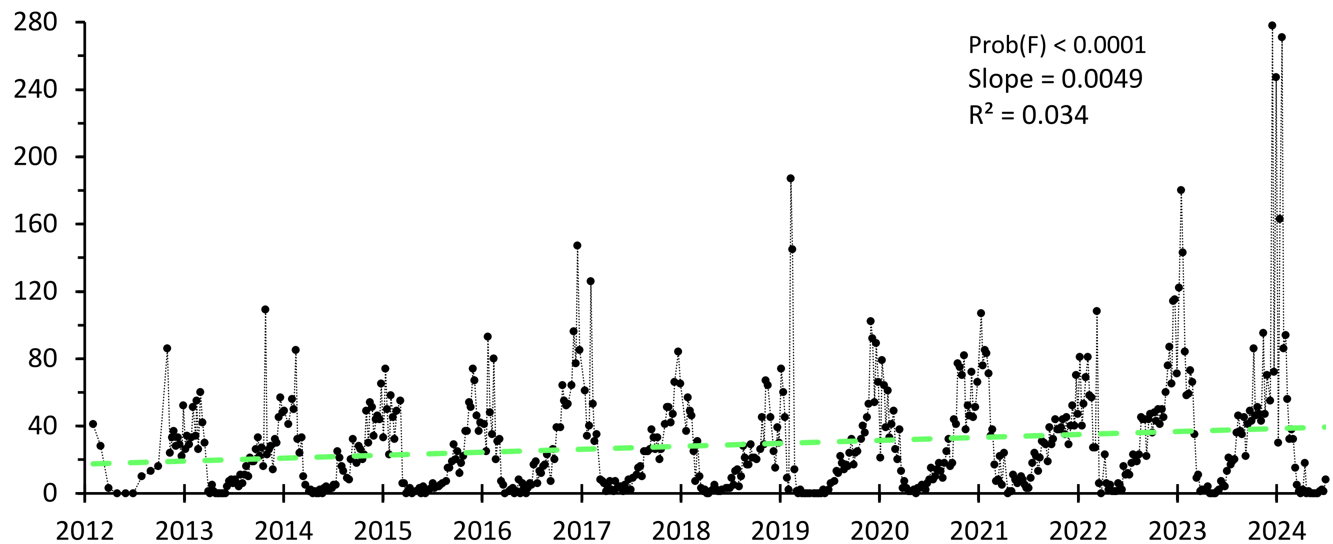


Figure 15. White Ibis Counts per Survey (2012 – June 2024)



Cattle egrets feed in pastures and fields and therefore are generally only seen on the river during the breeding season. They have nested in varying numbers along the upper river within the park on and off since the early 1990s, peaking in 2020 (see summer river survey counts in Appendix C). They nested in colonies just down river from the boat dock from 2012 through 2014, then relocated in 2015 to the multi-species colony along the second mile of the river below the spring. Since then, they have exhibited a significant positive trend (see Figure 16).

The **yellow-crowned night-heron** is a summer breeder present in small numbers (monthly means of one to three) during the non-breeding season (August - March) with peak counts (monthly means of four to seven) during the breeding season (April - July). They feed primarily on crustaceans (The Cornell Lab of Ornithology, 2019) – mostly crayfish on the upper Wakulla River (personal observation). The species exhibits a significant positive long-term trend in counts per survey over the period of record, 1992-2024 (see Appendix C) as well as during the post-hydrilla management period (see Figure 17).

Figure 16. Cattle Egret Counts per Survey (May-Aug, 2015-2023)

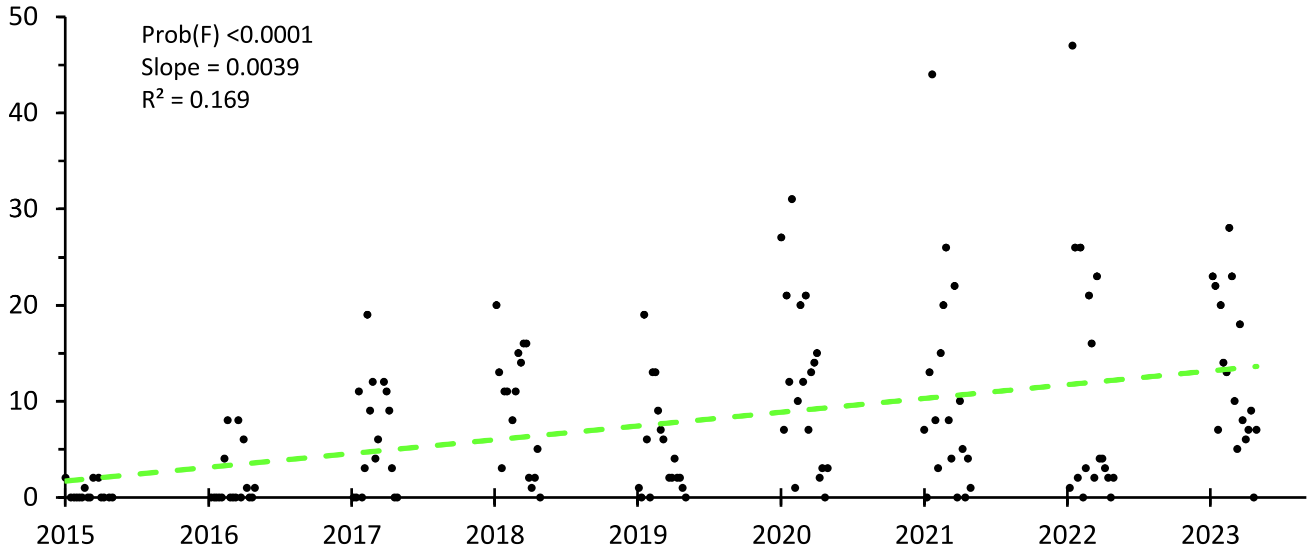
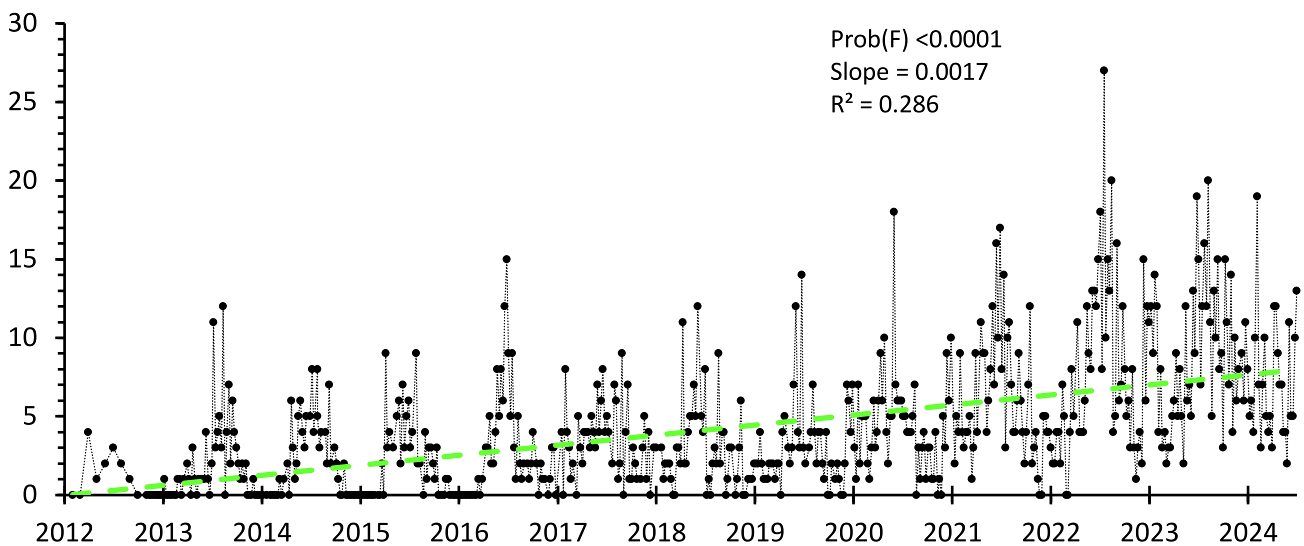


Figure 17. Yellow-crowned Night Heron Counts per Survey (2012 – June 2024)



As shown in Figure 18, recent increases in the abundance of hooded mergansers, white ibis, and yellow-crowned night herons are associated with the precipitous decline in pied-billed grebe numbers.

The chart reveals a robust inverse relationship between pied-billed grebe abundance and annual mean counts of both hooded mergansers and white ibis with pronounced increases of the latter coinciding with the abrupt decline in pied-billed grebes in 2022. As shown in Table 4, Pearson's r correlation tests demonstrate that these relationships are statistically significant.[10] Figure 18 also shows a steady increase in the abundance of the yellow-crowned night heron beginning in 2021.

The **double-crested cormorant**, which feeds predominantly on fish (The Cornell Lab of Ornithology, 2019), is a year-round resident of the upper Wakulla River. It has bred in colonies in the second mile of the river below the spring every year since at least 1989, as documented by the park's summer full-river

[10] Pearson's correlation coefficient provides a sense for strength of the apparent relationships: r = 1 indicates a perfect positive correlation and r = -1 indicates a perfect negative correlation.

Figure 18. Dominant Crayfish Consumers – Annual Mean Counts per Survey 2012-2023

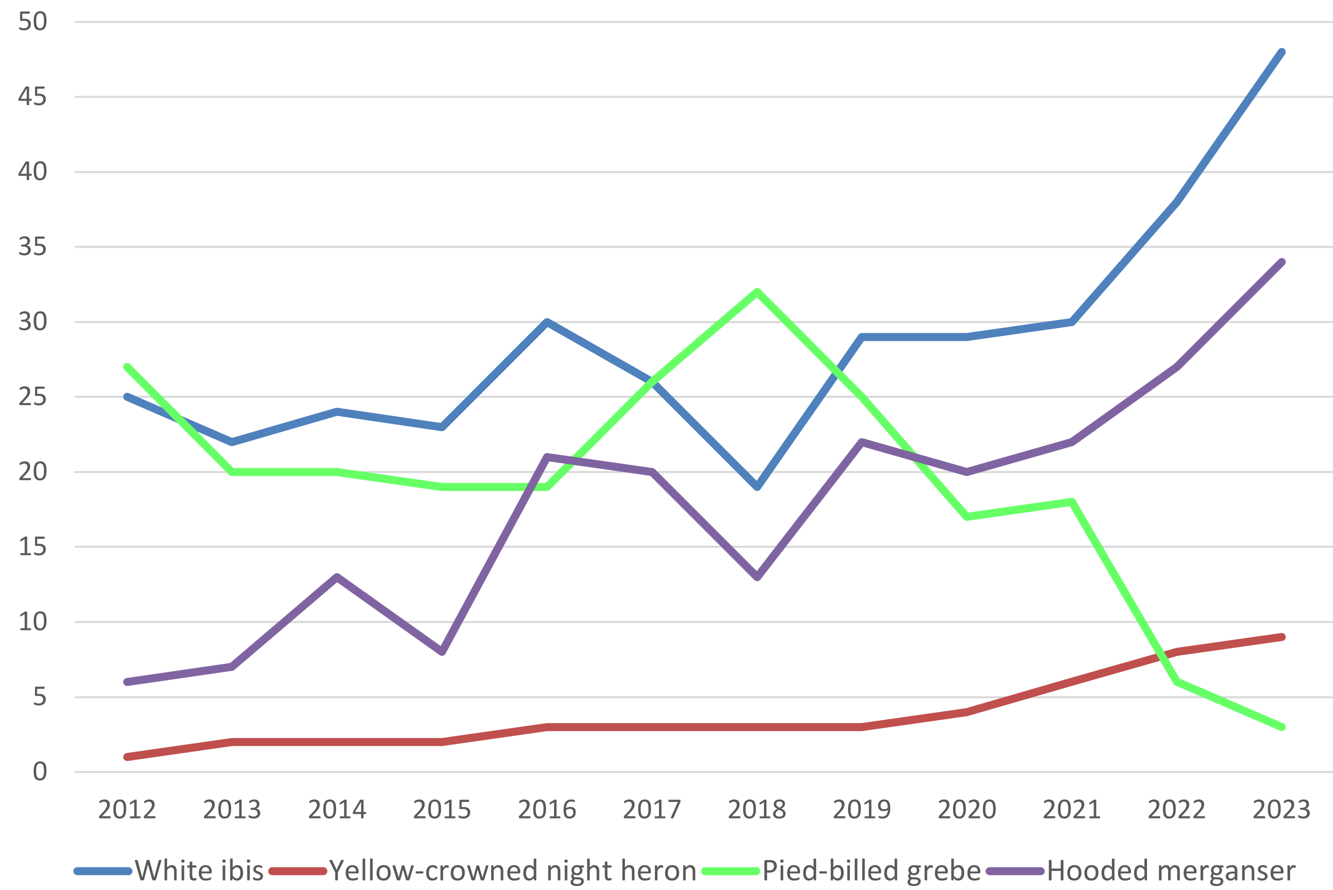


Table 4. Species Abundance Rates of Change: 2012 through May 2021 and June 2024

Pearson's Correlation Coefficient	r*	p value
Pied-billed grebe vs white ibis	-0.8644	<0.0001
Pied-billed grebe vs hooded merganser	-0.6705	0.0003

* Degrees of freedom = 22

wildlife surveys (see Figure 19).[11] The cormorant had exhibited no significant long-term trend in counts per survey for the period of record through 2018. However, with the addition of data for January 2019 through May 2021, a significant positive trend emerged which has persisted with the data extended through June 2024 (see Appendix C). The recent increase in abundance is evident from the counts per survey data shown in Figure 20 with an all-time high count of 89 in September 2023. Peak counts typically occur in August and September, so the 2024 peak would not yet have been observed in June. Cormorants were observed eating crayfish for the first time in the summer of 2021. They continue to do so which may reflect declining fish populations while expanding the competition for crayfish.

[11] Park staff and volunteers have conducted a synoptic survey of wildlife along the entire length of the Wakulla River twice each year since 1989: once in winter (late January or early February) and once in summer (late July or early August). Three teams conduct the survey simultaneously, one on each of three river segments: spring to "upper bridge" (CR 365); upper bridge to "lower bridge" (US 98); and lower bridge to St. Marks River confluence.

Figure 19: Double-Crested Cormorant Count Summer River Survey, Park Section, 1989-2024

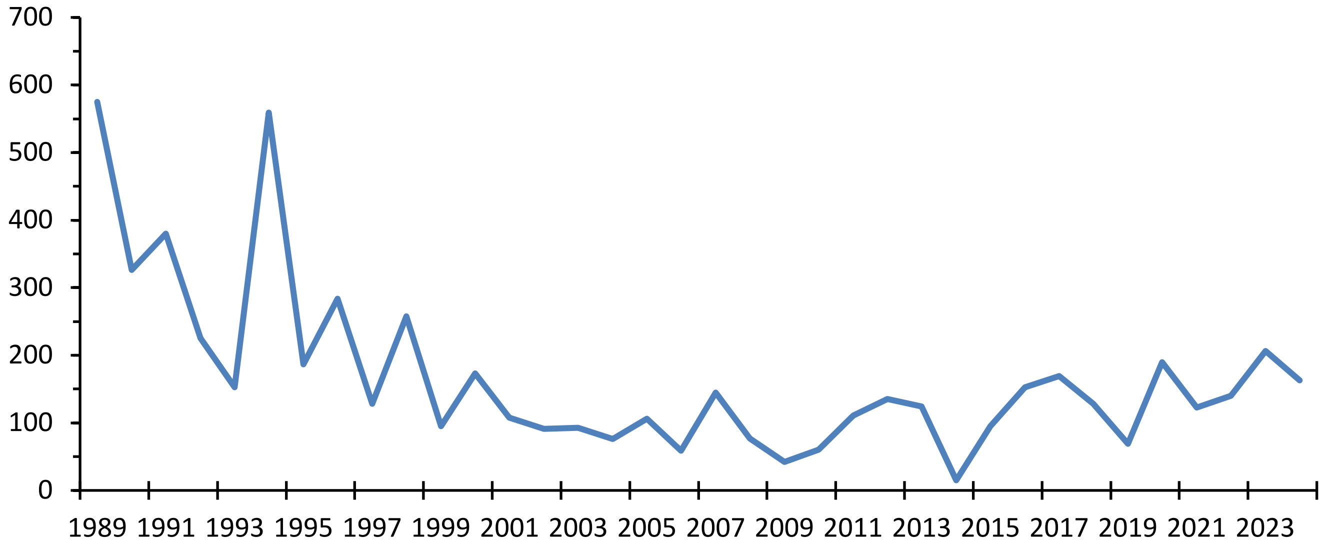
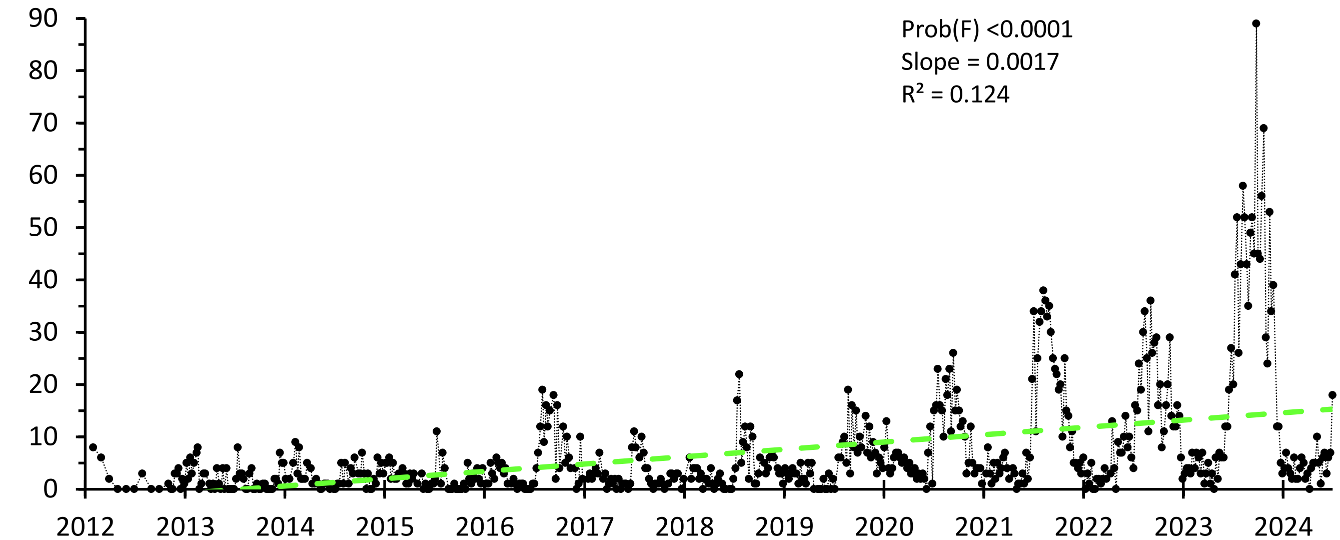


Figure 20. Double-Crested Cormorant Counts per Survey (2012 – June 2024)

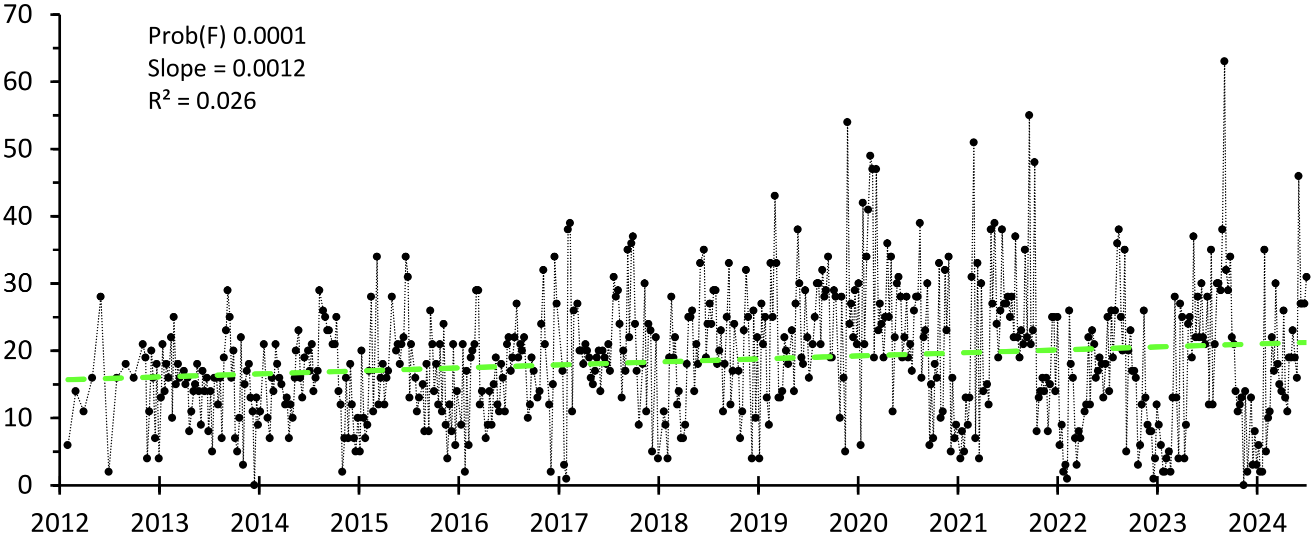


As a top predator in the aquatic food web, the **American alligator**'s abundance may be indicative of aggregate changes in the biological productivity of the ecosystem (Gabrey, 2010; Mazzotti et al., 2009). The long-term trend since 1992 is significantly negative (see Appendix C). However, its counts per survey turned around beginning in 2013, yielding a significant increasing trend in counts per survey since 2012 (see Figure 21), a possible indication of increasing biological productivity.

Another possible explanation for the recent increases in alligator counts is the choice of nesting locations by female alligators. Three females began nesting along the tour boat route sometime after 2013 (personal observation) resulting in higher counts when young were visible. No formal data are available on when that began, and other accounts indicate that young alligators have been observed along the tour route in previous years (Wakulla Springs Archive, 2004). Nevertheless, we began splitting alligator survey counts into two size classes as of April 2018 to provide some control for juveniles inflating the count: less than three feet and greater than or equal to three feet (see Appendix A).

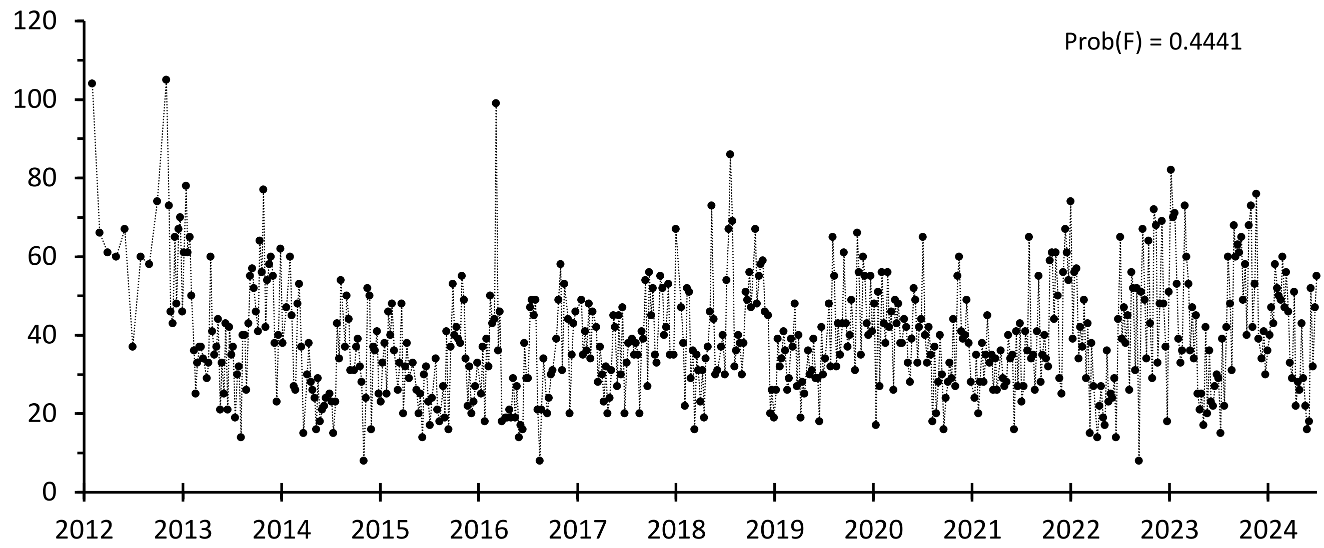
Multivariate analysis of counts per survey between November 10, 2012, through May 29, 2021, reveals that alligator counts are higher when river stage is lower (more basking areas), air temperature is warmer, and the weather is clear or has some clouds (Deyle, 2022).

Figure 21. American Alligator Counts per Survey (2012 – June 2024)



The **common gallinule** is a predominantly surface-feeding herbivore that is a year-round breeder on the upper Wakulla River, with late fall and early winter populations apparently increased by migrants from the north. Those peaks have diminished since 2013 resulting in a significant long-term negative trend (see Appendix C). As shown in Table 3, the post-hydrilla management period trend had been significantly negative for 2012 through May 2021. However, extending the data through June 2024 yields no significant trend for this period (see Figure 22) suggesting perhaps that the gallinule has attained its carrying capacity for the current conditions in the upper river ecosystem.

Figure 22. Common Gallinule Counts per Survey (2012 – June 2024)



The **little blue heron** is often a solitary feeder with a diverse diet including insects, shrimp, amphibians, and fish (Florida Fish and Wildlife Conservation Commission, 2003). It has bred in nesting colonies along the second mile of the upper Wakulla River periodically since 1989, as documented by the park's summer full-river wildlife surveys, most recently nesting there since 2016 (see Figure 23). It exhibits no significant long-term abundance trend (see Appendix C) which persisted during the post-hydrilla management period through May 2021. However, extending the data through June 2024 resulted in a significant positive trend due sustained higher counts during the breeding season in 2021, 2022, and 2023 (see Figure 24).

Figure 23. Little Blue Heron Summer River Survey, Park Section, 1989-2024

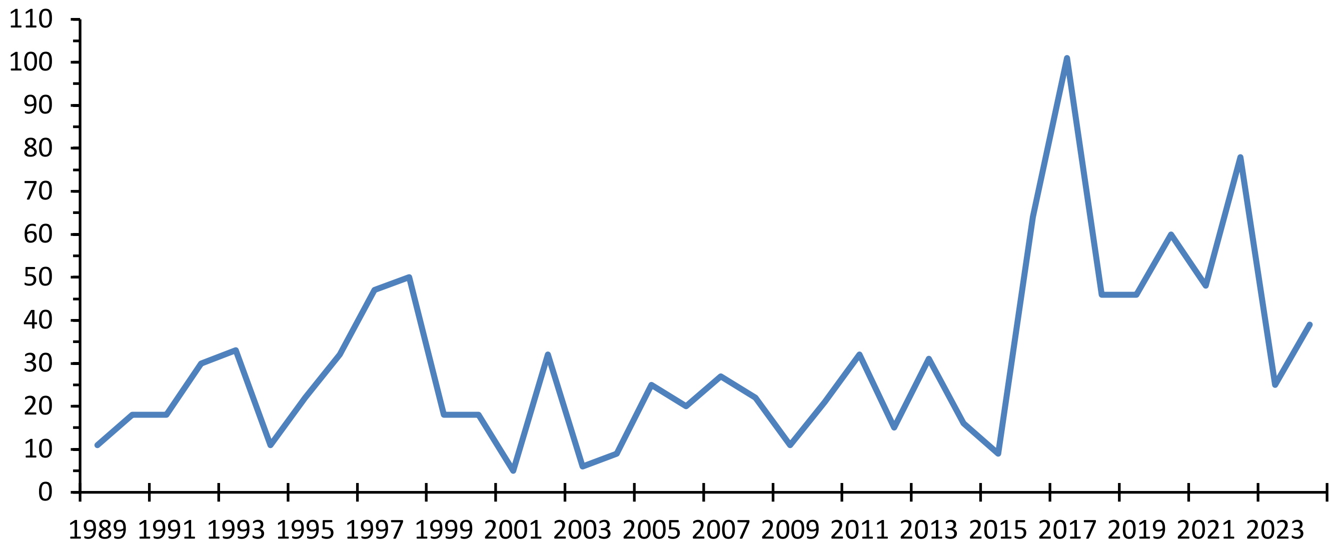
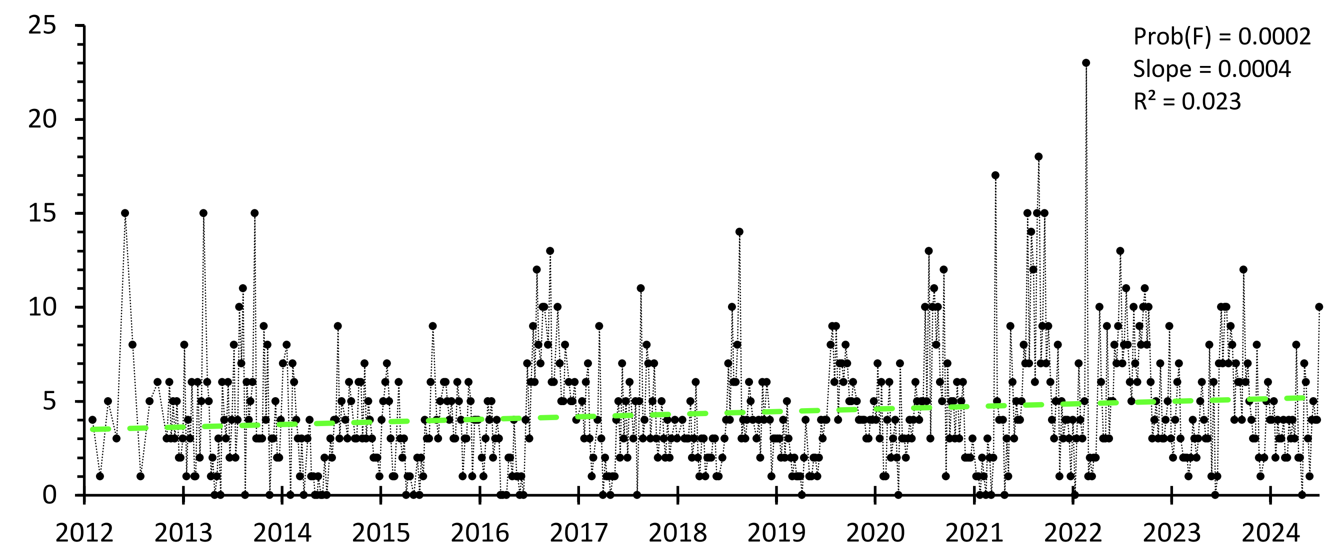
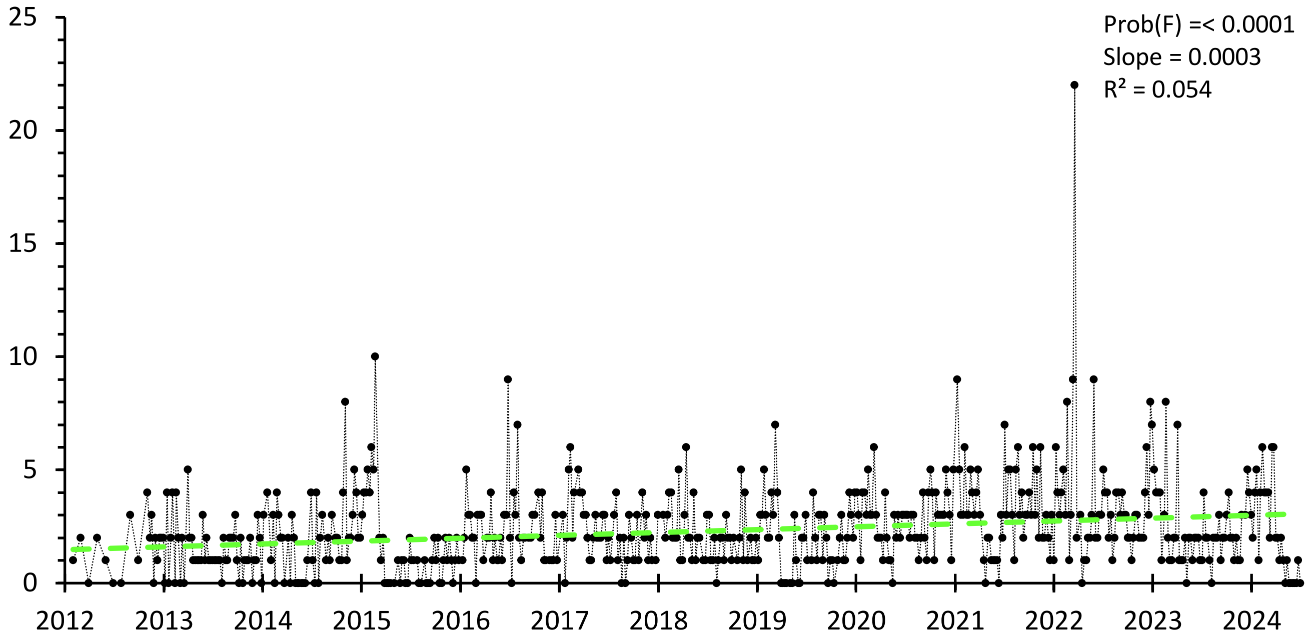


Figure 24. Little Blue Heron Counts per Survey (2012 – June 2024)



Great egrets are present in relatively low numbers with annual means between one and six and individual counts as high as 22 to 24 (see Appendix C). They exhibit no significant long-term trend over the period of record. Like the great blue heron, they consume a variety of prey including fish, reptiles, amphibians, invertebrates, small mammals, and other birds (The Cornell Lab of Ornithology, 2019). Great egrets have nested along the upper river on occasion, most recently in 2009 and 2010 (personal communication Bob Thompson), and along the second mile of the river in association with cattle egrets and little blue herons. A significant trend of increasing abundance emerged during the post-hydrilla management period, albeit at the very slow rate of 0.0003 animals per survey (see Figure 25). As with other very low-density carnivorous wading birds, this may be an artifact of random movements.

Figure 25. Great Egret Counts per Survey (2012 – June 2024)



As noted above, **manatee** were first observed in the park in 1997 and appeared sporadically in small numbers until 2003, which was the first year for which counts were compiled from the regular wildlife monitoring surveys.[12] They over-wintered at the spring for the first time in 2007-2008. As shown in Figure 26, there was a steady increase in annual monthly means from 2007 to 2012 as more and more manatee travelled to the spring, followed by a steep decline through 2015, a levelling off through 2021, and a second peak in 2022 and 2023.

The initial influx has been attributed to carrying capacity pressure at Crystal River from which the Wakulla manatee emigrated (P. Wilbur, personal communication). However, Jess Van Dyke (2019) reports that scouring of the river bottom that resulted from the initial hydrilla herbicide treatment in 2002 opened a passageway through shallow water at the park boundary just north of the county route 365 (Shadeville Road) bridge that had previously been largely impassable because of dense hydrilla and/or shallow sediments. Sediments remain largely bare in that area today with sufficient water depth facilitating regular manatee movement into the upper river.

The post-2012 decline tracks the failure of the hydrilla to recover from manatee grazing over the winter of 2012-13 coupled with the decrease in nitrogen discharges to the spring from the Tallahassee T.P. Smith wastewater treatment plant (see Appendix B). The resulting trend in counts per survey for the post-hydrilla management period was significantly negative through May 2021 (see Table 3). However, substantial increases in the winters of 2023 and 2024 have resulted in no significant trend with the extension of the analysis through June 2024 (see Figure 27).

Tricolored herons are present in small numbers, with annual mean counts per survey of one. Frederick (2013) reports that the tricolored heron feeds almost exclusively on small fish and tends to feed alone or at the edge of mixed flocks. This species, which has experienced a significant long-term trend of decreasing abundance (see Appendix C), has recorded several outlying high counts recently which have resulted in a significant positive trend during the post-hydrilla management period (see Figure 28).

[12] Manatee were not included on the survey form until 2007. Data prior to 2007 are likely incomplete. Observations recorded in 2003 and 2005 are from the open-ended “Comments” section at the bottom of the survey form. None were recorded for 2004 or 2006.

Figure 26. Manatee Annual Mean Abundance (1994-2023)

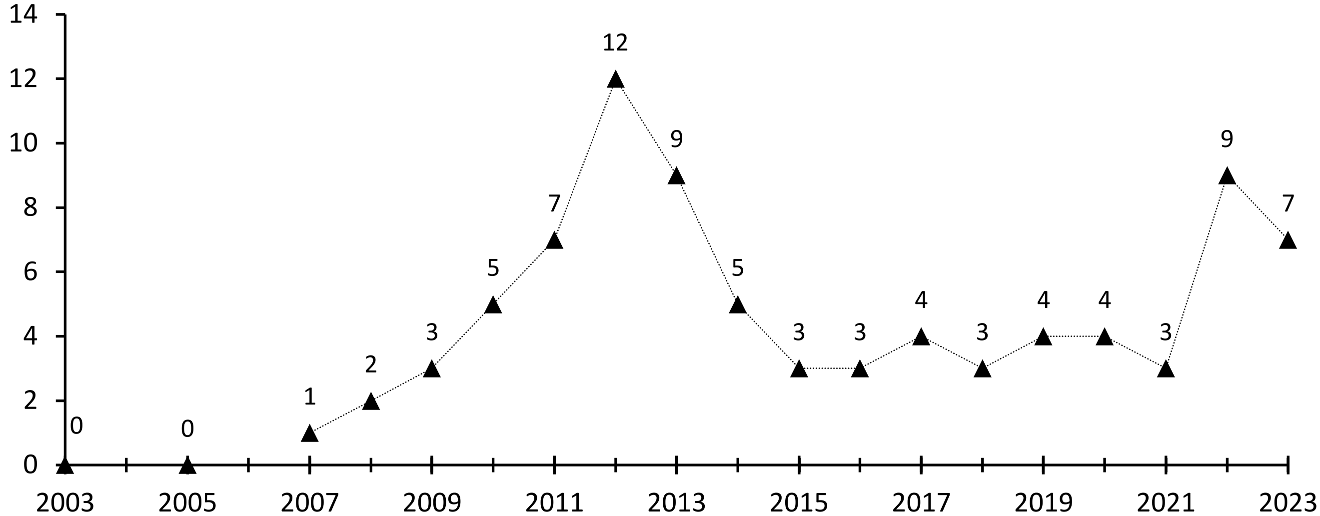
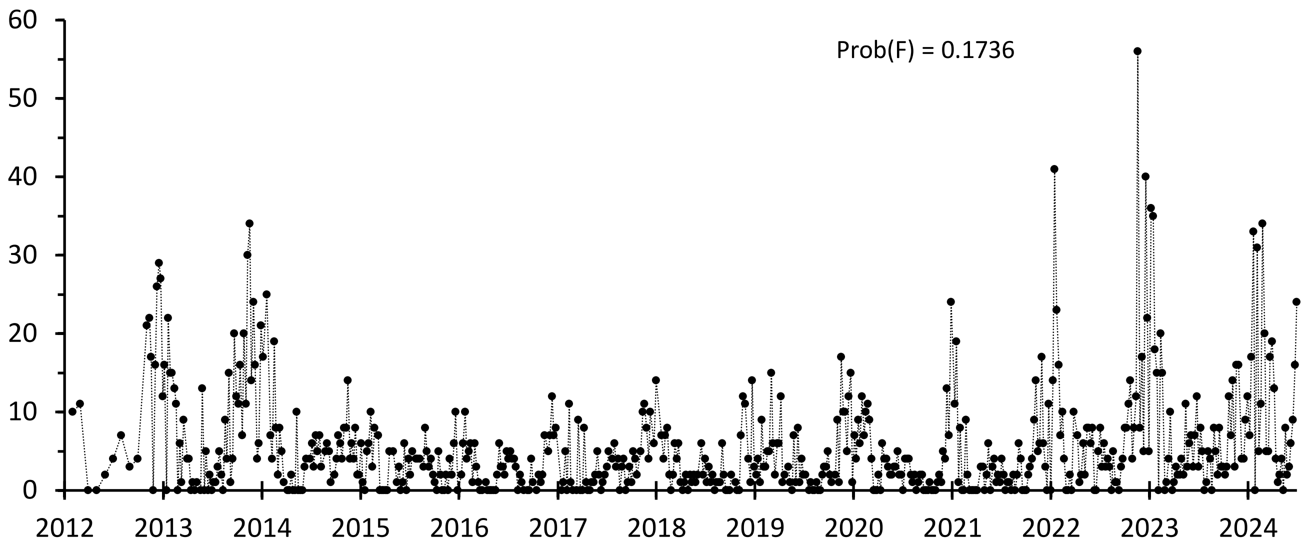


Figure 27. Manatee Count per Survey (2012 – June 2024)

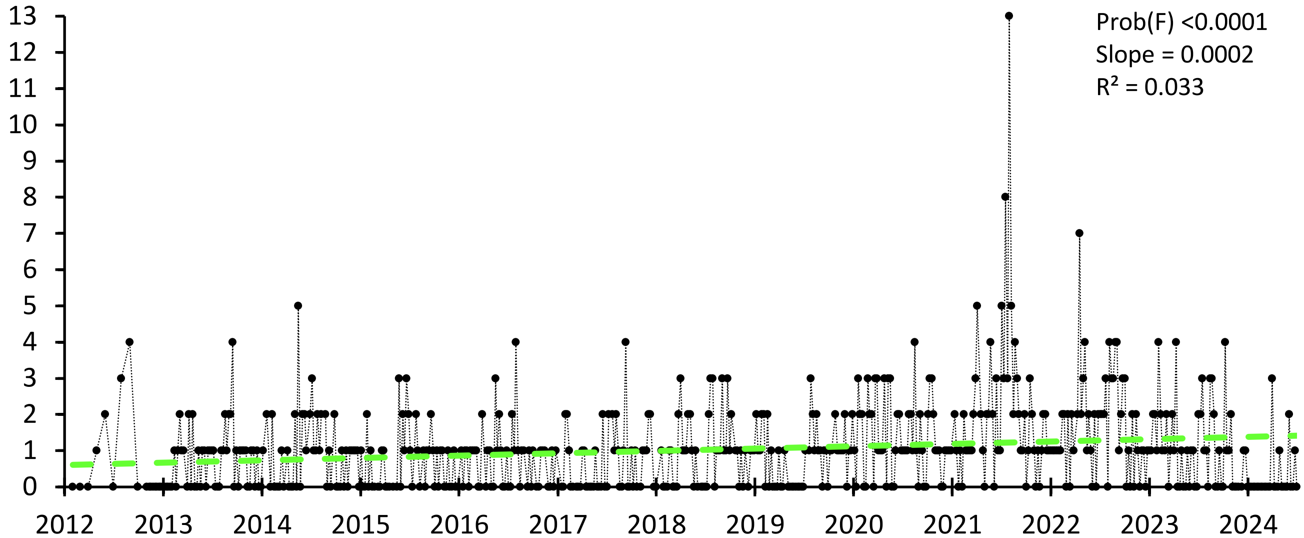


Anhinga are year-round breeders that almost exclusively eat small to medium-size fish (The Cornel Lab of Ornithology, 2019). Anhinga annual means dropped substantially after the onset of efforts to control the hydrilla invasion in 2001 and have oscillated between 9 and 17 since then (see Figure 29). Counts per survey during the post-hydrilla management period exhibited a significant increase through May 2021, but the trend is no longer significant after extending the analysis through June 2024 (see Figure 30).

Figures 31 and 32 reveal a very different seasonal distribution of anhinga than the long-term pattern of average monthly abundance.[13] Abundance is higher during the breeding season in 2024 but lower during the remainder of the year. This may be an artifact of reduced nesting. Anhinga males are highly territorial during the nesting season (Kearns, 2009). While there were as many as five active nests along the tour route as recently as 2015, there have only been one or two since 2017 (personal observation). With fewer defended nesting territories, breeding season counts could be higher.

[13] Red columns in Figure 32 are two or more counts less than the long-term average monthly mean. Green columns are two or more counts more. Blue columns are no more than one count higher or lower than the long-term average monthly mean.

Figure 28. Tricolored Heron Counts per Survey (2021 – June 2024)



Reduced nesting may be the result of decreases in the numbers of small and medium size fish. However, there are no comprehensive fish population data with which to test this hypothesis. In July and August 2021, park staff observed some anhinga eating crayfish (Jackie Turner, personal communication, July 13, 2021). They have continued to do so since then. While they are known to eat aquatic crustaceans (Kearns, 2009), doing so has historically been unusual on the upper Wakulla River.

Figure 29. Anhinga Annual Mean Abundance (1994-2023)

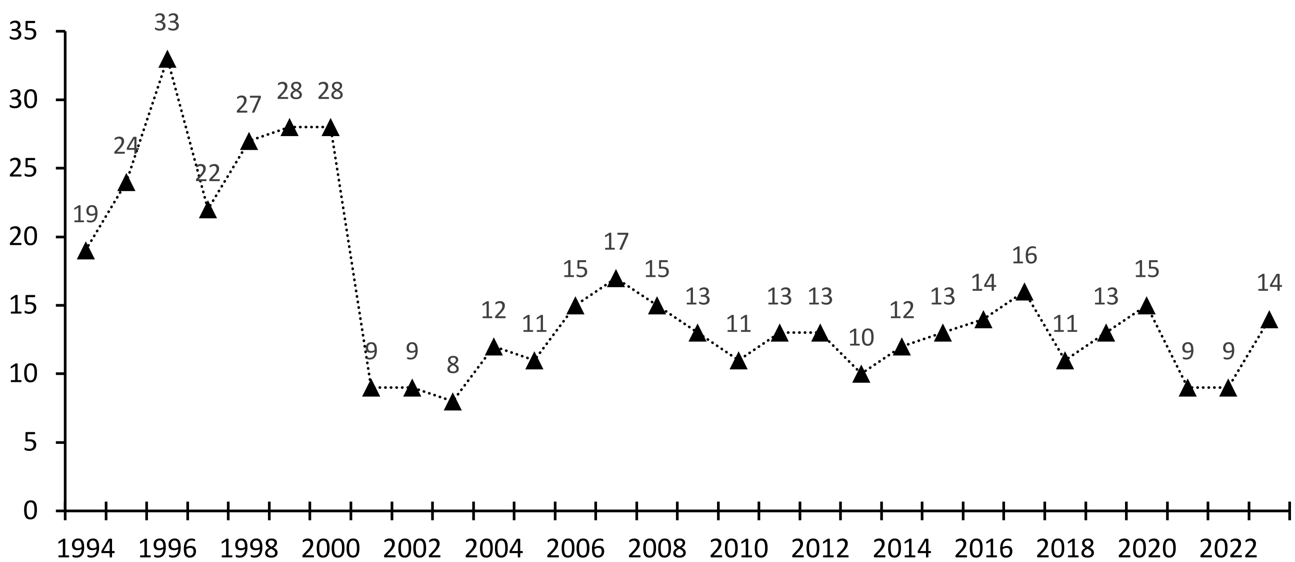


Figure 30: Anhinga Counts per Survey (2012 – June 2024)

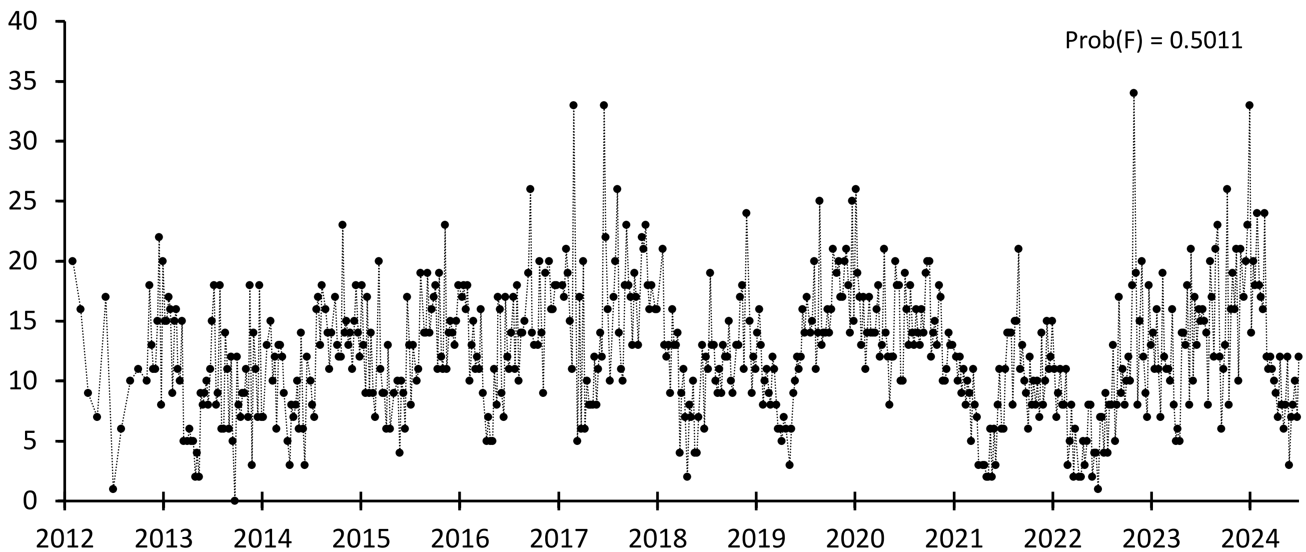


Figure 31. Anhinga Monthly Mean Abundance (1992 – June 2024)

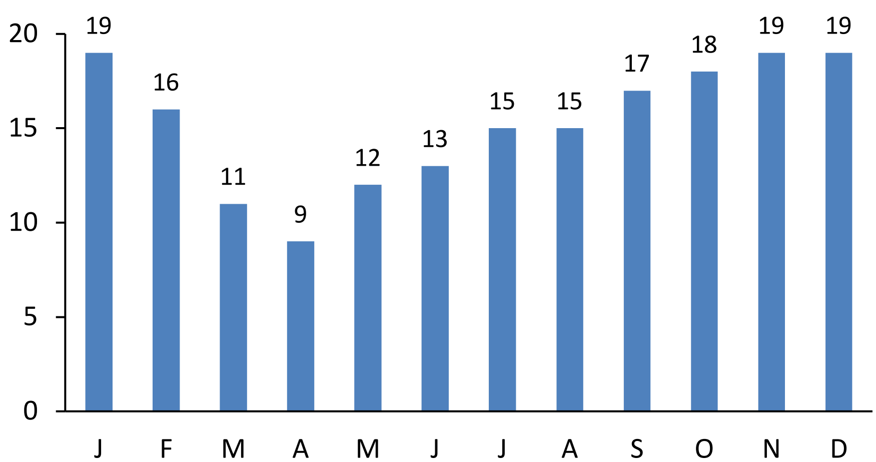
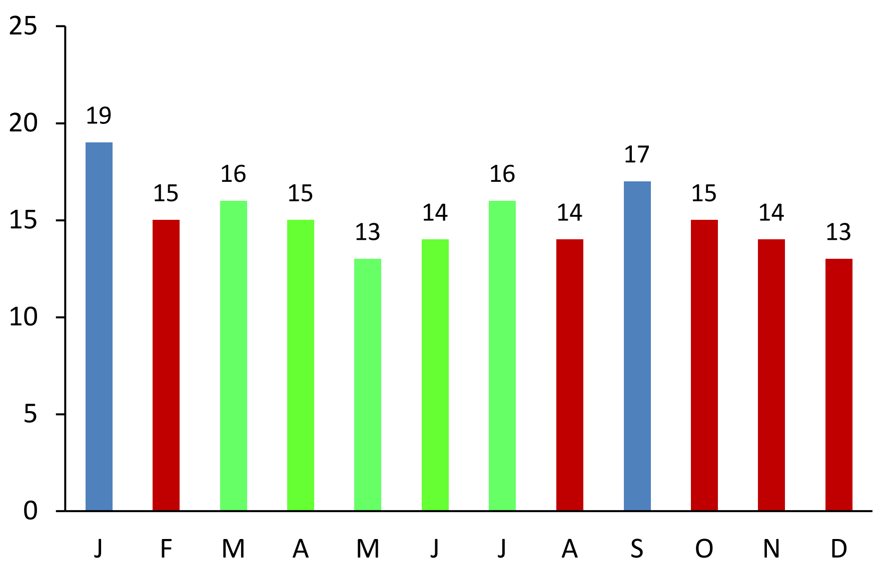
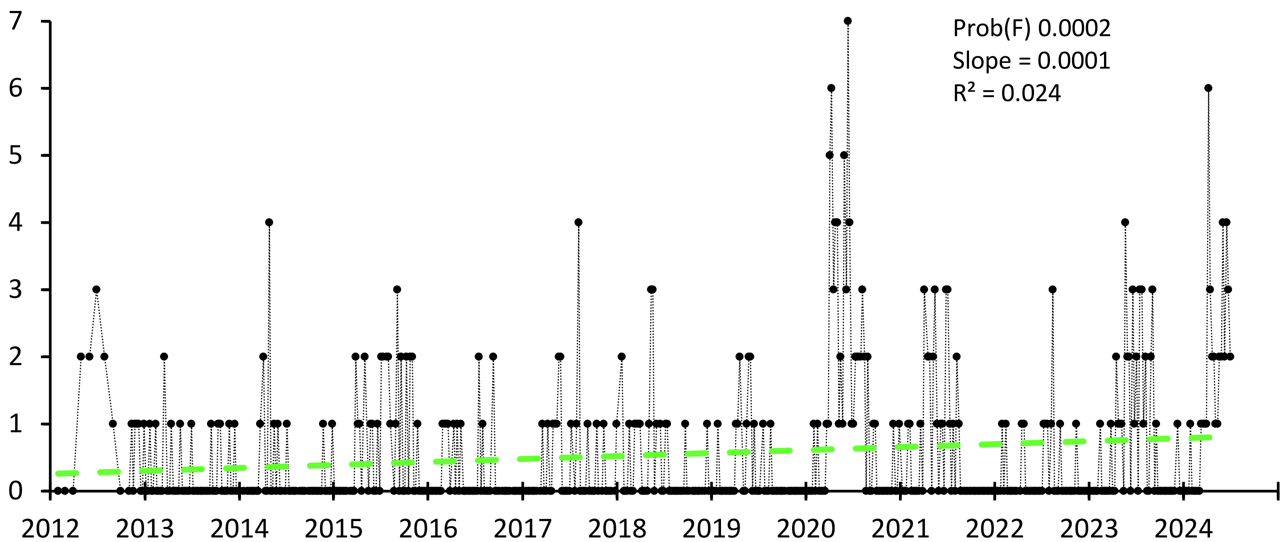


Figure 35. Anhinga Monthly Mean Abundance (2024)



Green heron counts are generally small throughout the period of record with annual means ranging from zero to seven between 1994 and 2023 (see Appendix C). While it has experienced a significant long-term decrease in counts per survey (see Appendix C), the green heron has demonstrated a consistent positive trend during the post-hydrilla management period due in part to nesting along the tour boat route (see Figure 36). The green heron eats mostly small fish as well as some macroinvertebrates, amphibians, reptiles, and small mammals (The Cornell Lab of Ornithology, 2019). Its diverse diet may have enabled it to adapt to the changing food web of the upper river ecosystem.

Figure 36. Green Heron Counts per Survey (2012 – June 2024)

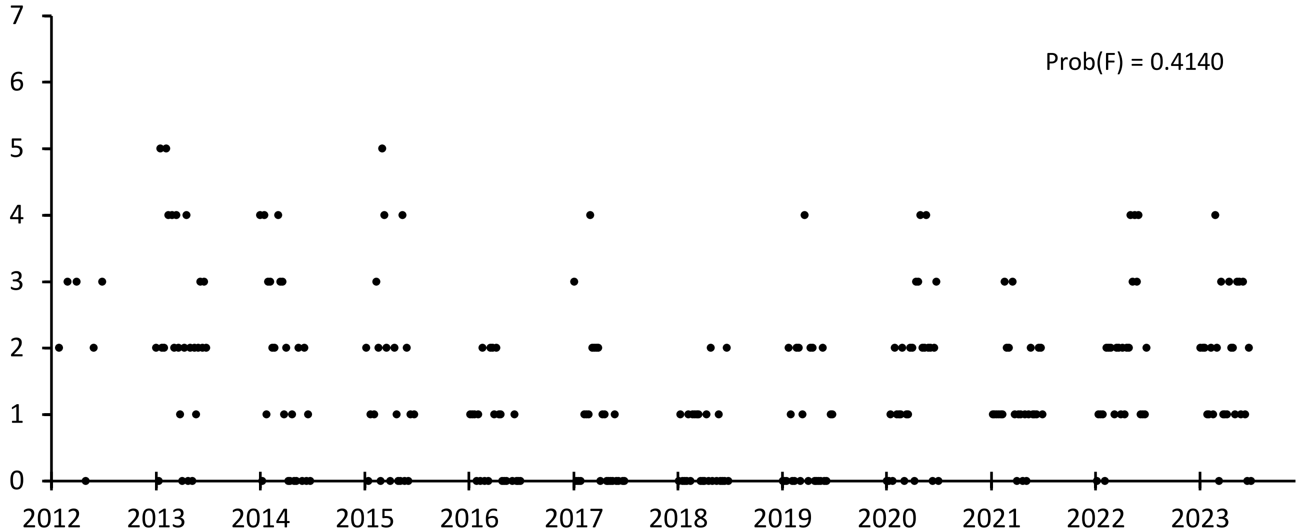


Although listed as a year-round occupant of North Florida, **ospreys** are present on the upper Wakulla River in small numbers, most commonly during the breeding season (February - July) when the monthly means over the period of record (1992 – June 2024) have been two or three (see Appendix C). Monthly means are zero between September and December. The osprey exhibits a significant decreasing trend over the long-term (see Appendix C) and during the post-hydrilla management period through May 2021 (see Table 3). Extending the post-hydrilla management period analysis through June 2024 has shifted the trend to not significant (see Figure 37).

As many as four or five active nests have been observed along the river boat tour route in the past (Bob Thompson, personal communication) with others further down the river including one about 0.25 mile below the tour boat turnaround (personal observation). Three active nests circa 2015 have given way to one or none for the past ten years (personal observation corroborated by Patty Wilbur). With an exclusive fish diet high on the food pyramid, the osprey's decline may be indicative of the apparent long-term decrease in biological productivity reflected in the period of record declines of the aggregate measures of wildlife abundance. A loss of fish in the size classes it typically consumes – six to twelve inches (The Cornell Lab or Ornithology, 2019) – may also be a factor, perhaps due in part to the dramatic shifts in the SAV community following the herbicide treatments of the early 2000s.[14]

[14] Unfortunately, no baseline data on fish or other aquatic vertebrates and invertebrates exist for the upper one mile of the Wakulla River so we can only speculate that the by-catch of juvenile fish and invertebrates from the mechanical harvesting and/or the dramatic fluxes in the SAV community may have been accompanied by other changes throughout the food web that contributed to the observed declines in species that are principally or exclusively fish eaters including anhinga and osprey. FDEP's stream condition index (SCI) monitoring site is located two miles downriver from the spring (Florida Springs Institute, 2014). The SCI evaluates the abundance and diversity of macroinvertebrates.

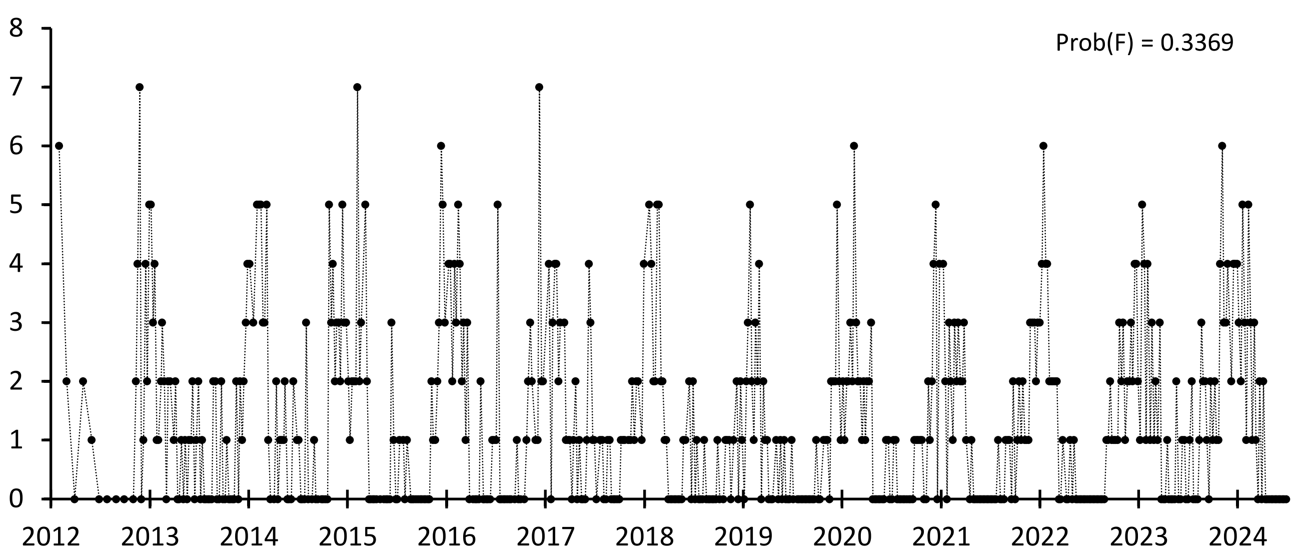
Figure 37. Osprey Breeding Season Counts per Survey (February – July, 2012 – 2023)



Great blue herons are year-round residents of the upper Wakulla River that sometimes breed there, with one or two active nests along the river boat tour route in 2015-2017 (personal observation). Counts have ranged as high as seven on several occasions, while annual means have varied from one to three (see Appendix C). The occasional higher counts have occurred during winter months from November through February. Monthly means also are higher at that time (see Appendix C), which may reflect an influx of winter migrants from northern breeding territories (The Cornell Lab of Ornithology, 2019). Neither the long-term period of record trend nor the post-hydrilla management trend is statistically significant (see Appendix C and Figure 38). The post-hydrilla management period trend shifted from negative to not significant with extension of the analysis from May 2021 to June 2024 (see Table 3).

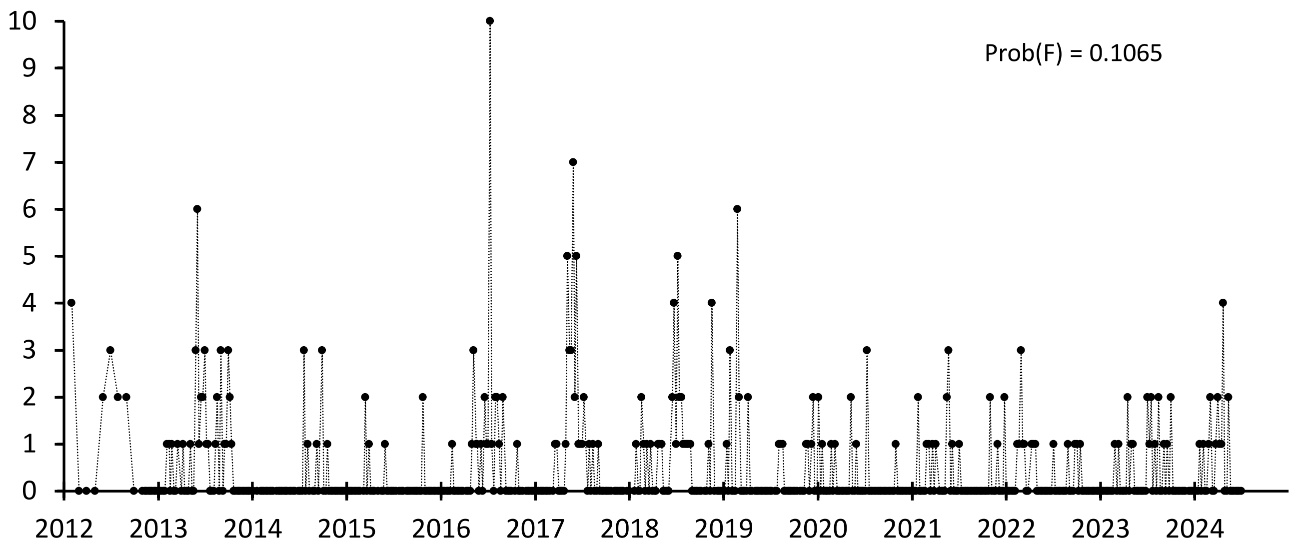
Great blues are solitary feeders that defend their feeding territories and consume a variety of prey including fish, reptiles, and amphibians, small mammals, and other birds, although they are primarily fish eaters (Vennesland and Butler, 2011). The carrying capacity of the upper river for great blue herons may have been reached.

Figure 38. Great Blue Heron Counts per Survey (2012 – June 2024)



The **snowy egret** eats mostly small fish as well as some macroinvertebrates, amphibians, reptiles, and small mammals (The Cornell Lab of Ornithology, 2019). It has exhibited a significant long-term decrease in counts per survey over the period of record during which annual means have been small ranging from zero to four (see Appendix C). Since 2009, annual means have ranged from zero to one. The snowy egret has exhibited no significant trend during the post-hydrilla management period (see Figure 39). Changes throughout the food web, including the apparent decline in fish populations of all sizes, may have contributed to the observed decline in this species.

Figure 39. Snowy Egret Counts per Survey (2012 – June 2024)



Summary of Abundance Trends

The long-term trend in aggregate wildlife abundance, measured as total numbers of individual animals counted per survey for all 19 species over the 31.5 years of this monitoring project, remains significantly negative. However, the passage of time explains less of the observed variation in abundance than it did in the previous analysis with an R-squared of 0.162 as of June 2024 rather than 0.228 as of May 2022.

Three species exhibited no statistically significant long-term trend, nine decreased, and six increased. Manatee abundance also has increased, starting in 2003, the first year in which they were surveyed.

The trend in aggregate wildlife abundance for all 19 species during the post-hydrilla management period shifted from a significant decrease for the period January 2012 through May 2021 to no significant trend with the analysis extended through June 2024. This reflects large increases in the numbers of hooded mergansers and white ibis in the winter of 2023-2024 associated with a dramatic decline in pied-billed grebes with which they compete for crayfish, their principal food source.

Three species exhibited significant decreasing trends during the post-hydrilla-management period through June 2024: American coot, cooter turtle, and pied-billed grebe. Ten species experienced significant increases: green heron, tricolored heron, great egret, little blue heron, American alligator, double-crested cormorant, yellow-crowned night heron, cattle egret, white ibis, and hooded merganser. The remaining six species exhibited no significant trend: snowy egret, great blue heron, osprey, anhinga, manatee, and common gallinule.

The five species that have increased in abundance during the period of record include (in decreasing rate of increase) hooded merganser, white ibis, cattle egret, pied-billed grebe, and double-crested cormorant. Among the 14 species that have decreased significantly, the five that have declined most rapidly include (in decreasing rate of decline) American wigeon, common gallinule, American coot, wood duck, and American alligator.

Notable changes observed since May 2022 include the following:

- Analysis was suspended for four species that are now rarely observed: blue-winged teal, limpkin, purple gallinule, and wood duck.
- American alligator abundance declined some although the post-hydrilla-management trend remains positive.
- The rate of decline in American coot numbers increased.
- The trend in anhinga abundance shifted from positive to not significant, reflecting a decrease in counts per survey. Since 2021, anhinga have been increasingly observed eating crayfish rather than fish.
- The trend for the common gallinule shifted from weakly negative to not significant.
- Cooter turtle abundance changed from no significant trend to negative; more prolonged dark water conditions may have been a factor, but available weekly visibility data do not indicate that has been the case.
- The double-crested cormorant maximum count trebled in 2023 from 30 to 90. It has been on an upswing since 2018, presumably because of the nesting colony down river. Similar to the anhinga, cormorants have been increasingly observed eating crayfish rather than fish since 2021.
- The abundance trend for the great blue heron is no longer significant; it had been weakly negative.
- The upward trend in hooded merganser counts continued. The rate of change increased as did the R-squared measure of the explanatory power of the trend, from 0.096 to 0.206.
- The trend for the little blue heron shifted from not significant to weakly positive.
- Manatee abundance changed from a decreasing trend to no significant trend reflecting higher counts between May 2021 and June 2024. The previous high single day count of 34 was exceeded on eight occasions with a maximum of 56.
- Osprey counts per survey changed from a decreasing trend to no significant trend reflecting a levelling off with just one active nest on the upper river.
- The pied-billed grebe population which had appeared to have achieved a new equilibrium is now in significant decline due to habitat loss from the disintegration of the bulrush island and the loss of knotweed.
- White ibis annual means increased in 2022 and 2023. Annual abundance has shifted from no significant trend to an increase.
- The yellow-crowned night heron trend has continued to be positive while annual means have been on a strong upward path since 2020.

The upper Wakulla River ecosystem appears to have shifted from a food web based primarily on submerged aquatic vegetation (SAV) to a more detrital-based food web. Species that feed primarily or substantially on crayfish, which are detrital feeders, i.e. hooded merganser, yellow-crowned night-heron, and white ibis, continue to exhibit stable or increasing trends. The exception is the pied-billed grebe which has declined precipitously with the disintegration of the bulrush island and the extensive loss of knotweed habitat. Counts of hooded mergansers and white ibis exhibit statistically significant negative relationships with those of pied-billed grebes, while annual means of yellow-crowned night herons have been on a strong upward path since 2020. These species appear to have taken advantage of the grebe decline.

Common gallinule and American coot, which feed predominantly on SAV, continue to decline (coots) or have levelled off after declining (gallinule). Those species that depend more heavily on medium to large fish also appear to have reached new, lower carrying capacities: osprey (a single nesting pair), great blue heron (no nesting), and anhinga (only a couple active nests).

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APPENDIX A
Current Survey Form

<u>Routing of Completed Surveys:</u> Please place in Wildlife Survey mail slot at the Waterfront

Weekly Wakulla Springs Tour Boat Route Wildlife Survey Report

DATE: ____ / ____ / ____ (Month, Day, Year); **SURVEY BEGIN TIME**: ____ : ____ (Hour:Minute) AM
NAME OF VOLUNTEER: ____
RIVER HEIGHT: ____ . ___ (Feet & tenths of a foot, measured on river stage gauge mounted on T-dock)
AIR TEMP _____ (Degrees F, measured on stick thermometer, cypress tree on WF deck)
WEATHER: ___ Clear; ___ Some Clouds; ___ Overcast; ___ Fog; ___ Raining (Check all that apply)

	Dock to Railroad	Railroad to Turn	Turn to Railroad	Railroad to Dock	Total
American Alligator < 3 ft					
American Alligator ≥ 3 ft					
Cooter (sp.)					
Florida Softshell Turtle					
Snake (any)					
Pied-billed Grebe					
Double-Cr Cormorant					
Anhinga					
American Bittern					
Least Bittern					
Great Blue Heron					
Great Egret					
Snowy Egret					
Tri-colored Heron					
Little Blue Heron					
Cattle Egret					
Green Heron					
Yellow-crowned Night H.					
White Ibis					
Wood Duck					
Blue-winged Teal					
Lesser Scaup					
Bufflehead					
Hooded Merganser					
Red-shouldered Hawk					
Bald Eagle					
Osprey					
Purple Gallinule					
Common Gallinule (Moorhen)					
American Coot					
Limpkin					
Spotted Sandpiper					
Barred Owl					
Belted Kingfisher					
Manatee					

Comments: Revised 4/6/18

APPENDIX B
Wakulla Springs Nitrogen Trends

Figure B-1. Total Nitrogen from City of Tallahassee Wastewater Sources

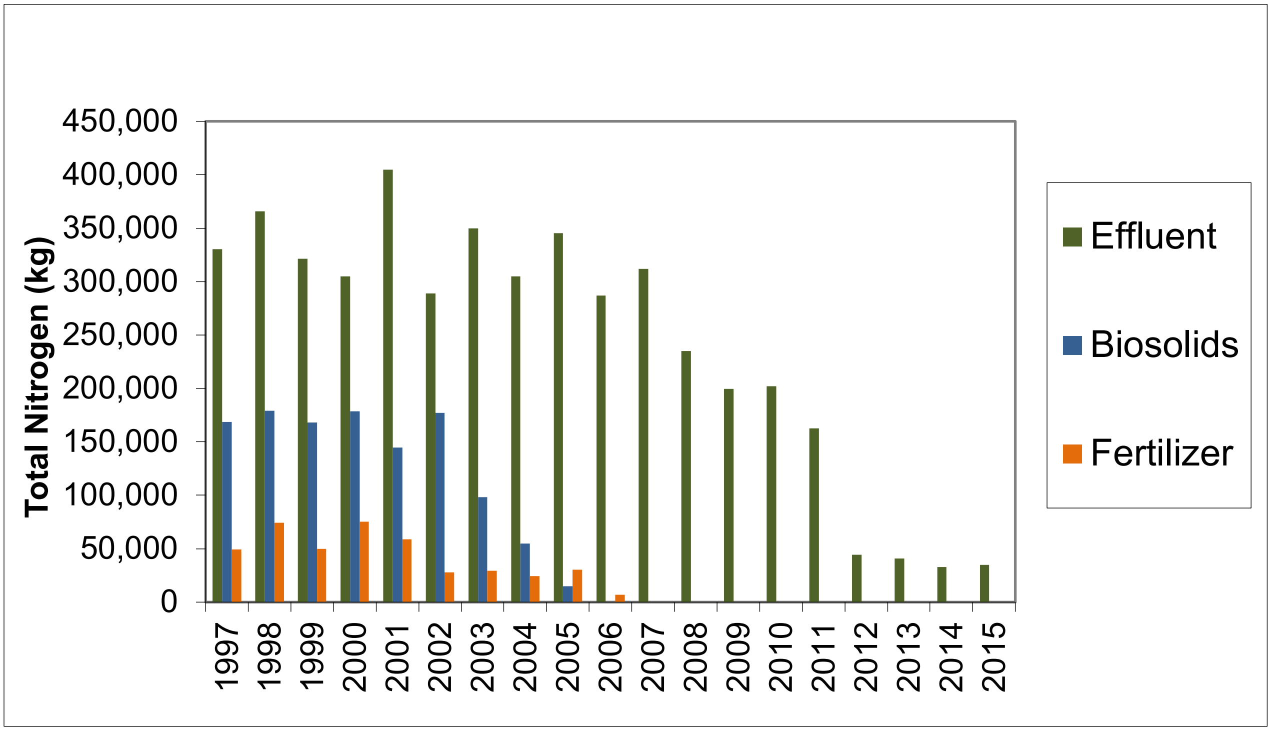
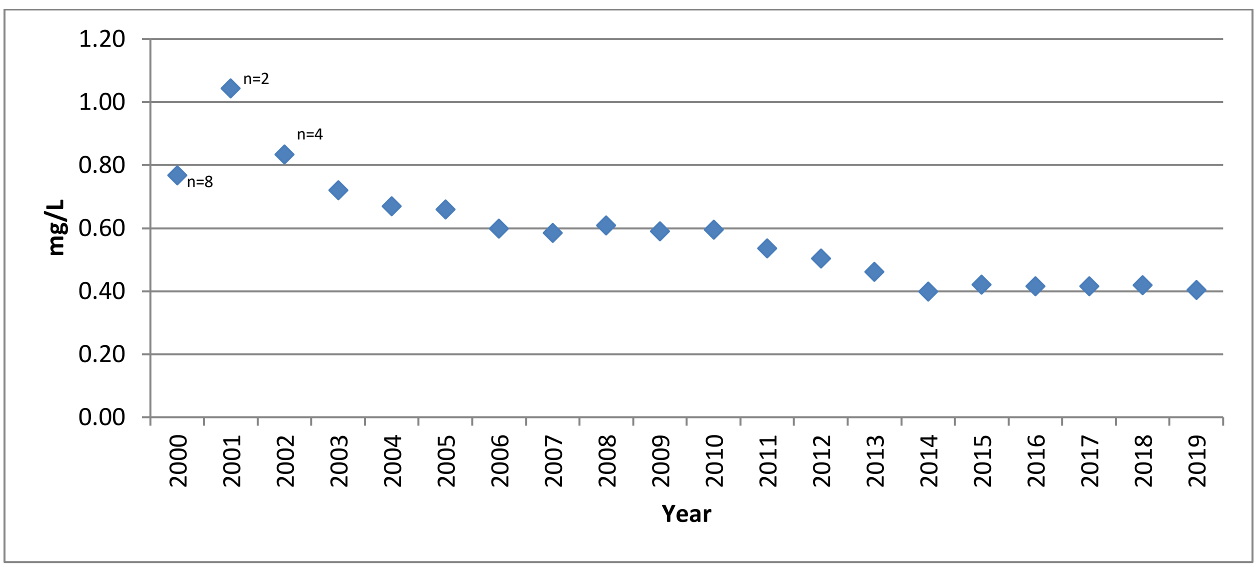


Figure B-2. Wakulla Spring Mean Annual Nitrate Concentration



Source: Barr (2020)

APPENDIX C
Wildlife Abundance Plots and Trends

This appendix presents plots of counts-per-survey and annual means for aggregate wildlife abundance, i.e. the total numbers of animals counted per survey, for the 19 species analyzed in this report. It also presents average monthly mean count histograms, counts-per-survey plots, annual or seasonal means, and short explanatory narratives for each wildlife species. Plots are included for the entire period of record, September 1992 through June 2024, and for the post-hydrilla management period (January 2012 through June 2024).[1]

Trend lines and associated linear regression statistics are depicted on counts-per-survey plots where the linear regression trend is statistically significant at the 95% level or better (Prob(F) $\leq$ 0.05). Where the regression model is not significant, only the Prob(F) value is reported on the graph. Where species abundance is strongly seasonal, i.e. individuals are entirely absent or nearly so for several months, statistical trend analysis is conducted only for the months when the species is predominantly present and annual seasonal monthly means are reported in lieu of annual means. Where seasonal data are analyzed, the counts-per-survey data are presented as scatter plots without lines connecting the data points because of the seasonal gaps.

Legend for Plots

- • Number of animals observed on survey date
- ▲ Annual or annual seasonal monthly mean number of animals observed during monitoring
- - - **Decreasing Abundance Trend**: Statistically significant linear regression trend line with a negative slope
- - - **Increasing Abundance**: Statistically significant linear regression trend line with a positive slope

Regression Statistics

- Prob(F): model fit (included in all counts-per-survey plots) - The F-test in ordinary least-squares regression tests the null hypothesis that the model tested is equal to a model with no predictor variables (Minitab Blog Editor, 2015). The F-test probability (Prob(F)) indicates the probability that the null hypothesis is correct, i.e. that the regression model provides no prediction of the dependent variable. The smaller the Prob(F) value, the better the "model fit," i.e. the greater the likelihood that the alternative hypothesis is true, that the observed variation in species abundance over time is better explained by the passage of time (and other variables in multivariate models) than by a model with no predictor variables.
- Slope (included for all statistically significant trends) – The slope of the regression trend line is *m* in the regression equation $y = mx + b$ where *y* is the value on the vertical axis for the animal counts per survey or annual mean number of animals counted on wildlife surveys, *x* is the survey date or year value on the horizontal axis, and *b* is the y intercept. The slope parameter *m* is calculated as the change in *y* divided by the change in *x*: $m = (y_2 - y_1)/(x_2 - x_1)$.

- R^2 model explanatory power (included for all statistically significant trends) – R-squared (R^2), the coefficient of determination, measures the percent of variation in counts-per-survey or mean counts explained by survey date or year. Thus, for example, where the R^2 value is 0.30 for a model of the long-term abundance trend of a species between 1992 and 2021, the predictor variable, date, explains 30% of the observed variation in the counts-per-survey of the species.

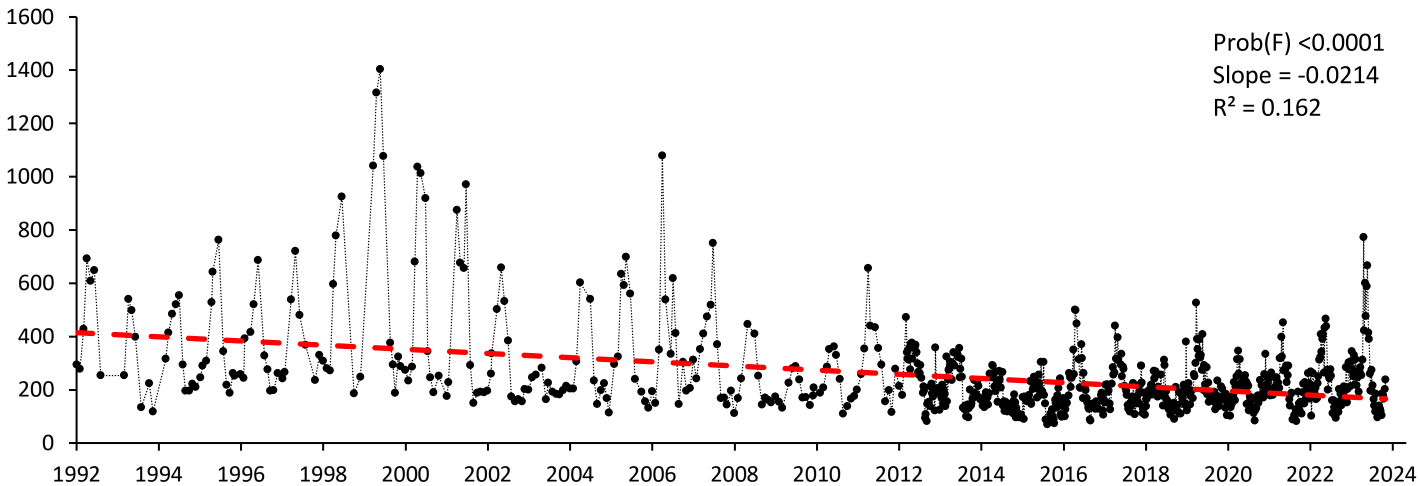
[1] Park staff conducted wildlife surveys monthly beginning in fall 1992. Volunteers began weekly monitoring in fall 2012 resulting in a higher density of data points thereafter.

AGGREGATE WILDLIFE ABUNDANCE

This section presents parallel analyses of the two aggregate abundance measures: the total numbers of animals counted annually per survey (a) for 12 months each year for the 19 species analyzed and (b) during the months of April through July for six year-round resident breeders.

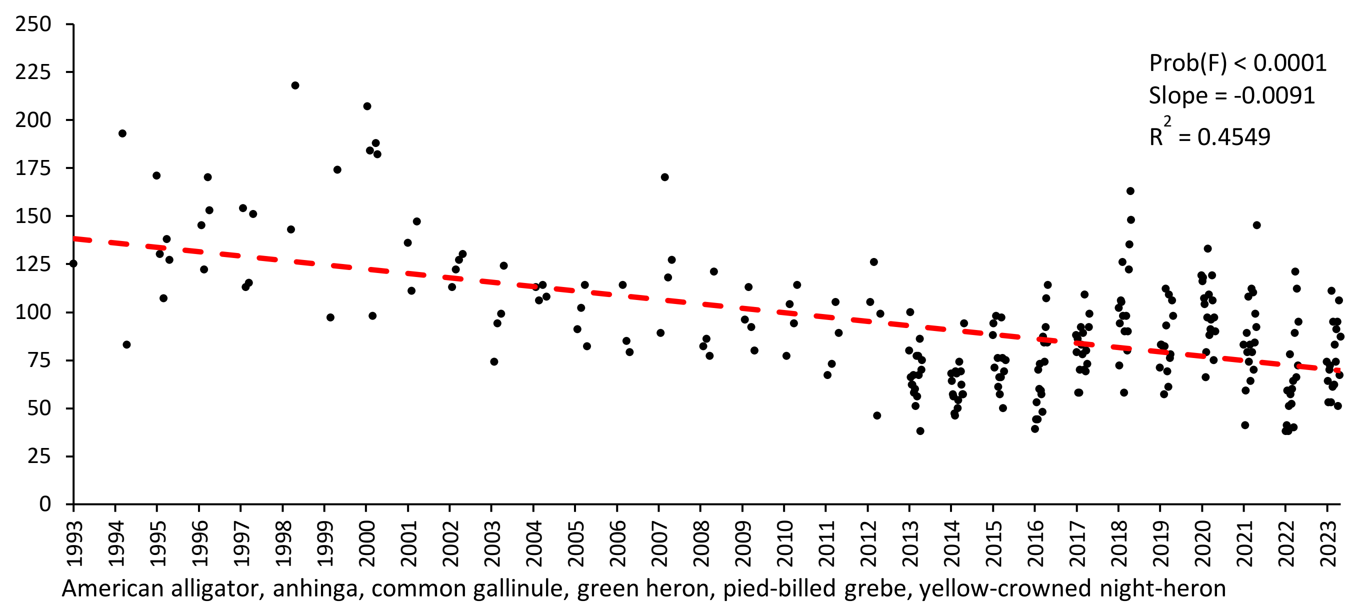
September 1992 - June 2024 Total Counts per Survey 19 Species

Total animal counts per survey for all 19 species on the upper Wakulla River exhibit a significant (better than 99.99% level) decreasing abundance trend of -0.0214 animals counted per survey over the period of record, 9/1/92 – 6/30/24. Survey date explains 16.2 % of the observed variation in counts per survey.



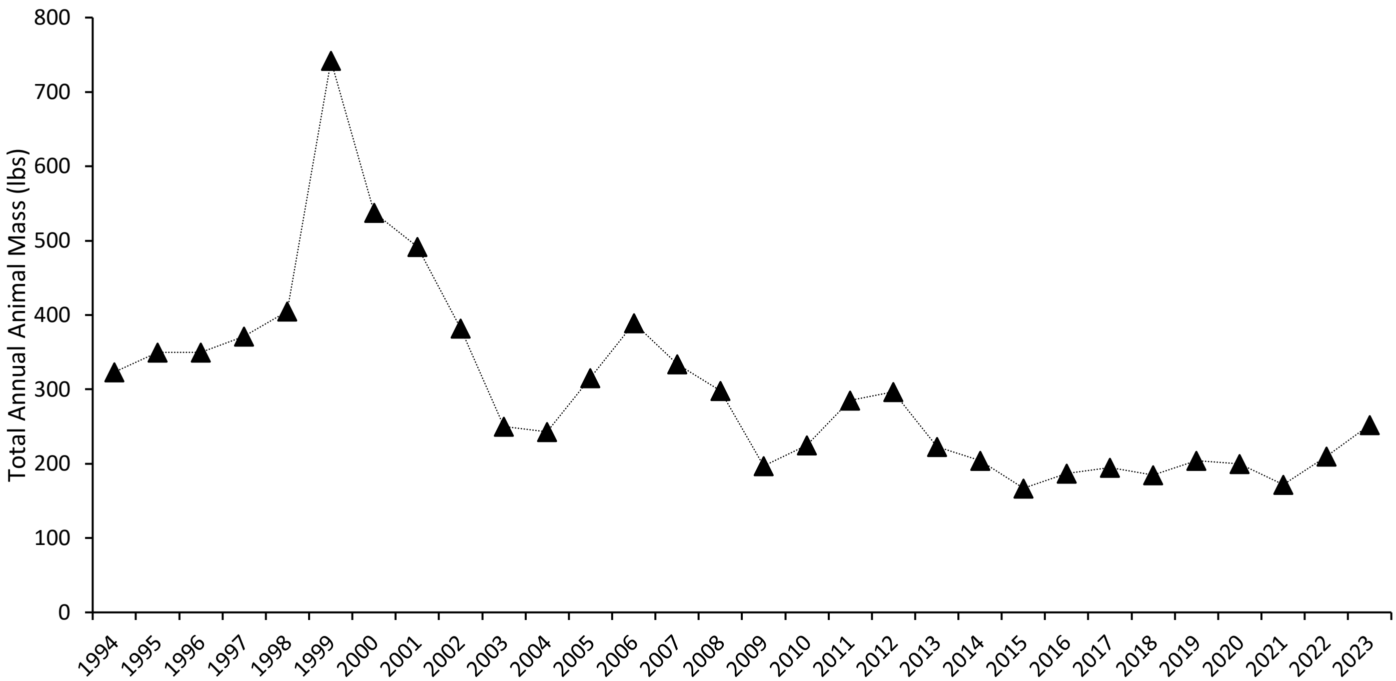
April - July 1993-2023 Total Counts per Survey Year-Round Resident Breeders

Total animal counts per survey during the months of April through July for the six year-round resident breeders on the upper Wakulla River also exhibit a significant (better than 99.99% level) decreasing abundance trend. However, the rate of decrease is slower: -0.0091 animals counted per survey over the period of record, 4/5/93 – 7/31/23. Survey date explains a much greater percentage of the observed variation in counts per survey – 45.49% – most likely reflecting the much lesser influence of factors outside the river ecosystem.



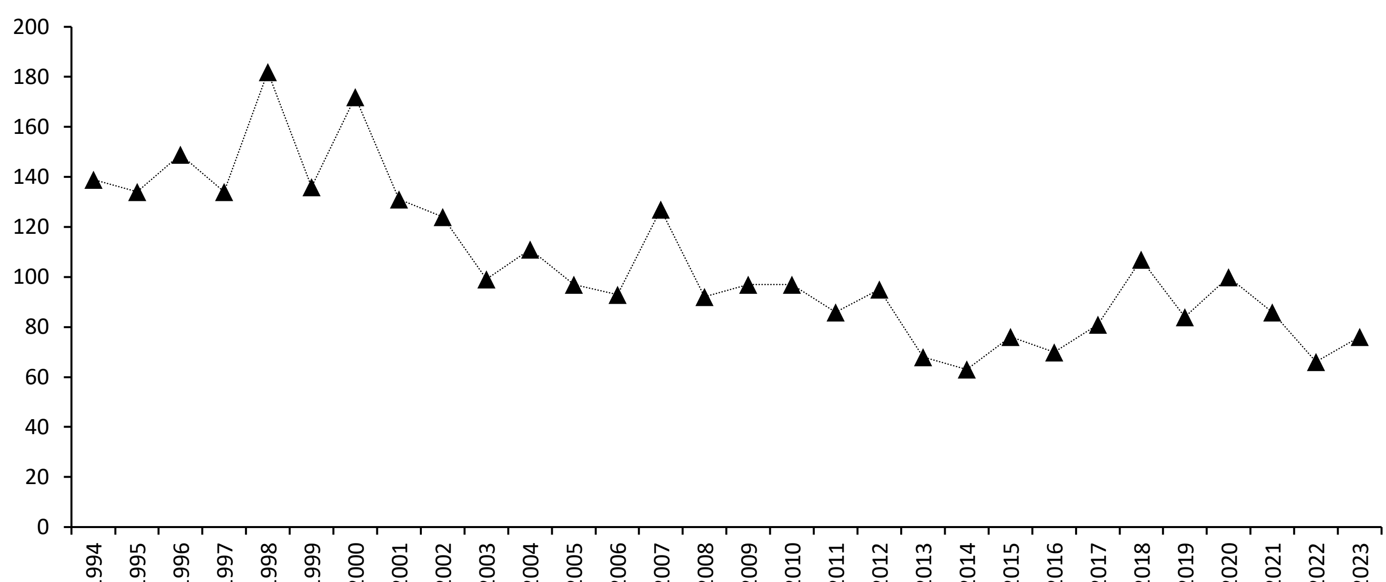
1994-2023 Total Annual Mean Counts per Survey for 19 Species

Annual means reveal the decreasing abundance trend in total animal counts per survey. Peak abundance occurred in 1999 followed by a steep decline. Secondary, much smaller peaks, occurred in 2006 and 2011-12. Annual means began to increase in 2016.



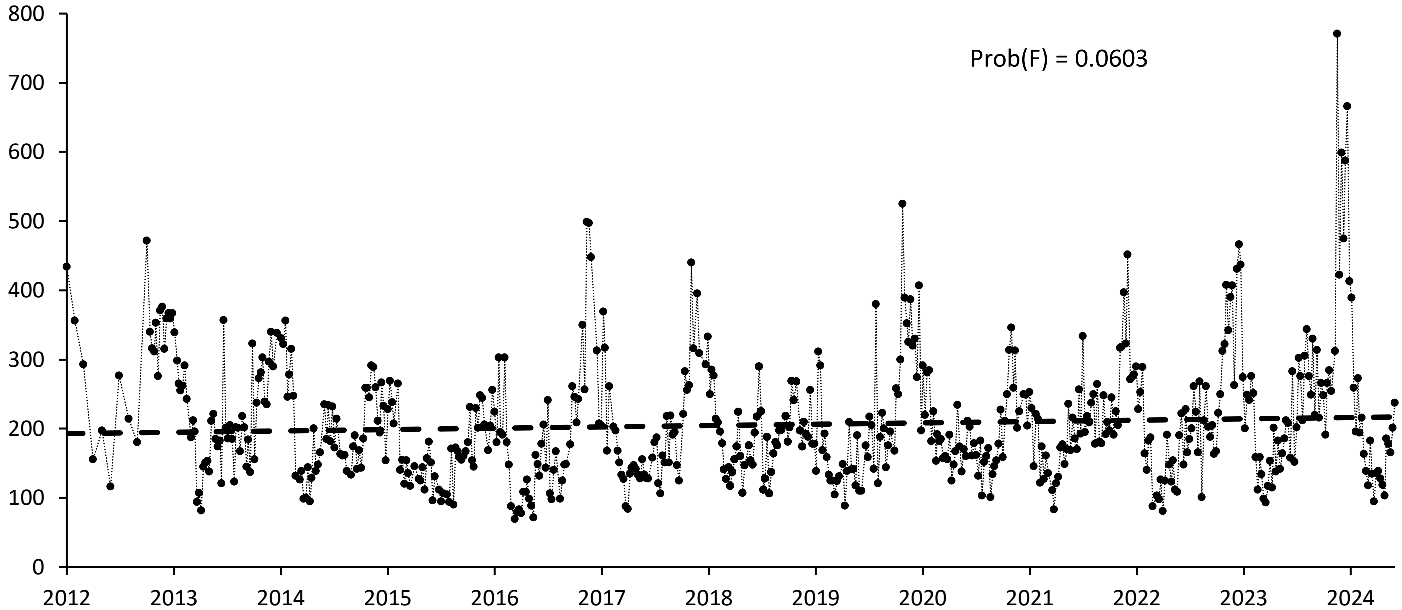
1994-2023 Total Annual Summer Mean Counts per Survey for 6 Year-Round Resident Breeders

Annual summer means for the six year-round resident breeders also exhibit a long-term decreasing abundance trend. However, peak abundance occurred in 1998 with secondary peaks in 2001 and 2007 followed by a steep decline. Annual summer means for these species began to increase in 2015.



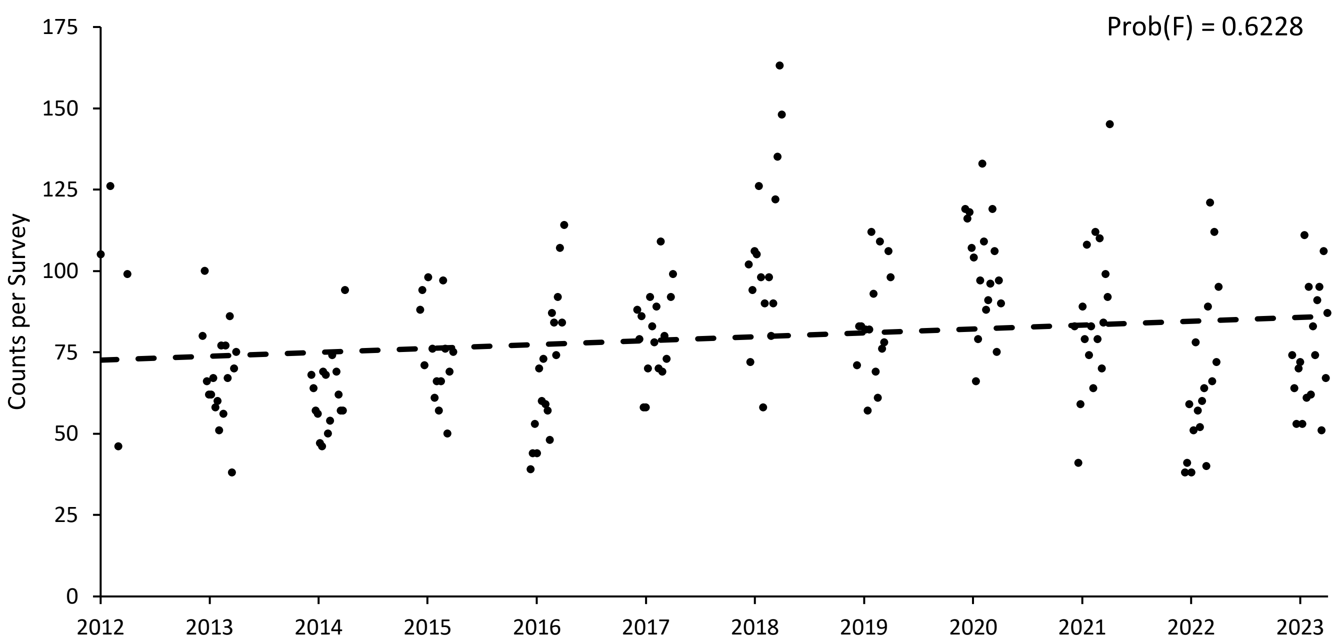
Abundance Post-Hydrilla Management: January 2012 – June 2024 for 19 Species (counts per survey)

The total animal abundance trend for the 19 species analyzed during post- hydrilla management period from 2012 through June 2024 was not significant. This may reflect attainment of the carrying capacity of the ecosystem for these species.



Abundance Post-Hydrilla Management: 2012 – June 2024 for 6 Year-Round Resident Breeders (counts per survey)

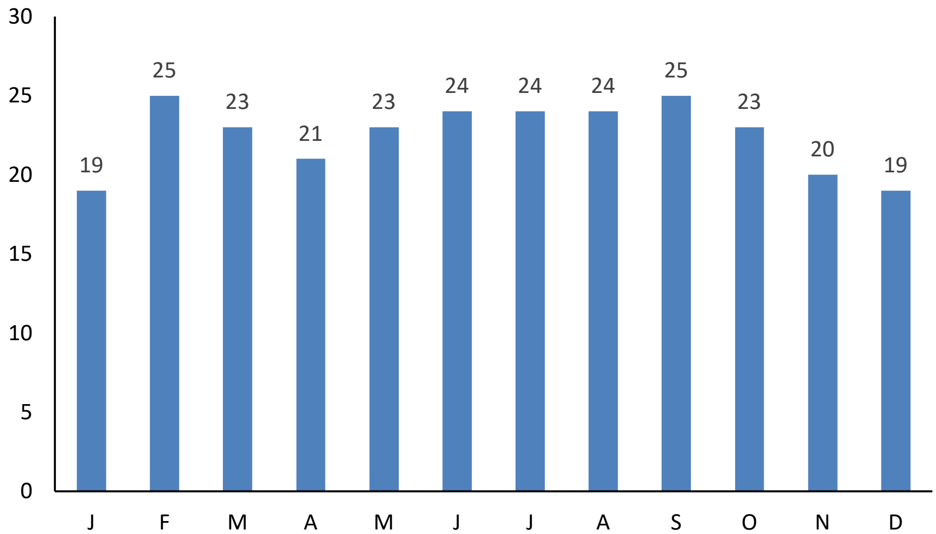
The total animal abundance trend for the 6 year-round resident breeders for the post- hydrilla management period also was not significant.



American alligator, anhinga, common gallinule, green heron, pied-billed grebe, yellow-

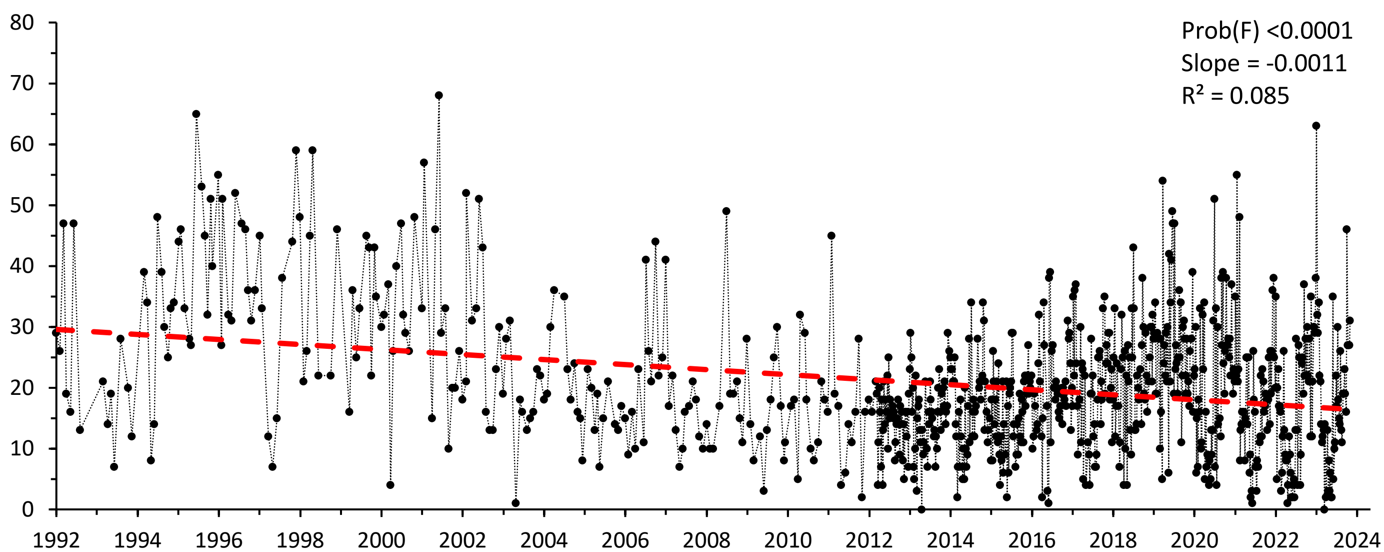
AMERICAN ALLIGATOR

Seasonal Abundance 1992 – June 2024 (average monthly means)



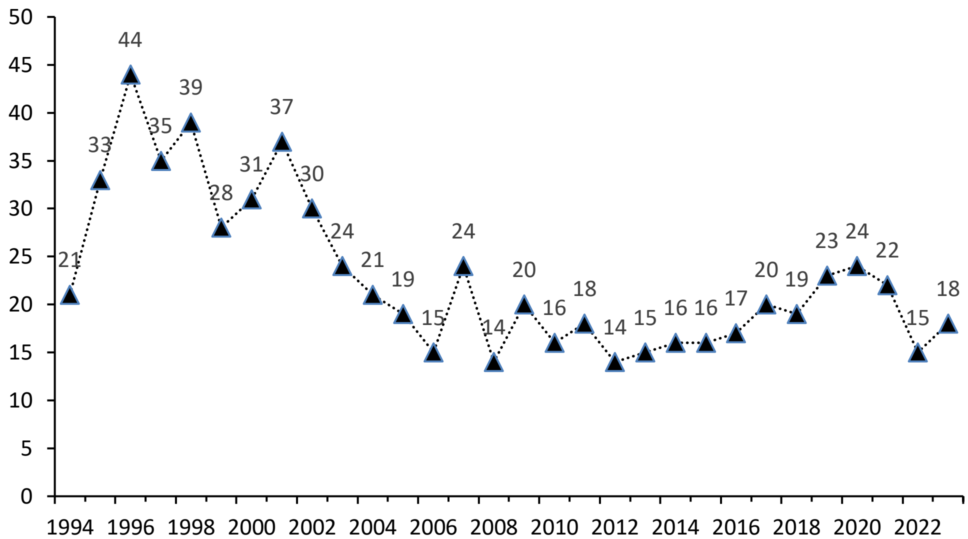
The American alligator is a year-round breeding resident of the upper Wakulla River. Abundance is fairly constant throughout the year.

Abundance 1992 – June 2024 (counts per survey)



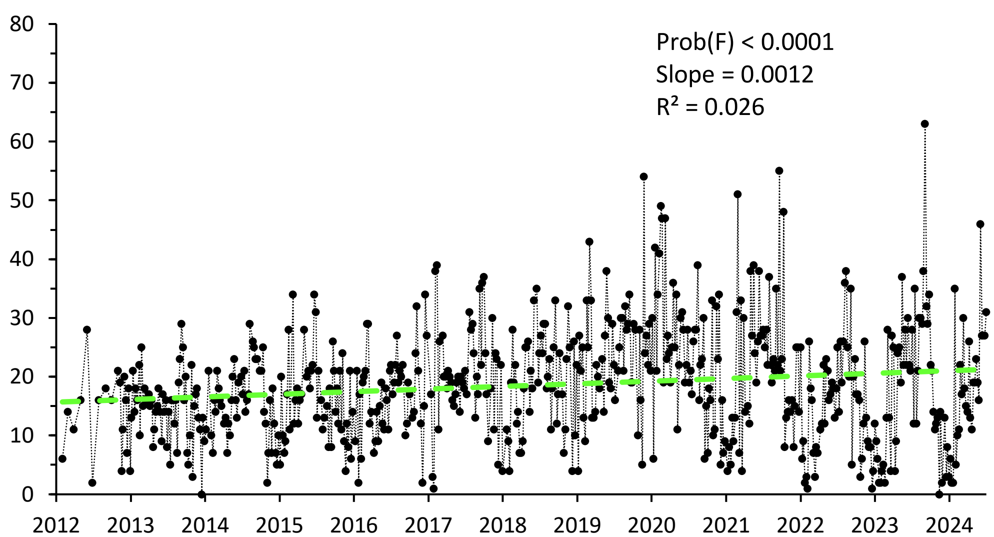
The alligator exhibited a significant (better than 99.99% level) decreasing abundance trend of -0.0011 animals counted per survey over the period of record, 9/1/92 – 6/30/24. Survey date explains 8.5% of the observed variation in counts per survey.

Abundance 1994-2023 (annual means)



Annual means reveal a decreasing abundance trend through 2012. Peak abundance occurred in 1996, while a sharp decline began in 2001 and continued to 2006. Annual means began a steady increase in 2013 but this was reversed beginning in 2021.

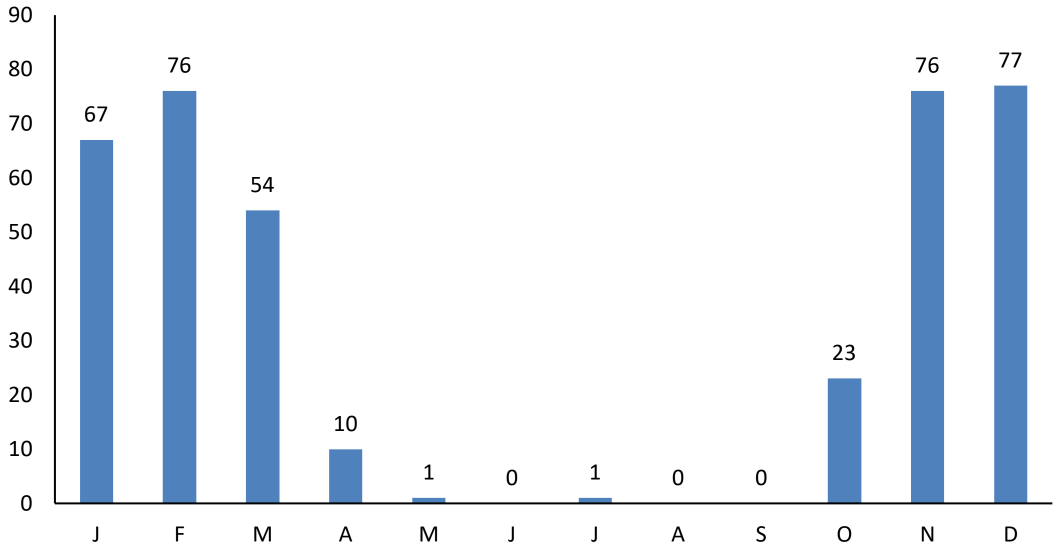
Abundance Post- Hydrilla Management: 2012 – June 2024 (counts per survey)



The post-hydrilla management trend was significantly positive (better than 99.99% level) through May 2021 and remained so after extending the analysis through June 2024. However, the linear regression model only explains 2.6% of the observed variation in counts per survey versus 11.8% for the trend through May 2021.

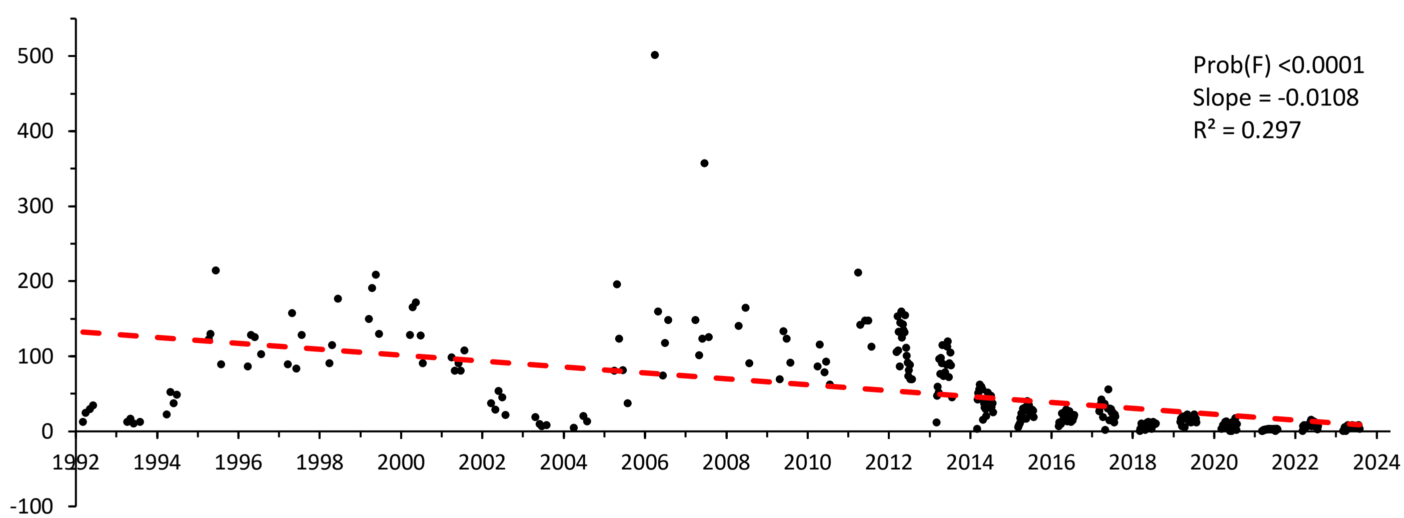
AMERICAN COOT

Seasonal Abundance 1992 – June 2024 (average monthly means)



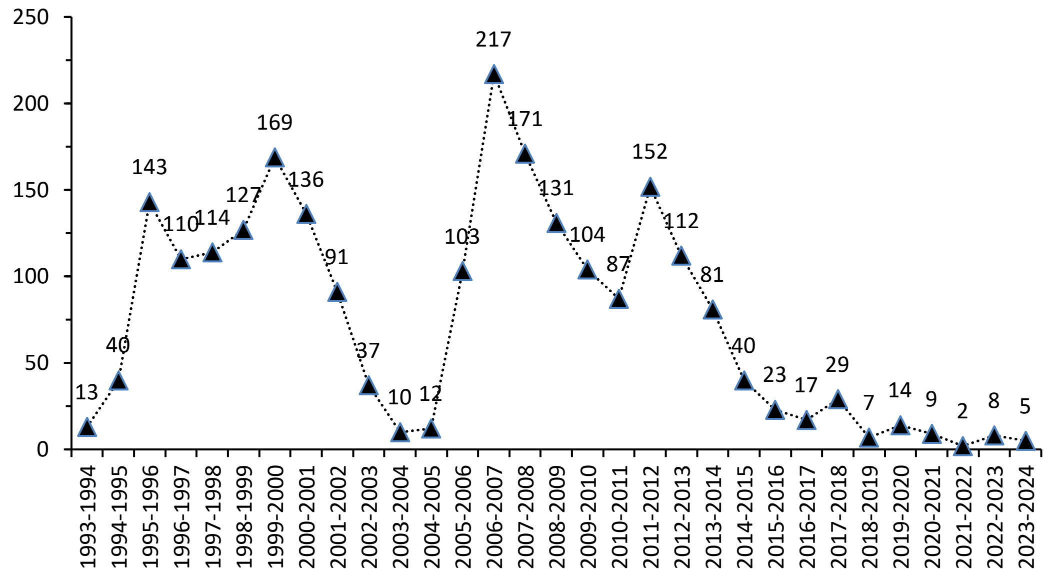
The American coot is a winter migrant to the upper Wakulla River. Abundance peaks during the months of November through March.

Seasonal Abundance Nov-Mar 1992-93 – 2023-24 (counts per survey)



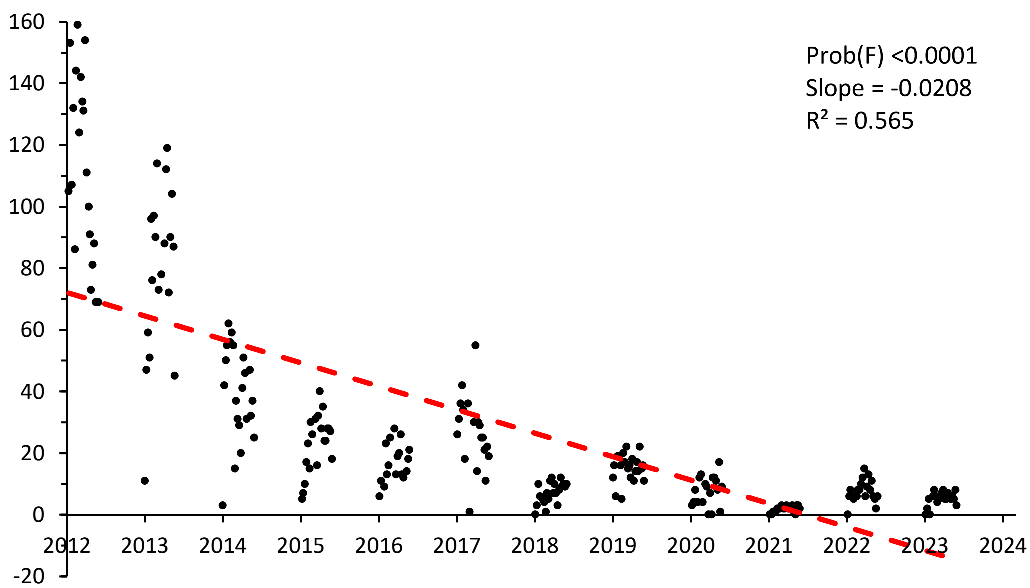
The American coot exhibited a significant (better than 99.99% level) decreasing seasonal abundance trend of -0.0108 animals counted per survey over the period of record, 9/1/92 – 6/30/24. Survey date explains 29.7% of the observed variation in counts per survey.

Seasonal Abundance Nov-Mar 1993-94 – 2023-24 (winter monthly means)



Winter monthly means reveal multiple peaks and valleys with an initial decline beginning in 2000-2001. Secondary peaks occurred in 2006-07 and 2011-12 after which winter monthly means have generally declined.

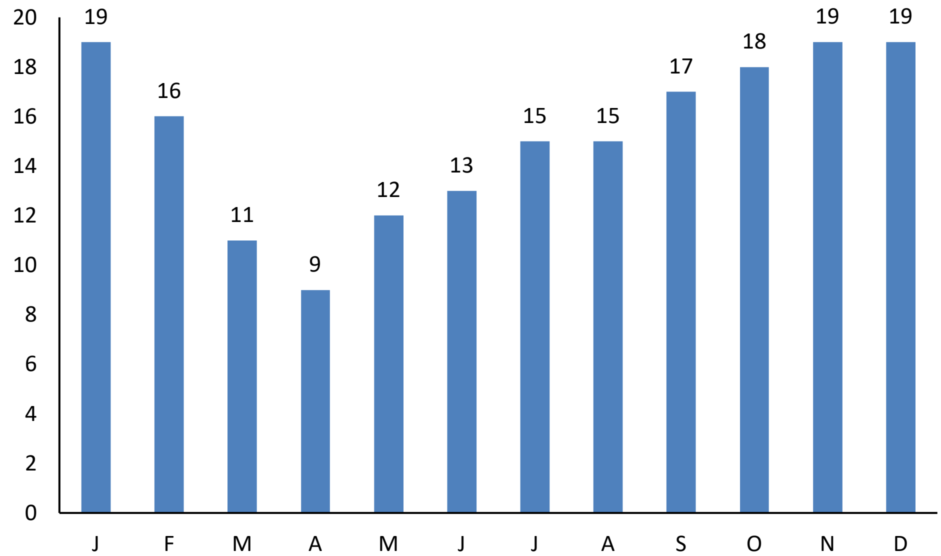
Seasonal Abundance Post- Hydrilla Management: Nov-Mar 2012-13 – 2023-24 (counts per survey)



American coot seasonal abundance decreased significantly (better than 99.99% level) during the post-hydrilla management period with a trend that explains 56.5% of the observed variation.

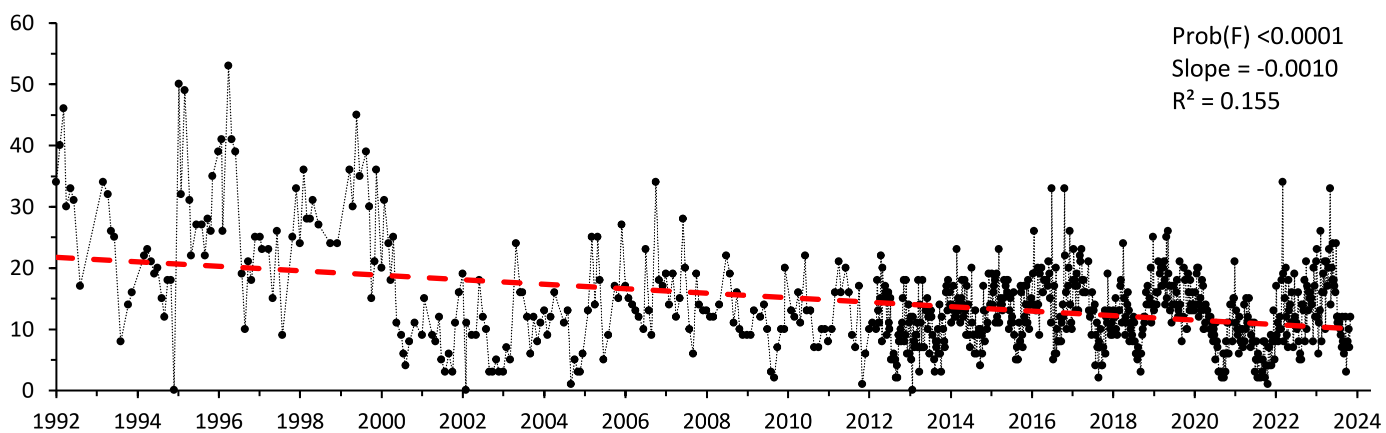
ANHINGA

Seasonal Abundance 1992 – June 2024 (average monthly means)



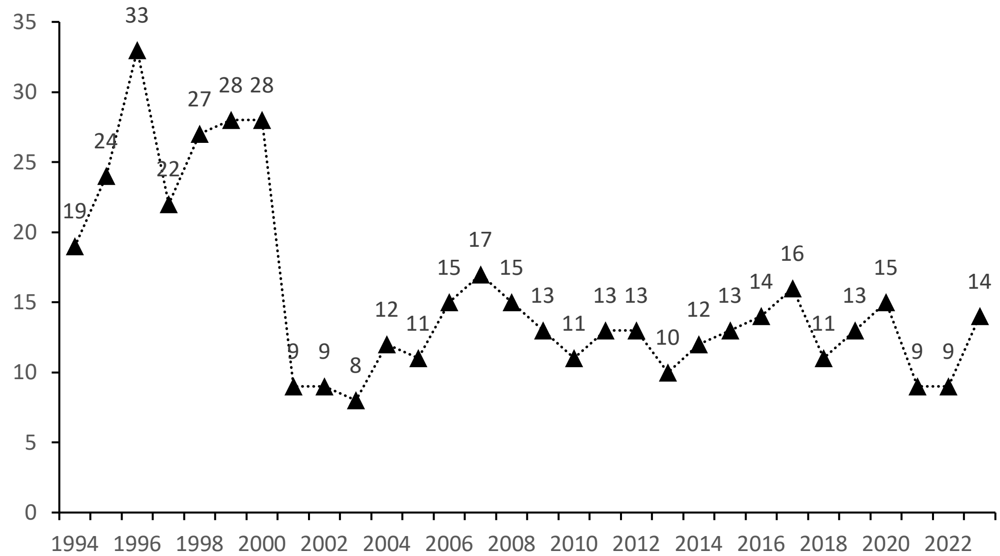
The anhinga is a year-round breeding resident of the upper Wakulla River. Abundance peaks during fall and early winter and is lowest leading into the late spring/early summer breeding period.

Abundance 1992 – June 2024 (counts per survey)



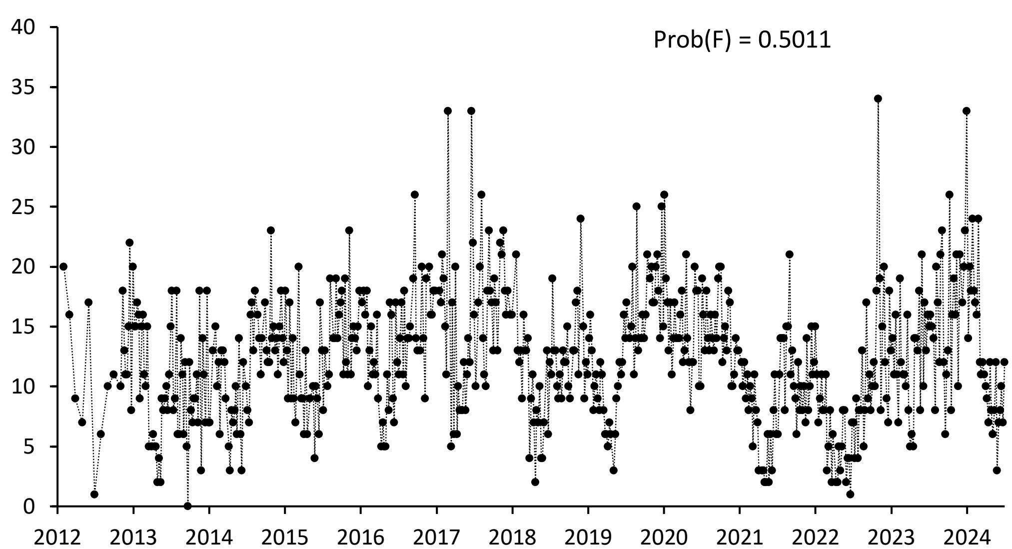
The anhinga exhibited a significant (better than 99.99% level) decreasing abundance trend of -0.0010 animals counted per survey over the period of record, 9/1/92 – 6/30/24. Survey date explains 15.5% of the observed variation in counts per survey.

Abundance 1994-2023 (annual means)



Annual means reveal a steep decrease in 2001 from which the species has not fully recovered exhibiting a fairly regular oscillation since 2005.

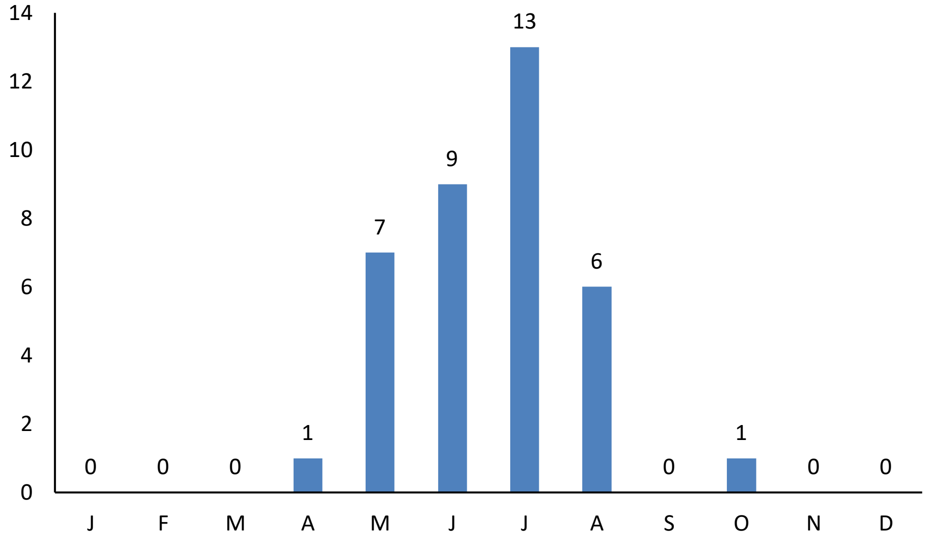
Abundance Post- Hydrilla Management: 2012 – June 2024 (counts per survey)



The post-hydrilla management period trend had been significantly positive through May 31, 2021. However, the trend is no longer significant with the analysis extended through June 30, 2024.

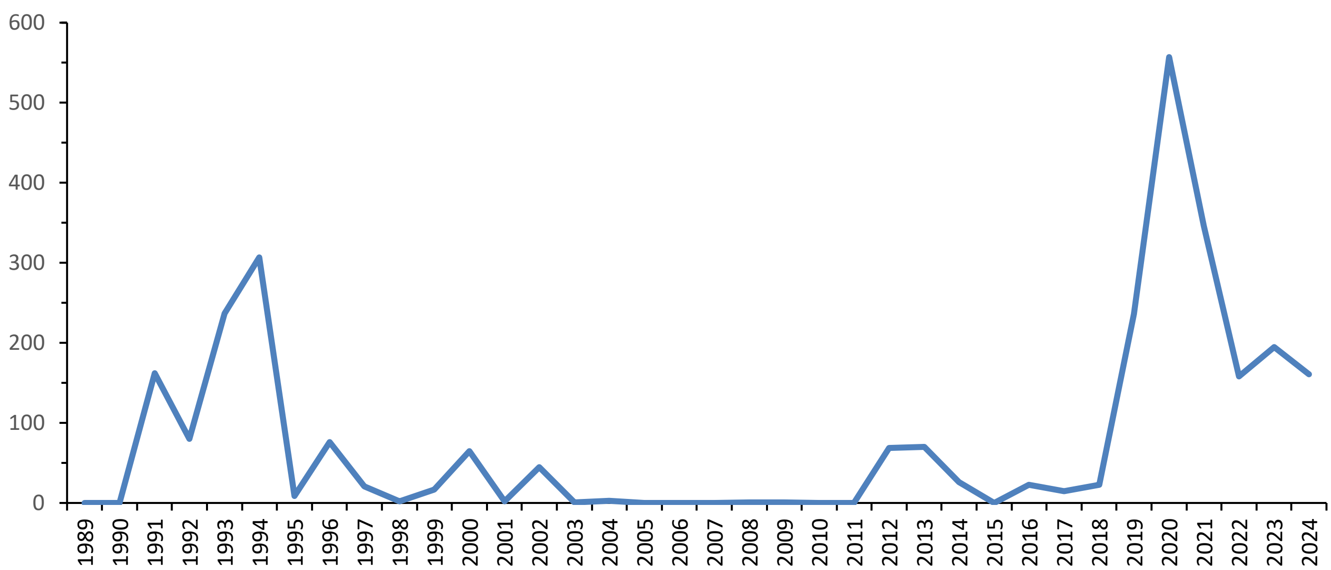
CATTLE EGRET

Seasonal Abundance 1992 - June 2024 (average monthly means)

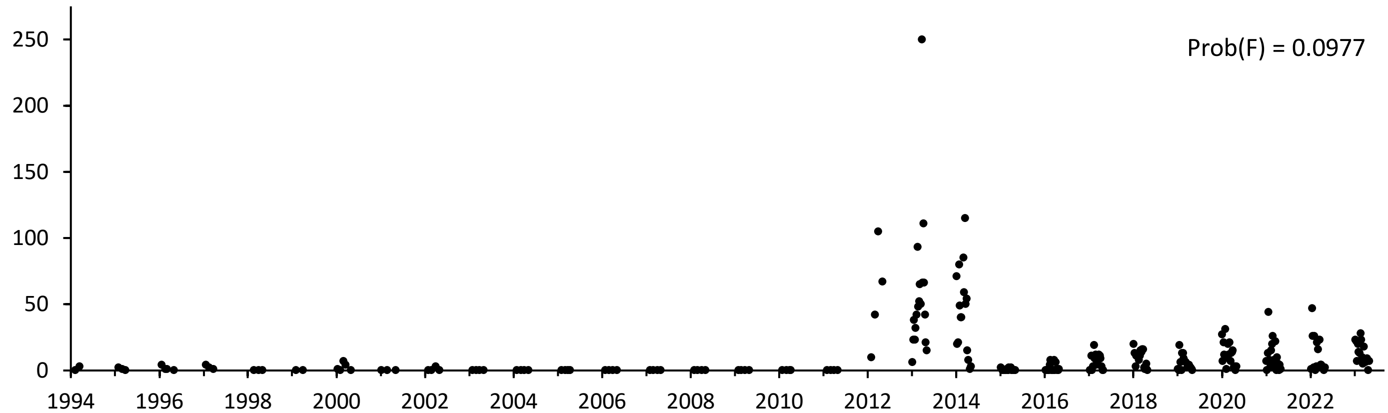


The cattle egret has been a periodic summer breeder (May-Aug) on the upper Wakulla River. It feeds in pastures and fields and therefore is generally only seen on the river during the breeding season. As shown in the following figure, it has nested in varying numbers along the upper river within the park on and off since the early 1990s, peaking in 2020. It nested in colonies along the river boat tour route from 2012 through 2014; in other years, the nesting colony has been along the second mile of the river below the tour boat turnaround.

Cattle Egret Count
Summer River Survey - Park 1989 - 2024

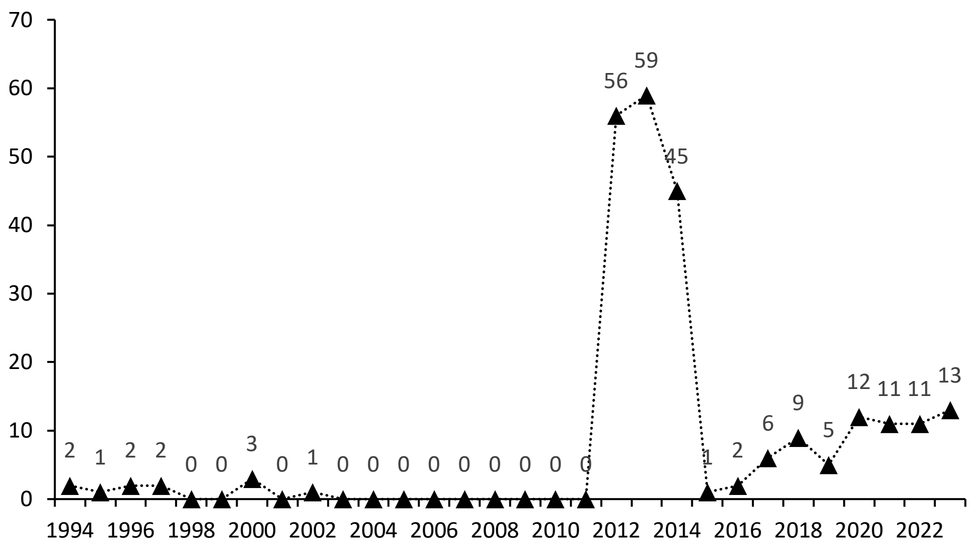


Seasonal Abundance May-Aug 1994 - 2023 (counts per survey) [2]



The cattle egret had exhibited a significant increasing seasonal abundance trend through August 2020. However, the trend is no longer significant after extending the analysis through August 2023. Abundance dropped from the highs of 2012-2014 when the nesting colony was moved down river. As shown above, the loss of the significant positive trend is due to reduced nesting in the down-river colony since 2020.

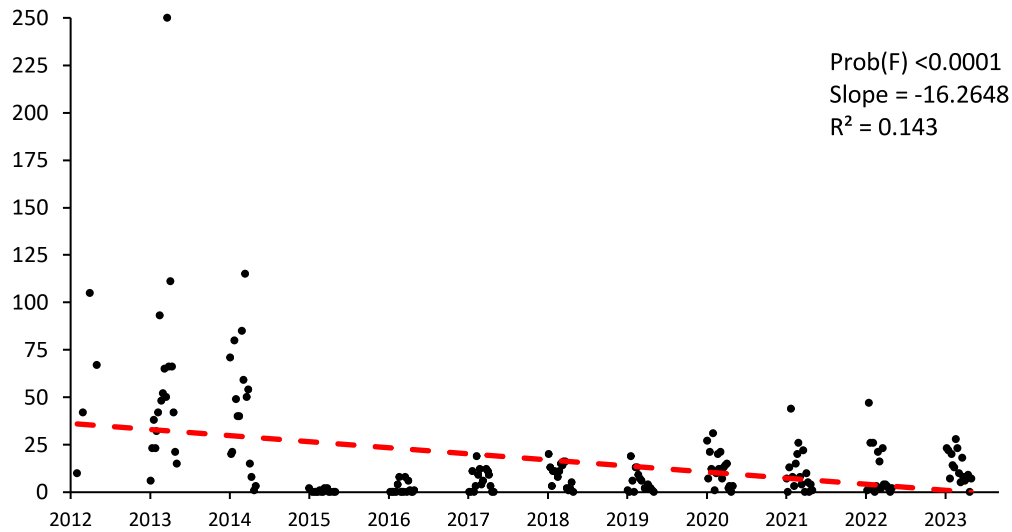
Seasonal Abundance May-Aug 1994-2023 (summer monthly means)



Summer monthly means reveal the peak cattle egret abundances associated with nesting along the tour boat route on the upper river in 2012-2014.

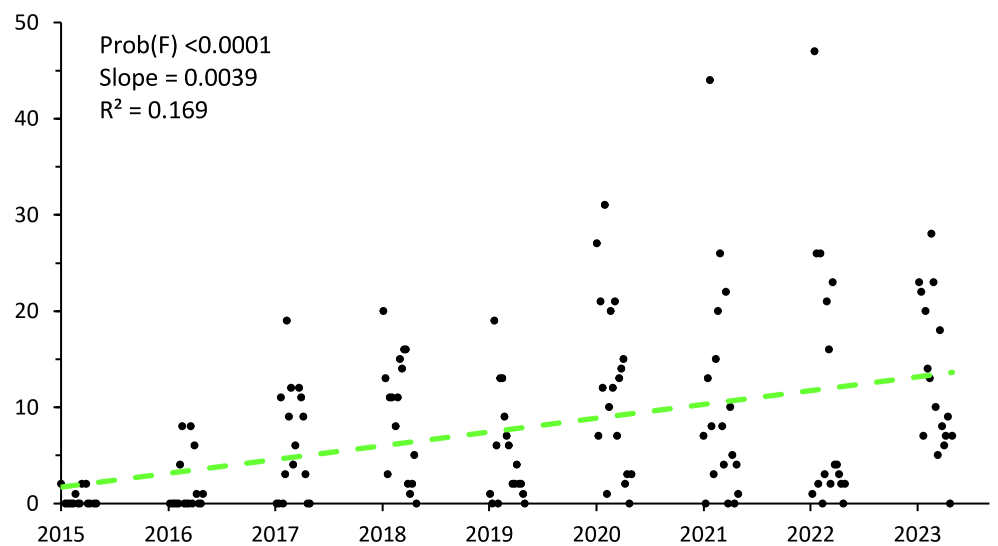
[2] No data were recorded for this species during its breeding season in 1992 or 1993.

Seasonal Abundance Post- Hydrilla Management: May-Aug 2012-2020 (counts per survey)



The relocation of nesting from the tour route to further down river resulted in a significant (better than 99.99% level) decrease in summer breeding season abundance during the post-hydrilla management period with a trend that explains 14.3 % of the observed variation in counts per survey.

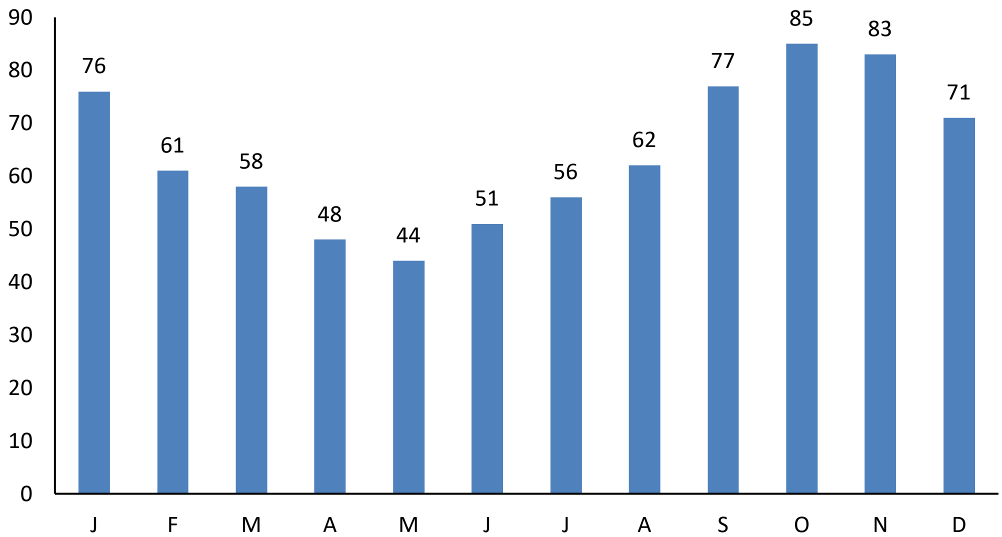
Seasonal Abundance After Nesting Colony Relocation: May-Aug 2015-2023 (counts per survey)



Counts per survey have increased significantly, however, since 2015 (better than 99.99% level), after relocation of the nesting colony to the second mile of the river in 2016. The trend explains 16.9 % of the observed variation in counts per survey.

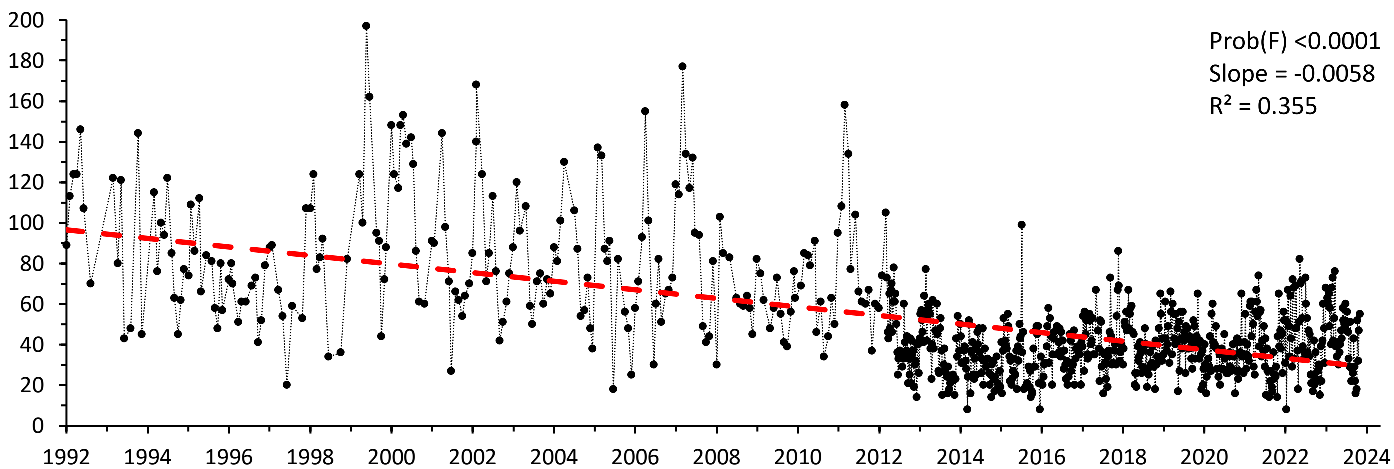
COMMON GALLINULE

Seasonal Abundance 1992-2020 (average monthly means)



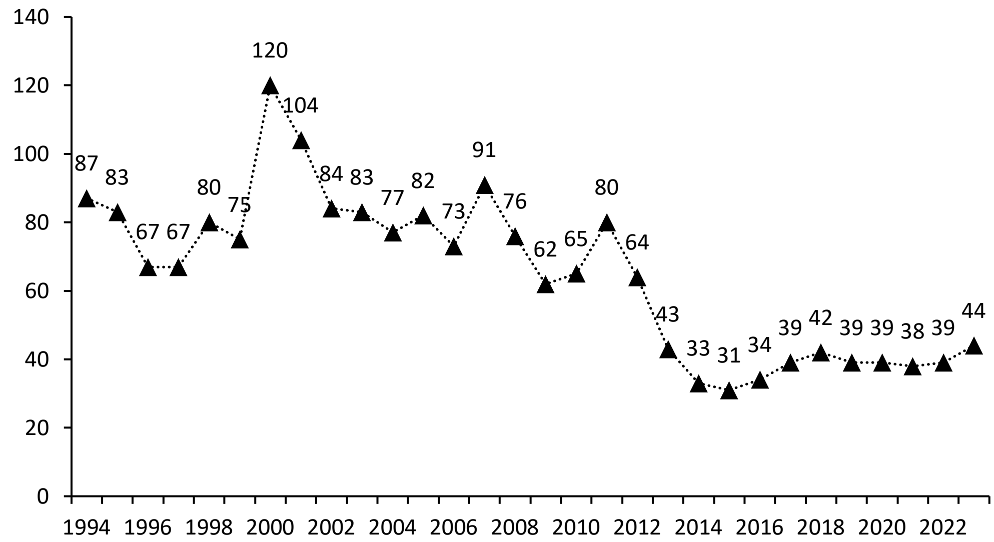
The common gallinule, formerly called the common moorhen, is a year-round breeding resident of the upper Wakulla River with a seasonal pattern of abundance which likely reflects both a summer breeding season with 2-3 broods per pair coupled and an influx of winter migrants joining the resident population (Bannor and Kiviat, 2002).

Abundance 1992 – June 2024 (counts per survey)



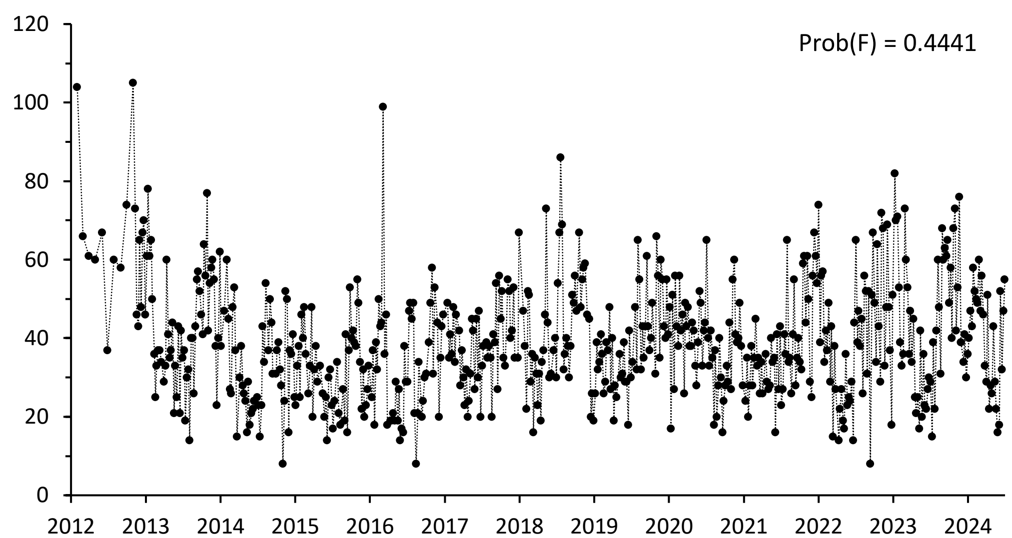
The common gallinule exhibited a significant (better than 99.99% level) decreasing abundance trend of -0.0058 animals counted per survey over the period of record, 9/1/92 – 6/30/24. Survey date explains 35.5% of the observed variation in counts per survey.

Abundance 1994-2023 (annual means)



Annual means reveal a generally declining pattern since a peak in 2000. A second steep decline began in 2012 following an oscillating but slowly declining pattern between 2000 and 2011. Most recently, annual means increased after 2015 and have since levelled off.

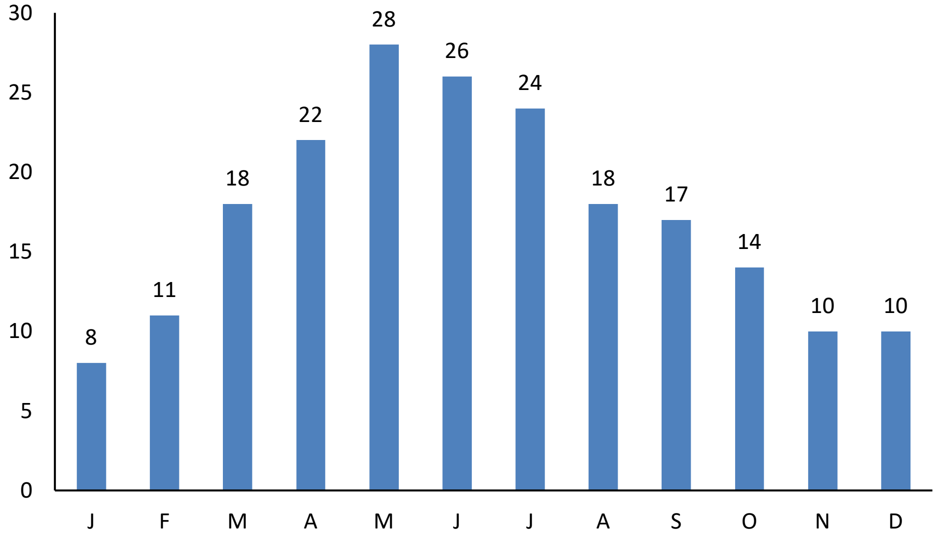
Abundance Post- Hydrilla Management: 2012 – June 2024 (counts per survey)



The trend through the post-hydrilla management period had been significantly negative through May 2021. However, extending the analysis through June 2024 has resulted in no significant trend suggesting that the common gallinule may have reached its carrying capacity under current ecosystem conditions.

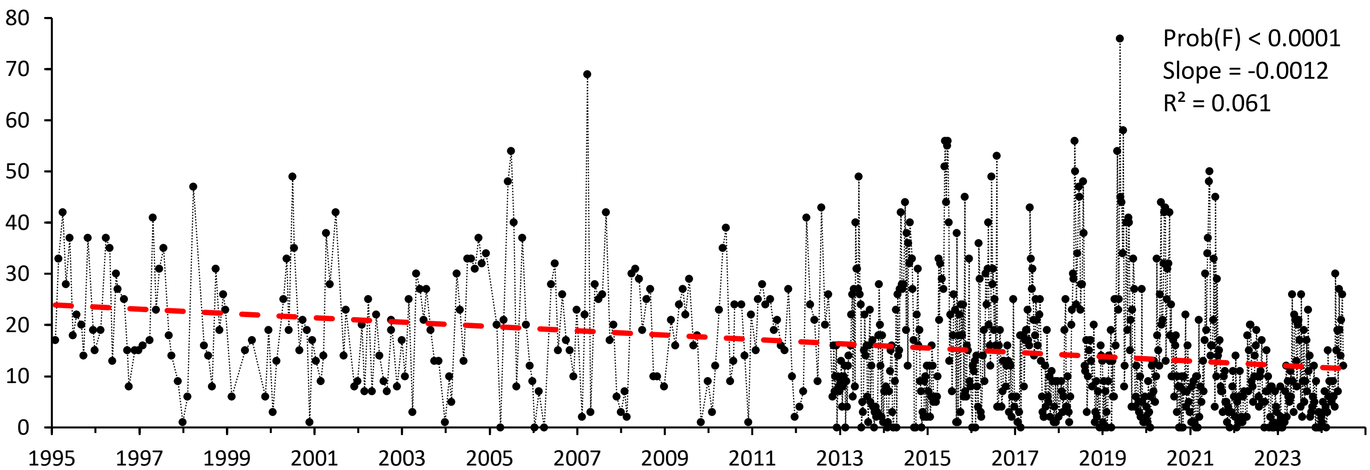
COOTER TURTLE

Seasonal Abundance 1995 – June 2024 (average monthly means)[3]



Cooter turtles, which include both the Suwannee cooter (*Pseudemys concinna suwanniensis*) and the coastal plain cooter (*Pseudemys floridana floridana*) (Krysko et al., 2019), are year-round breeding residents of the upper Wakulla River with a distinctive seasonal pattern of abundance that peaks in May. This may be due in part to the turtles' reproductive cycles with multiple clutches laid during spring and summer, peaking in May and June (pp. 262; 264).

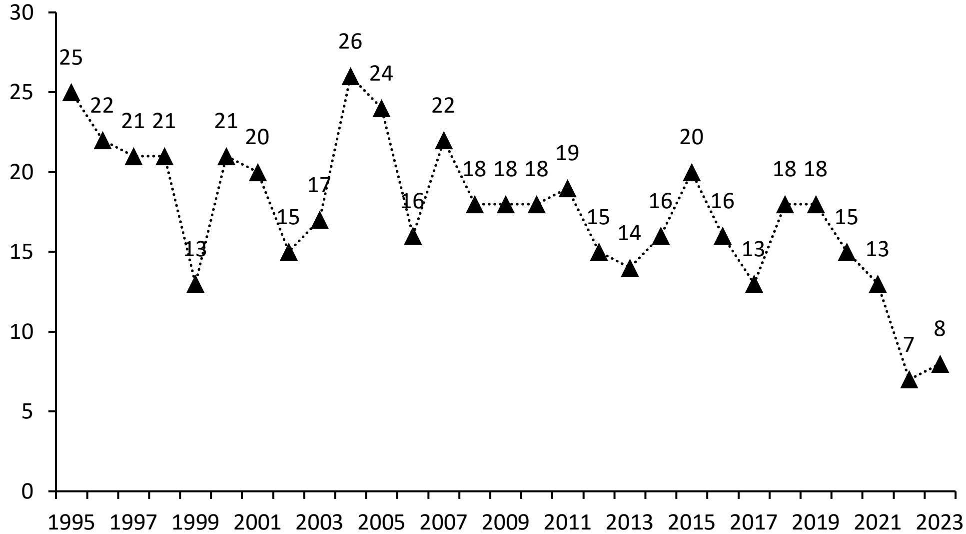
Abundance 1995 – June 2024 (counts per survey)



Cooter turtles exhibited a significant (greater than 99.99% level) decreasing abundance trend of -0.0012 animals counted per survey over the period analyzed, 1/30/95 – 6/30/24. Survey date explains 6.1% of the observed variation in counts per survey. High variation between surveys likely reflects the effects of air temperature and cloud cover on basking behavior and the effects of varying water visibility depth on observing turtles.

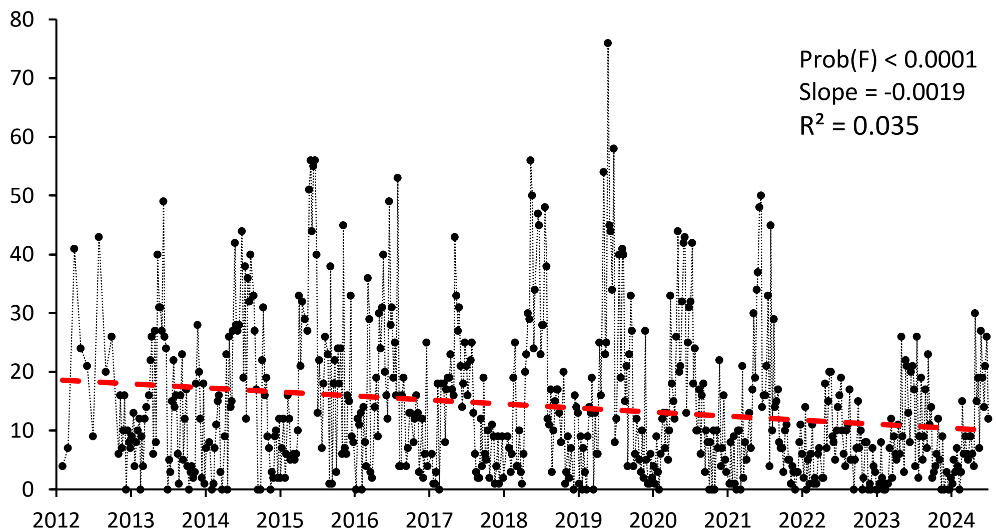
[3] Data excluded from 1992-1994 for these analyses because of apparent counting irregularities; i.e. multiple zero counts in 1993 and 1994.

Abundance 1995-2023 (annual means)



Annual means reveal an abundance pattern with multiple peaks and valleys and a steep decline between 2021 and 2022.

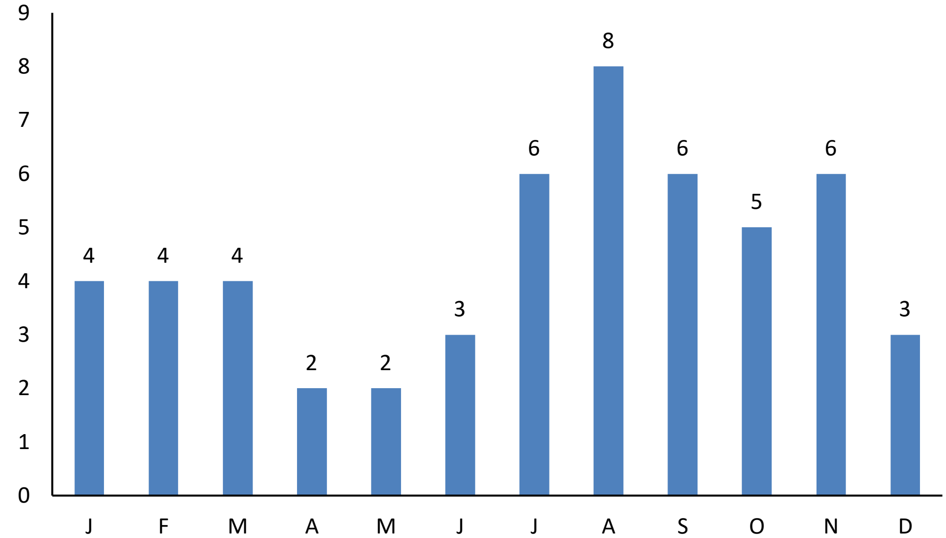
Abundance Post- Hydrilla Management: 2012 - June2024 (counts per survey)



The post-hydrilla management trend was not significant for the period through May 2021 but shifted to significantly negative after extending the analysis through June 2024.

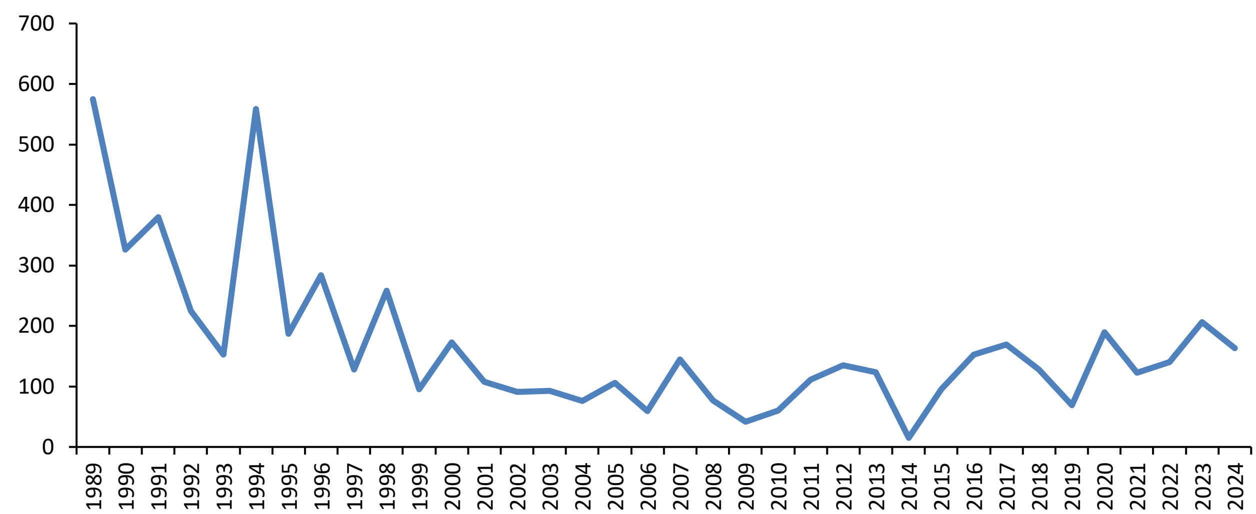
DOUBLE-CRESTED CORMORANT

Seasonal Abundance 1992 – June 2024 (average monthly means)

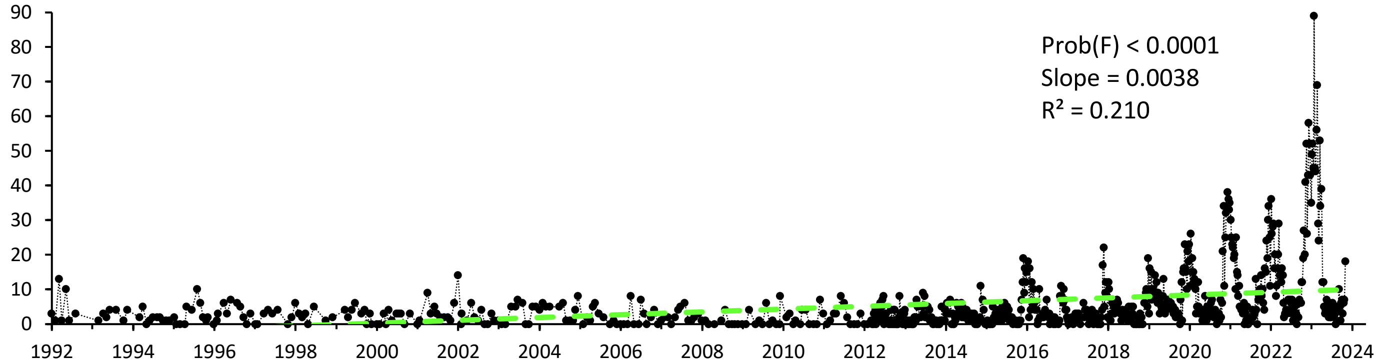


The double-crested cormorant is a year-round resident of the upper Wakulla River that has bred in colonies in the second mile of the river below the spring every year since at least 1989, with the possible exception of 2014, as documented by the park's summer full-river wildlife surveys (see next figure). Local breeding may explain the high monthly means in July and August while higher means in November through March may reflect an influx of winter migrants from northern breeding territories (Dorr, Hatch, and Weseloh, 2014). (Two or three pair nested along the tour boat route for the first time in 2025.)

Double-Crested Cormorant Count
Summer River Survey - Park 1989 - 2024

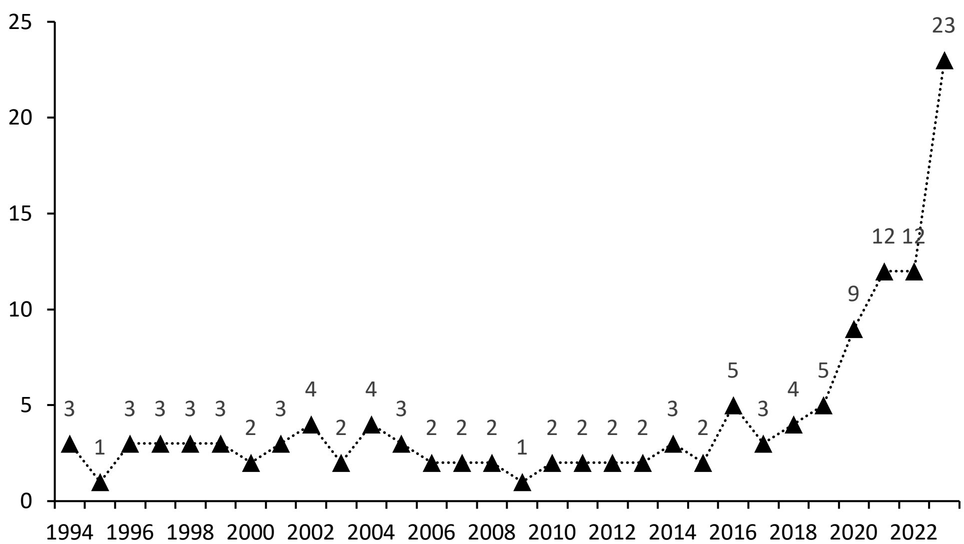


Abundance 1992 – June 2024 (counts per survey)



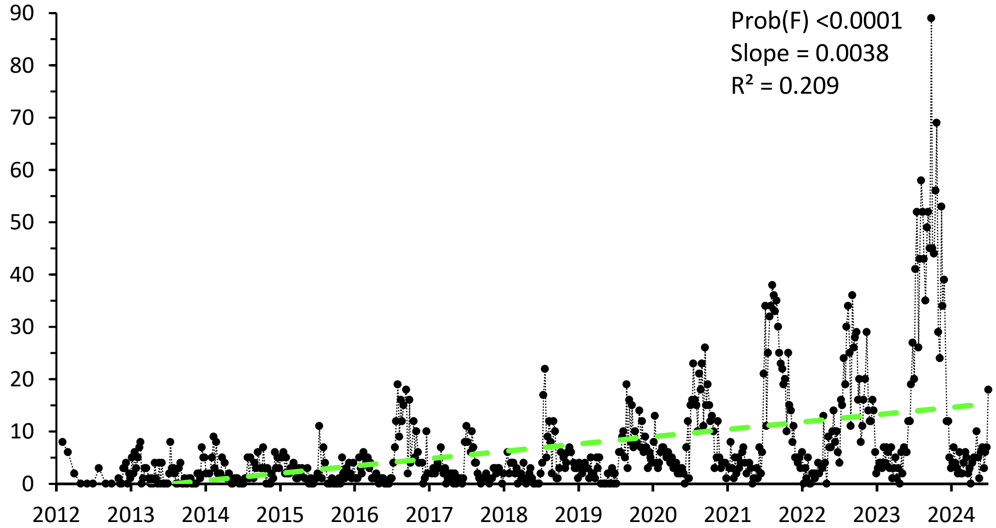
Continued nesting by the double-crested cormorant in colonies on the second mile of the river has resulted in the development of a long-term significant (better than 99.99% level) increasing abundance trend of 0.0038 animals counted per survey over the period analyzed, 9/1/92 – 6/30/24. Survey date explains 21.0 % of the observed variation in counts per survey.

Abundance 1994-2023 (annual means)



Annual mean counts per survey had been low, ranging from 1 to 5 until 2020. They have since continued to increase but not in proportion to the summer river survey trend.

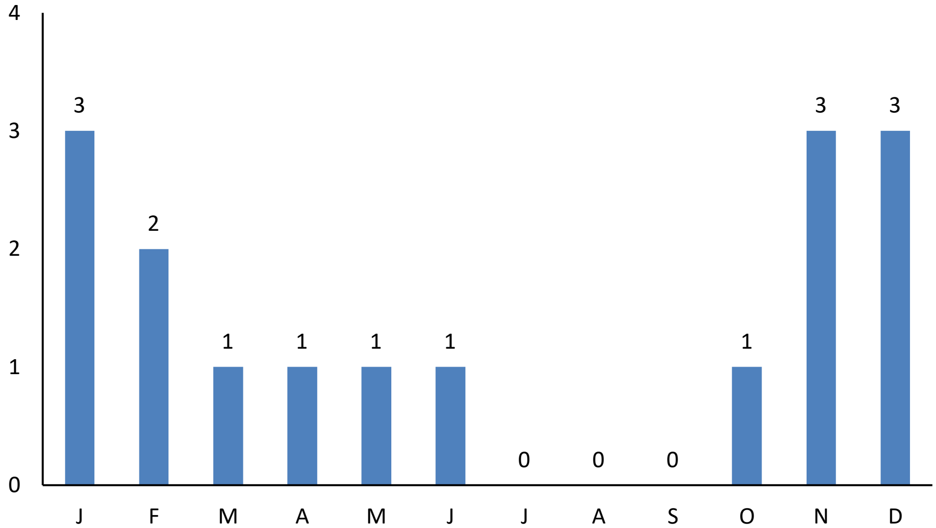
Abundance Post- Hydrilla Management: 2012 – June 2024 (counts per survey)



The cormorant abundance trend, which had been significantly negative during the hydrilla management period, reversed during the post-hydrilla management period. The positive trend is significant at better than the 99.99% level and explains 20.9% of the observed variation in counts per survey during this period.

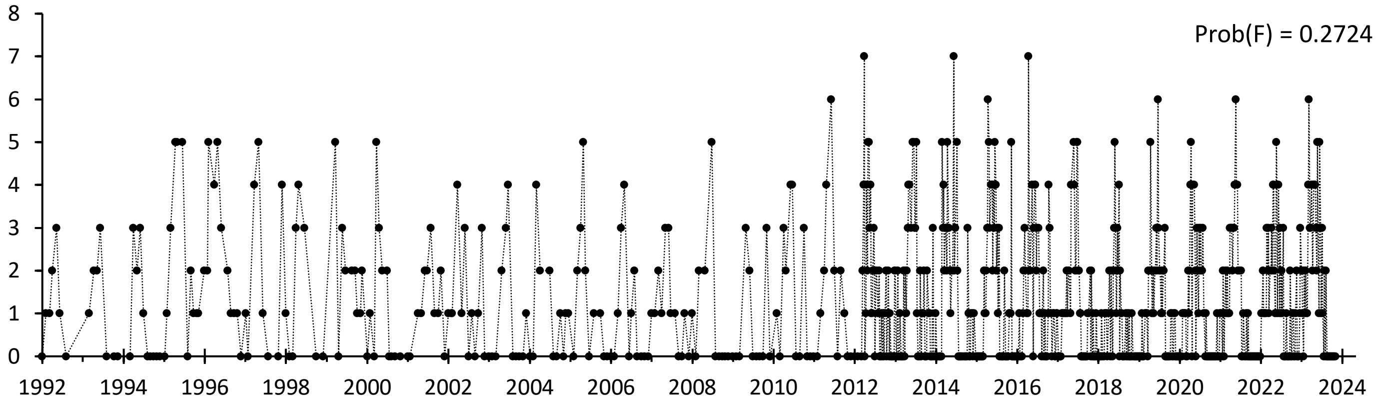
GREAT BLUE HERON

Seasonal Abundance 1992 – June 2024 (average monthly means)



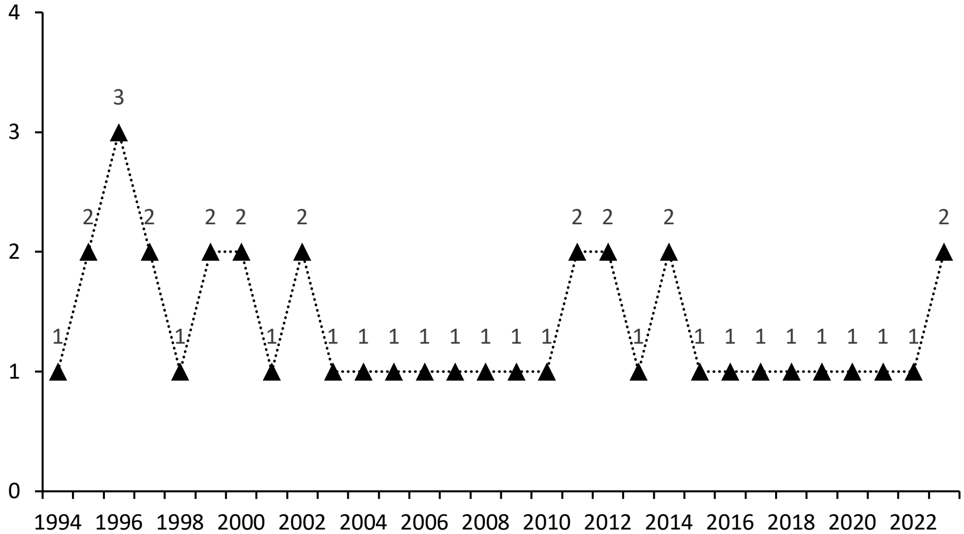
The great blue heron is a year-round resident of the upper Wakulla River that sometimes breeds along the river boat tour route (personal observation). Numbers are small throughout the year, likely reflecting relatively large feeding territories. Higher means in November through February may reflect an influx of winter migrants from northern breeding territories (The Cornell Lab of Ornithology, 2019).

Abundance 1992 – June 2024 (counts per survey)



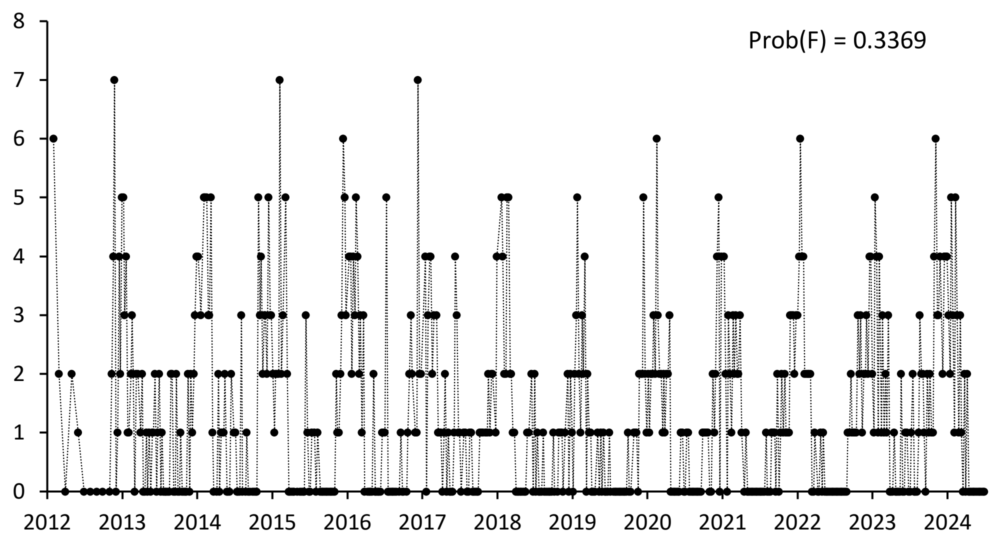
The great blue heron has been present in small numbers and exhibited no significant long-term abundance trend over the period of record, 9/1/92 – 6/30/24. Counts per survey ranged from 0 to 7 with an average of 1.3. Higher counts occurred during winter months when the local population may have been augmented by winter migrants.

Abundance 1994 - 2023 (annual means)



Annual mean counts per survey are very low ranging from 1 to 3. With such low numbers, no trends are apparent.

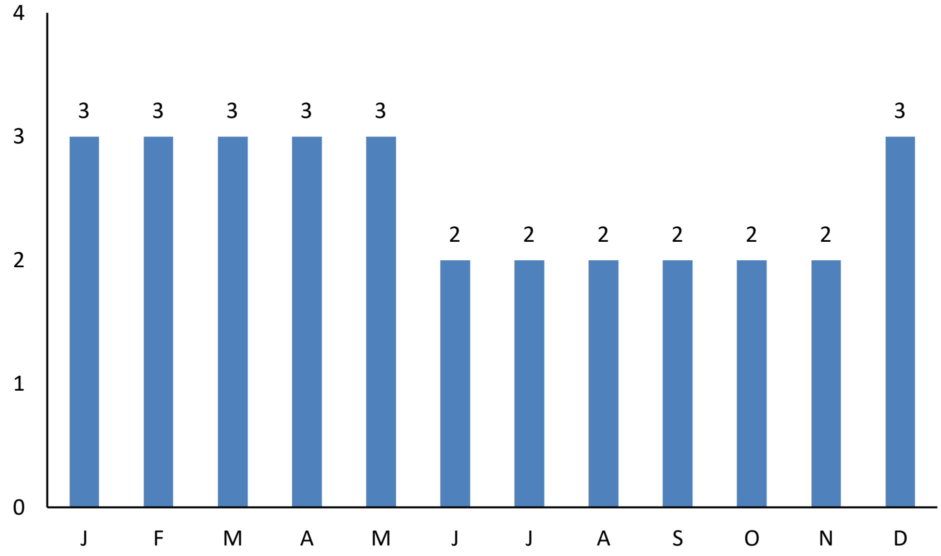
Abundance Post- Hydrilla Management: 2012 – June 2024 (counts per survey)



The great blue heron did not exhibit a significant trend during the post-hydrilla period suggesting that it may have attained its carrying capacity for the current state of the upper river ecosystem.

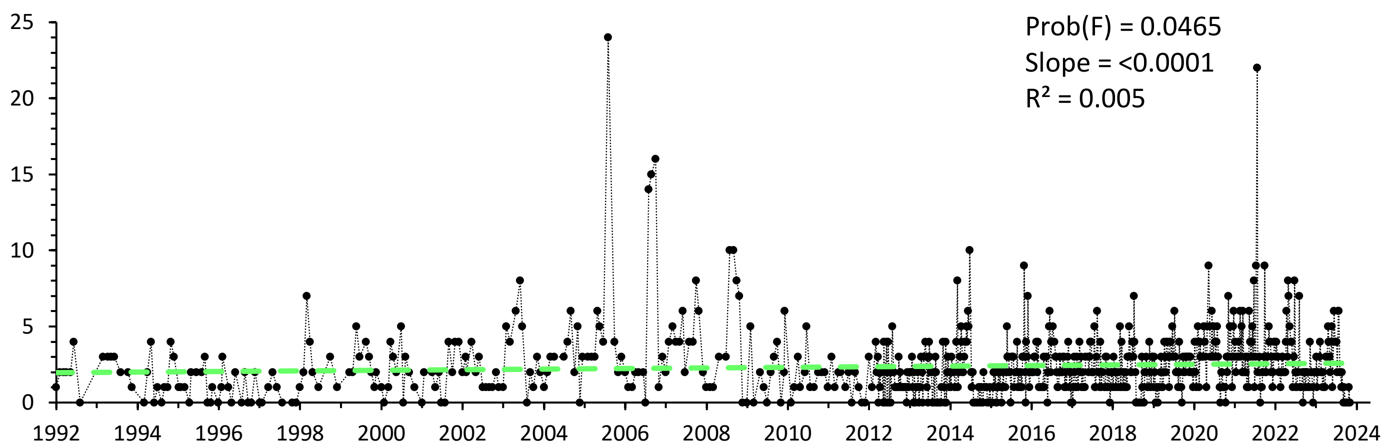
GREAT EGRET

Seasonal Abundance 1992 – June 2024 (average monthly means)



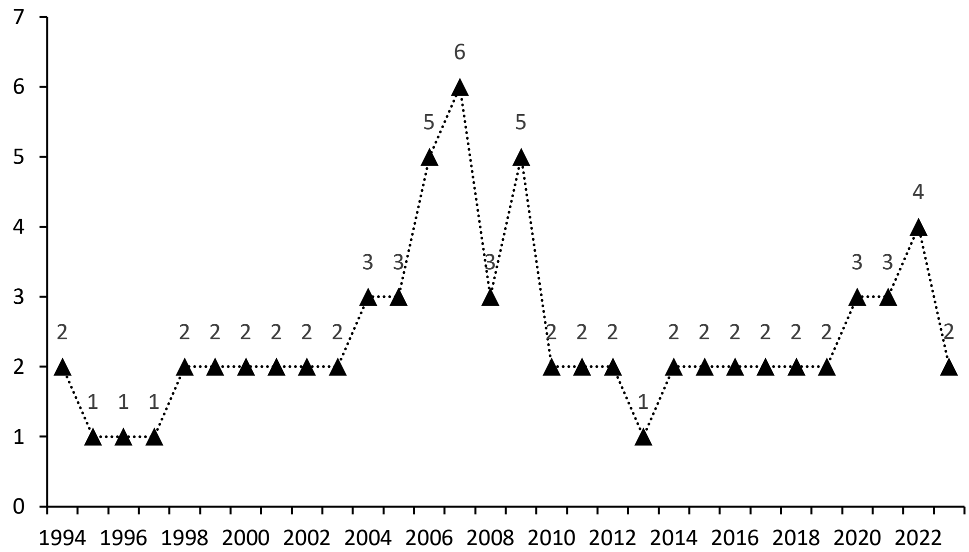
The great egret is a year-round resident of the upper Wakulla River that has bred at times along the upper river (Bob Thompson, personal communication) and along the second mile of the river (personal observation). Numbers are small throughout the year, likely reflecting relatively large feeding territories.

Abundance 1992 – June 2024 (counts per survey)



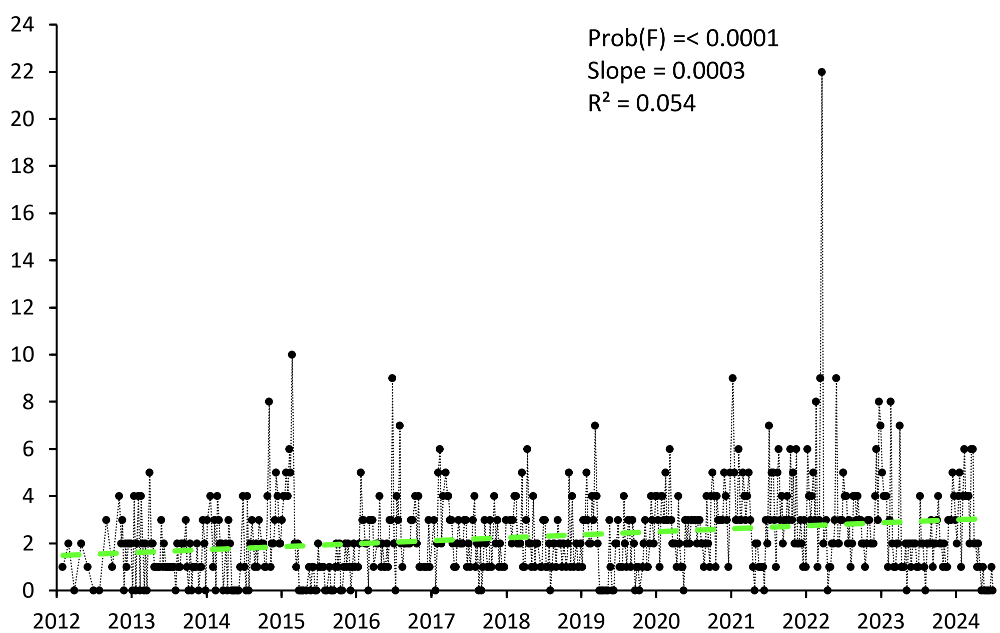
The great egret has been present in small numbers and had exhibited no significant long-term abundance trend over the period of record from September 1992 through May 2021. However, an outlier count of 22 on March 19, 2022, shifted the trend enough to become significantly positive through June 2024. The slope and R-squared statistic are both very small. The previous high count of 24 occurred on March 31, 2006. These were likely migrating flocks passing through.

Abundance 1994 - 2023 (annual means)



Annual mean counts per survey are very low, ranging from 1 to 6. Peaks in 2006, 2007, and 2009 were followed by a return to annual means of 2. The 2006, 2007, and 2022 peaks may reflect migrating flocks. Bob Thompson documented nesting along the river boat tour route in 2009 and 2010.

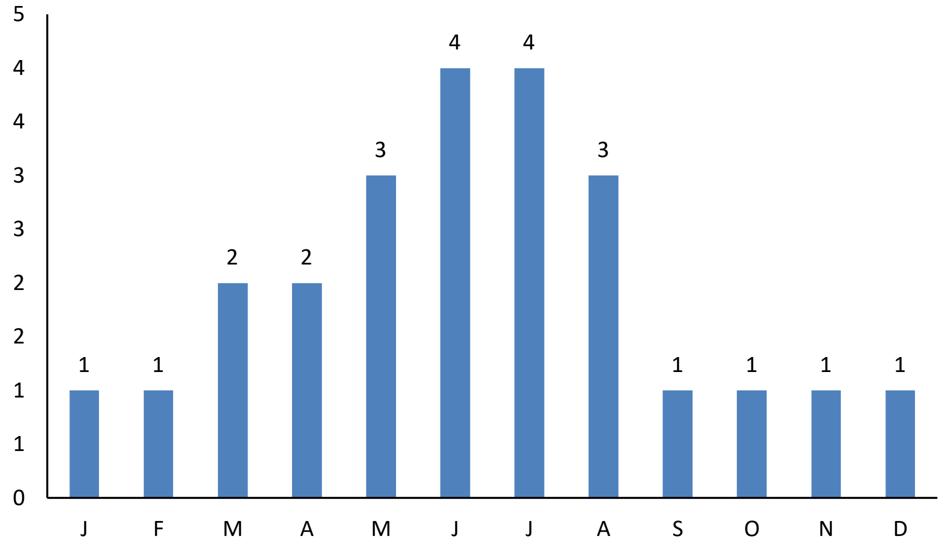
Abundance Post- Hydrilla Management: 2012 – June 2024 (counts per survey)



The great egret did exhibit a significant increase in abundance (better than 99.99% level) during the post-hydrilla management period with a trend that explains 5.4% of the observed variation in counts per survey.

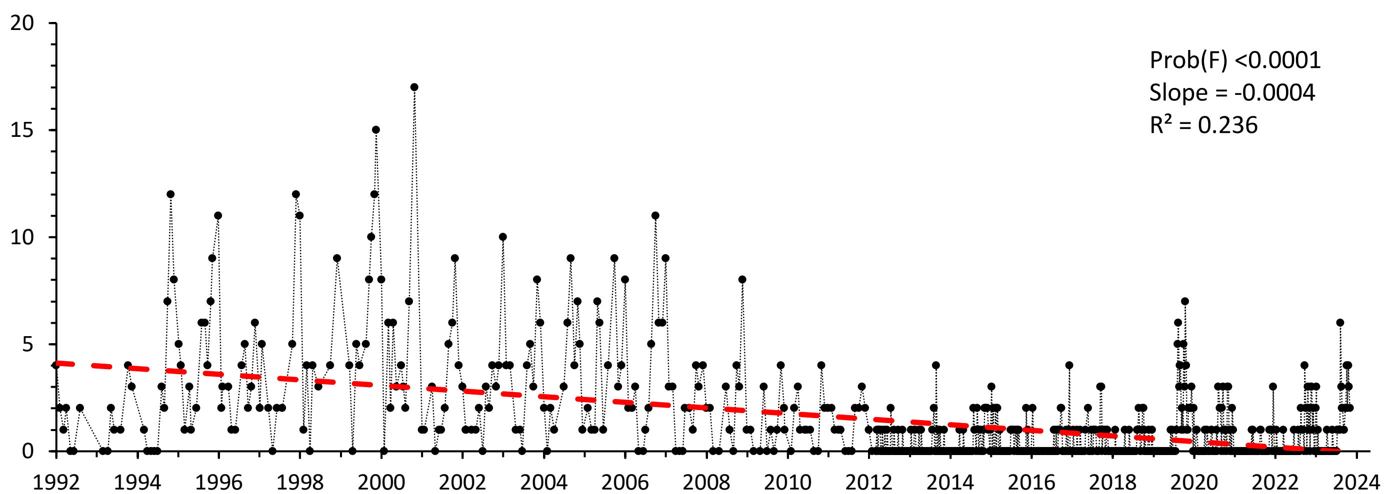
GREEN HERON

Seasonal Abundance 1992 – June 2024 (average monthly means)



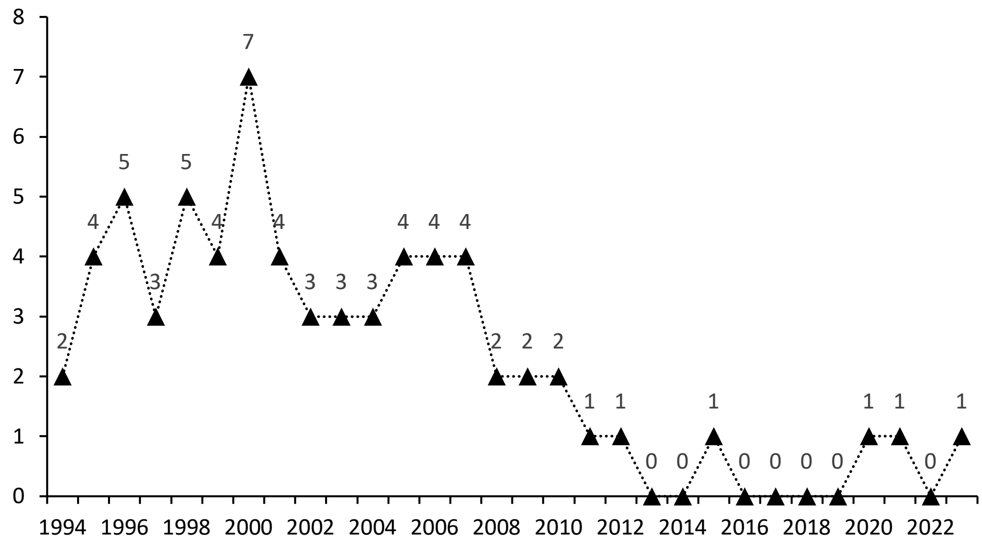
The green heron is a secretive year-round resident breeder on the upper Wakulla River. Peak abundance in May through August may reflect the breeding cycle. Small numbers throughout the year likely reflect relatively large breeding territories and their tendency for solitary rather than colony nesting.

Abundance 1992 – June 2024 (counts per survey)



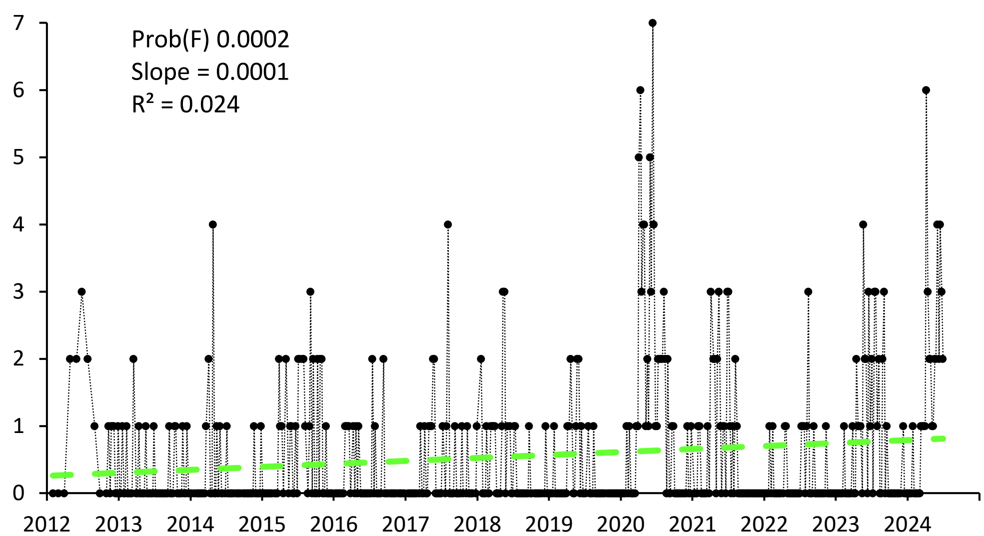
The green heron exhibited a significant (better than 99.99% level) decreasing abundance trend of -0.0004 animals counted per survey over the period analyzed, 9/1/92 – 6/30/24. Survey date explains 23.6% of the observed variation in counts per survey.

Abundance 1994-2023 (annual means)



Annual mean counts per survey of the green heron peaked in 2000 when hydrilla was widespread. They have been fairly stable since 2011.

Abundance Post- Hydrilla Management: 2012-2021 (counts per survey)



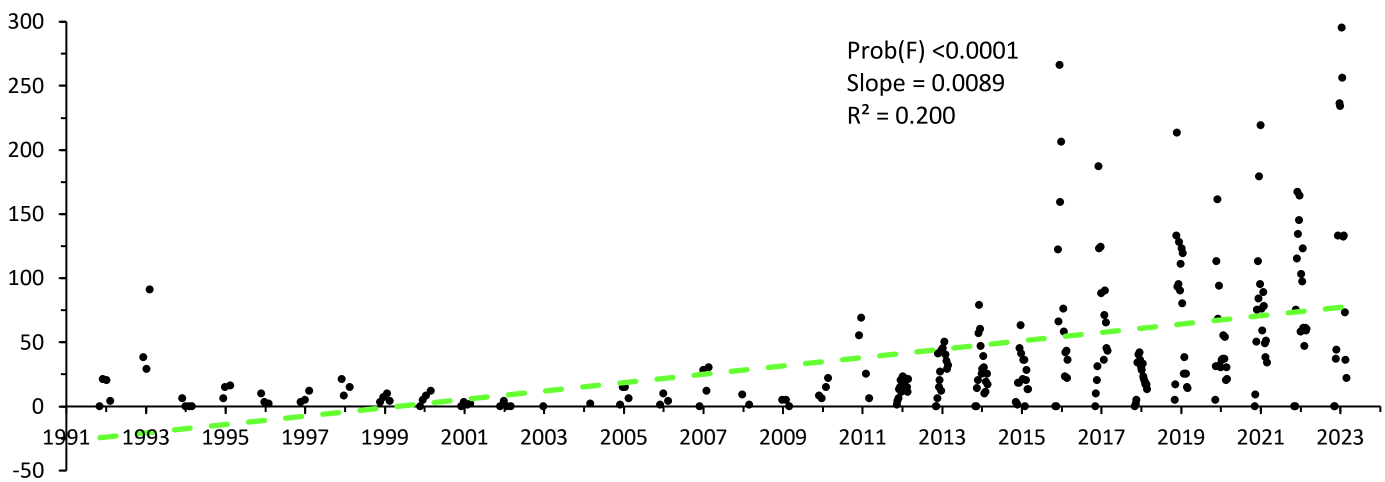
The green heron exhibited a significant (better than 99.99% level) increasing trend in abundance during the hydrilla management period which explains 2.4% of the observed variation in survey counts per day. The higher counts in 2020 and 2024 reflect nesting at the turnaround on the river boat tour route.

HOODED MERGANSER

Seasonal Abundance 1992 – June 2024 (average monthly means)

The hooded merganser is a winter migrant typically observed between November and March each year. Monthly means for December and January have increased substantially with extending the analysis from May 2021 through June 2024.

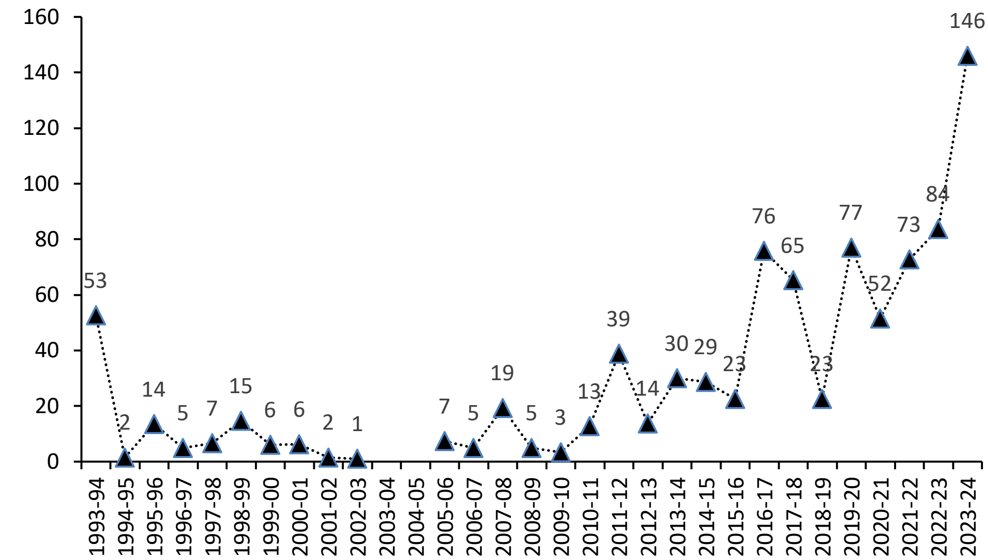
Seasonal Abundance Nov-Feb 1992-93 – 2023-24 (counts per survey)[4]



The hooded merganser exhibited a significant (better than 99.99% level) increasing abundance trend of 0.0089 animals counted per survey over the period analyzed, 11/3/92 – 2/28/24. Survey date explains 20.0% of the observed variation in counts per survey.

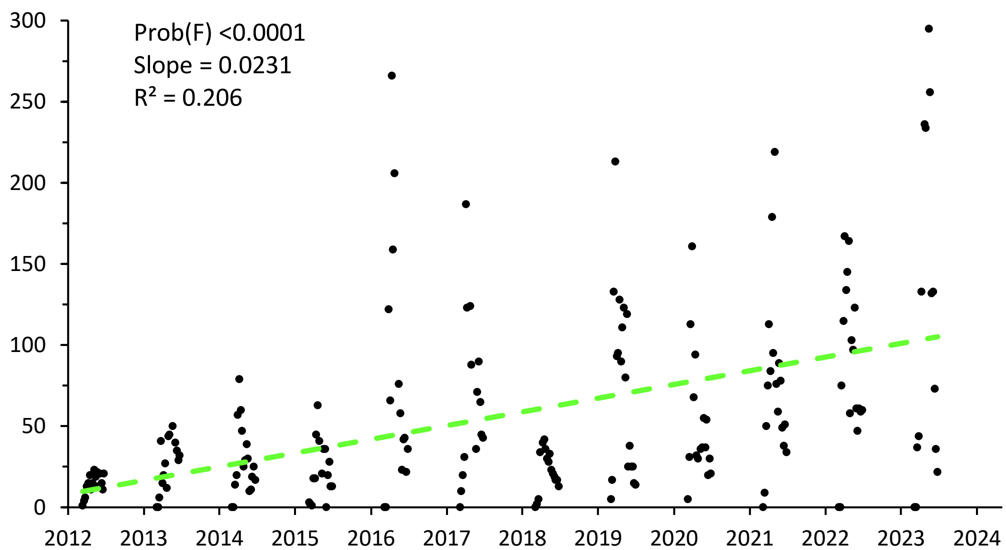
[4] No data available for 2004.

Seasonal Abundance Nov-Feb 1993-94 – 2023-24 (winter monthly means)[5]



Annual winter monthly mean counts per survey of the hooded merganser began with a high in 1993-94, then settled into relatively low numbers before beginning an up-and-down ascending trend in 2011-12.

Seasonal Abundance Post- Hydrilla Management: Nov-Feb 2011-12 – 2023-24 (counts per survey)

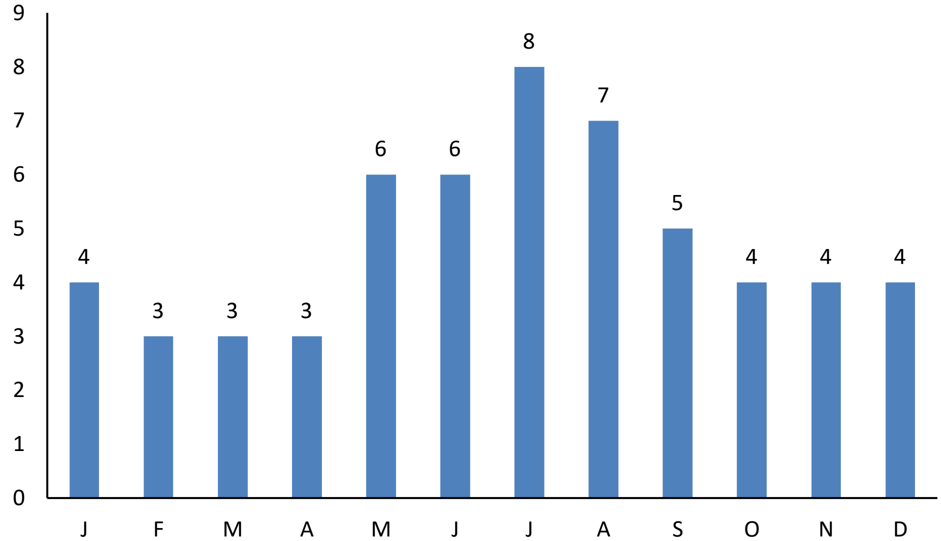


Hooded merganser winter seasonal abundance continued to increase with a significant trend (better than 99.99% level) during the post-hydrilla management period. The trend explains 20.6 % of the observed variation in survey counts per day.

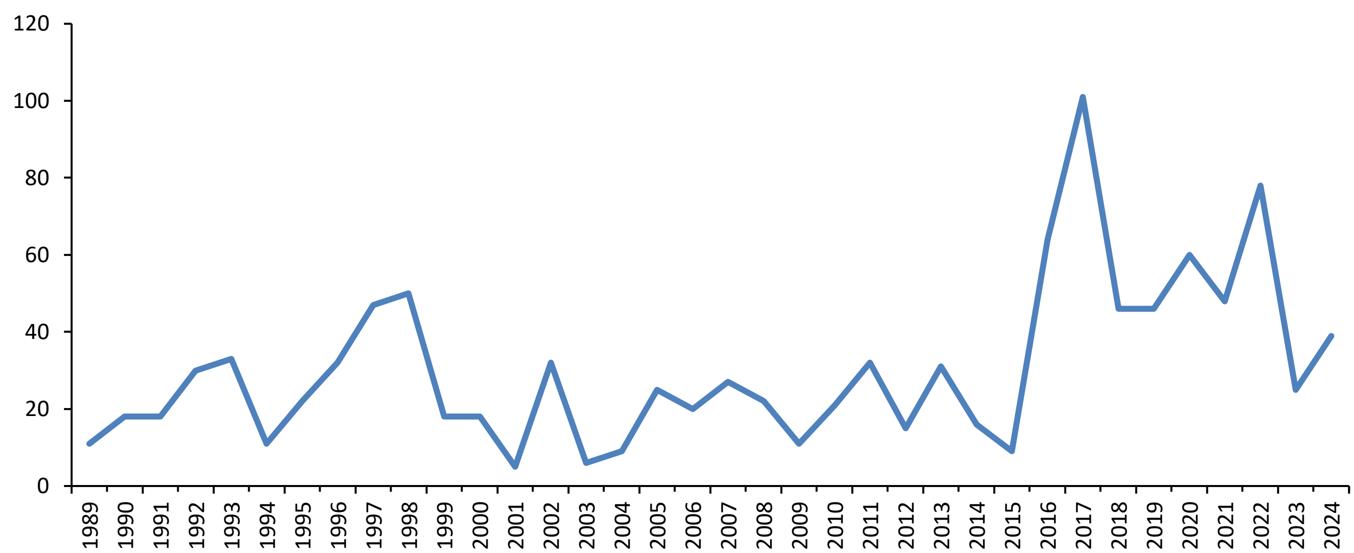
[5] No data for 2003-2004 and 2004-2005

LITTLE BLUE HERON

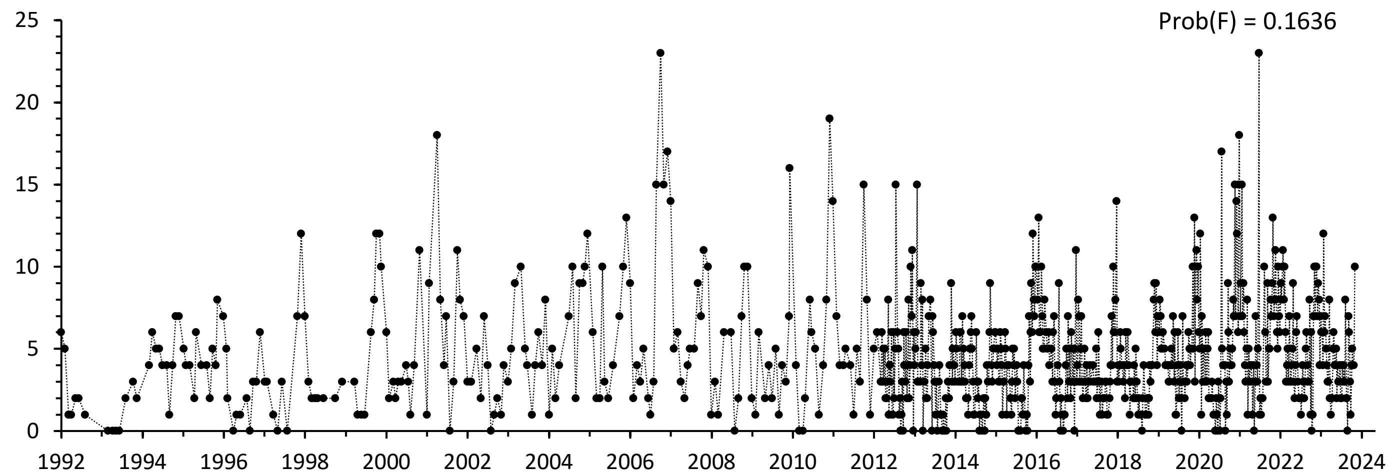
Seasonal Abundance 1992 – June 2024 (average monthly means)



The little blue heron is a year-round resident that has bred in nesting colonies along the second mile of the upper Wakulla River periodically since 1989, as documented by the park's summer full-river wildlife surveys (see next figure). Most recently it has nested there since 2016. Lower monthly means from October through April likely reflect this species's tendency to wander after the breeding season (Kaufman, 2019).

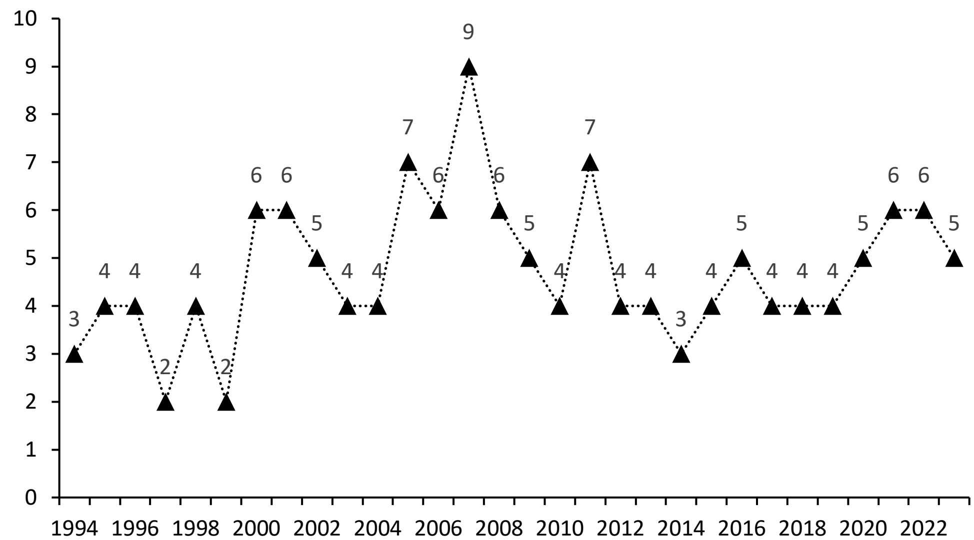


Abundance 1992 – June 2024 (counts per survey)



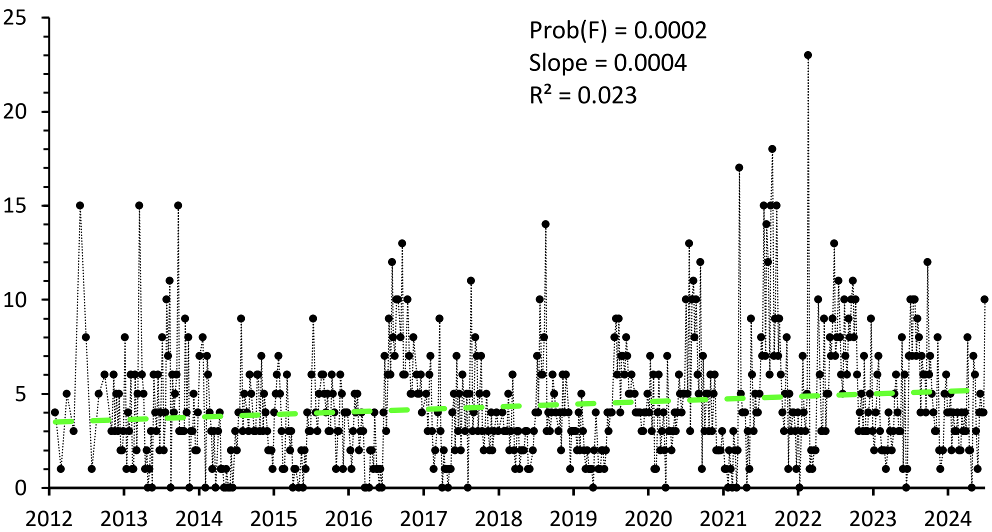
While little blue heron counts per survey during the period of record, 9/1/92 – 6/30/24, have ranged from 0 to 23, they exhibited no significant long-term trend, averaging 4.5 birds counted per survey.

Abundance 1994-2023 (annual means)



Annual mean counts per survey of the little blue heron exhibited substantial variation with now apparent trend.

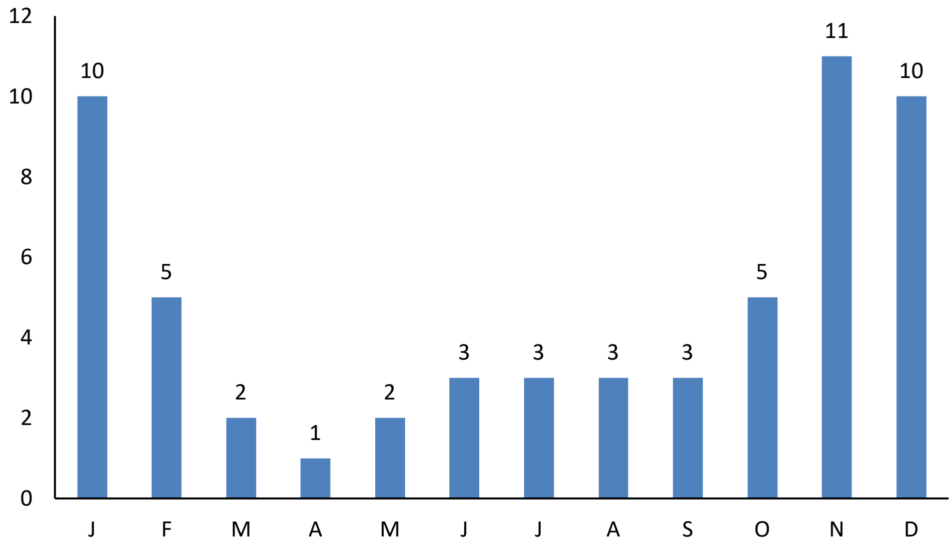
Abundance Post- Hydrilla Management: 2012 – June 2024 (counts per survey)



The abundance trend for the little blue heron during the post-hydrilla management period shifted from not significant to significantly positive with extension of the analysis from May 2021 through June 2024. The trend explains 2.3 % of the observed variation in survey counts per day.

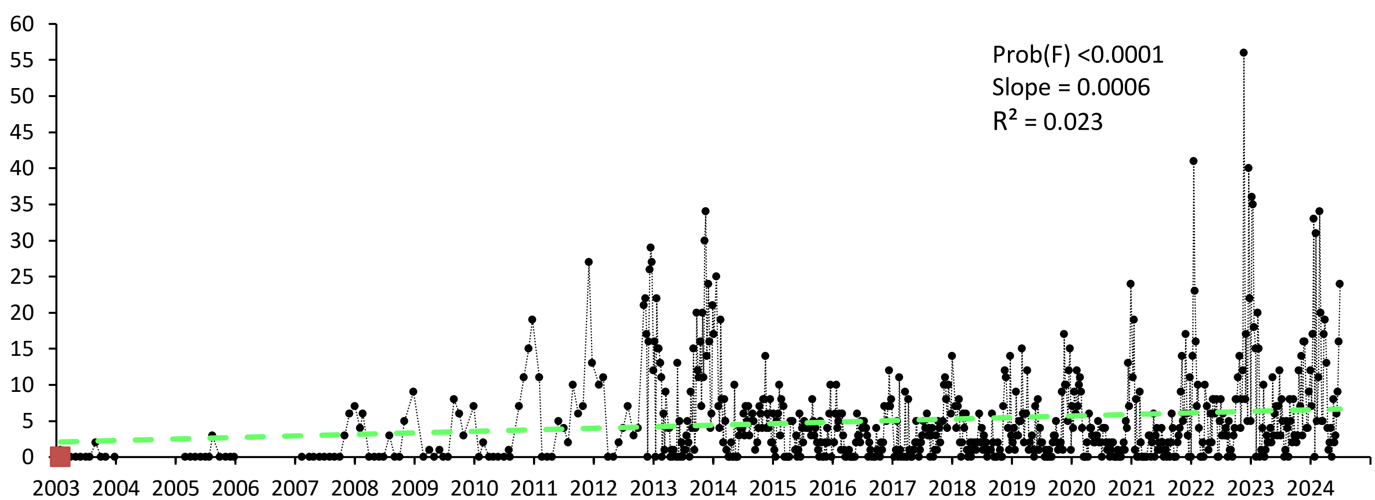
MANATEE

Seasonal Abundance 2003 – June 2024 (average monthly means)[6]



The manatee is a year-round resident of Wakulla Spring and the upper Wakulla River, present in higher numbers in the winter (October – February) when manatee seek thermal refuge in the 69-70º F (21 C º) spring.

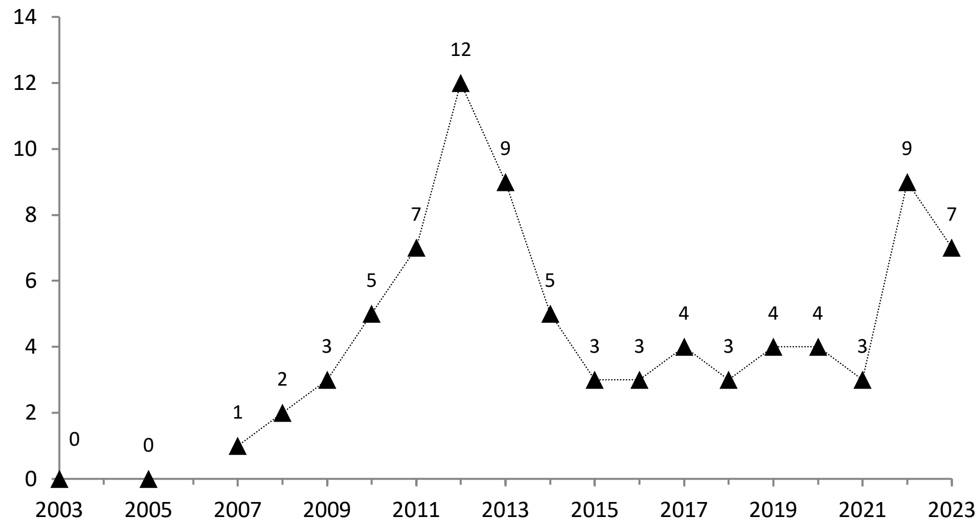
Abundance 2003 – June 2024 (counts per survey)



New high counts of 41 on January 15, 2022, and 56 on November 19, 2022, shifted the long-term trend to significantly increasing at a rate of 0.0006 animals counted per survey over the period analyzed, 1/27/03 – 6/30/24. Survey date explains 2.3 % of the observed variation in counts per survey.

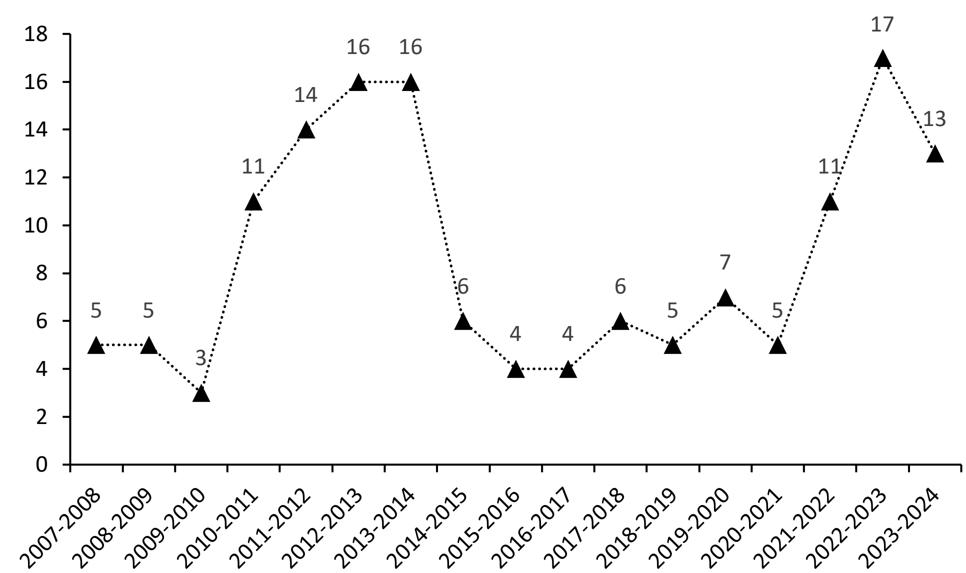
[6] Manatee were not included on the survey form until 2007. Data prior to 2007 are likely incomplete. Observations recorded in 2003 and 2005 are from the open-ended "Comments" section at the bottom of the survey form. None were recorded for 2004 or 2006.

Abundance 2003-2023 (annual means)[7]



Manatee annual mean counts per survey gradually increased to a peak of 12 in 2012 and then declined levelling off at 3 to 4 from 2015 through 2021, followed by an upswing in 2022 and 2023.

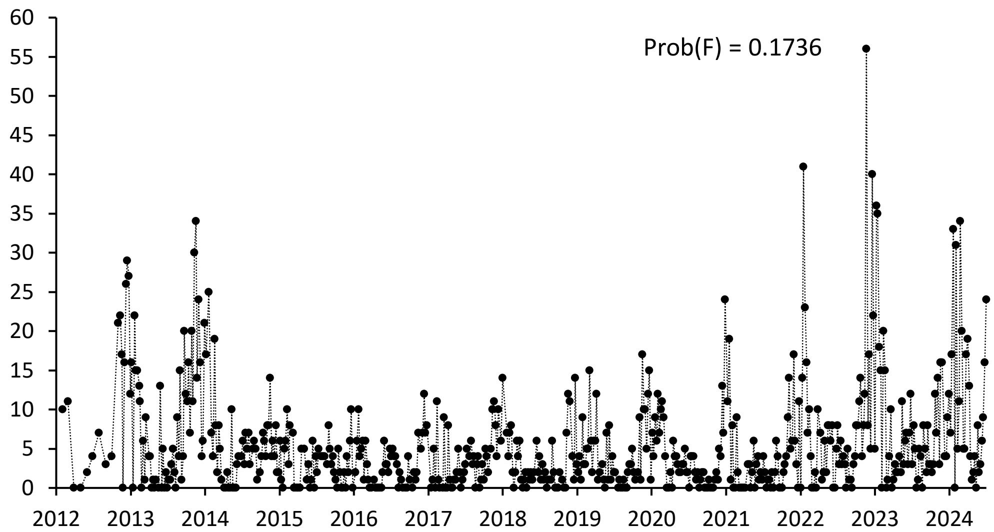
Seasonal Abundance Oct-Feb 2007-08 - 2023-24 (winter monthly means)



Examination of winter monthly means reveals a more gradual increase peaking in the winters of 2012-13 and 2013-14 then rising to a new peak high in 2022-2023.

[7] No data for 2004 and 2006.

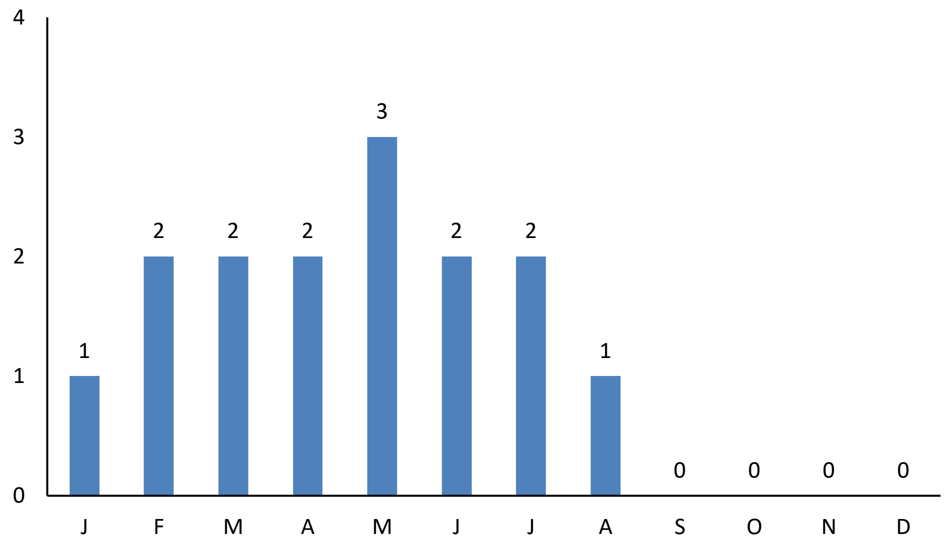
Abundance Post- Hydrilla Management: 2012 – June 2024 (counts per survey)



The decline in manatee abundance following the peak winters of 2012-13 and 2013-14 resulted in a significant decrease (better than 99.99% level) through May 2021. However, new highs in 2022 resulted in no significant trend with the analysis extended through June 2024.

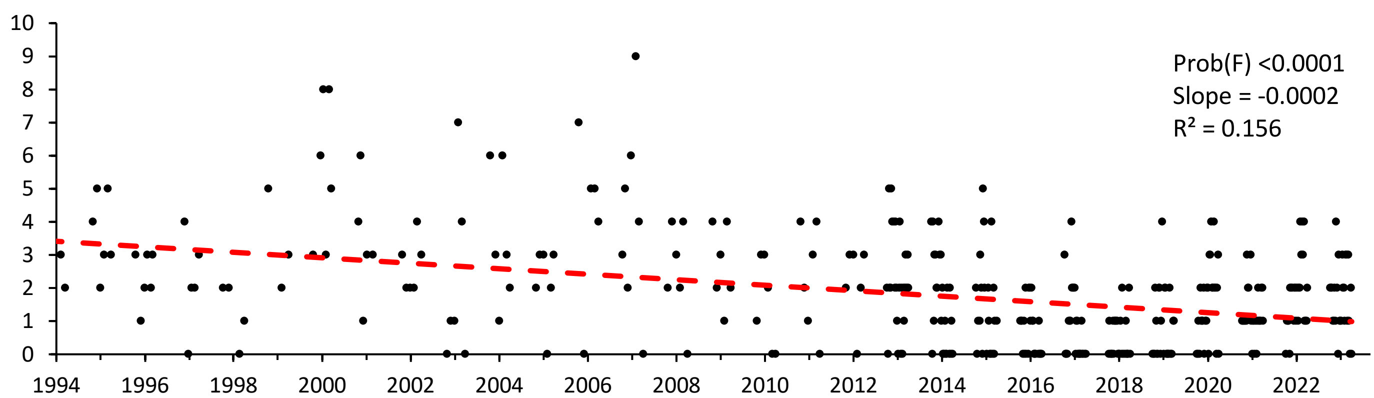
OSPREY

Seasonal Abundance 1992 - 2024 (average monthly means)



The osprey is a spring-summer breeder (Feb-Jul) on the upper Wakulla River that is seen occasionally in other months of the year.

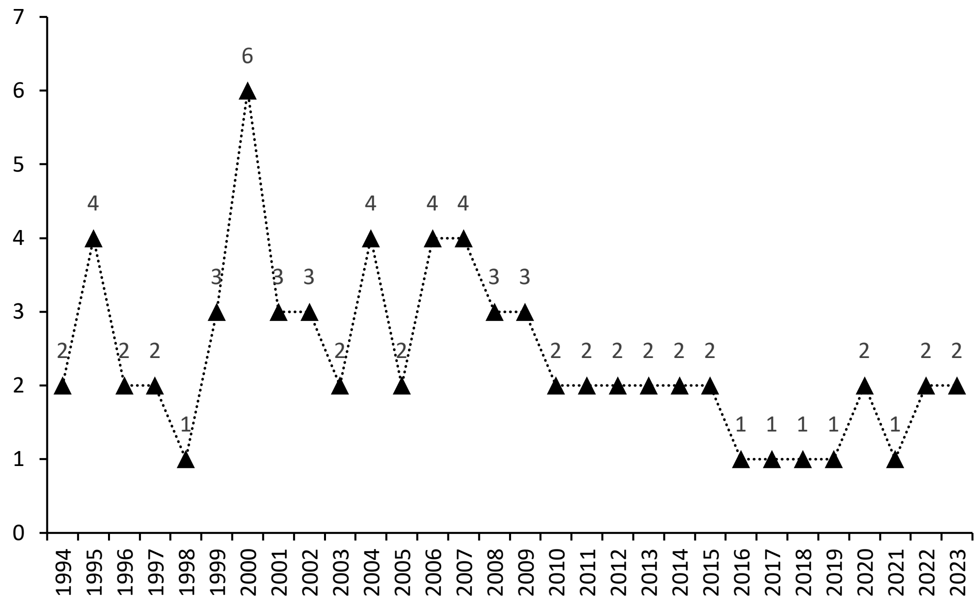
Seasonal Abundance Feb-Jul 1994 – 2023 (counts per survey)



The osprey exhibited a significant (better than 99.99% level) decreasing seasonal abundance trend of -0.0002 animals counted per survey over the period analyzed, 2/3/94 – 6/30/24.[8] Survey date explains 15.6 % of the observed variation in counts per survey.

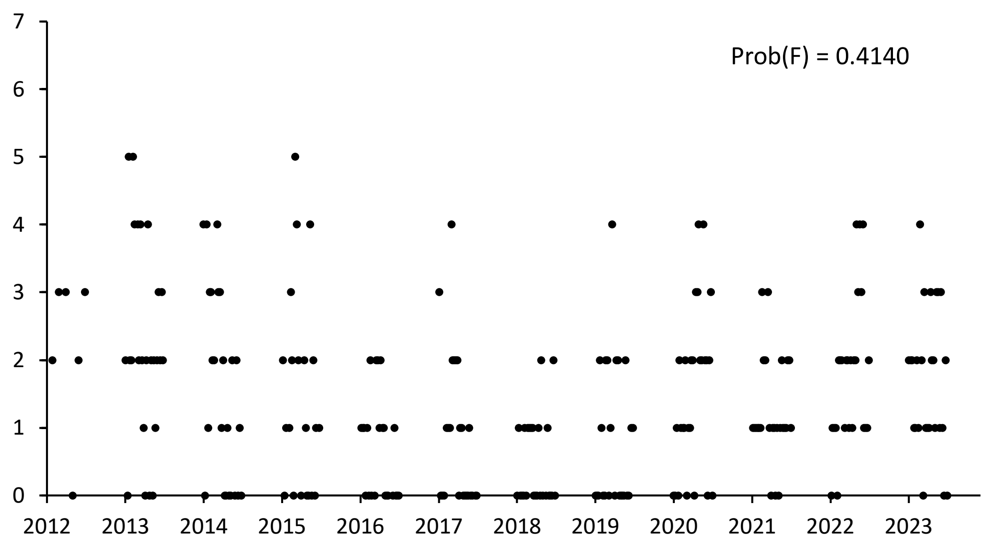
[8] The period of analysis begins 2/3/94 because of incomplete seasonal data in 1992 and 1993.

Seasonal Abundance Feb-Jul 1994-2023 (breeding season monthly means)



Breeding season monthly means range from 1 to 6, most likely as a function of the number of active nests which have varied from as many as 4 or 5 to none (Bob Thompson, personal communication).

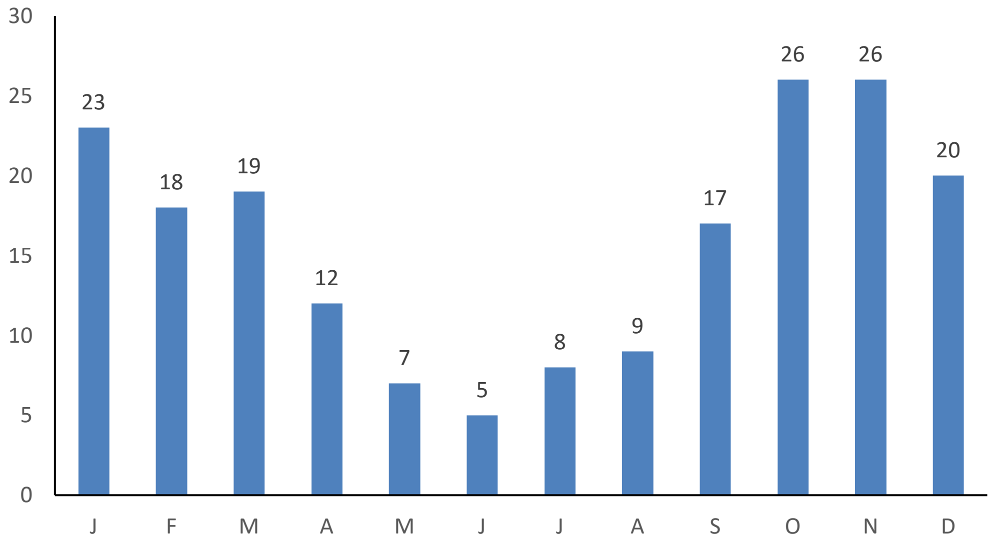
Seasonal Abundance Post- Hydrilla Management: Feb-Jul 2012-2023 (counts per survey)



The post-hydrilla management trend was significantly decreasing through May 2021. Successful nesting in 2021-2022 and 2022-2023 resulted in no significant trend through June 2024.

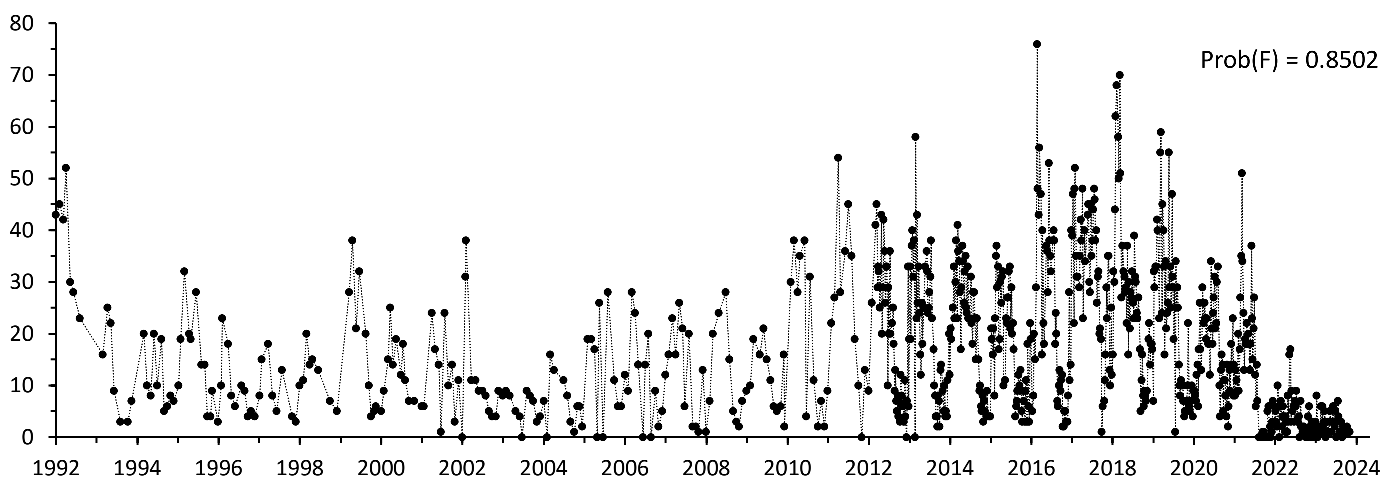
PIED-BILLED GREBE

Seasonal Abundance 1992 – June 2024 (average monthly means)



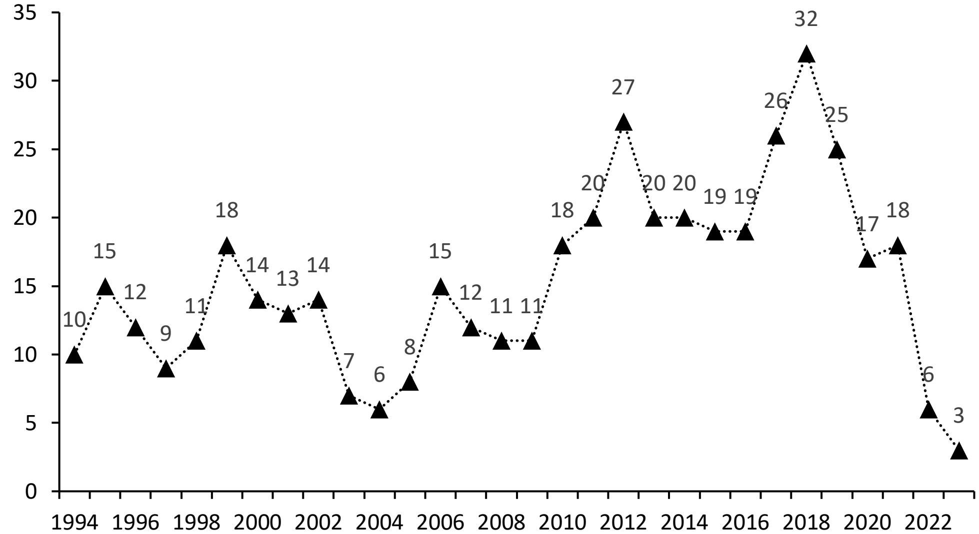
The pied-billed grebe is a year-round breeding resident whose numbers are augmented by winter migrants from September through March (Muller Storer, 1999).

Abundance 1992 – June 2024 (counts per survey)



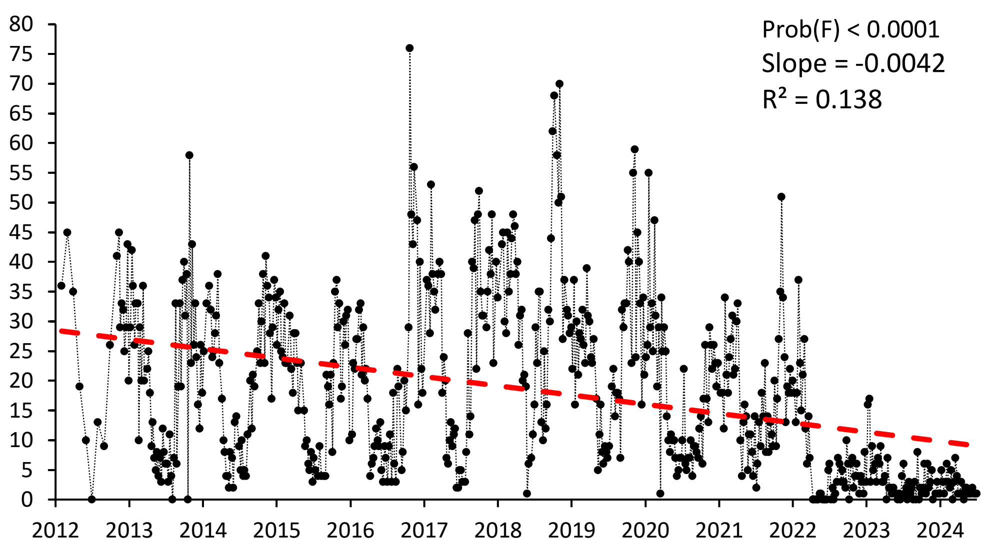
The pied-billed grebe had exhibited a significant (better than 99.99% level) increasing trend through May 2021. However the trend is no longer significantly increasing as very low counts have continued through June 2024 due to loss of the knotweed habitat that it uses for nesting and shelter.

Abundance 1994-2023 (annual means)



The recent decline is dramatically illustrated by annual mean counts per survey.

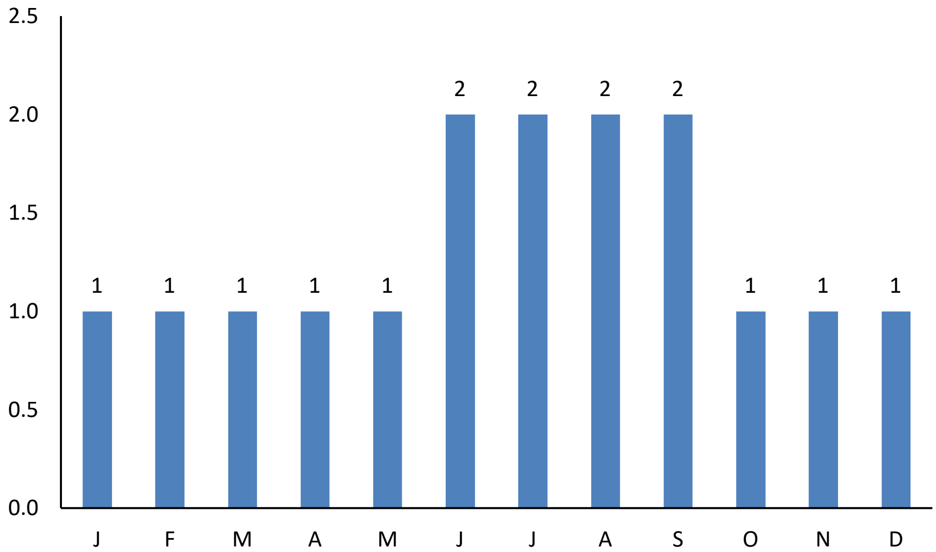
Abundance Post- Hydrilla Management: 2012 – June 2024 (counts per survey)



The pied-billed grebe had exhibited a significant increasing abundance trend during the post-hydrilla management period through 2018. Lower counts in 2020 and 2021 rendered the trend no longer statistically significant through May 2021. Extension of the analysis through June 2024 now yields a significant decreasing trend.

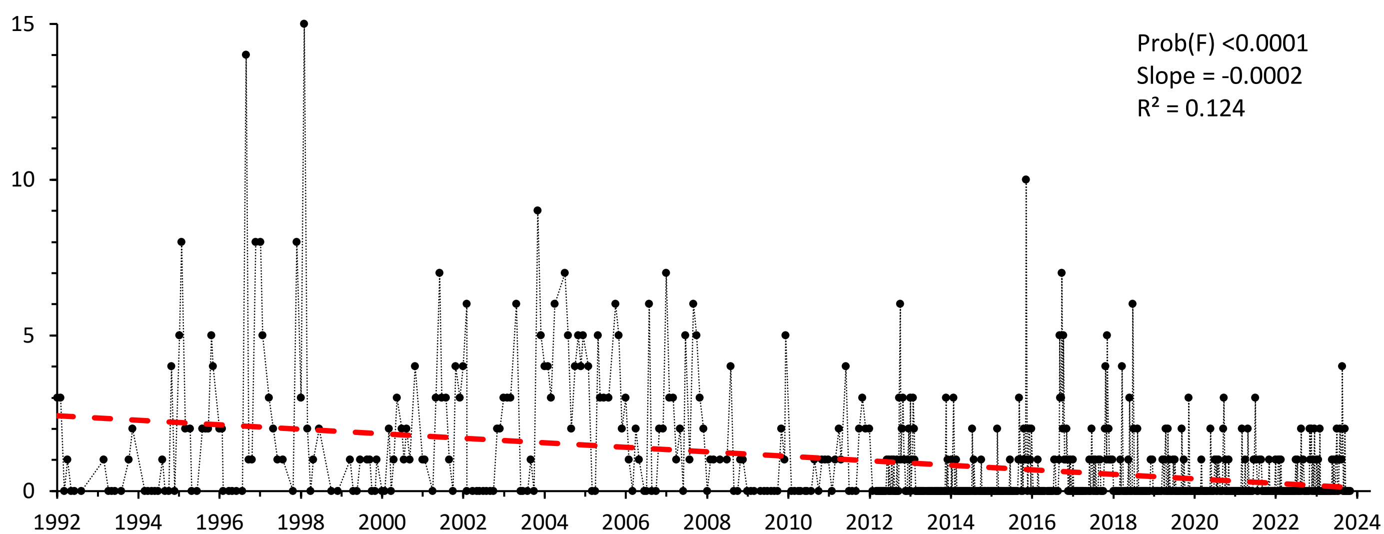
SNOWY EGRET

Seasonal Abundance 1992 – June 2024 (average monthly means)



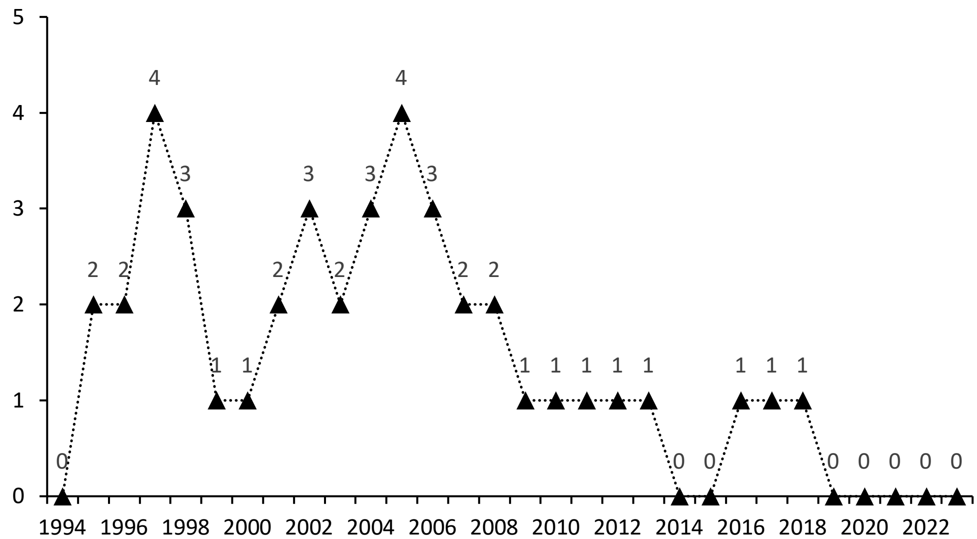
The snowy egret occurs in small numbers on the upper Wakulla River. It is somewhat more common during the summer months of June through September. Monthly means range from 1 to 2.

Abundance 1992 – June 2024 (counts per survey)



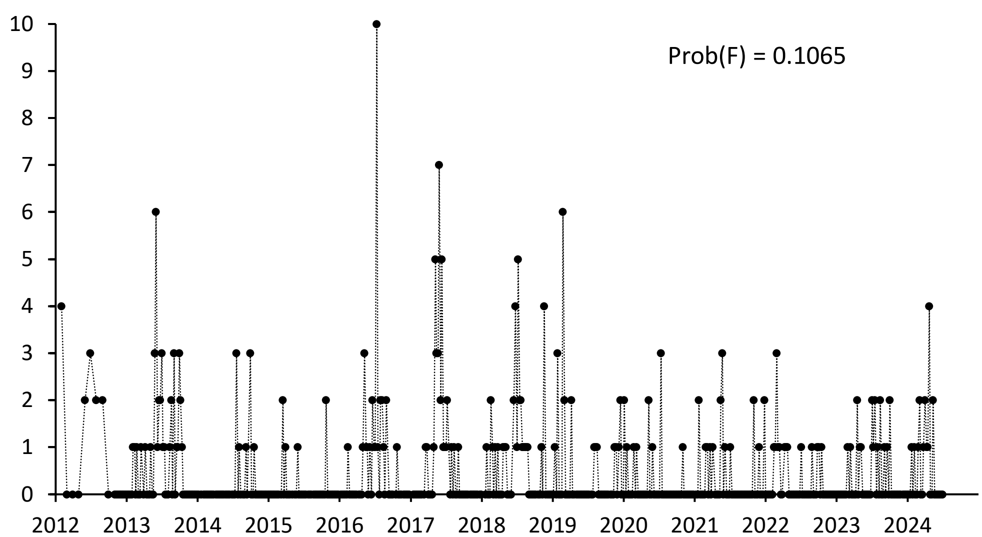
The snowy exhibited a significant (better than 99.99% level) but very slowly decreasing trend of -0.0002 animals counted per survey over the period of record, 9/1/92 – 6/30/24. Survey date explains 12.4 % of the observed variation in counts per survey.

Abundance 1994-2023 (annual means)



Annual mean counts per survey of the snowy egret were quite variable through 2008 but have declined since then and bottomed out at zero since 2019.

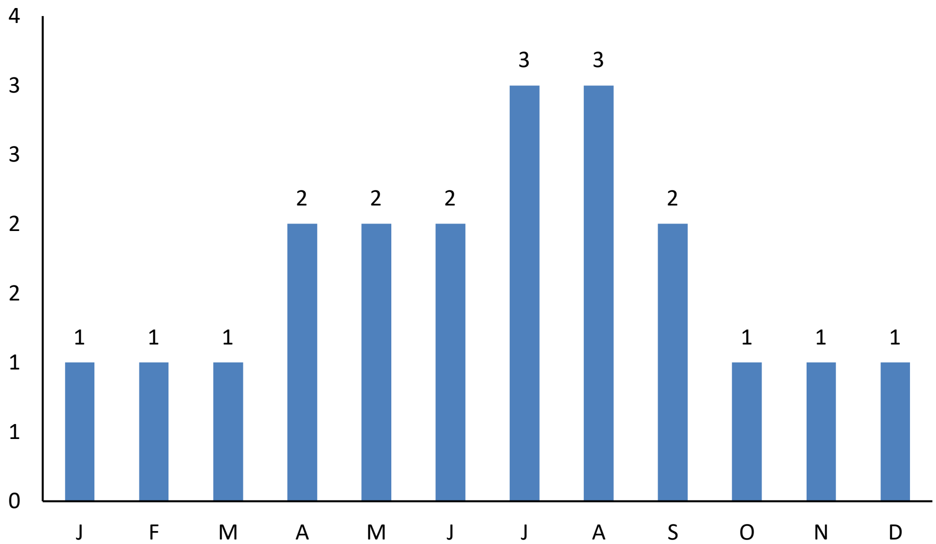
Abundance Post- Hydrilla Management: 2012 – June 2024 (counts per survey)



The snowy egret has exhibited no significant abundance trend during the post-hydrilla management period with counts ranging from 0 to 10 and an average of 0.46.

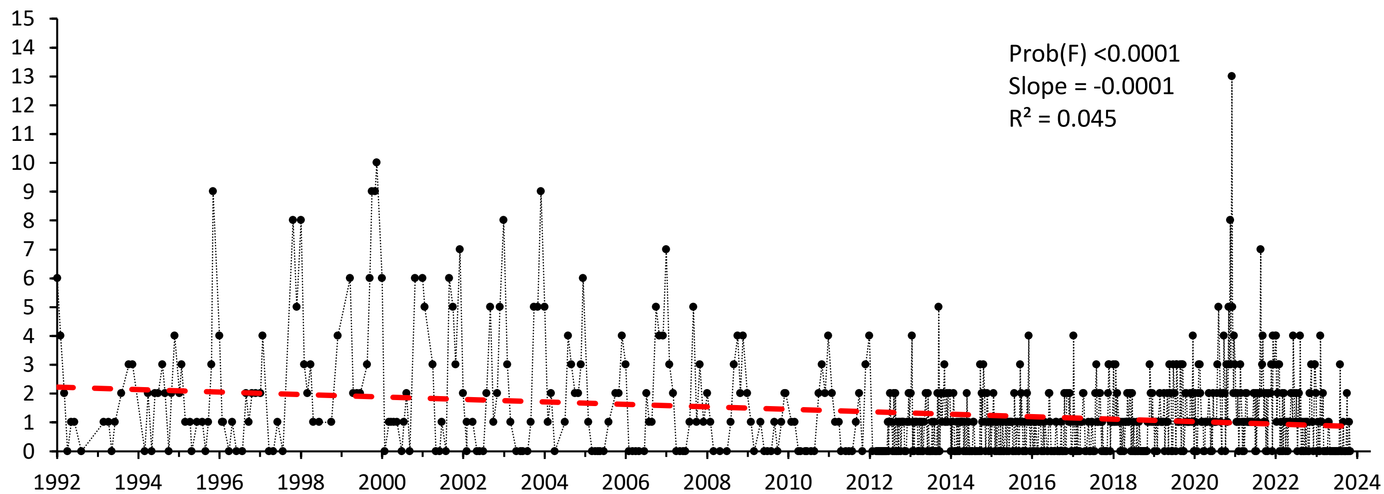
TRICOLORED HERON

Seasonal Abundance 1992 – June 2024 (average monthly means)



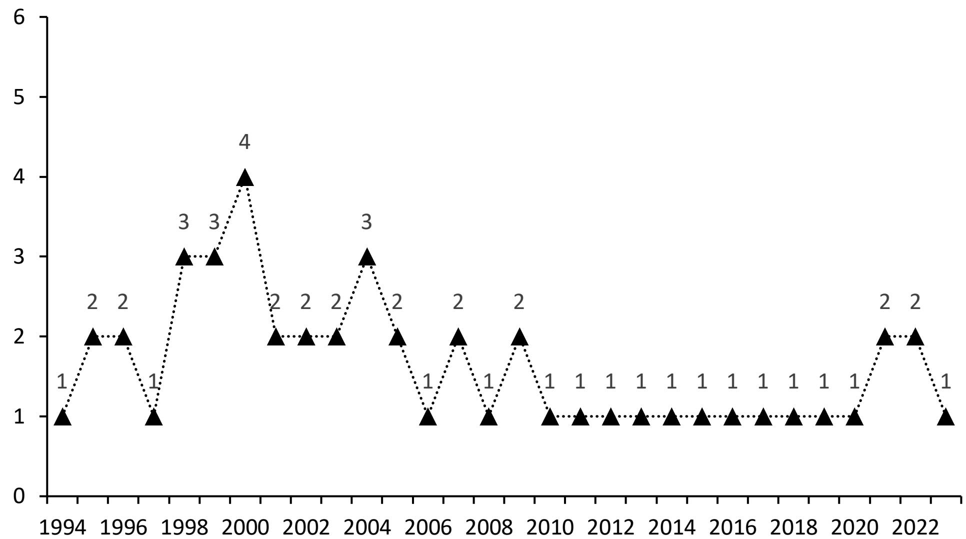
The tricolored heron also occurs in relatively small numbers on the upper Wakulla River. It is somewhat more common during the summer months of July and August. Monthly means range from 1 to 4.

Abundance 1992 – June 2024 (counts per survey)



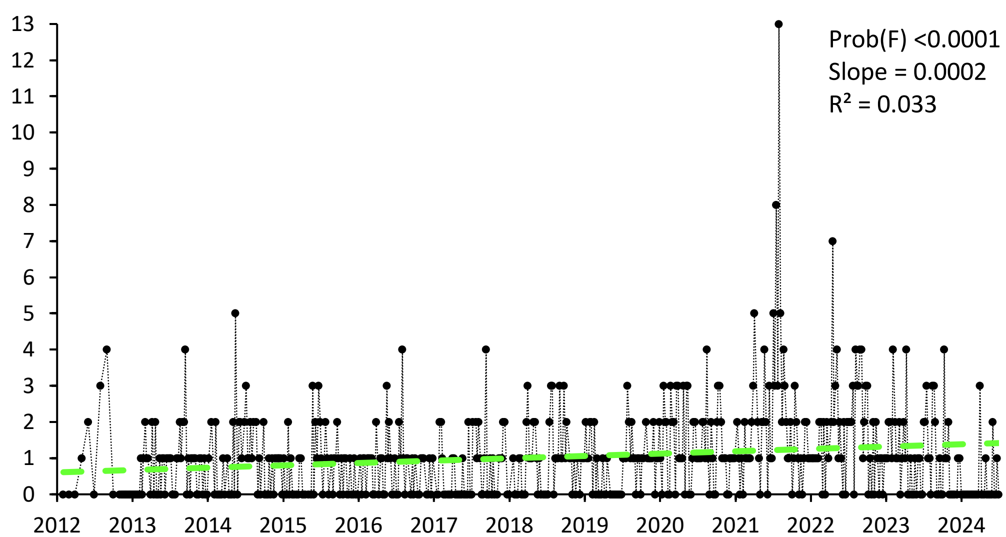
Despite some outlying high counts in July 2021, the tricolored heron exhibited a significant (better than 99.99% level) but very slowly decreasing trend of -0.0001 animals counted per survey over the period of record, 9/1/92 – 6/30/24. Survey date explains 4.5 % of the observed variation in counts per survey.

Abundance 1994-2023 (annual means)



Annual mean counts per survey of the tricolored heron are quite variable from 1994 to 2005 after which there is a general decline flattening out to a mean annual count of 1 from 2010 through 2020 followed by a small increase to 2 for 2021 and 2022.

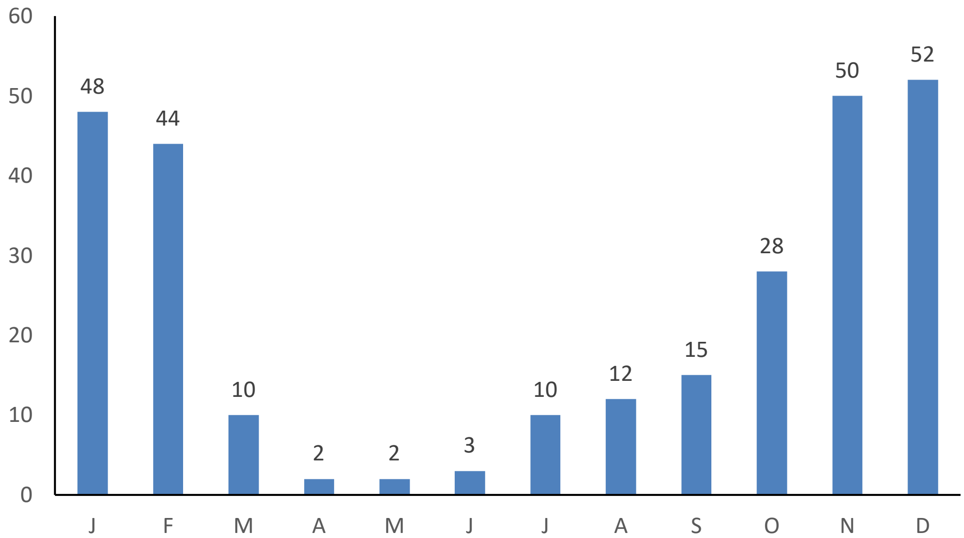
Abundance Post- Hydrilla Management: 2012 – June 2024 (counts per survey)



What had been no significant abundance trend for the tricolored heron during the post-hydrilla management period is now significantly positive due to some higher counts in 2020 and 2021. However, the slope is slight at 0.0002 animals counted per survey.

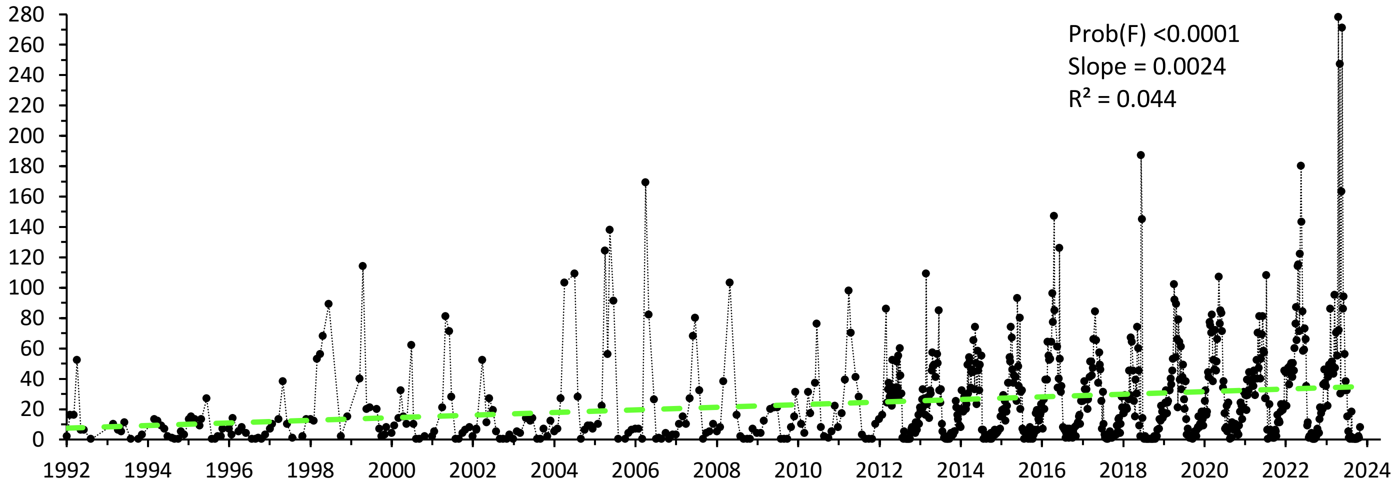
WHITE IBIS

Seasonal Abundance 1992 – June 2024 (average monthly means)



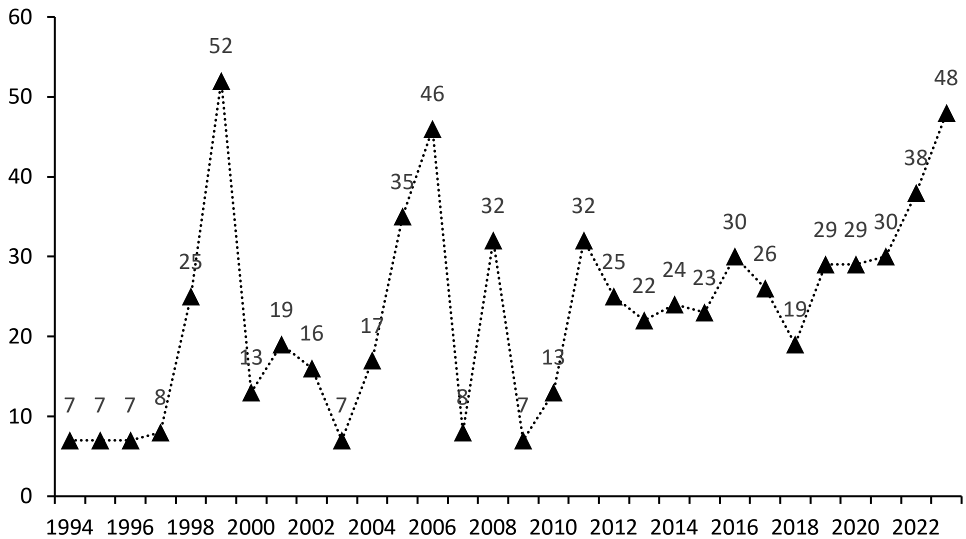
The white ibis does not breed on the upper Wakulla River. However, adults congregate there outside the breeding season beginning in July. Late spring and early summer populations comprise primarily juveniles (personal observation).

Abundance 1992 – June 2024 (counts per survey)



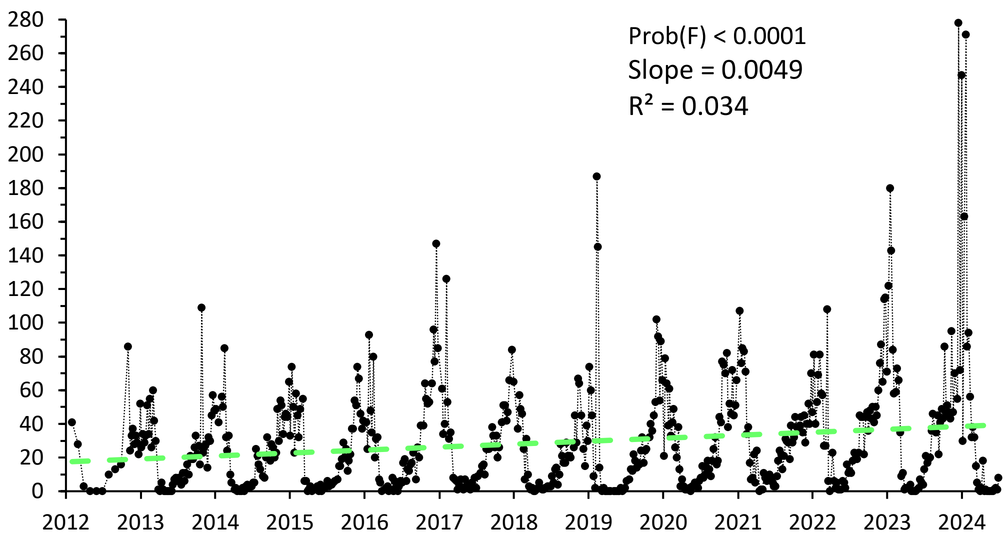
White ibis have exhibited a significant (better than 99.99% level) increasing abundance trend of 0.0024 animals counted per survey over the period of record, 9/1/92 – 6/30/24. Survey date explains 4.4 % of the observed variation in counts per survey.

Abundance 1994-2023 (annual means)



Annual mean counts per survey of the white ibis vary substantially with high peaks and deep valleys, particularly between 1997 and 2011. The trend had been more stable through 2021 but has risen steeply since then.

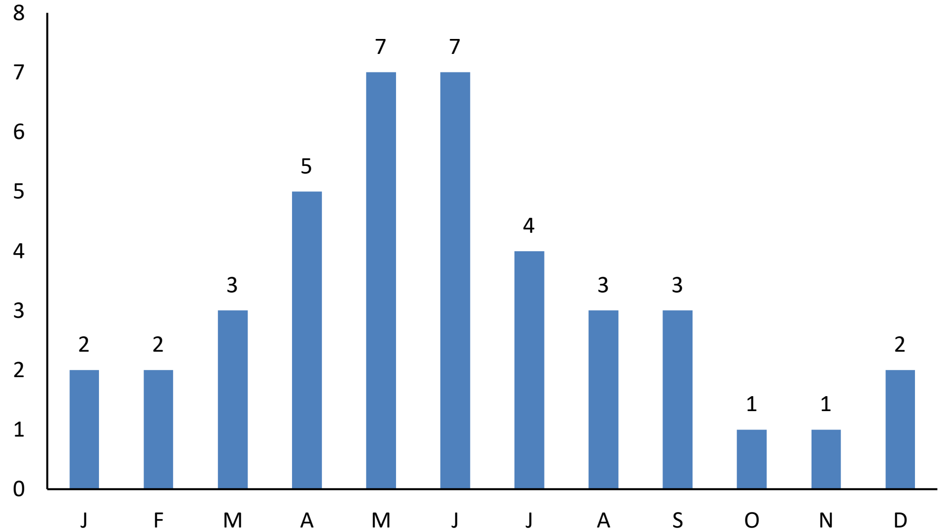
Abundance Post- Hydrilla Management: 2012 – June 2024 (counts per survey)



The white ibis had exhibited no significant abundance trend during the post-hydrilla management period through May 2021. However, three very high counts in December 2023 and January 2024 have shifted the trend to significantly increasing.

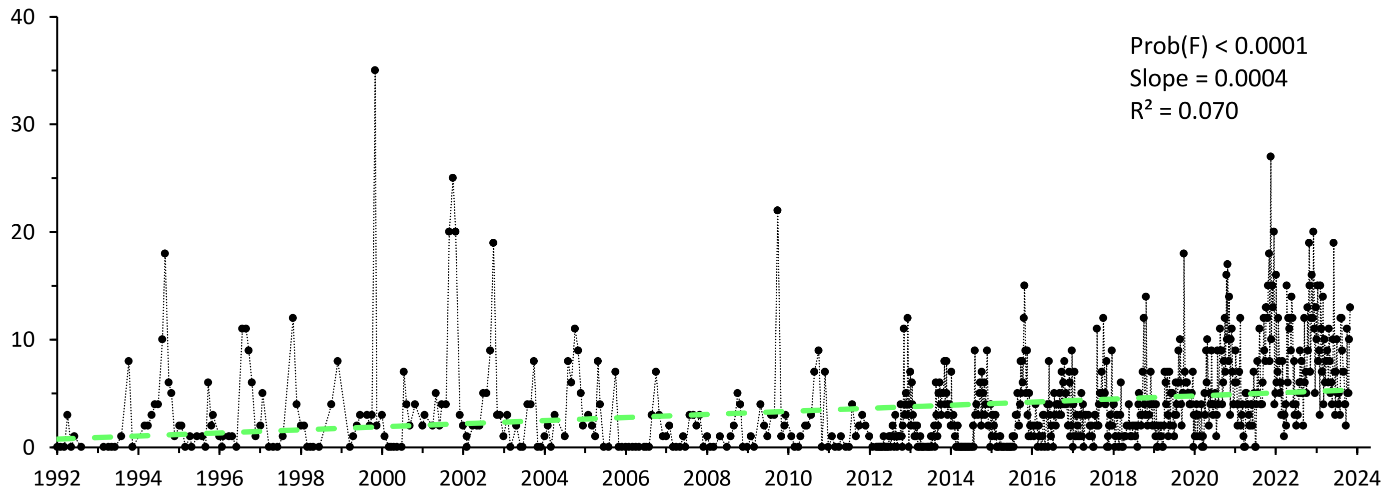
YELLOW-CROWNED NIGHT-HERON

Seasonal Abundance 1992 – June 2024 (average monthly means)



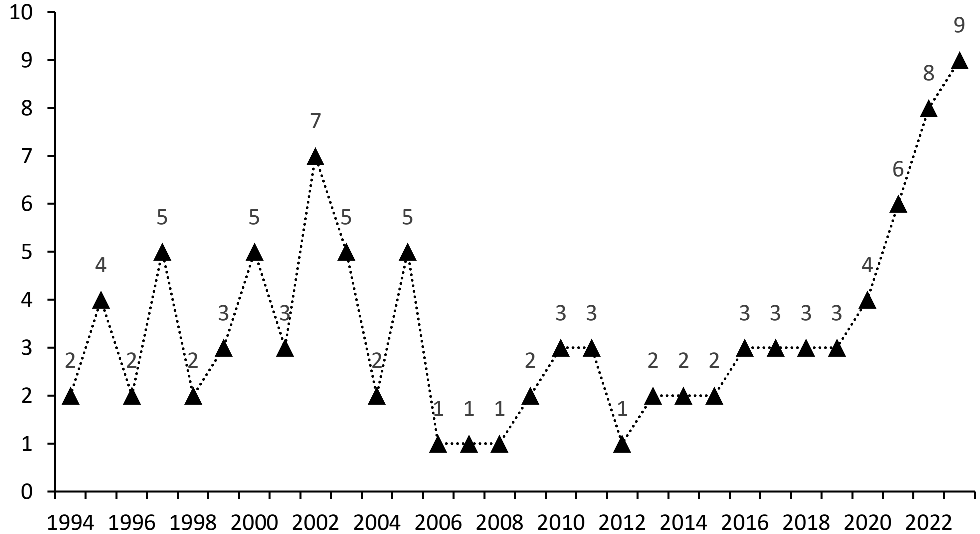
The yellow-crowned night-heron is a year-round resident that breeds in the summer. However, some individuals may migrate to south Florida or beyond in the winter (Watts, 2011).

Abundance 1992 – June 2024 (counts per survey)



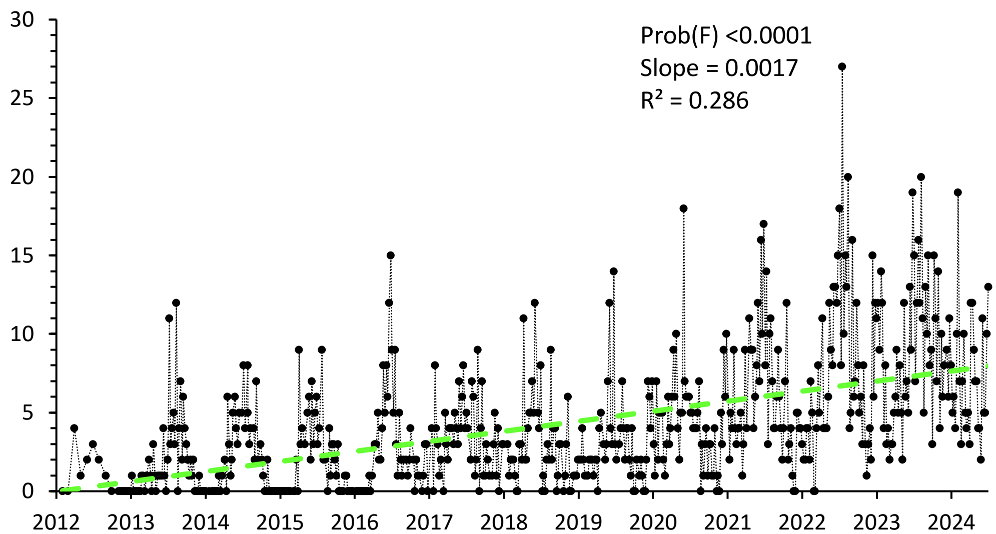
Continuing increases in yellow-crowned night-heron counts have shifted the long-term trend from no significance to a significant increase (better than 99.99% level) with extension of the analysis from May 2021 through June 2024: 0.0004 animals counted per survey. Survey date explains 0.7 % of the observed variation in counts per survey.

Abundance 1994-2023 (annual means)



The recent upswing is clear from the trend in annual means since 2019.

Abundance Post- Hydrilla Management: 2012 – June 2024 (counts per survey)



The yellow-crowned night-heron abundance trend is significantly increasing during the post-hydrilla management period (better than 99.99% level) explaining 28.6 % of the observed variance in counts per survey.

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