

Recreational Boating & Water Quality

Does heavy use change water quality?

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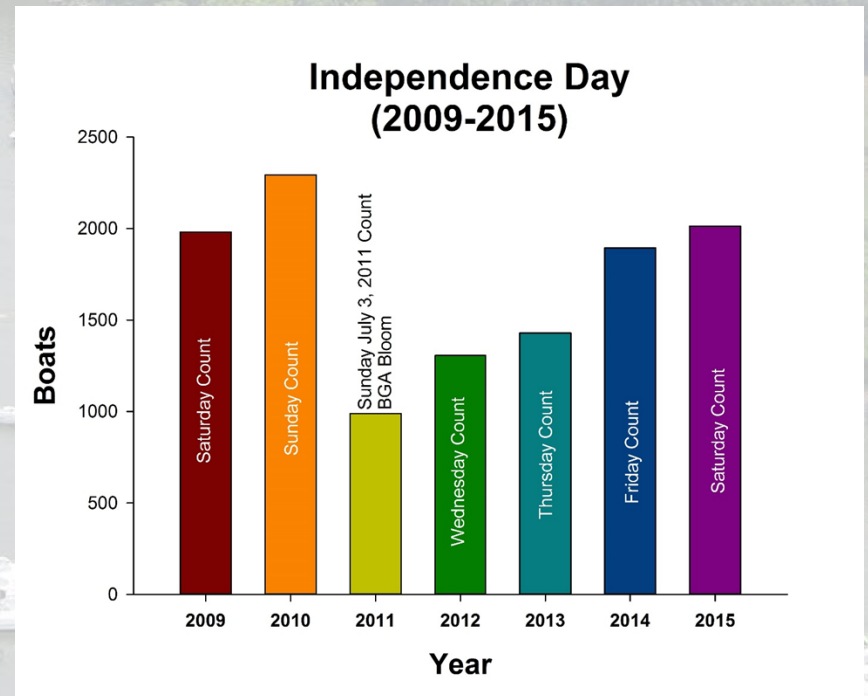
Introduction

- Recreational Boating is popular...
 - ~11.8 million registered boats in the USA (USCG, 2015)
 - ~204,000 boats registered in Oklahoma (USCG, 2015).
 - Boats have increased in size and horsepower over time

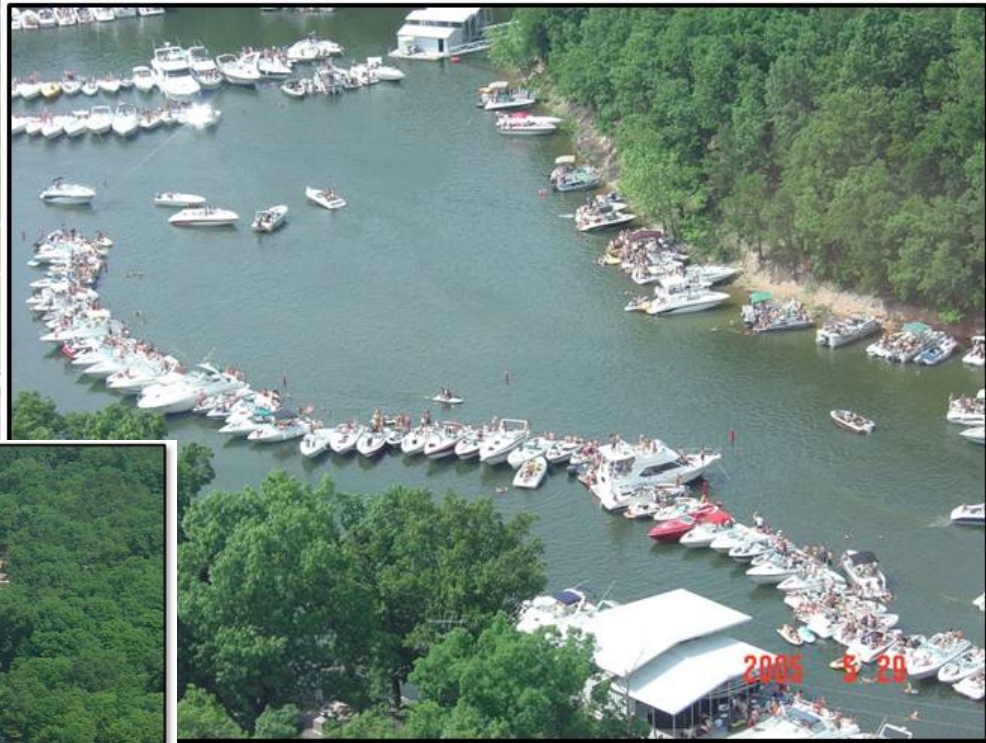
Grand Lake O' the Cherokees

Grand Lake independence day boat counts

- Important lake in Oklahoma for recreation
- Claimed to be the "3rd largest city in Oklahoma" on summer holiday weekends (anecdotal)
- Crowds concentrate in relatively small coves on holiday weekends



Rafting



Research Question

- Does "heavy use" lead to deleterious effects on water quality in popular coves?
- "Heavy Use" Defined:
 - *coves that experience a high volume of recreational boaters who engage in swimming and rafting (boats tied together).*
 - ≥ 75 boats

Previous Work

- Boating activity has shown to affect water clarity nutrients , and algal growth (Yousef et al, 1980; Asplund, 1996).
 - Increases in Turbidity, Algae, and TP
 - Deeper lakes, turbid lakes, appear to be less affected.
 - Slow no wake zones tend to minimize impacts and are suggested BMPs



Expectations

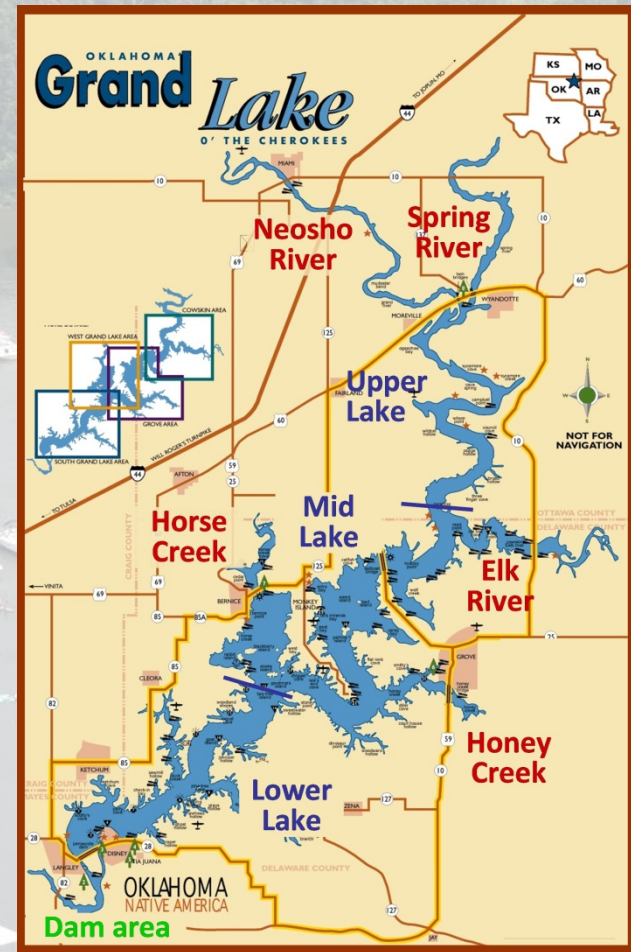
- The number of boats in coves will be significantly greater on peak weekends vs off peak weekends.
- We expected to see positive relationships between changes in nutrients, chlorophyll, bacteria, and turbidity and the number of boats in a cove.
- We expected to see decreases in water clarity with increasing boats.

An aerial photograph of a large body of water, likely a lake or reservoir, filled with numerous small boats, mostly white, arranged in long, curved rows. The water is a murky green-brown color. The shoreline is heavily forested with dense green trees. In the upper left, some residential houses and a paved road are visible. The overall scene suggests a busy day at a recreational water park or a large boat show.

METHODS

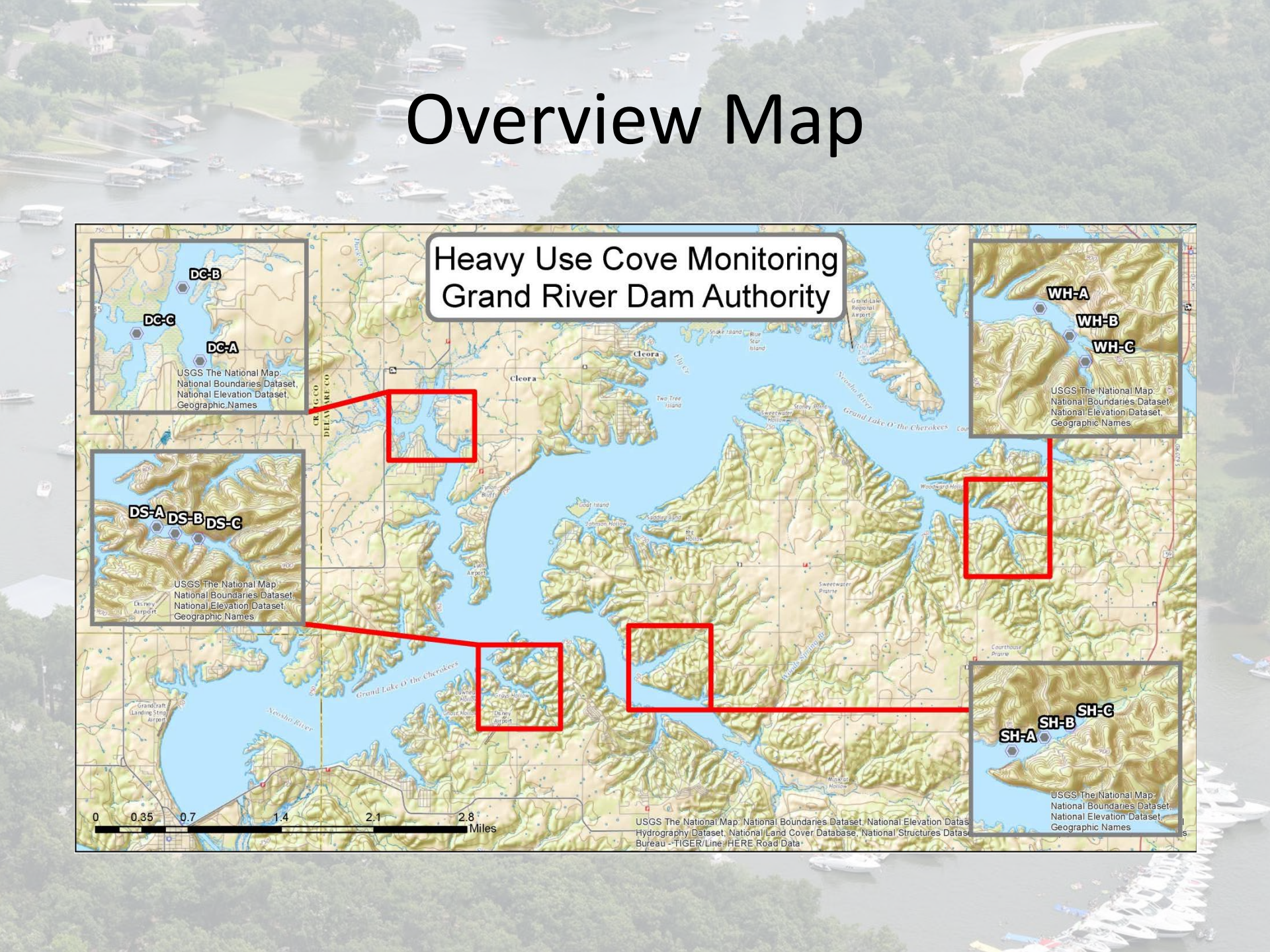
Study Lake

- Lake: Grand Lake O' the Cherokee's
- Heavy Use Coves Selected:
 - Woodward Hollow (WH) 50 acres
 - Summerfield Hollow (SH) 40 acres
 - Dripping Springs (DS) 20 acres
 - Duck Creek (DC) 50 acres
 - All coves no wake except duck creek

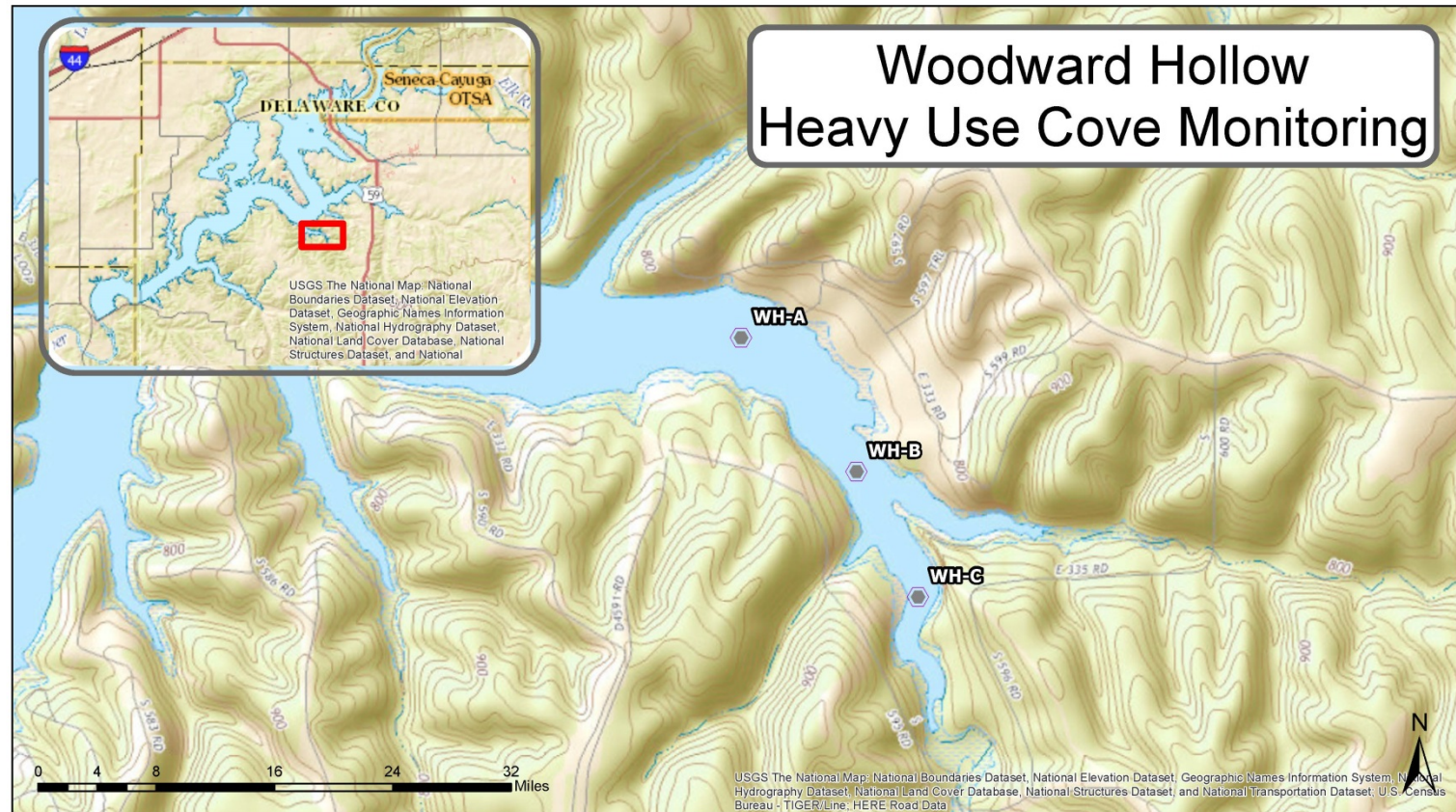


Overview Map

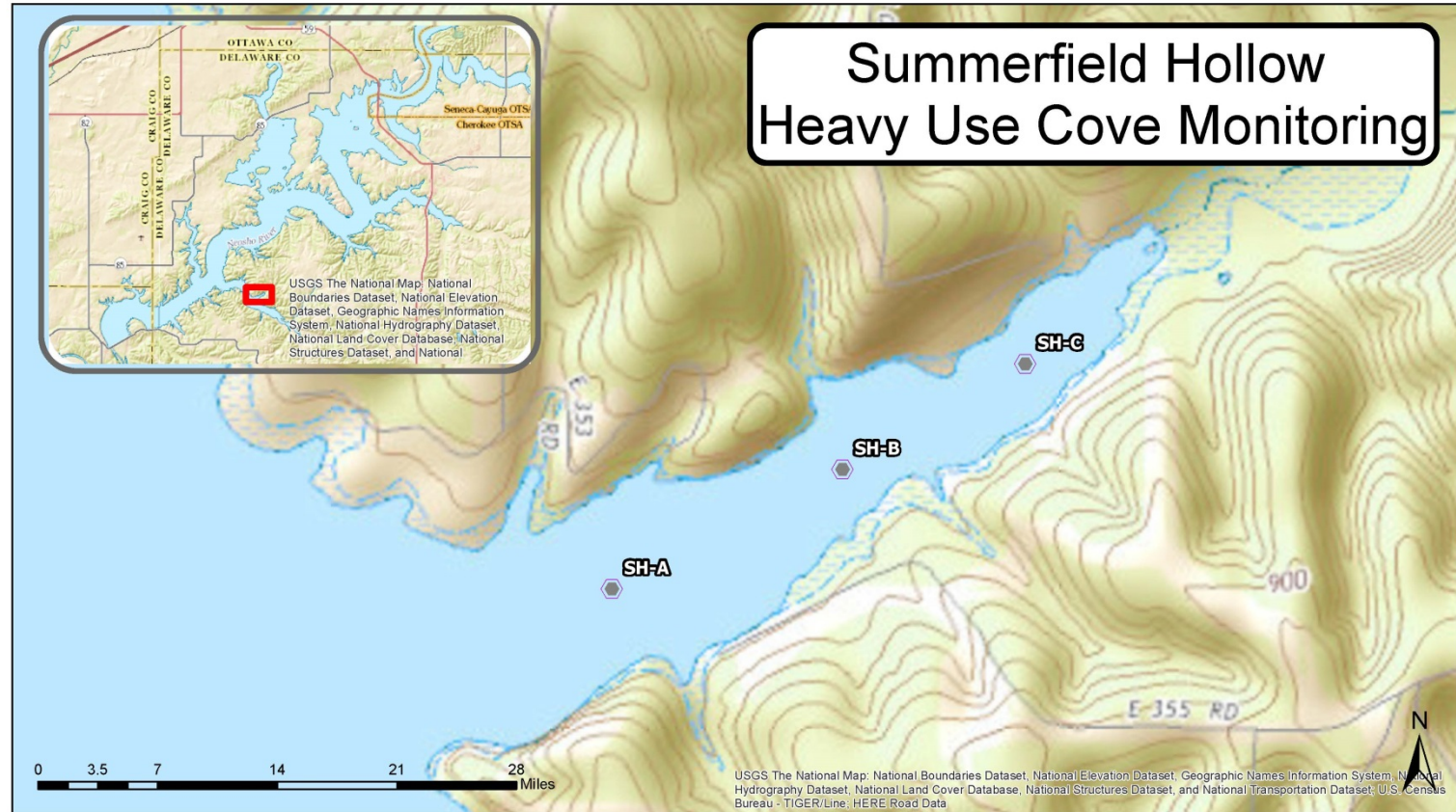
The map displays Grand Lake O' the Cherokees with various monitoring sites marked. A central text box reads "Heavy Use Cove Monitoring Grand River Dam Authority". Four inset maps provide detailed views of specific areas: DC-A, DC-B, DC-C (top left); DS-A, DS-B, DS-C (middle left); WH-A, WH-B, WH-C (top right); and SH-A, SH-B, SH-C (bottom right). Red rectangular boxes highlight several areas of interest on the lake. A scale bar at the bottom left indicates distances from 0 to 2.8 miles. Source information at the bottom right includes USGS data and TIGER/Line HERE Road Data.



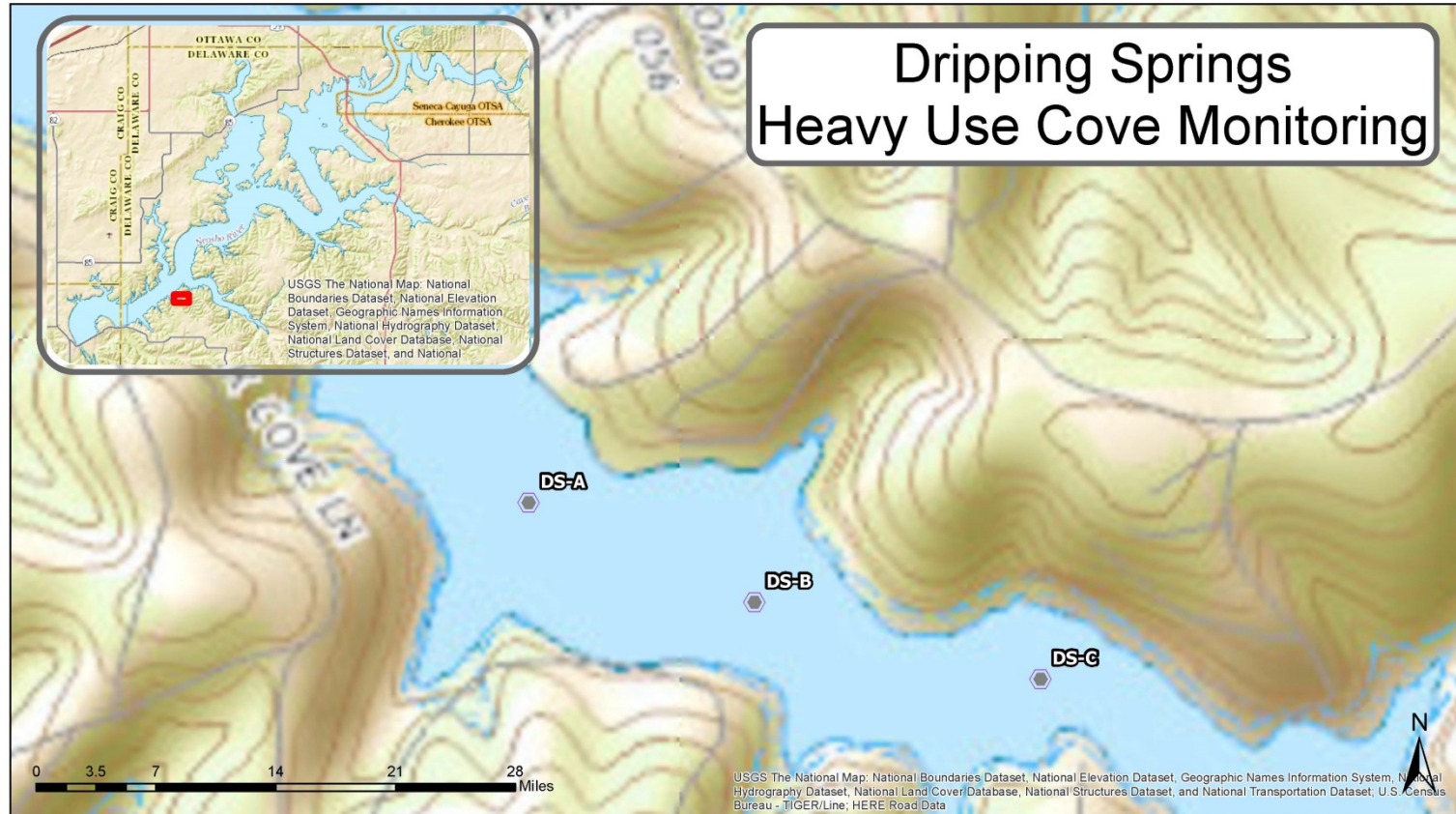
Woodward Hollow



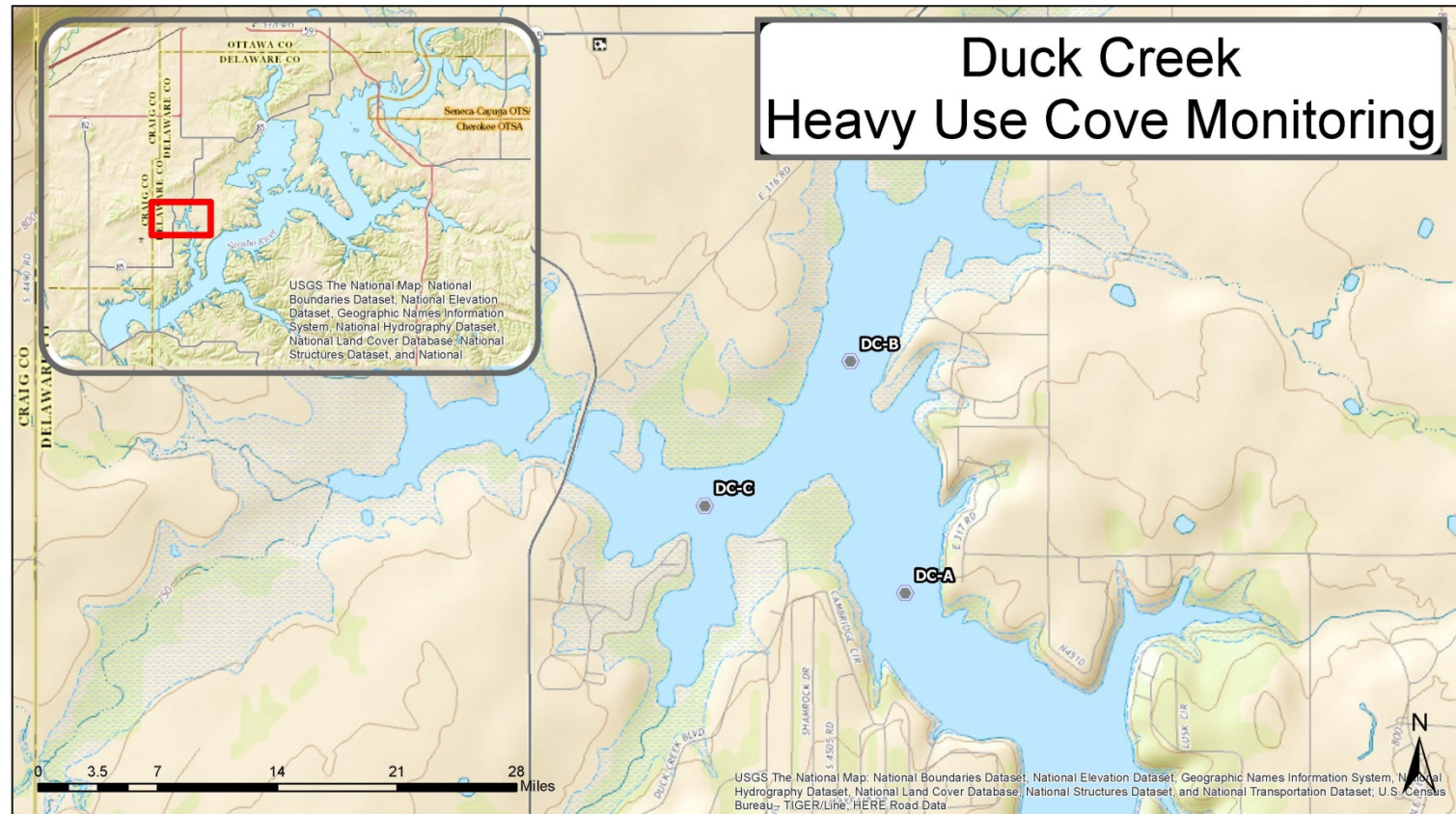
Summerfield Hollow



Dripping Springs



Duck Creek



Sampling Schedule

- Sampled Before and After on 3 holiday (“peak”) and 3 “off peak” weekends from 3 sites per cove
- Counted Boats via Helicopter in the early afternoon

Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.	Mon.
		Sample WQ		Count (12-3 pm)		Sample WQ

Sampling Methods

- Water samples were collected from 1 m using a van dorn
- Physiochemical parameters were collected using a YSI 6 series sonde.
- Samples were placed on ice for transport to the lab.



Statistical Methods

- Paired t-test (boat counts)
- $\bar{\Delta}$ Parameter=(Post weekend – Pre weekend)
- Pearson Product Moment Correlation
 - $\bar{\Delta}$ Parameter vs. Number of Boats
- Linear Regression

An aerial photograph of a large body of water, likely a lake or reservoir, filled with numerous small boats, mostly white, arranged in long, winding rows. The water is a murky green-brown color. The shoreline is heavily forested with dense green trees. In the upper left, some residential houses and a paved road are visible. The overall scene suggests a busy day at a recreational water area, possibly a boat show or a regatta. The word "RESULTS" is overlaid in large, bold, black capital letters on the left side of the image.

RESULTS

Boat Counts

DATE	WEEKEND	LOCATION	BOATS
28-May-16	Memorial Day	Dripping Springs	183
28-May-16	Memorial Day	Duck Creek	34
28-May-16	Memorial Day	Summerfield Hollow	98
28-May-16	Memorial Day	Woodward Hollow	307
18-Jun-16	Off Peak	Dripping Springs	38
18-Jun-16	Off Peak	Duck Creek	48
18-Jun-16	Off Peak	Summerfield Hollow	45
18-Jun-16	Off Peak	Woodward Hollow	34
2-Jul-16	Independence Day	Dripping Springs	259
2-Jul-16	Independence Day	Duck Creek	126
2-Jul-16	Independence Day	Summerfield Hollow	273
2-Jul-16	Independence Day	Woodward Hollow	322
30-Jul-16	Off Peak	Dripping Springs	63
30-Jul-16	Off Peak	Duck Creek	6
30-Jul-16	Off Peak	Summerfield Hollow	21
30-Jul-16	Off Peak	Woodward Hollow	40
13-Aug-16	Off Peak	Dripping Springs	48
13-Aug-16	Off Peak	Duck Creek	13
13-Aug-16	Off Peak	Summerfield Hollow	17
13-Aug-16	Off Peak	Woodward Hollow	50
4-Sep-16	Labor Day	Dripping Springs	196* via water
4-Sep-16	Labor Day	Duck Creek	18*
4-Sep-16	Labor Day	Summerfield Hollow	116*
4-Sep-16	Labor Day	Woodward Hollow	325*

Boat Count Summary

	Off-Peak Weekends	Peak Weekends	Memorial Day	Independence Day	Labor Day
Mean	35	188	156	245	164
Median	39	190	141	266	156
s.d.	± 17	± 105	± 102	± 73	± 112

- Peak Weekends have ~5X the occupancy as off peak weekends
- Duck Creek tended to be variable; only displaying “heavy use” during Independency Day weekend
- During “Off-Peak” weekends, coves did not meet the definition of “heavy use”.

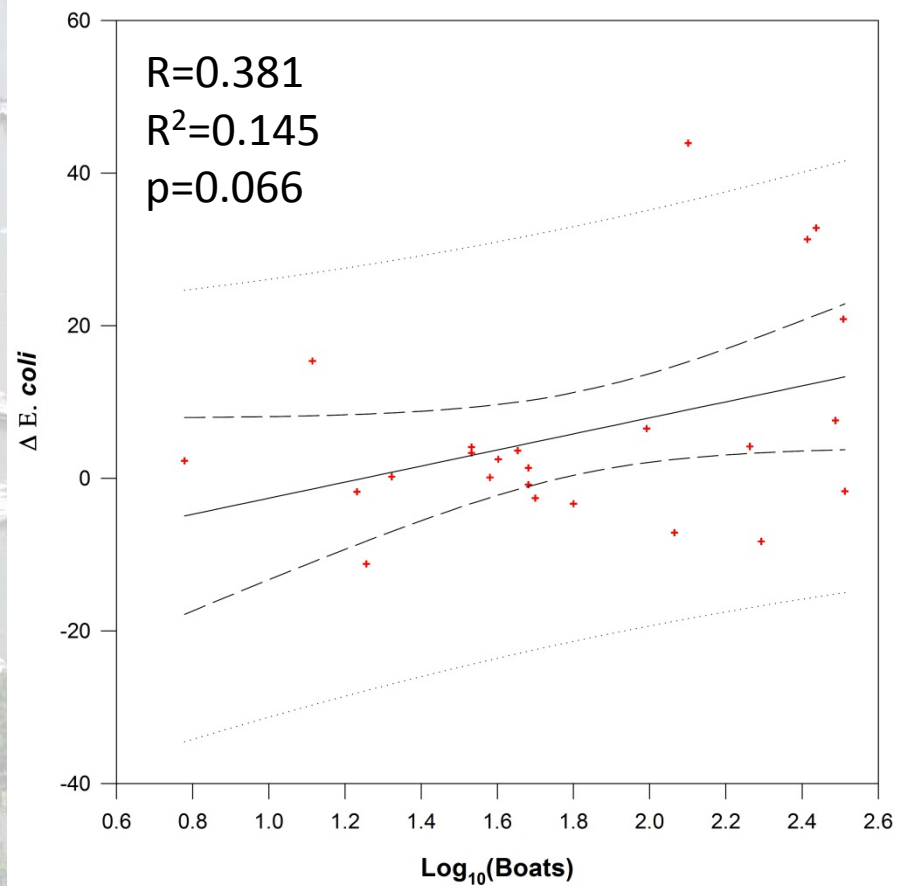
$\bar{\Delta}$ vs. $\log_{10}(\text{Boats})$

$\bar{\Delta}$ Parameter	r	p/n	P value
$\bar{\Delta}$ Elevation	0.597	+	0.00207*
$\bar{\Delta}$ E. coli	0.381	+	0.0661*
$\bar{\Delta}$ <i>enterococcus</i>	-0.0483	-	0.840
$\bar{\Delta}$ Chlorophyll α	0.343	+	0.101*
$\bar{\Delta}$ Secchi	-0.288	-	0.173
$\bar{\Delta}$ Total Suspended Solids	-0.131	-	0.518
$\bar{\Delta}$ Total Phosphorus	0.108	+	0.616
$\bar{\Delta}$ Total Nitrogen	0.224	+	0.343
$\bar{\Delta}$ Orthophosphorus	-0.0257	-	0.914
$\bar{\Delta}$ Ammonia	-0.105	-	0.627
$\bar{\Delta}$ Nitrate + Nitrite	-0.0209	-	0.923

$\bar{\Delta}$ vs. $\log_{10}(\text{Boats})$

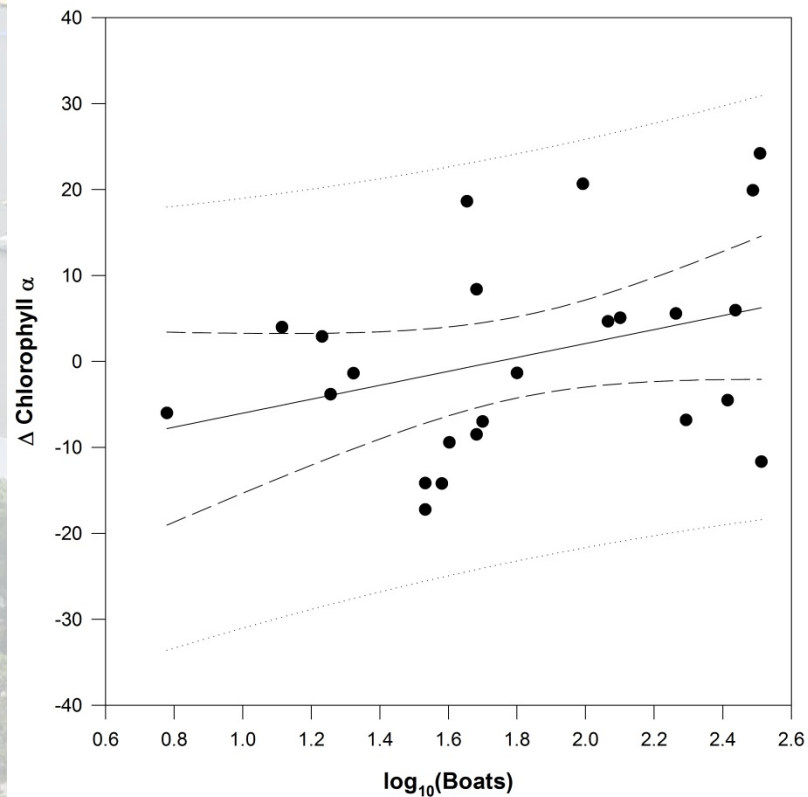
$\bar{\Delta}$ Parameter	r	p/n	P value
$\bar{\Delta}$ Temperature	.0448	+	0.843
$\bar{\Delta}$ Conductivity	-0.156	-	0.511
$\bar{\Delta}$ pH	0.00652	+	0.977
$\bar{\Delta}$ YSI Chlorophyll α	0.355	+	0.105*
$\bar{\Delta}$ YSI Chlorophyll RFU	0.699	+	0.0122*
$\bar{\Delta}$ Dissolved Oxygen %	0.146	+	0.539
$\bar{\Delta}$ BGA (YSI Pycocyanin)	0.192	+	0.403
$\bar{\Delta}$ YSI Turbidity			

E. Coli

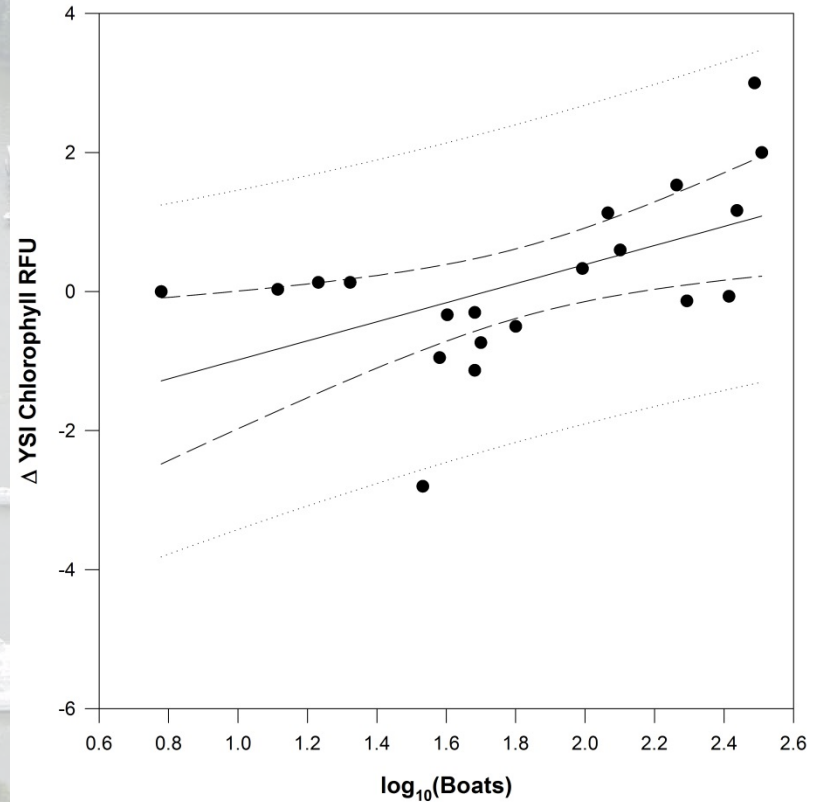


Power of performed test
< desired power.

Chlorophyll α



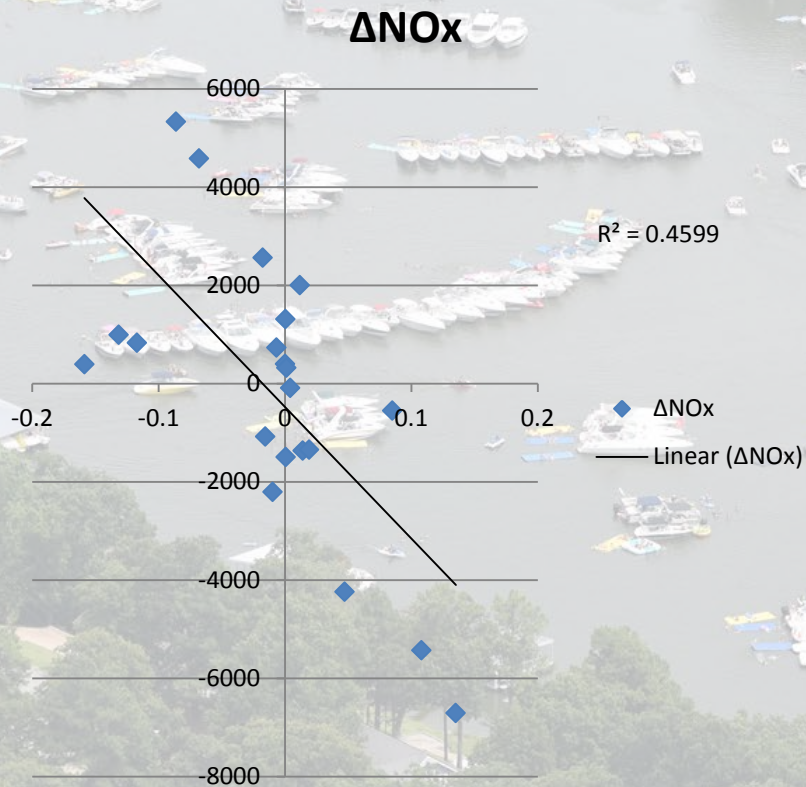
$R=0.343$; $R^2=0.117$; $p=0.101$
*power below desired value



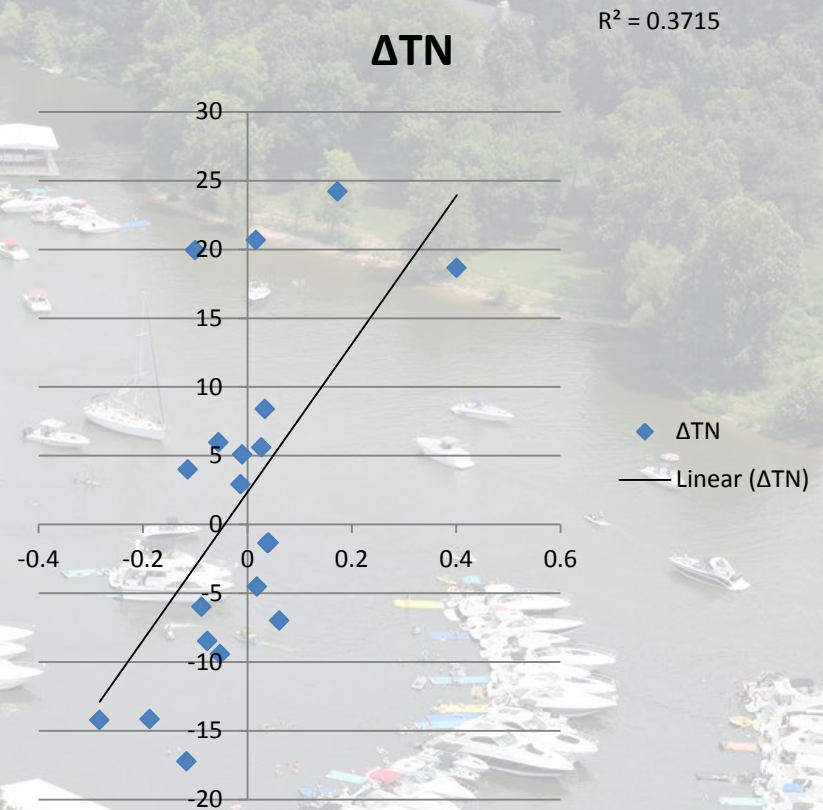
$R=0.549$; $R^2=0.301$; $p=0.012$

Interesting Relationships

Nitrate+Nitrate and BGA



TN and Chlorophyll



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CONCLUSIONS

Expectations vs Reality

- Expected relationships between nutrients, algae, bacteria, and turbidity vs. the number of boats in the cove at peak recreation time were not observed.
 - Could be due to low power
 - Slow no wake may limit resuspension of nutrient
 - Occupancy may be a poor predictor of change
 - Additional study will be conducted in 2017

Possible reasons for Negative Results

- Changes in water quality as a result of “heavy use” may be:
 - Short Lived (i.e. “recovered” by the time we sample following heavy use)
 - Within the uncertainty of our current measurements
 - Overwhelmed by natural processes of nutrient cycling, algal growth dynamics, inflow etc.
 - Abated by existing slow no wake zones

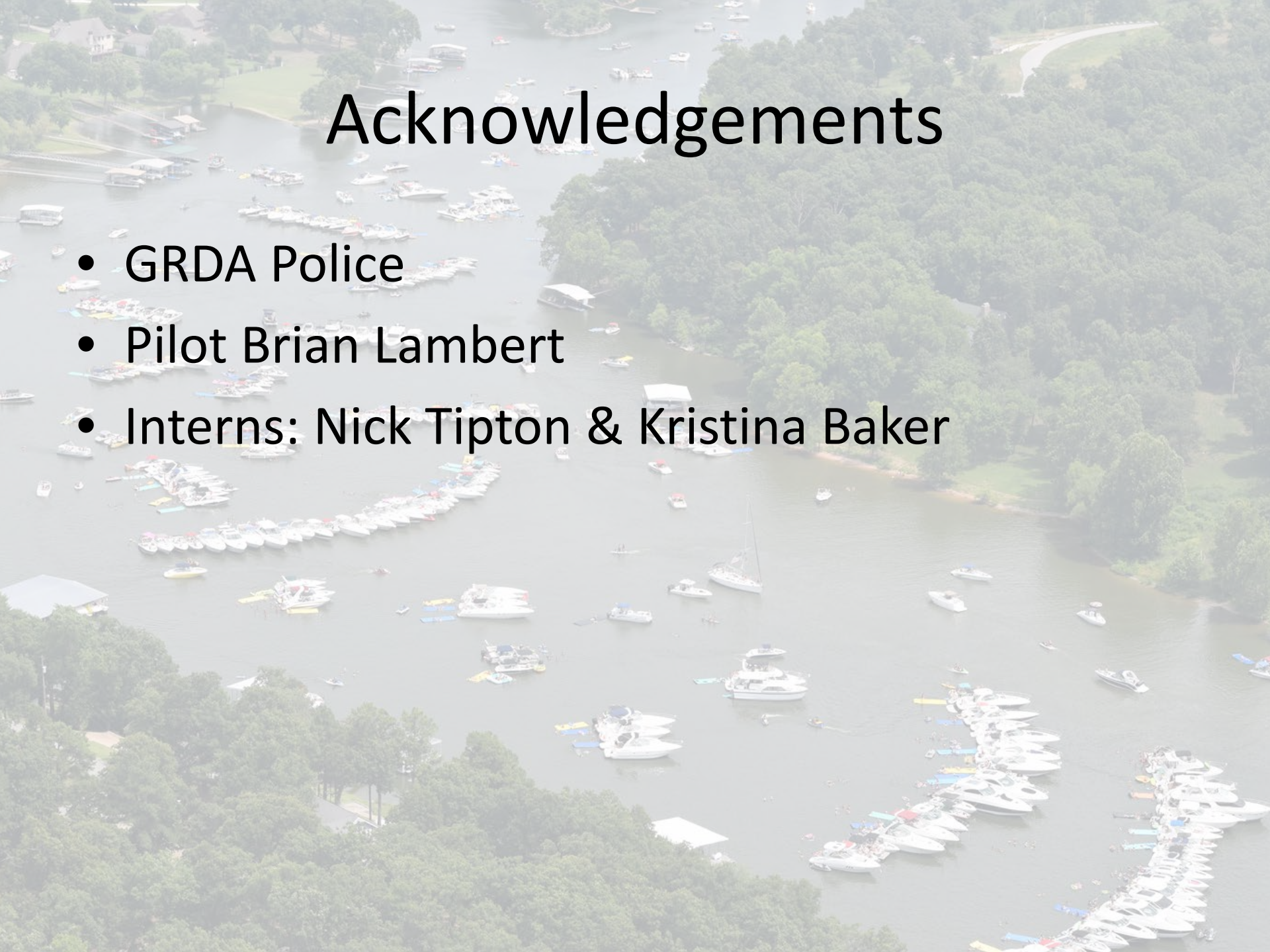
Future Study

- Grand Lake “heavy use” coves will be sampled again in the same design in 2017.
- GRDA may deploy sondes unattended if safe locations can be found.
- Analysis of HF183



Acknowledgements

- GRDA Police
- Pilot Brian Lambert
- Interns: Nick Tipton & Kristina Baker



Questions/Comments

