“ALTERNATIVE STABLE STATES OF CENTRAL FLORIDA LAKES BASED ON A COMPARISON OF HYDROACOUSTIC AND PHYSICAL SAMPLING OF AQUATIC MACROPHYTES, AND MEASURED CHLORORPHYLL LEVELS”

BY

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2015

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Acknowledgments:

I would not be where I am today, and would not have been able to complete this research without the many people in my life who have helped me along the way. First and foremost, my loving wife who’s supported me through thick and thin. I’m a better person because she is in my life. My parents taught me invaluable lessons about hard work and dealing with people, and I have carried those lessons with me through all my endeavors. My friends and family who have simultaneously pushed me to strive further and kept me level headed at the same time, I cannot thank them enough for being there for me. I must thank, The City of Winter Haven and it’s residents for caring so much about your natural resources, especially Mike Britt for his vision and mentorship. The field component of this work would not have been possible without the help of people like Jacob Kalogridis, Mary Thornhill, and the others who were vital in the collection of data. I would be remiss to leave out my gratitude for the many teachers, professors, and advisors that have taken the time to take an interest in me throughout my studies; the time they gave me is invaluable. I must also thank the incredible group of scientist I have had the privilege of working with throughout my career, each one of you has impacted me in ways you may never know, and I thank you for that, I thank you for challenging me. Finally, I must thank the scientist that have come before me and laid the ground work for this field of study, their work makes it possible for us to ask the research questions we do today.

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Abstract:

The Winter Haven Ridge area of Central Florida is home to an array of lakes, of significant importance to the area socially, economically, and ecologically. As such, management goals for these lakes are set to a level of quality not achievable by adhering only to the current State and Federal minimum regulations. To achieve the desired level of quality, lake managers are striving to understand how these lakes function specific to the dynamics of the area. They have embarked on a number of scientific studies to provide sound data on which to base their management decisions. The focus of this study was to determine if lakes in the area follow a pattern of alternative stable states, classifying into either macrophyte dominated systems or algal dominated systems. Additionally, this study aims to explore if the distribution of species plays a role in that bifurcation. This information will allow lake managers to create management regimes for lakes that address the feedback mechanisms of each alternative state.

Determining bifurcation was accomplished by comparing manually and hydroacoustically collected vegetation data with chlorophyll-A levels from a chemical analysis conducted for each of 8 lakes in the area. That data was then analyzed for species richness, diversity, and evenness. Of the 8 lakes sampled all of them did bifurcate towards one alternative stable state or another with a significant correlation (R^2 = 0.7165) between macrophyte abundance and Chlorophyll-A. It appears species evenness may play a role in how lakes bifurcate, with many macrophyte dominated lakes having a more even species distribution than their algal dominated counterparts.

Introduction:

The Winter Haven Ridge is an interesting area of study. It has numerous surface water features with varying morphology. Furthermore many of these lakes are connected to one another through man-made waterways altering their natural hydrology. The region also sits near the top of the State of Florida groundwater potentiometric surface and lies along a major east west divide in that surface (Spechler & Kroening, 2006). This causes variation in the way groundwater interacts with the lakes across the landscape (Schiffer, 1998). The density of waterbodies in the region creates a unique area of study. It presents a variety of lakes experiencing similar external drivers, such as climate. The minimization of these regional variables makes the lakes well suited for localized comparison.

From a social and economic standpoint these lakes are valuable to the local community, and are a major component of residents sense of place (Winter Haven Chamber of Commerce, 2000). As such, the management goals set for these lakes cannot be achieved by adhering solely to the minimum regulations imposed by State and Federal agencies. While the regulation may be effective at a large scale, they will not restore the lakes in this area back to the benchmark of excellence the community desires them to be (Winter Haven Chamber of Commerce, 2012).

Therefore, lake managers have embarked on a number of empirical studies to thoroughly understand how this area functions with the current level of development. The intent, is to include that knowledge as part of a basis for decision making, under the premise that sound scientific knowledge provides the best possible foundation for public policy development (Pedersen, 2014). The city intends to incorporate this information when addressing management issues with balancing future growth and the restoration of healthy natural systems.

The theory of alternative stable states in shallow lakes proposes that lakes will classify into either an algae dominated system or a macrophyte dominated system (Scheffer, 1998). This theory is based on the premise that there are stabilizing feedback mechanisms that will maintain each system in one alternative state or another (Scheffer, 1998). Lake managers who understand what state a waterbody is in can design management strategies to manipulate the drivers of stability in these systems. Residents have observed this phenomenon in the study area for many years, according to local testimonial. Quantifying it specific to the region using empirically collected data will paint a new picture increasing the understanding of the local natural systems. The literature on alternative stable states in Florida lakes follows the theory to an extent but mainly at an extreme end of the spectrum and without clear sight of what the actual drivers of the system are (Bachman, Horsburgh, Hoyer, Mataraza, & Canfield Jr., 2002)

By determining which of the alternative states a lake is in, lake managers can create plans to address the specific needs of each system with a goal of restoring systems that should historically function as macrophyte dominated systems and maintaining systems that are currently in a macrophyte dominated state. Ecologically speaking, systems with a healthy and diverse community, that create a continuum of overlapping sets of species, each responding to different environmental cues, are more resilient to abiotic drivers, and thus more stable (Mitsch & Gosselink, 2007). This principle should apply to maintaining stable states of macrophyte dominated systems.. This has important social and economic implications as well. Even though a lake cannot be all things to all people, Hoyer et. al has shown that at least some of the population desire traits in Florida lakes that resemble macrophyte dominated oligotrophic and mesotrophic systems (Hoyer, Brown, & Canfield Jr., Relations Between Water Chemistry and Water Quality as Defined by Lake Users in Florida, 2004). Lakes exhibiting these traits, while not the only condition that can provide a productive fishery, are capable of supporting sport fish communities (Hoyer & Canfeild Jr., Largemouth Bass Abundance and Aquatic Vegetation in Florida Lakes: An Empirical Analysis, 1996) as well as an ideal environment for recreation (Hoyer, Brown, & Canfield Jr., Relations Between Water Chemistry and Water Quality as Defined by Lake Users in Florida, 2004)

The Landscape:

The Central Florida area near the Winter Haven Ridge is at the top of the Peace River Watershed and is largely an ombrotrophic system. Much of the ridge area is dominated by A hydro group soils Figure 1. These are well drained soils that allow water to move freely through them. The low lying areas surrounding the ridge are less well drained and fall more into the B/D and C hydro group soils Figure 1, these soils are more restrictive to water than A type soils with B/D soils displaying varying properties based on saturation (Soil Survey Staff). The area around the ridge was historically dominated by wetlands but has been drained for other land uses, as has much of the state of Florida. The Peace Creek watershed drains through the Peace Creek Canal to the Peace River Figure 2.

Karst Geology underlies the majority of the region and has contributed to formation of many of the lakes (Schiffer, 1998). The area contains lakes that are very old sinkholes, some of which have experienced allogenic and autogenic succession (Mitsch & Gosselink, 2007). More recently formed sinkhole lakes with a classic steep sided conical shape exist as well. The area also has shallow lakes of unknown origin and even a lake that is said to be the product of a historic peat fire.

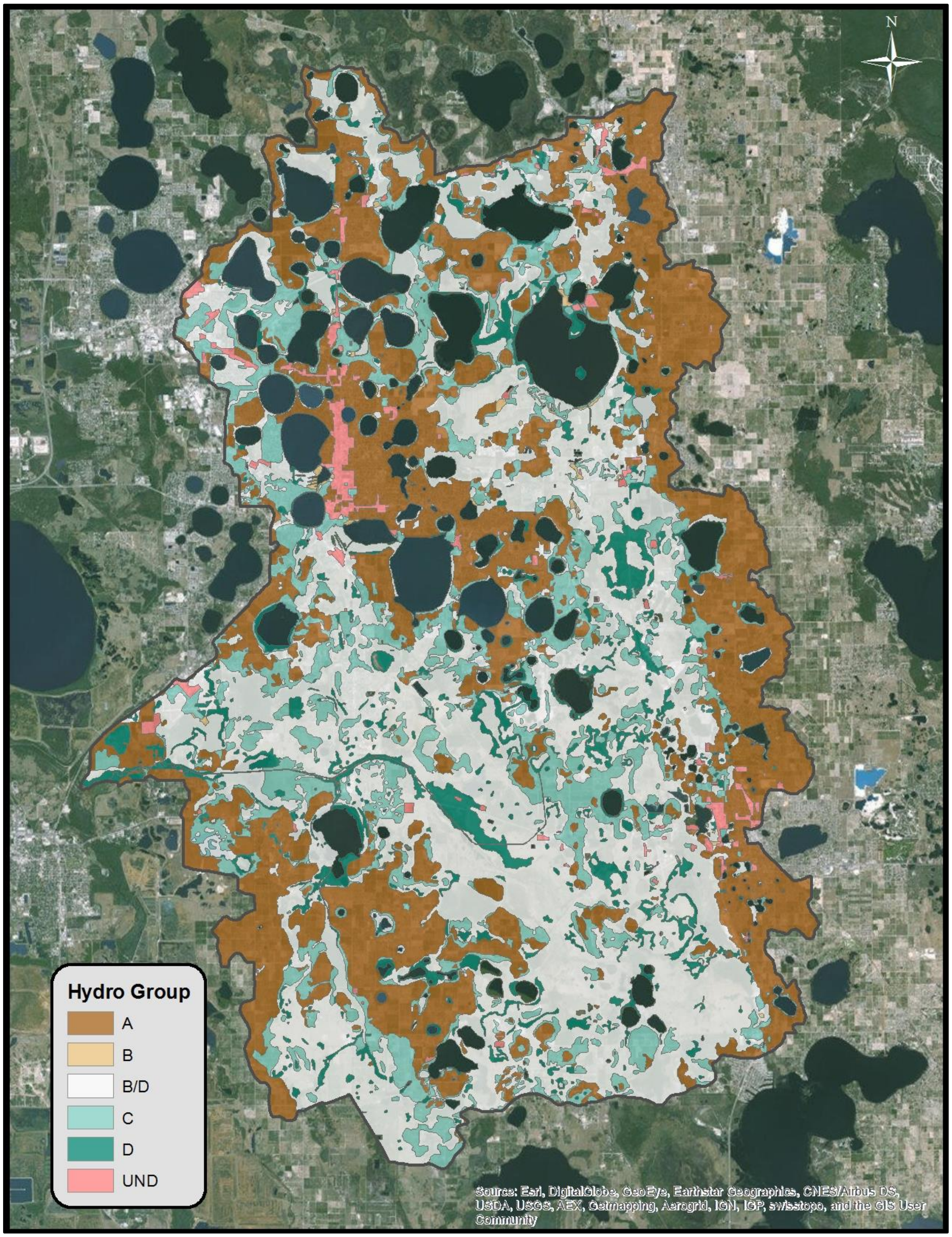


Figure 1: Map of soil hydro groups in the Peace Creek Watershed in Polk County Florida as defined by the USDA NRCS (Soil Survey Staff). A type soils allow water to move freely through the soil, B type soils allow water to move unimpeded through he soil matrix. C type soils are somewhat restricted in terms of water transmission. D type soils have very restricted water movement. The B/D soil hydrogroup exhibits characteristics of a B type soil when drained but a D type soil when saturated. Undetermined soils in this case are mostly 16 – Urban Land Complex and are overall highly unpredictable soils. It is clear to see the areas of the larger watershed that water moves freely through and the areas where it slows down.

Much of the land directly around the study area has been developed over the last 100 years. The largest City, Winter Haven, was founded in 1911 and has gone through multiple stages of development (Winter Haven Chamber of Commerce). From the early 1900's until mid to late 1900's the major land use in the area was citrus agriculture. As the area has developed the natural functions provided by the landscape have been diminished, manifesting in a variety of ecological issues such as, altered regional hydrology, shifts in diversity of plant communities, and eutrophication of local lakes.

Hydrologic Changes:

As previously stated the area of study presents a somewhat unique hydrologic situation, it is an ombrotrophic system at the top of a watershed receiving about 132 centimeters of rainfall annually (range 78-177 cm) (Spechler & Kroening, 2006). Regional evapotranspiration (ET) ranges from around 65cm to upwards of 100 cm per year (Spechler & Kroening, 2006). The margin for rainfall retention in this area is slim, and has been at a deficit in recent years.

To further compound this deficit, changes in land use have ditched and drained much of the area as well as paved a large portion of the watersheds that feed these lakes (PBS&J, 2010). The major drainage feature for the watershed is the Peace Creek Canal which was originally dug in the early 1900's (PBS&J, 2010) and has been deepened and widened several times over the years increasing the potential to further lower regional aquifer levels. It runs the southwestern border of the larger watershed Figure 2. As the regional surficial aquifer has been draw down along with changes in the upper Floridan aquifer and recharge constraints due to expansion of impervious surface, the natural hydrology of the area has undergone considerable alterations (PBS&J, 2010).

An additional hydrologic complication in this area is the connection of the lakes through surface water canals. Many of the lakes are a part of what is known locally as the “Winter Haven Chain of Lakes”. These connections were started around the turn of the 20th century, and have been maintained since (Lakes Region Lake Managment District). Some of these lakes would have had no obvious natural surface water connection, others were most likely connected by wetlands during periods of inundation, and other may have had a natural channel between them. Regardless of what the natural connectivity was, connecting these lakes and effectively equalizing their level has also altered the local hydrology.

These changes in hydrology all contribute to physiographic changes that can contribute to a decrease in the overall health and resilience of the systems and a decrease in perceived water quality. For example there are wetlands adjacent to some of these lakes that under historic conditions would have been inundated and provided biogeochemical benefits such as elemental cycling, water treatment, and contribution of dissolved organic matter among other things; services that can be valued at as much as $19,580 per Hectare (Reddy & Delaune, 2008). Another impact driven by altered hydrology is a change in surface water flushing rates. Many of the changes to these systems have constricted surface water outflow limiting flushing and increasing residence time (PBS&J, 2010). This can have negative implications as far as the overall health of the system is concerned.

Plant Communities:

Plant communities in the area vary from lake to lake. Emergent vegetation around the lakes is heavily influenced by the anthropogenic changes to the landscape. Many homeowners have cleared their lakeshore completely of vegetation. Therefore, less developed lakes in the area are likely to have greater diversity and density of emergent vegetation then the more developed lakes. Submerged species also vary across the lakes and have been the subject of a variety of treatments to manage species that have caused conflicts with other management goals such as recreation. As such the species diversity information collected will provide valuable insight into the present state of the aquatic vegetation in the areas lakes, and how they have potentially been affected by changes in nutrient concentrations and treatments of excess vegetation.

Water Quality:

Increased development has brought along with it increases in nutrient concentrations and decreased water quality. Many of the 50 lakes in the area appear on the FDEP 303d impaired water bodies list (PBS&J, 2010). State and Federal agencies strive to address water quality issues in a number of different ways. While these methods can be effective they are often broad rules, rather than specific recommendations. These investigations will help explore local drivers of water quality and provide insight into management options, as well as gaps in information to make such determinations.

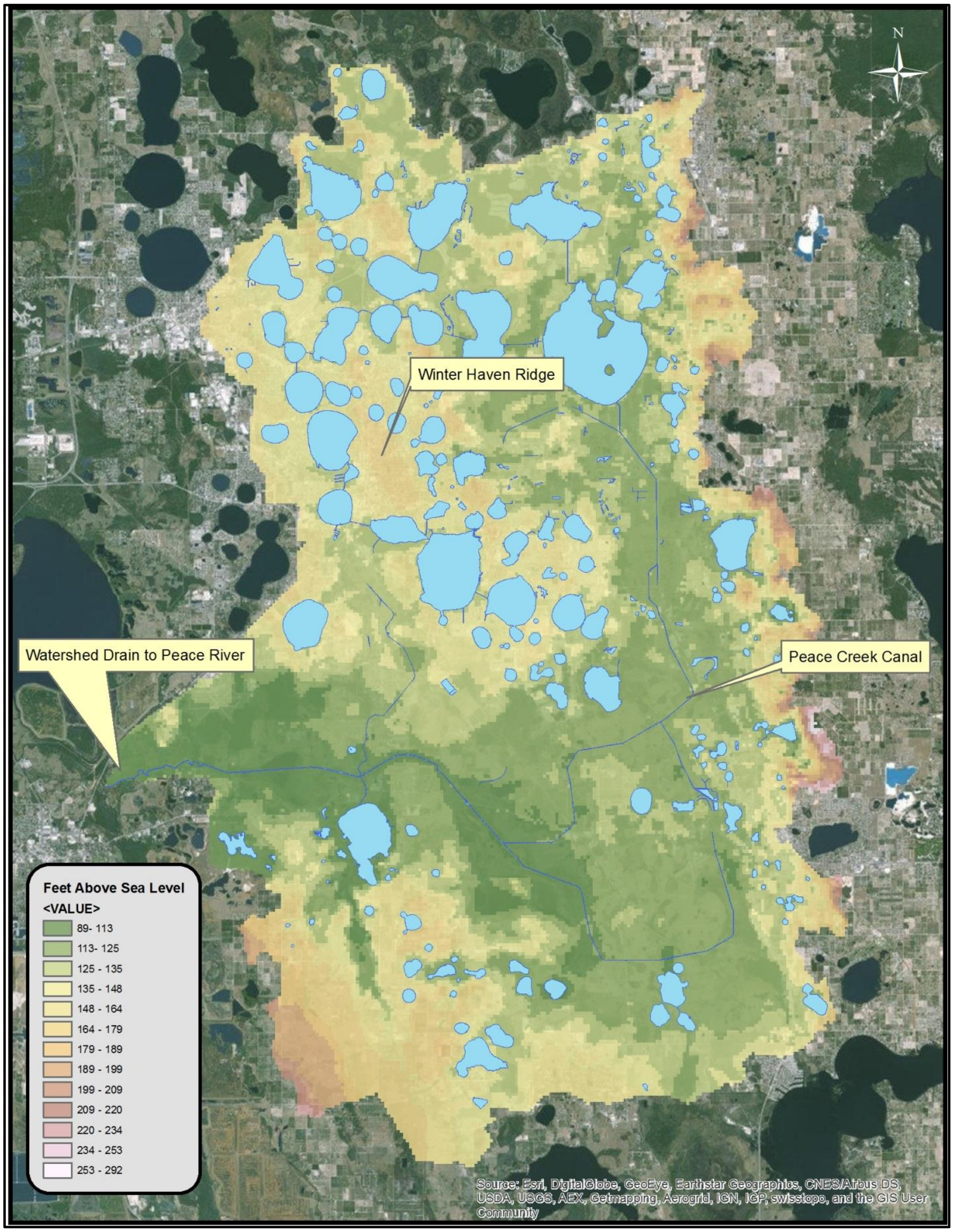


Figure 2: Map of the Peace Creek Watershed in Polk County Florida showing topographic relief based on points derived from Li-dar data and geostatistically analyzed by kriging elevation points together. The green areas are at lower elevations then the red and white areas and represent the pathway water takes out of the system. Yellow areas lie somewhere in between in elevation.

Importance to the community:

The main industries in the region historically have been citrus production, cattle ranching, and phosphate mining. In the previous few decades those industries have dwindled, and in a day and age when people can commute more readily, quality of life factors are increasingly important to people when deciding where to live. No matter what the status of employment, a major draw to the area has always been the lakes and the mild winter climate (Winter Haven Chamber of Commerce). The lakes have always been deemed of great importance to the community. In 1919 a special taxing district was formed to maintain the recreational accessibility of the lakes (Lakes Region Lake Managment District). In 2000 the community came together and went through a visioning process called “Our Vision By Design” (Winter Haven Chamber of Commerce, 2000) to determine the future of the community. One of the major directives from that process was the critical importance of the lakes as an asset in the community, and the desire to improve and protect them moving forward. This sentiment was echoed again in 2012 during the “Aspire” (Winter Haven Chamber of Commerce, 2012) visioning process.

As previously stated the perceived water quality of lakes may vary with different user groups (Hoyer, Brown, & Canfield Jr., Relations Between Water Chemistry and Water Quality as Defined by Lake Users in Florida, 2004). Residents in Winter Haven identified traits that foster productive fisheries and functional recreational waterways as important to them (Winter Haven Chamber of Commerce, 2000). It is worth noting that according to local testimonial, both algal dominated and macrophyte dominated lakes where of concern to the community but only where macrophytes conflicted with recreation. Otherwise the lakes referenced as “high quality” where still macrophyte dominated but with species such as *Vallisineria Americana* that did not cause recreational conflict.

Change in management regime:

In the past, lake water quality issues were dealt with by addressing lake contributions, mainly stormwater. After spending a significant amount of money and not seeing substantial improvement a shift in local management theory to manage all water resources; lakes, stormwater, floodwater, rainfall, and groundwater as one interconnected finite resource occurred (PBS&J, 2010). This shift began to look more at the functions provided by the natural infrastructure prior to development, and how to restore those functions while accommodating both existing and future land use changes. One of the aspects of natural infrastructure recommended for further examination to be used in strategic planning for lake management was the health of the lake macrophytic communities (PBS&J, 2010).

Other new techniques include using stormwater to drive hydrologic restoration as opposed to rapidly removing it from the system, as was the case under the previous school of thought. This is done with a variety of Low Impact Development (LID) strategies and is a crucial part of regional natural resource management. It is important to understand this shift in management regime to appreciate the mindset of local resource managers and comprehend the way they are making decision based on research such as this.

Research Objectives:

Objective 1:

Determine if lakes in the Winter Haven Ridge area bifurcate into alternative stable states of either macrophyte dominated or algal dominated systems based on hydroacoustic measurements of biovolume and percent area cover, and chlorophyll-A (CHL-A) chemical analysis.

Hypothesis 1:

Lakes in the Winter Haven Ridge area will bifurcate into alternative stable states based on a comparative analysis of macrophyte abundance vs. chlorophyll-A levels in 8 lakes in central Florida. We anticipate that when the measurements for average biovolume and percent area cover are combined to create a three dimensional measurement for macrophyte abundance in each lake, lakes with higher macrophyte abundance will have lower CHL-A levels, and lakes with a lower abundance of macrophytes will have a higher CHL-A.

Plant life in shallow lakes is driven by a number of factors such as nutrient availability (Scheffer, 1998). The way a lake responds to these drivers will change based on the alternative stable state they are in. Therefore lakes that have a higher abundance of macrophtic vegetation will be less amenable to the growth of algae as the macrophytic vegetation will regulate the drivers, such as nutrient availability. Comparatively, algae dominated systems will not have their drivers regulated by macorphytic vegetation. This would cause an algae dominated system to remain an algae dominated system. A macrophyte dominated system may be more prone to transition than an algae dominated system as the drivers increase beyond a systems capacity to effectively assimilate them. Again, using nutrient availability as an example. A macrophyte dominated system that is overloaded with more nutrients than can be used by the existing macrophyte communities may begin to shift towards a system where lower level organisms can outcompete the more complex ones.

Objective 2:

Determine if macrophyte species diversity plays a role in the alternative stable state distribution in central Florida lakes.

Hypothesis 2:

Lakes with a greater diversity of macrophytes are likely to be macrophyte dominated more often than lakes with less diversity. We believe this trend will surface when species data for submerged aquatic vegetation is analyzed for richness, diversity, and evenness.

Diversity in ecological communities generally increases resilience. A system with a more resilient population of macrophytes can propagate more prolifically over greater stretches of time than a system with less diversity. This ability to withstand change in external drivers such as climate makes a system more resilient and more likely to sustain a macrophyte dominated system.

Methods:

Study area:

As a protocol for lake sampling was developed for this project, multiple factors where taken into account. Since the project was publicly funded, one of the first factors in determining which lakes to sample was that a lake must have improved public access. On the Winter Haven Chain of Lakes this includes lakes that are connected by canals to a lake with improved public access. The physical sampling was done by the City of Winter Haven and prioritization for that included presence on the State of Florida 303d Impaired Water Bodies List (PBS&J, 2010), as well as the amount of existing data for both water quality and hydrology to be used in future analysis. The hydroacoustic sampling was conducted by a number of organizations following the same sampling protocol including; Florida Fish and Wildlife Commission, Polk County Natural Resources, and the City of Winter Haven.

Sampling:

Traditional and Structure Scan sonars are attached to a vessel along with a concordantly placed Wide Area Augmentation System enabled GPS receiver. The ping rate is set to 15 pps, frequency for the traditional sonar is set to 200KHz and the Structure Scan sonar is set to 455KHz. Transects are plotted across the lake using a 130 foot minimum plotted spacing to ensure accurate coverage. The transects are then followed using the GPS. Data points are recorded for every $5m^2$ by the sonar unit along these transects and each data point is then geospatially referenced and available for use in analysis.

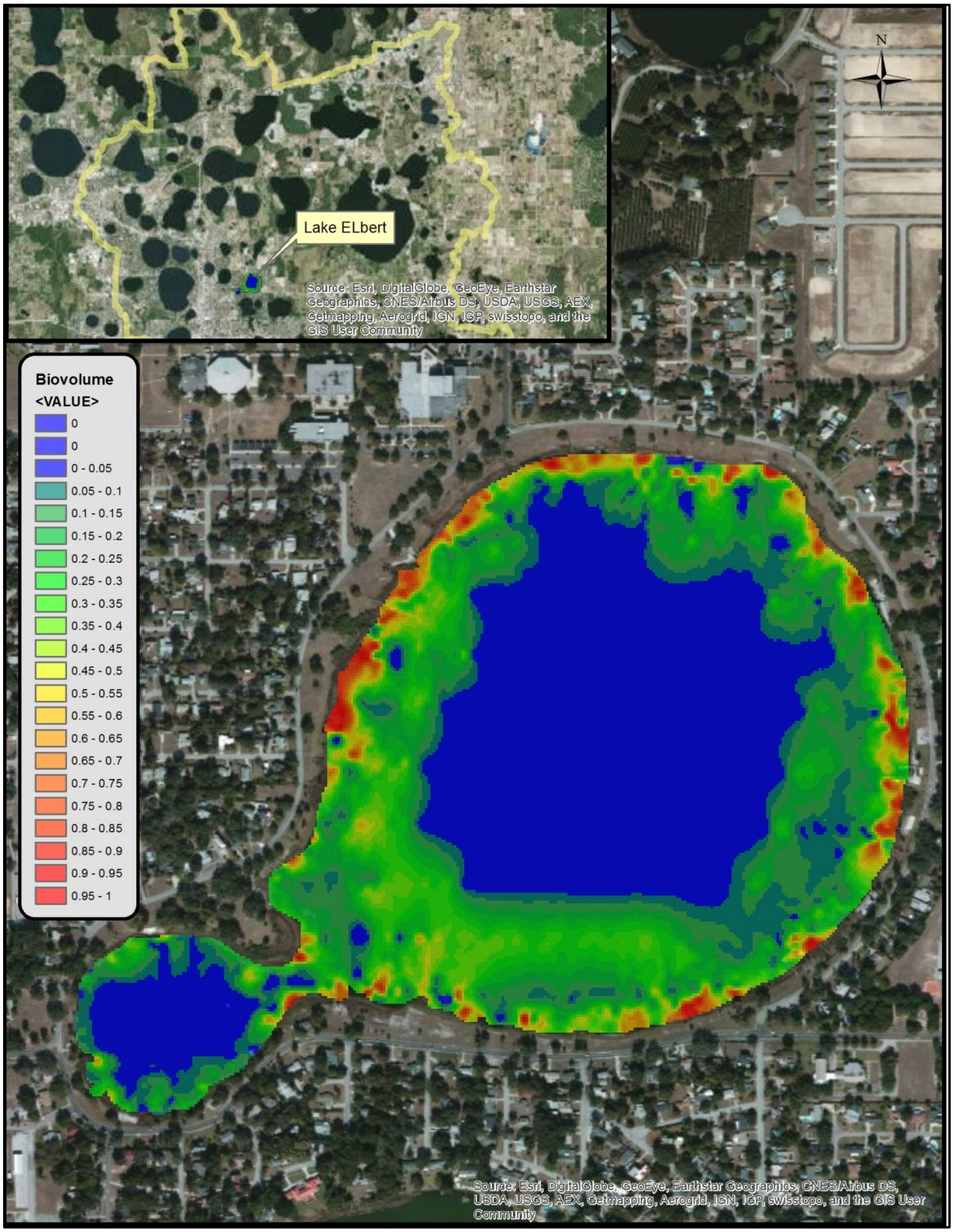


Figure 3: Heat map of Lake Elbert in Polk County Florida showing biovolume or ratio of water column filled with vegetation. Created from georeferenced hydroacostic data, Blue represents open water with little to no vegetation, Green is representative of short stature vegetation filling approximately 5 to 50 percent of the water column, Yellow colors are representative of vegetation filling 50 to 75 percent of the water column, and Red colors represent 75 to 100 percent of the water column being occupied by vegetation.

A suite of chemical samples are collected and analyzed by Polk County quarterly on the study lakes. They follow strict sampling and chemical analysis protocols outlined by the Florida Department of Environmental Protection as part of a statewide ambient monitoring program (Florida Department of Environmental Protection). For this study, samples from timeframes that coincide with the sonar work on each lake where used for analysis.

The physical sampling protocol is an expanded version of the Florida Department of Environmental Protections Lake Vegetation Index protocol (Department of Environmental Protection, 2011). The first step in the sampling protocol is to divide the lake into twelve equal parts. This was done using ArcGIS with the coordinates for each point of the twelve lines recorded into a GPS unit. Having these coordinates mapped and recorded creates repeatability to allow sampling of the same area from year to year. Once the initial section is arrived at, the next step is to divide the emergent vegetation, into up to three sections, and to estimate the width of each section. Then the percent cover for the major species are recorded for each section along with one dominant or co-dominant species per section. Once all emergent data is recorded the researcher will begin to sample a 5 meter wide transect taking five samples with a frodus working from shore toward the middle of the lake.

Data analysis:

The data collected by way of the physical sampling was coded and entered into a geospatial database allowing for a variety of future analysis options. The sonar data was uploaded to CI Biobase, a software service that interprets the sonar data and generates a dataset of points that have both biovolume, the percent of the water column containing vegetation, and a binary code for vegetative presence at each point. This allows for GIS to interpret the information as percent cover and map biovolume percentage as well Figure 3 To account for the three dimensional nature of macrophytic communities an average biovolume number was calculated and multiplied by percent area cover, resulting in a number representative of macrophytic abundance in each lake. This number was used to conduct a linear regression against CHL-A levels for each lake. The CHL-A numbers were produced from the chemical analysis conducted by Polk County. This regression allows the researcher to examine the potential relationship between these parameters to determine if hypothesis 1 is supported.

To analyze what role species diversity plays in alternative stable states, the data from the physical sampling was analyzed using Hill's family of diversity numbers (Ludwig & Reynolds , 1988). To examine species richness, the Marglef and Menhinick indexes where used. A series of indexes where used to explore diversity. These include, N0 which is equivalent to the total number of species, N1 is $e^{H'}$ where H' is Shannons Index, and N2 which is 1/λ where λ is Simpsons Index. These numbers where then used to calculate species evenness. Five evenness indices, each meant to explain slightly different variations on species evenness, were calculated these include:

- E1 = *(ln(N1)/ln(N0)*
- E2 = *N1/N0*
- E3 = *((N1-1)/(N0-1))*
- E4 = *N2/N1*
- E5 = *((N2-1)/(N1-1))*

Results:

Eight lakes were suitable for bivariate analysis of the relationship between macrophytes and CHL-A, based on the data collected. A linear regression of macrophyte abundance against CHL-A, proved to be strong with a coefficient of determination equal to 0.7165. This demonstrates a fairly strong relationship between the level of macrophytic abundance and the levels of CHL-A in a lake. The lakes where clearly divided into two opposite ends of the spectrum, those with high CHL-A and low levels of macrophyte abundance and those with high macrophyte abundance and low CHL-A.

The species information yielded less clearly defined patterns, the results of which can be seen in Figure 6 and Table 1. The implications of which are discussed below.

Table 1: Raw species count data represented for 8 lakes in Polk County Florida. Species are identified with database codes; CHARA = *Chara Sp.*, CEDE3 = *Ceratophyllum demersum*, HYVE2 = *Hydrilla verticillata,* NAMI = *Najas guadalupensis*, Nitella = *Nitella Sp.*, POIL = *Potamogeton illinoensis*, UTRIC = Utricularia gibba, VAAM = Vallisneria americana

Species Occurrence									
Lake	CHARA	CEDE3	HYVE2	NAMI	NITELLA	POIL	UTRIC	VAAM	Total
Buckeye		52	3	13	1			28	97
Elbert		44		6	2			47	99
Hartridge			5	2	4	31	11	3	56
Howard			3	16	3	30	12	14	78
Jessie	3	1	9	14			2	36	65
Lulu	7		4	40		6	17	17	91
Mirror		5	22	22	23	9	4	44	129
Winterset		7	29	26	11	41	2	44	160

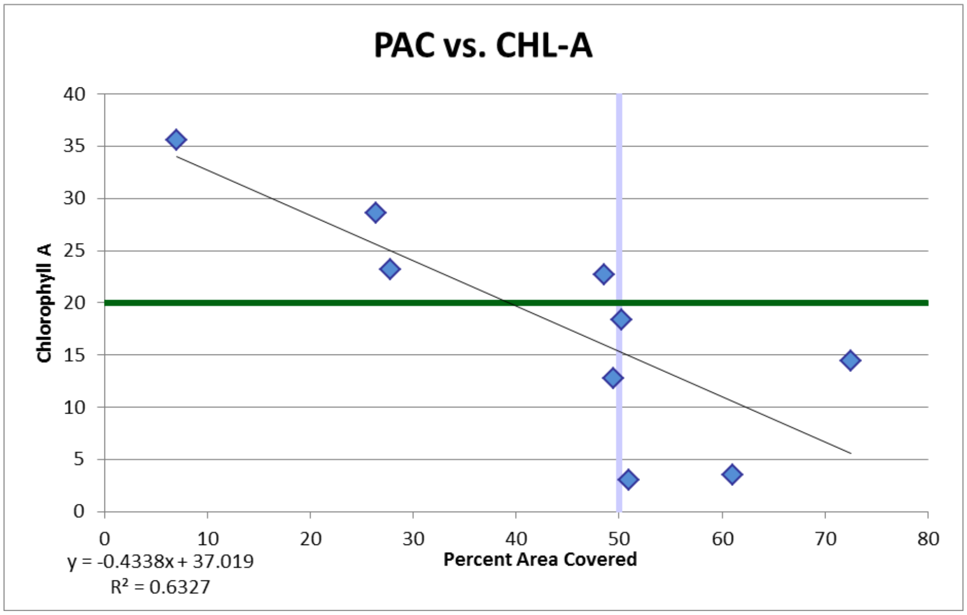


Figure 4 Scatter plot showing percent area cover graphed against Chlorophyll-A levels with a line of best fit added having an R2 of 0.6327. while there is some relationship among the data, the groupings remain unclear.

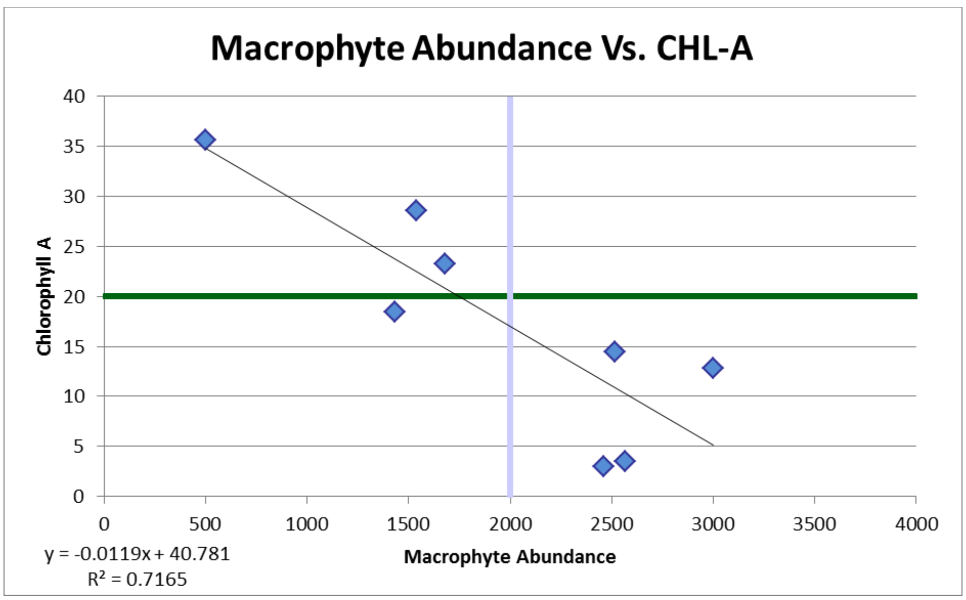
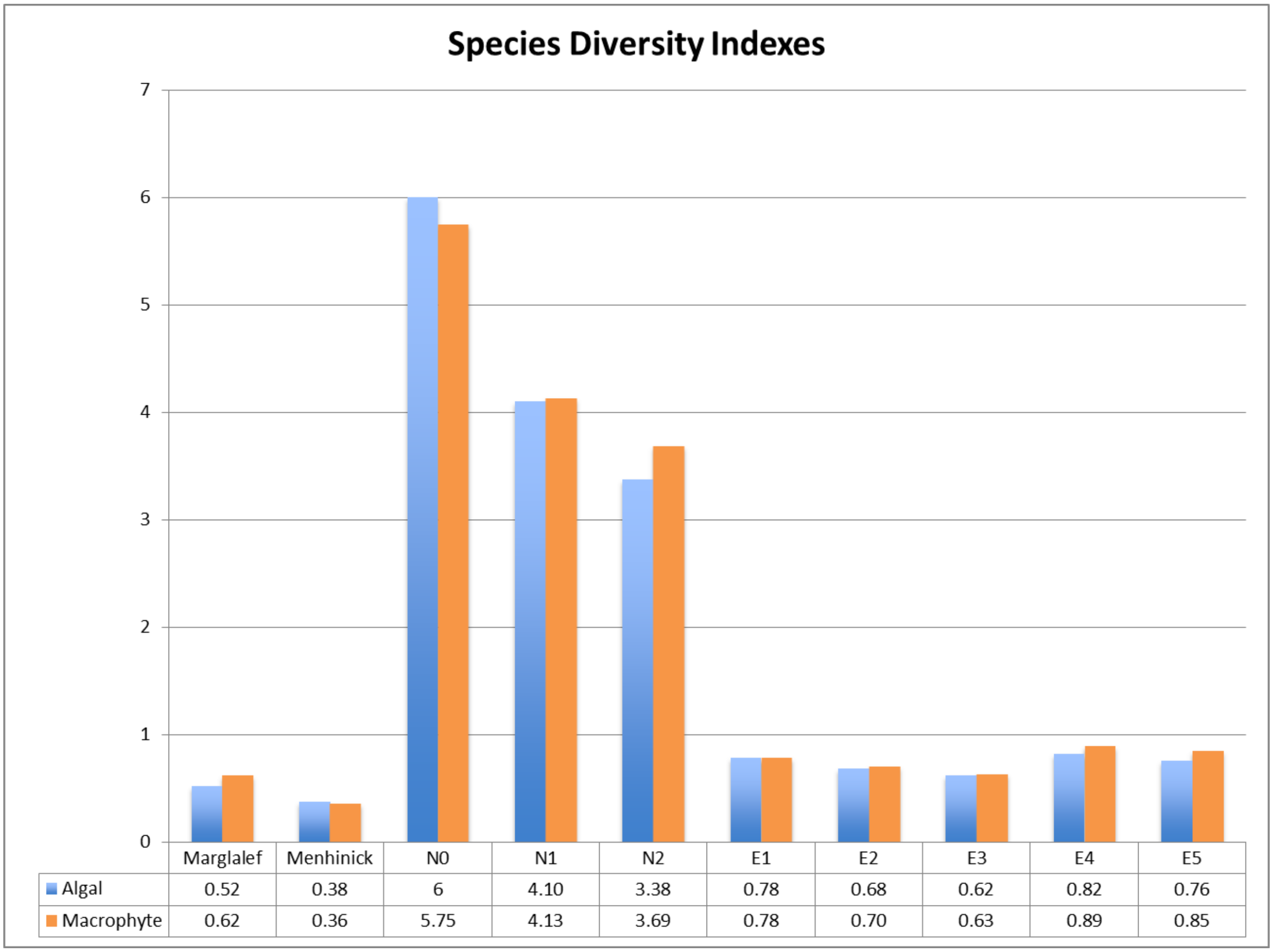


Figure 5: Scatter plot showing macrophyte abundance graphed against chlorophyll-A with a line of best fit with an R2 of 0.7165. This demonstrates an increase in the strength of the relationship over percent area cover gained by including the three dimensional factor of aquatic vegetation structure. There is groupings of lakes have become tighter then percent area cover as well. This graph shows lakes that have high macrophyte abundance are more likely to have lower chlorophyll-A levels and Lakes with less macrophyte abundance are more likely to have elevated levels of chlorophyll-A



	Marglalef	Menhinick	N0	N1	N2	E1	E2	E3	E4	E5
Algal	0.52	0.38	6	4.10	3.38	0.78	0.68	0.62	0.82	0.76
Macrophyte	0.62	0.36	5.75	4.13	3.69	0.78	0.70	0.63	0.89	0.85

Figure 6: Species richness, diversity, and evenness indexes graphed for both macrophytic and algal communities

Discussion:

Percent area covered is a metric often used to look at the relationship between water quality parameters and aquatic vegetation. By including the biovolume number and using a three dimensional metric to examine the CHL-A relationship, the researcher has seen an increase in the R^2 from 0.6327 in Figure 4 to 0.7165 in Figure 5 as well as the bifurcated grouping of the lakes. It would appear that lakes with a macrophyte abundance above 2000 are more likely to have a lower CHL-A and lakes below a macophyte abundance of 2000 are more likely to have a higher CHL-A splitting the lakes into two groups supporting hypothesis 1's theory on bifurcation. Moving forward it would be worthwhile to include data from additional lakes to see if the existing pattern continues. Resampling these locations over time will also yield additional insight into the stability of these systems further confirming or disputing the theory of alternative stable states.

The analysis of species information yielded interesting results. The Margalef index showed a higher species richness in macrophyte dominated lakes, while the Menhinick index showed a slightly higher richness in the algal dominated lakes. N0 was higher in the algae dominated lakes, but since this is merely representative of the number of species present and not weighted, it in and of itself is not a great indicator. It is generally higher than both N1 and N2. N1 examines species abundance using Shannon's index and is a measure of abundant species. N1 was higher for the macrophyte abundant lakes, which is to be expected. N2 is a measure of very abundant species and again was higher for macrophyte abundant lakes as would be expected. The species evenness indices presented some of the most interesting information. E1 was equal between both sets of lakes, being influenced by richness more than the rest this was unexpected. E2, E3, and E5 showed slightly higher species evenness in the macrophyte dominated systems while E4 moves toward one as a single species dominates. Based on E2, E3, and E5, it seems that species evenness may have a greater role than species diversity. While this does not necessarily support hypothesis 2 it does seem explainable. A lake with even populations can rebound from a negative impact to one population such as a seasonal senescence or freeze damage, better than a lake that has one species dominating the diversity of the lake. These species indexes are a useful tool to get an idea of the relationship species might have to alternative stable states of a lake. The researcher believes that in the next phases of the study it would be worth defining a minimum threshold for including species presence in a lake. A few lakes had species included in their population even if only one specimen was found; this may unintentionally skew the data and certain indexes.

Conclusion:

Lake managers can begin to use this information as part of the basis for making decisions on future management strategies. Based on this research, if the goal for a lake is to maintain a macrophyte dominated system, then understanding what the current state that lake is in is helpful. If a lake has almost no macrophytic vegetation for instance, a potential management technique could be a planting program. In many cases the researcher believes that what can actually be done to increase these populations is inaction or a more targeted reaction. By limiting what vegetation is controlled by herbicide for various purposes you may be able to increase the quantities and evenness of macrophyte population in certain lakes. It is important to keep in mind that for implemented practices to be truly fruitful, factors such as recreational management goals must be considered. For instance you would not want a lake that is the focus of a water ski show to be dominated by *Potamogeton illinoensis*, whereas a macrophyte community of *Vallisineria Americana*, *Chara*, and *Najas guadalupensis*, with a healthy periphyton community may provide similar benefits to water quality, while not conflicting with the intended use.

This information can be used in helping to prioritize projects for funding. It can be used as an indicator to weigh how stable one lake is vs, another and weigh the potential risk associated with a management investment. The inclusion of additional data showing these relationships over time will paint a clearer picture into the strength of these relationships. It will also be more prudent to include additional chemical analysis information at that point. This would help to better understand the drivers of the particular temporal changes that are witnessed, which again, can be addressed through better management practices.

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Biographical Sketch:

M.J. Carnevale is an interdisciplinary ecologist working on the relationships between uplands and water ways. He holds a bachelor's degree in Forest Resource Management, a master's degree in Business with an agricultural specialization, and if all goes as planned will complete a master's degree in Soil and Water Science in May of 2015. M.J. has aspirations of completing a PhD in Soil and Water Science with the continued study of lakes and their interactions with the urban area of Winter Haven Florida.

He began his career with the University of Florida studying things like, wetland logging impacts, springs water quality, watershed scale nutrient movement, net ecosystem exchange of carbon as it relates to landscape patterning in the Everglades, and pre and post sampling to quantify restoration success on the Kissimmee River. He has been with the City of Winter Haven for almost 3 years and is driving a new approach to understanding those ecosystem and using that knowledge to drive management practices.

Additionally, M.J. loves Florida and it's ecosystems spending as much time in them as he can manage, whether it's camping, hiking, boating, hunting, fishing, surfing, canoeing, kayaking, or some combination of those. M.J. is dedicated to understanding the systems that support our natural infrastructure and finding a way we can live in balance with them while continuing to thrive economically, and improve quality of life.

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