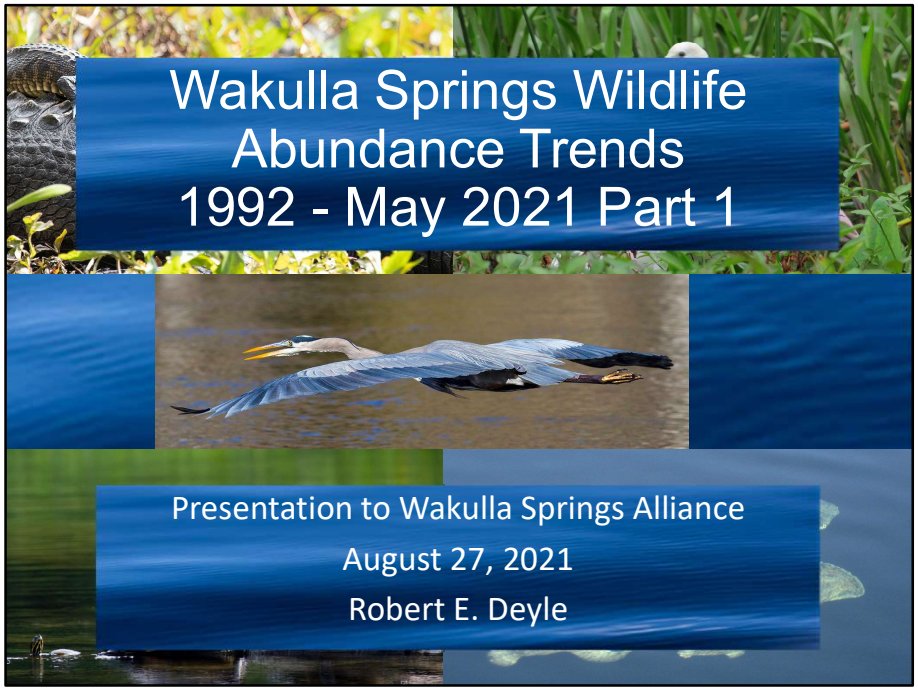
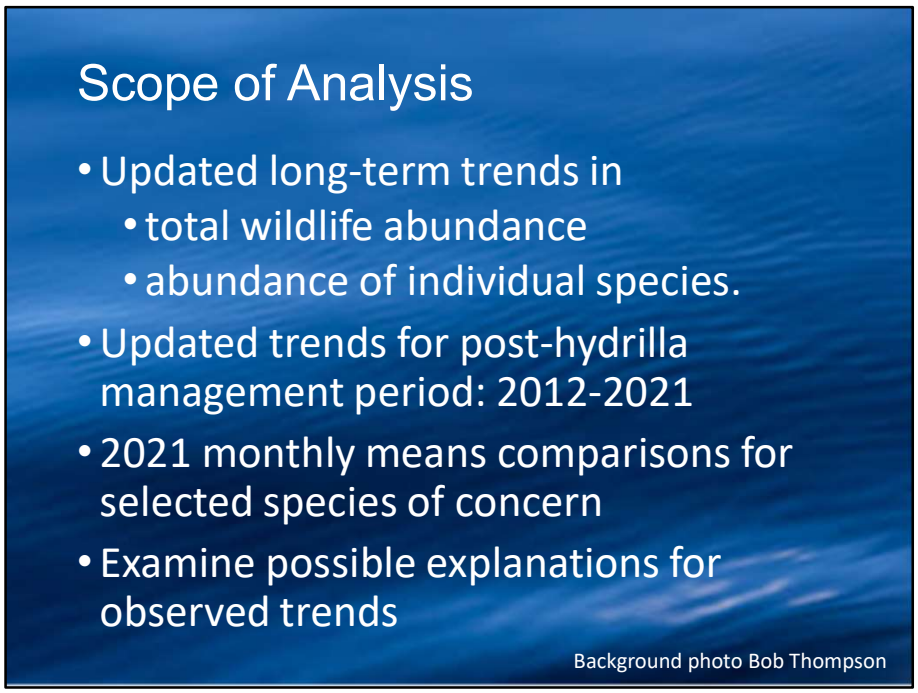


- Because of the other important business on our agenda today I am splitting my presentation on Wakulla Springs wildlife abundance trends into two parts.
    - Today I will share with you aggregate trends over the 29.5 years the park has been monitoring wildlife along the 2-mile river boat tour route
    - In September we'll look at the detailed stories behind the trends of a selection of individual species

Photo credits:

- Upper left – Bob Thompson
- Upper right – Doug Alderson
- Center – Bob Thompson
- Bottom left – Bob Thompson
- Bottom right – Bob Deyle



- Today's presentation is based on an update to the report I prepared for the State Park in 2018
- The park biologist, Patty Wilbur, is reviewing a draft of my updated report
- The report presents
    - **[click]** Updated long-term trends in
        - total wildlife abundance and
        - abundance of individual species
    - **[click]** Updated
    - **[click]** Comparisons of 2021 monthly means to 2020 for selected species of concern:
        - anhinga, common gallinule, and pied-billed grebe
    - **[click]** It also examines possible explanations for the observed trends, drawing on scientific literature and documented changes to the river ecosystem

- Long-term total animal abundance and individual species abundance trends are presented as
    - **[click]** Total animal counts for each survey from
    - **[click]** Annual mean or annual seasonal monthly mean total animal counts for the years 1994 thru May 2021
    - Mean abundance trends are reported as annual seasonal monthly means rather than annual means where regression models for annual seasonal monthly means provide a better fit to the data for animals that are not year-round residents **[see next slide]**
    - [Data from 1992 and 1993 are excluded from the long-term analyses of annual means and annual seasonal monthly means because data were only collected for a few months in each of those years and the distribution of those months was not seasonally balanced. Thus, data for any species whose abundance varies seasonally are skewed for those two years.]

Seasonal Abundance Patterns

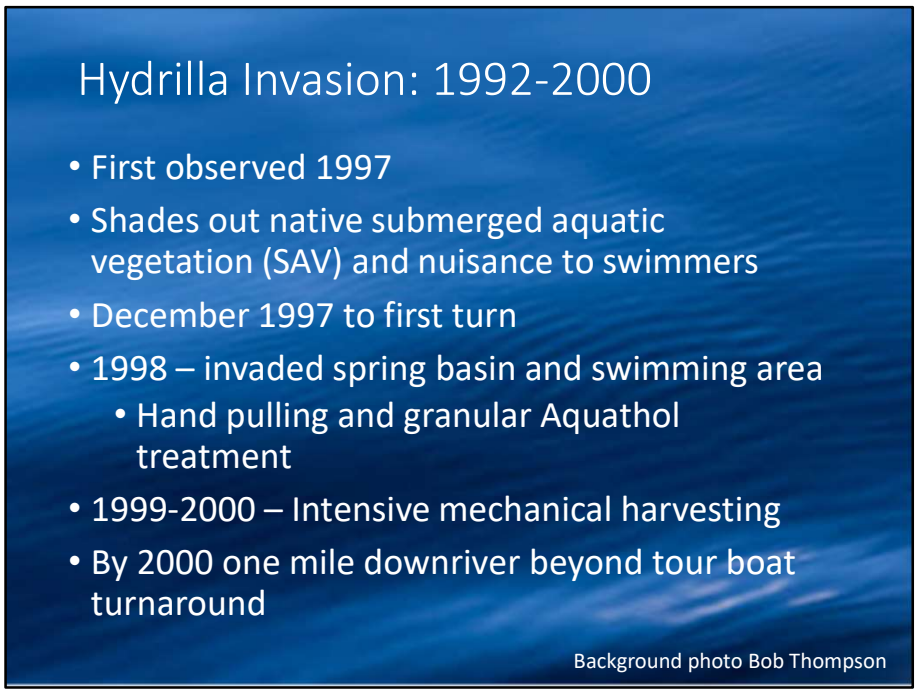
Abundance Pattern	Species
Year-round breeder (YB)	American alligator, anhinga, common gallinule,* cooter turtle, green heron, pied-billed grebe,* wood duck, yellow-crowned night-heron
Year-round occasional breeder (YOB)	Double-crested cormorant,** great blue heron, great egret,** little blue heron**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

*Year-round breeding populations probably supplemented by winter migrants.
**Occasionally nest along the tour boat route; frequently nest in sanctuary.

- I've defined seven different seasonal abundance patterns

- Total animal abundance and individual species abundance trends also are analyzed for three perturbation periods:
  - **[click]** Hydrilla invasion: 1992-2000
  - **[click]** Hydrilla management: 2000-2012
  - **[click]** Post-hydrilla management: 2012-present (May 2021)

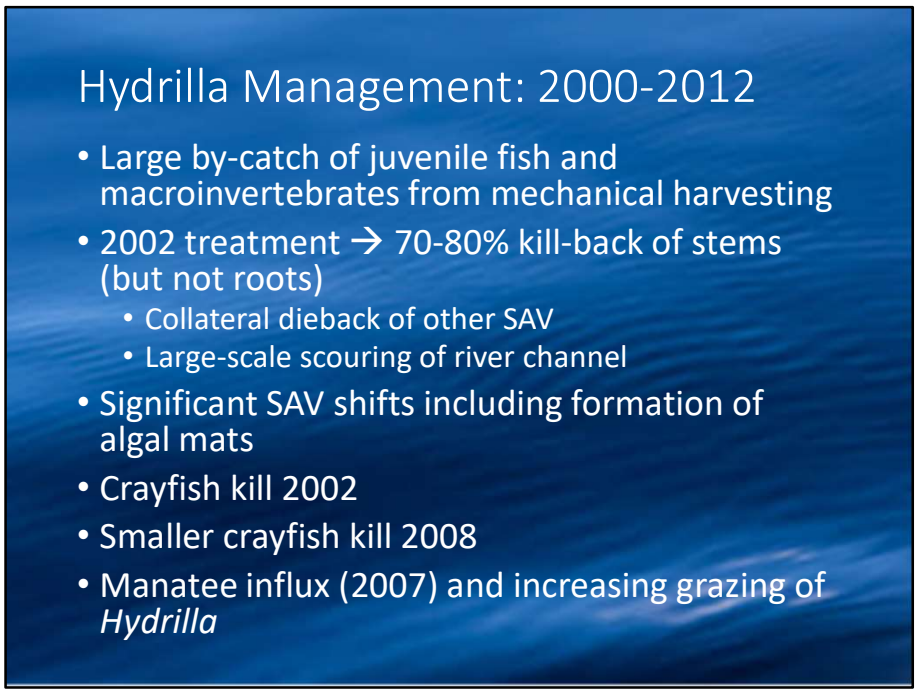
- This nine-year period encompasses the time prior to and during the invasion of the exotic plant, *Hydrilla verticillata,* and the first three years of efforts to control it.
- Looking up-river toward the boat dock



- **[click]** Hydrilla was first observed near the boat dock in April 1997.
- **[click]** 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.
- **[click]** By December of that year, it had spread down the river to the first turn, approximately one quarter mile past the boat dock.
- **[click]** During 1998 it invaded the spring basin, the swimming area, and the area behind the spring.
    - **[click]** 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, and the hydrilla continued to spread down river.
- **[click]** Intensive mechanical harvesting was implemented along with hand pulling in 1999 and 2000 to clear the swimming area and boat tour routes.
- **[click]** By 2000 the hydrilla had spread one mile down river beyond the tour boat turnaround.

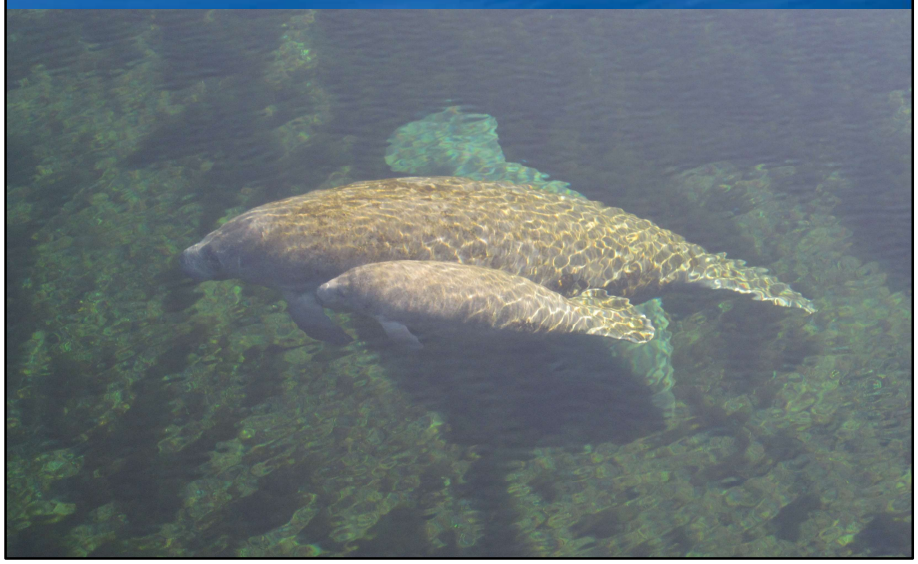
- The hydrilla management period spans the time when more aggressive mechanical harvesting was used along with large-scale application of herbicides

- **[click]** Mechanical harvesting plus hand pulling through 2001 but with no success
- **[click]** Large –scale liquid Aquathol treatments 2002-2010
- **[click]** Granular treatments 2011
- **[click]** Liquid Aquathol in swimming area 2012



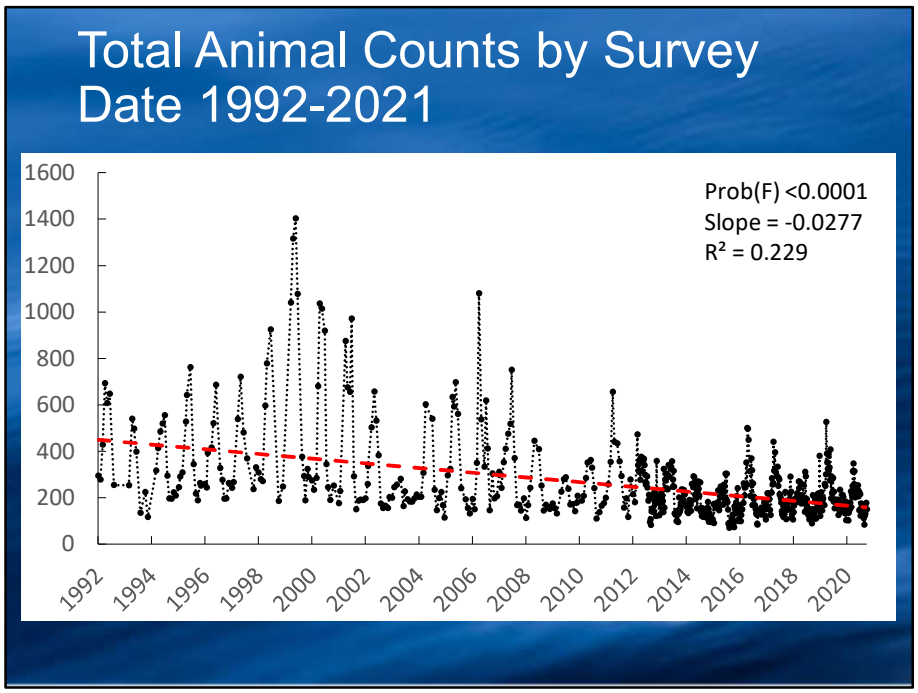
- Read bullets

Post-Hydrilla Management: 2012-2021

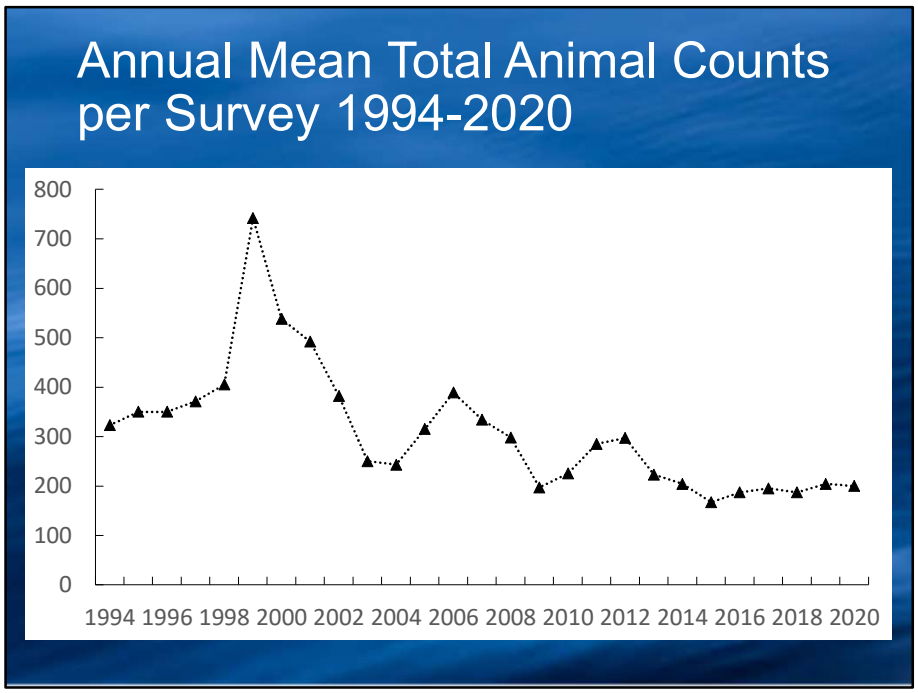


- The cessation of herbicide treatments after 2012 marks the onset of the post-hydrilla management period

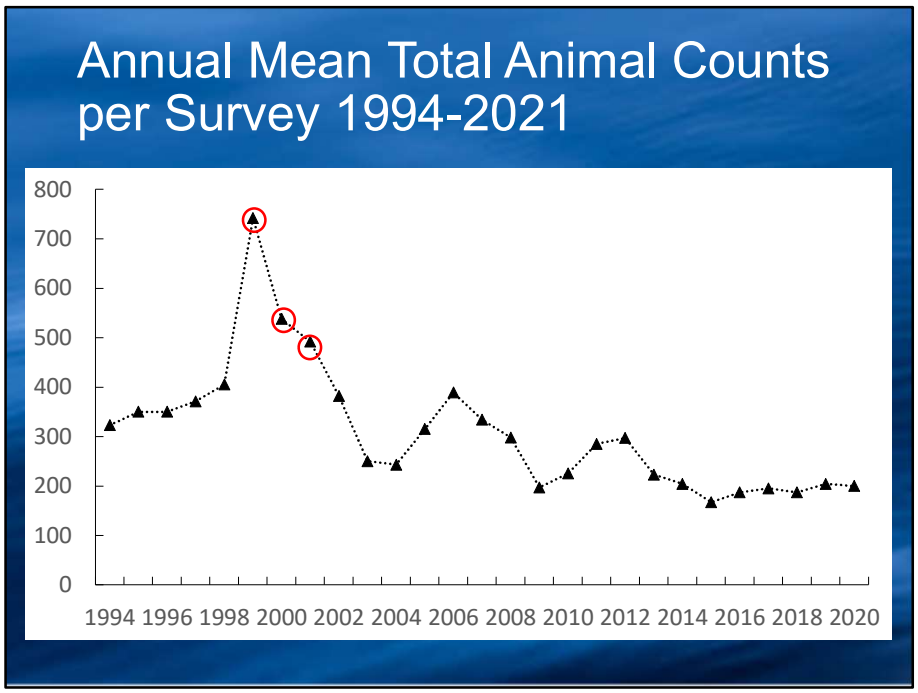
- Last Aquathol treatment occurred in May 2012 and was confined to the swimming area
- Final upgrades to the City of Tallahassee's T.P Smith wastewater treatment facility went online in November 2021 resulting in a 73% decline in nitrogen loading from Tallahassee spray field between 2011 and 2012
- November 2012 also marked the shift from monthly wildlife surveying by park staff to weekly surveying by volunteers



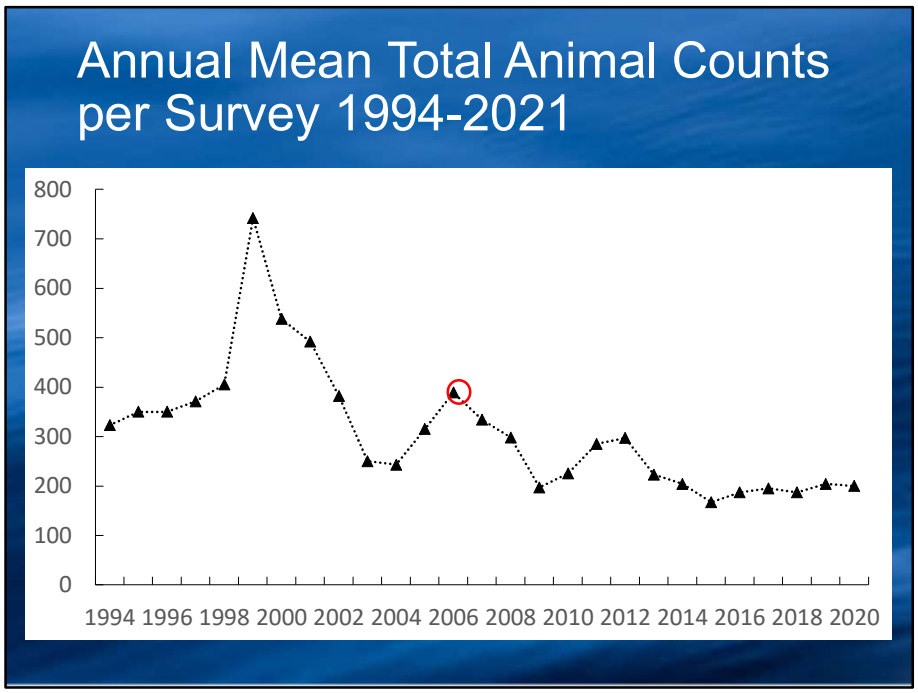
- This graph depicts changes in the total numbers of individual animals counted per survey over the full period of record: September 1992 through May 2021
- This can serve as an indicator of shifts in relative productivity of the upper river ecosystem.
- The long-term trend analyzed here indicates a statistically significant decline over the past 29.5 years
    - The Prob(F) value indicates the relationship is significant at a confidence level of greater than 99.99%,
    - i.e. we can be 99.99% certain that there is a true statistical correlation between total animal counts per survey and the passage of time
- The slope of -0.0277 animals counted per day translates into a decrease of 10 animals counted per year
- The R^2 of 0.229 indicates that the passage of time explains 22.9% of the observed variation in total animal counts per survey



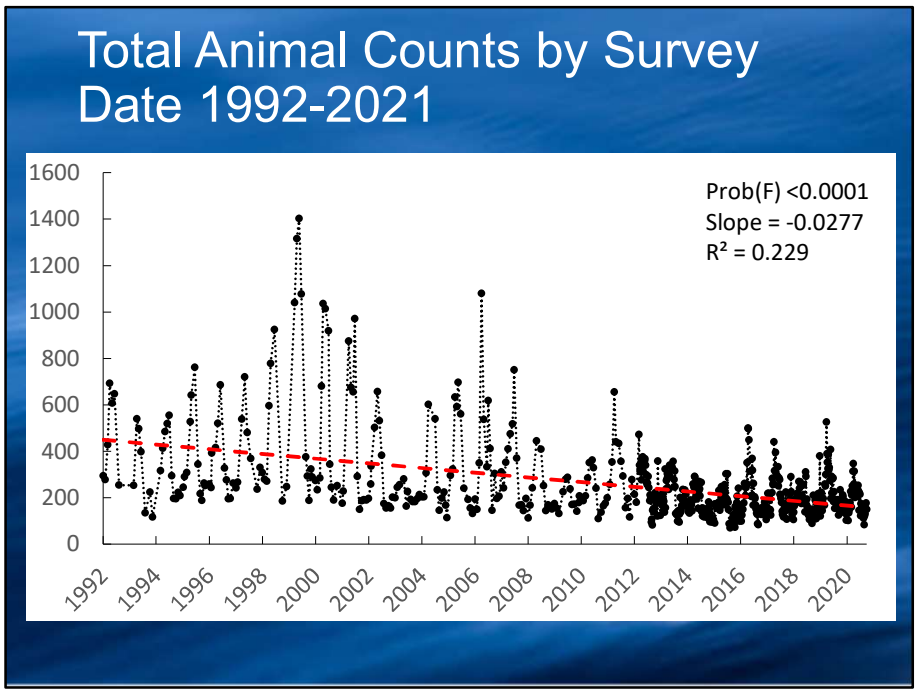
- This graph presents total wildlife abundance over time measured as the annual mean number of animals counted per survey
- Smoothing the data in this manner makes it easier to discern year-to-year changes.



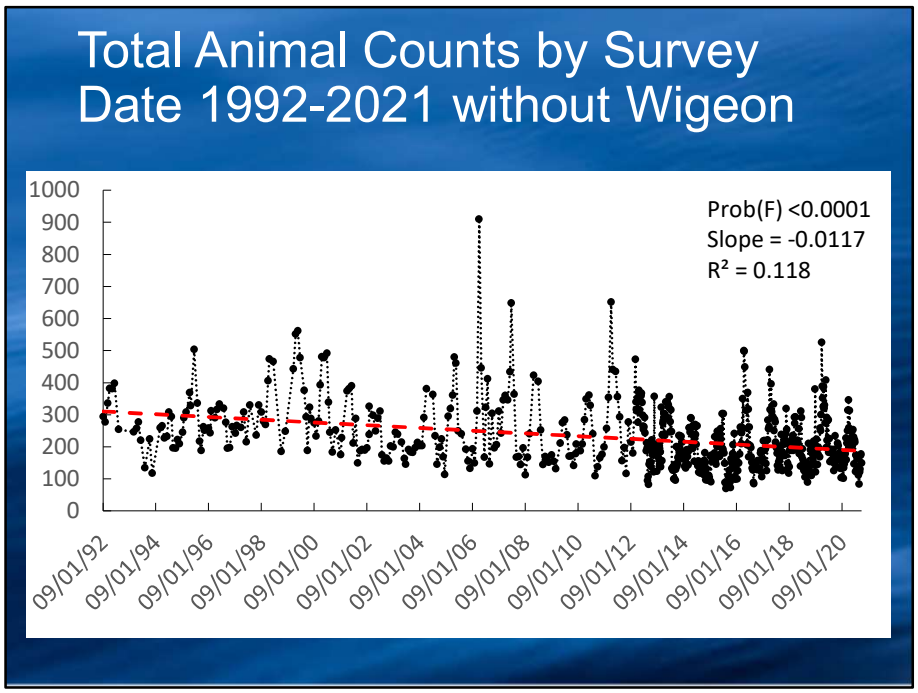
- The high annual sample mean peaks in 1999, 2000, and 2001 were driven in part by very high counts of American wigeon



- The secondary peak in 2006 was more broadly distributed with especially high counts on of American coot, American wigeon, white ibis, and common gallinule.



- Removing American wigeon counts from the analysis of total animal counts does not change the findings substantially, however **[click to next slide]**.

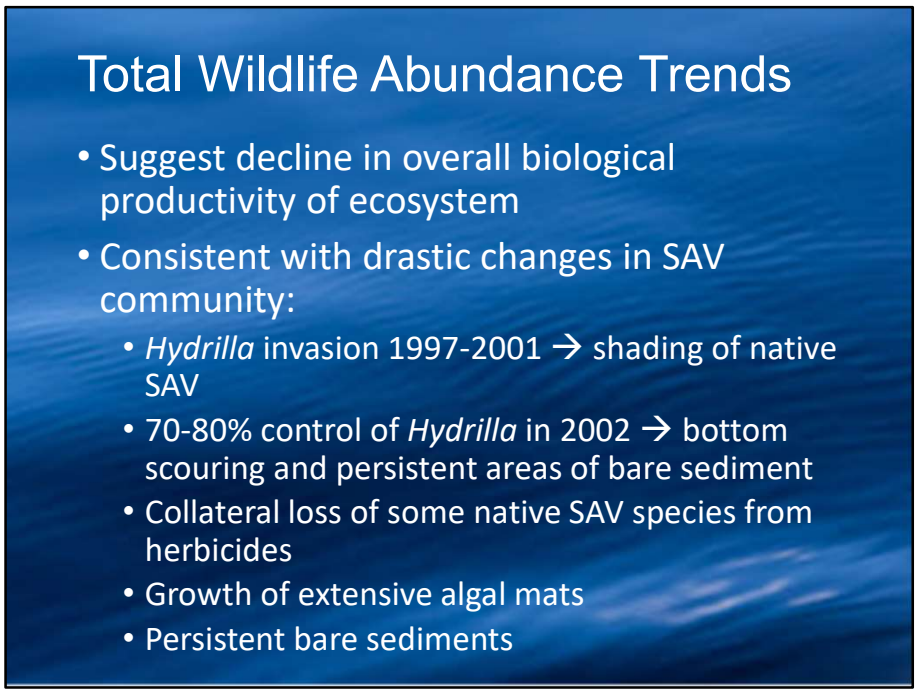


- The significant negative trend remains with a somewhat lower R^2 value of 0.118 for total animal counts without wigeon versus 0.229 including wigeon.

Total Wildlife Abundance Trends During Perturbation Periods

Perturbation Period	Trend	Confidence Level
Hydrilla invasion (1992 – 2000)	Increase	96.50%
Hydrilla management (2000 – 2012)	Decrease	99.94%
Post-hydrilla management (2012 – 2021)	Decrease	99.86%

- Regression analyses of total animal abundance during the individual perturbation periods reveals the following:
  - **[click]** A significant increase in total animal abundance during the hydrilla invasion period, 1992-2000 (96.5% confidence level)
  - **[click]** followed by significant decreases during both the hydrilla management period, 2000-2012 (99.94%)
  - **[click]** and the post-hydrilla management period, 2012-2021 (99.86%)



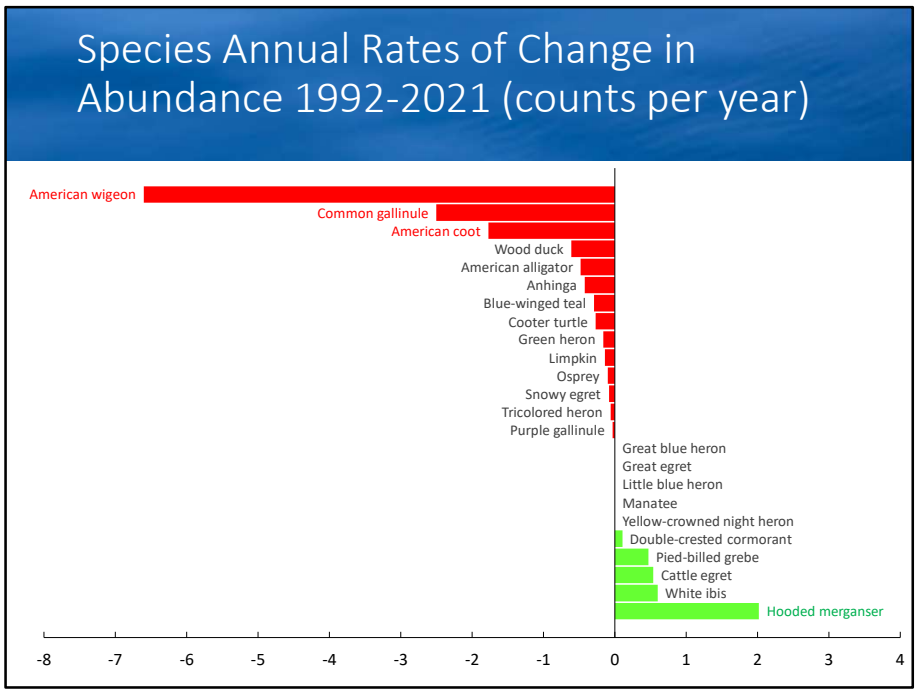
- **[click]** These findings suggest a decline in the overall biological productivity of the upper Wakulla River ecosystem
- **[click]** Consistent with the drastic changes in the SAV community that began with the Hydrilla invasion and have been manifest in the aftermath of the herbicide treatments
    - Hydrilla invasion 1997-2001 → shading of native SAV
    - 70-80% control of Hydrilla in 2002 → bottom scouring and washing away of other SAV
    - Collateral loss of some native SAV species from herbicides
    - Growth of extensive algal mats which recovered from the herbicides more quickly
    - Persistent bare sediments documented by quarterly SAV sampling conducted by volunteers and park staff since 2013

Long-Term Trends in Wildlife Species Counts per Survey (1992-2021)

Decreasing (14)	
American alligator*	Green heron**
American coot**	Limpkin**
American wigeon***	Osprey**
Anhinga*	Purple gallinule*
Blue-winged teal*	Snowy egret*
Common gallinule**	Tricolored heron*
Cooter turtle*	Wood duck**
Increasing (5)	
Cattle egret*	Hooded merganser*
Double-crested cormorant*	Pied-billed grebe*
	White ibis*
No significant trend (5)	
Great blue heron	Little blue heron
Great egret	Manatee
	Yellow-crowned night heron

* $R^2 < 20$
** $R^2 \geq 20$ and < 50
*** $R^2 \geq 50$

- Turning to long-term trends for the individual wildlife species monitored we see the following for the period 1992-2021
  - **[click]** 14 of the 24 species analyzed experienced statistically significant decreasing trends over the period of record
  - **[click]** Only five experienced significant increases
  - **[click]** While five remained unchanged

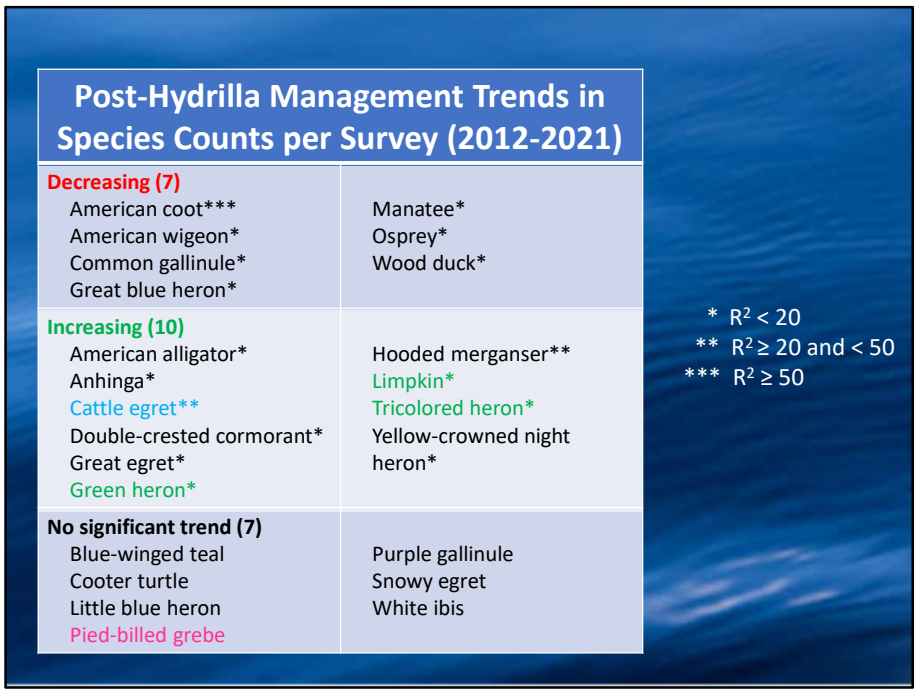


- This slide depicts annual rates of change for individual species in counts per year
- **[click]** The American wigeon, common gallinule, and American coot have experienced the most rapid rates of decline since 1992
- **[click]** While the hooded merganser exhibited the most rapid rate of increase.

Species Abundance Trends During Perturbations

Perturbation Period	Total Abundance	Counts Per Survey Trends		
		Increasing	Decreasing	No Trend
Hydrilla Invasion (1992-2000)	Increasing	9	2	13
Hydrilla Mgmt (2000-2012)	Decreasing	4	12	8
Post-Hydrilla Mgmt (2012-2021)	Decreasing	10	7	7

- Taking a look at abundance trends during the three perturbation periods we see that
- **[click]** During the hydrilla invasion, total abundance increased as did nine species
  - Two species decreased in abundance: the limpkin and pied-billed grebe
  - 13 exhibited no significant trend
- **[click]** During the hydrilla management period, total abundance decreased as did 12 species
  - Four species increased: cattle egret, hooded merganser, manatee, and pied-billed grebe
  - 8 exhibited no significant trend
- **[click]** During the post-hydrilla management period, total abundance continued to decrease as did four species
  - While three others began to decline for the first time: American coot, great blue heron, and manatee
  - Meanwhile 10 species exhibited increasing trends
  - And 7 showed no significant trend
- Now let's look at how individual species fared during each perturbation period



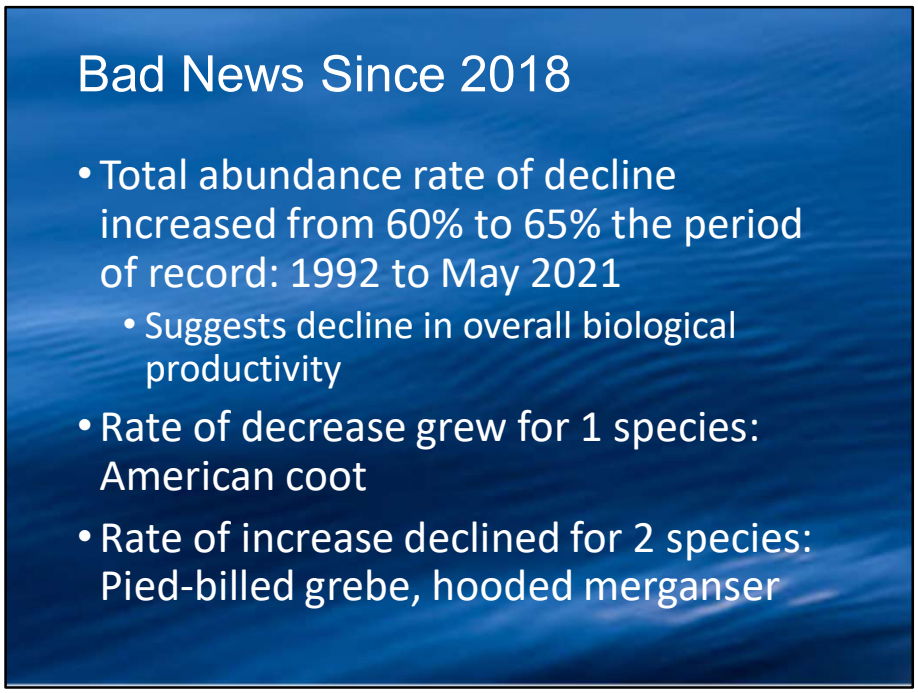
- This chart displays the species exhibiting each trend in counts per survey during the post-hydrilla management period
- **[click]** Three species now have statistically significant increasing trends in counts per survey since 2012 that did not as of 2018: cattle egret, green heron, limpkin, and tricolored heron
- **[click]** As we will see next month when we look at individual species in detail, the cattle egret's post-2012 trend actually is negative as a result of shifting their nesting colony from the river boat tour route to the second mile of the river,
    - However, the trend since 2015 has been a significant increase presumably because that downriver nesting colony has gotten progressively larger.
- **[click]** Meanwhile, the pied-billed grebe's status changed from significant positive trend to no significant trend

Long-Term Trend Changes Since 2018

- Cormorant shifted to significant increase from no significant trend

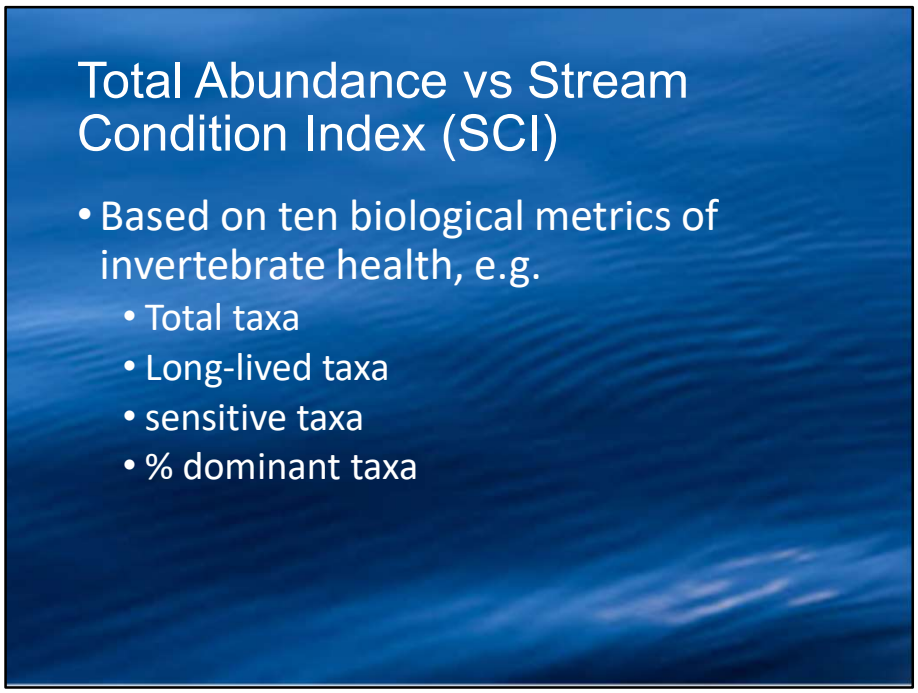
Shifts in Rate of Change per Year ≤ 0.05 Count Per Year	Species
Rate of decrease declined	Common gallinule, American alligator, anhinga
Rate of decrease grew	American coot
Rate of increase grew	Double-crested cormorant, white ibis, hooded merganser
Rate of increase declined	Pied-billed grebe, hooded merganser

- Changes in long-term individual species abundance trends since 2018 are mostly positive
- **[click]** The double-crested cormorant shifted from no significant trend to positive, likely because of continued large numbers of nesting pairs in the colony in the sanctuary about two miles downriver
- Rates of change in counts per year have shifted for several others:
    - **[click]** Rate of decrease declined by 0.05 or more count per year for common gallinule, American alligator, and anhinga
    - **[click]** Rate of decrease grew by more than 0.05 count per year for American coot
    - **[click]** Rate of increase grew by 0.05 or more count per year for cormorant, white ibis, and hooded merganser
    - **[click]** Rate of increase declined by 0.05 or more for pied-billed grebe and hooded merganser

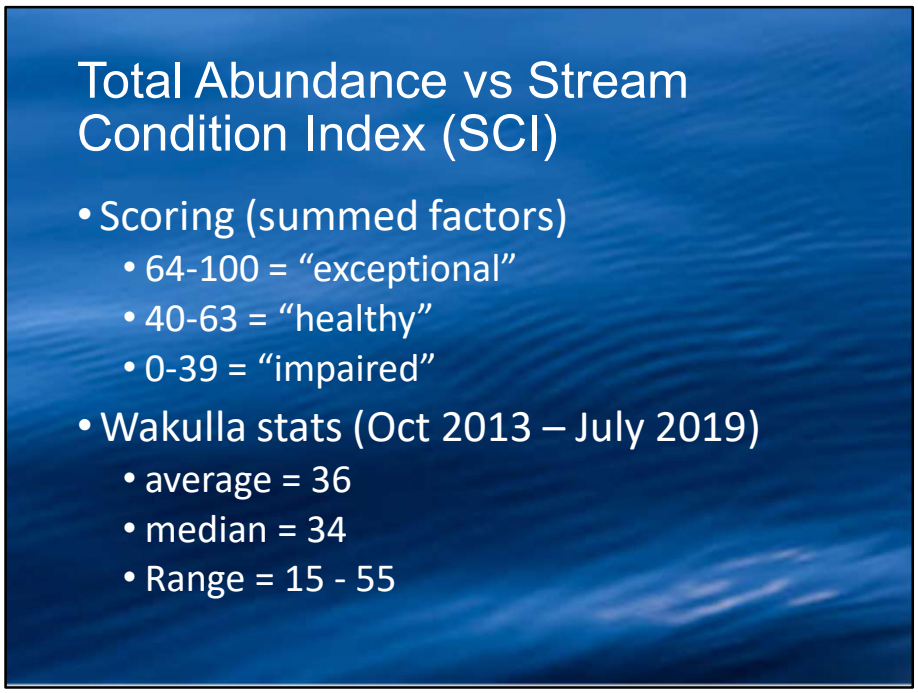


- Let's finish with a summary of the Good News and Bad News that has emerged from extending the analysis an additional 2.5 years from December 2018 to May 2021
- Bad news since 2018:
    - **[click]** Total abundance rate of decline increased from 60% to 65% the period of record: 1992 to May 2021
        - **[click]** Suggests decline in overall biological productivity
    - **[click]** Rate of decrease grew for 1 species: American coot
    - **[click]** Rate of increase declined for 3 species: Pied-billed grebe, hooded merganser
- I'll share some thoughts on what may be happening to the ecosystem next month after we examine the details for a selection of individual species

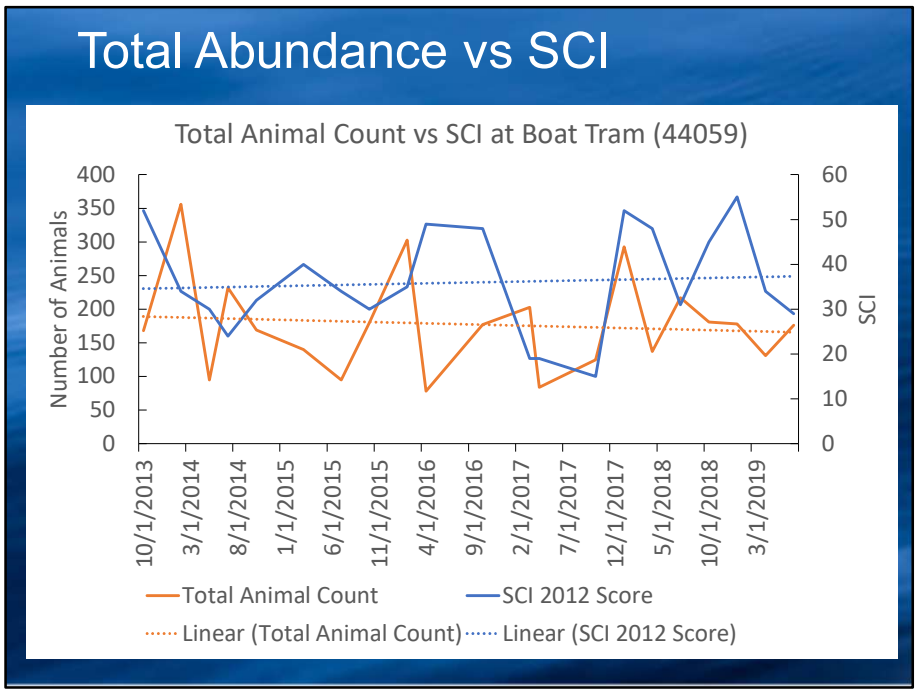
- Good News Since 2018:
  - **[click]** Double-crested cormorant shifted to significant increase from no significant trend
  - **[click]** Rate of increase grew for 3 species: cormorant, white ibis, hooded merganser
  - **[click]** Rate of decrease declined for 3 species: Common gallinule, American alligator, anhinga



- The Stream Condition Index (SCI) is a multi-metric index that FDEP uses to assess the biological health of stream ecosystems by the evaluation of the population and diversity of macroinvertebrates that are found in a 100-meter stream reach.
- The SCI is based on ten biological metrics of invertebrate health
- Many of these are geared towards "pollution tolerance " and are not specific to stressors affecting the Wakulla River ecosystem, i.e.
    - previous herbicide treatments,
    - stream sediment loss,
    - SAV decline in diversity and abundance
    - declining river stage,
    - salinity spikes



- The points from each of these metrics are summed to determine an overall score of biological health:
  - 64-100 = "exceptional"
  - 40-63 = "healthy"
  - 0-39 = "impaired"
- Stats for 10/30/2013 – 7/17/2019 (I haven't obtained more recent data):
  - average 36
  - median 34
  - minimum 15
  - maximum 55



- Plotting SCI versus total animal abundance for the closest sample dates shows now obvious correlation over the period for which SCI data available
- Regression model is not statistically significant
- The nature of the metrics and the short time period for which data have been collected make the SCI an inferior means of assessing biological community trends for the Wakulla ecosystem