July 21, 2004

TECHNICAL MEMORANDUM

TO: File, NTB II

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SUBJECT: Use of Biologic Indicators for the Establishment of Historic Normal Pool

The concept of "normal pool" was developed by the Southwest Florida Water Management District (District) to establish a standard elevation datum that can be used to facilitate the comparison of hydrology between wetlands and lakes (Hull et. al., 1989). Some plant species cannot survive at high inundation frequencies, or show a common physical marker at the elevation of high inundation frequencies. Therefore, these plant species can provide relatively consistent indicators of long-term historic water levels. This elevation, referred to as "normal pool", has been used in the design of wetland storm water treatment systems for many years (SWFWMD, 1988), and, more recently, for the development of minimum levels for lakes and isolated cypress wetlands (SWFWMD, 1999a,b).

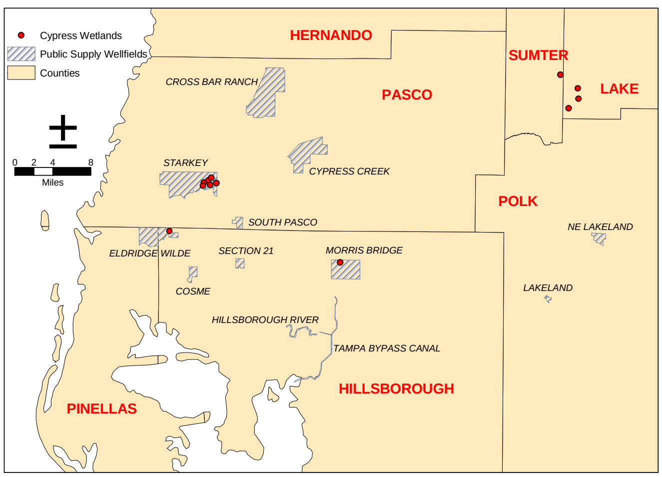
Currently, the District is in the process of re-evaluating the Wetland Assessment Procedure (WAP) of Tampa Bay Water's Environmental Management Plan (Tampa Bay Water, 2000). As part of this process, the District re-evaluated the methodologies used to determine normal pool, which, among other things, is used as a primary step in establishing a transect to assess wetland health. Carr and Rochow (2004) performed a data collection effort and evaluation of normal pools, and are referenced throughout this document. This paper presents a variation of the analysis performed in Carr and Rochow (2004) study, as well as other analyses, as technical support for the procedures that will be included in the documentation of the revised WAP.

Previous Work

Three indicators commonly used as a measurement of normal pool are 1) the inflection point (point of most dramatic slope change) of buttresses of *Taxodium ascendens* (aka cypress buttress swelling), 2) the elevation of the base of *Lyonia lucida*, 3) the lower elevation limit of epiphytic bryophytes (aka moss collars). To quantify the relationship between these and other indicators, Carr and Rochow (2004) compared the elevations of six biologic indicators to median water levels of 12 isolated cypress wetlands in the northern Tampa Bay area believed to have relatively natural hydrology (Figure 1). Wetlands with natural hydrology are those that are believed to be unaffected by ground-water withdrawals or surface-water management. The wetlands were shallow, relatively circular, cypress-dominated domes that ranged from one to nearly sixteen acres, with little to no hydrologic impacts. The wetlands were selected based on the following criteria:

1.) The wetland was a palustrine cypress wetland.
2.) The wetland had a sufficient quantity of biologic indicators.
3.) The wetland was rated as healthy using one of the District's wetland assessment procedures.
4.) The wetland's hydrology had not been significantly altered by man-induced influences.
5.) The wetland's area was greater than one-half acre.
6.) There was water level data available for a least the May1989 to April 1999 period.

Figure 1. Location of the 12 isolated, Cypress wetlands.



The six biologic indicators assessed were: 1) the inflection point elevation at the angular change of the *Taxodium ascendens* buttress swellings (cypress buttress), 2) the elevation of the root crown base of *Lyonia lucida* (lyonia), 3) the lower elevation limit of epiphytic bryophytes (moss collars), 4) the ground elevation at the water-ward most *Serenoa repens* (saw palmetto), 5) the elevation of the uppermost woody adventitious roots of *Hypericum fasciculatum* (hypericum), and 6) the ground elevation at the landward-most *Taxodium ascendens* (outermost cypress). The number of samples of each indicator is presented in Table 1 (based on a preliminary assessment of sampling requirements – see Carr and Rochow, 2004).

Two environmental scientists experienced in wetland ecology collected the elevation data. Each environmental scientist visited each wetland independently during the periods February 2000 to April 2000 and December 2001 to February 2002 to identify and mark sets of individual biologic indicators.

Table 1. **Number of data points collected for each biological indicator (modified from Carr and Rochow, 2004):**

Biologic Indicator	Number of Samples
Lyonia	15
Moss Collar	6
Cypress Buttress	10
Hypericum	5
Saw Palmetto	10
Outermost Cypress	31

The data from each environmental scientist was compared using the non-parametric Kruskal-Wallis One-Way ANOVA test (alpha = 0.05)[1]. The result was that there was no statistically significant difference between the two sets of measurements. Thus, the data collection methodology was reproducible. Subsequent analyses combined the two sets of data in order to increase the effective sample size.

The positions of the various biologic indicators were measured in terms of elevation. This poses no problem for examining data from a single wetland but prohibits comparison between wetlands since absolute elevations can vary significantly. To permit comparison the data needs standardization by some means. Carr and Rochow (2004) standardized the data by subtracting the data values from the 10-year median water level for each wetland. They then performed various analyses on the resulting data. These results are presented in Carr and Rochow (2004), and are reference in the conclusions section of this report.

Recent Work

The analysis presented in this paper uses a different standardization method than that used by Carr and Rochow (2004). Using the 10-year median water level presumes to some extent that each indicator is synonymous in terms of the hydrologic regime. At the very least, it would presume that each of the indicators was a relatively stable indicator of some hydrologic regime. In fact this is not the case as seen in Table 2.

[1] The Kruskal-Wallis One-Way ANOVA test is a nonparametric substitute for the one-way ANOVA when the assumption of normality is not valid. The null hypothesis is that the medians are equal versus the alternative that at least one median is different from the rest.

Table 2. Stage Frequency Results of Biologic Indicators

Index		Median of Indicators Stage Frequency Values of Indicators - 1990 - 1999 Water Levels					
		Buttress	Hypericum	Lyonia	Moss Collar	Outer Cypress	Palmetto
A	Green Swamp #1	0.2%	19.7%	0.0%	1.4%	40.8%	0.0%
B	Green Swamp #3	1.9%	16.2%	1.0%	2.8%	32.3%	3.8%
C	Green Swamp #4	3.5%	20.5%	3.0%	5.3%	17.4%	4.8%
D	Green Swamp #5	3.2%	13.0%	3.2%	3.2%	15.7%	7.2%
E	EW – 11	0.7%	19.8%	0.7%	0.7%	18.0%	12.2%
F	MBW X-4	1.7%	5.9%	2.1%	2.2%	20.6%	4.3%
G	STW "M"	0.5%	30.8%	0.5%	1.3%	33.8%	18.0%
H	STW "N"	0.0%	13.5%	0.0%	0.0%	45.7%	13.7%
I	STW "DD"	5.6%	35.3%	3.7%	3.7%	52.6%	37.2%
J	STW E.REC.	2.1%	17.9%	1.2%	0.8%	32.7%	17.3%
K	STW S75	6.2%	21.5%	5.2%	2.0%	21.5%	12.4%
L	STW S97	2.7%	5.8%	3.0%	3.5%	28.2%	19.7%

Range	6.2%	29.5%	5.2%	5.3%	36.9%	37.2%
Minimum	0.0%	5.8%	0.0%	0.0%	15.7%	0.0%
Maximum	6.2%	35.3%	5.2%	5.3%	52.6%	37.2%
Average	2.4%	18.3%	2.0%	2.2%	29.9%	12.6%

In this table, the median value of each indicator is compared to the stage-frequency of the water level measurements of the period 1990 – 1999. For example, the average of all 12 wetlands for cypress buttress measurements is 2.4%. Therefore, on average in the inspected wetlands, the elevation of the water exceeds the buttress elevation 2.4% of the time. Looking further, one sees that the average exceedance, or inundation frequency, of cypress buttress, lyonia, and moss collars are approximately equal. Saw palmetto, hypericum, and outermost cypress have average inundation frequencies ranging from approximately 13% to 30%. The assumption that all six indicators are synonymous appears to be false. Further, examination of the minimum, maximum and the range for inundation frequency shows that the while buttresses, moss collars, and lyonia are fairly stable, the other three vary dramatically in the inundation frequency.

Because the indicators are not consistent in their indication of stage-frequency, it is argued that centering the data on the median water level is not optimal for any indicators except moss collars, buttresses and lyonia. Therefore, the analysis presented in this paper uses an alternative method for standardization. Because the inflection points of cypress buttresses have been used essentially as the historic definition of normal pool, the elevation data from the various biologic data can be subtracted from the median elevation of the cypress buttress inflection points.[2] Cypress buttresses are a common feature in cypress wetland systems, and are thought to be very stable when hydrology changes.

To assess the differences between the biologic indicators, a Kruskal-Wallis One-Way ANOVA test (alpha = 0.05) was performed to compare the median of all wetlands standardized to the cypress buttress indicator. The results show that the standardized medians of all six biologic indicators are not statistically equivalent to each other. Therefore, the six biologic indicators are not interchangeable. However, there may be *some* indicators that are interchangeable with the cypress buttress indicator. To test this, a Kruskal-Wallis Multiple-Comparison Z-Value test[3] was performed, and the results are presented in Table 3. If the reported Z-value is greater than 1.96, than the median of the biologic indicators are significantly different. Therefore, the medians for lyonia and moss collar are not significantly different from cypress buttress, while the medians of saw palmetto, hypericum, and outermost cypress are significantly different from cypress buttress.

Table 3. Kruskal-Wallis Multiple-Comparison Z-Value Test

	Cypress Buttress	**Hypericum**	**Lyonia**	**Moss Collar**	**Outermost Cypress**	**Saw Palmetto**
Cypress Buttress	0.00					
Hypericum	11.38	0.00				
Lyonia	1.02	12.91	0.00			
Moss Collar	0.13	10.23	1.01	0.00		
Outermost Cypress	21.87	3.81	26.59	17.89	0.00	
Saw Palmetto	9.00	3.93	10.88	7.74	10.80	0.00

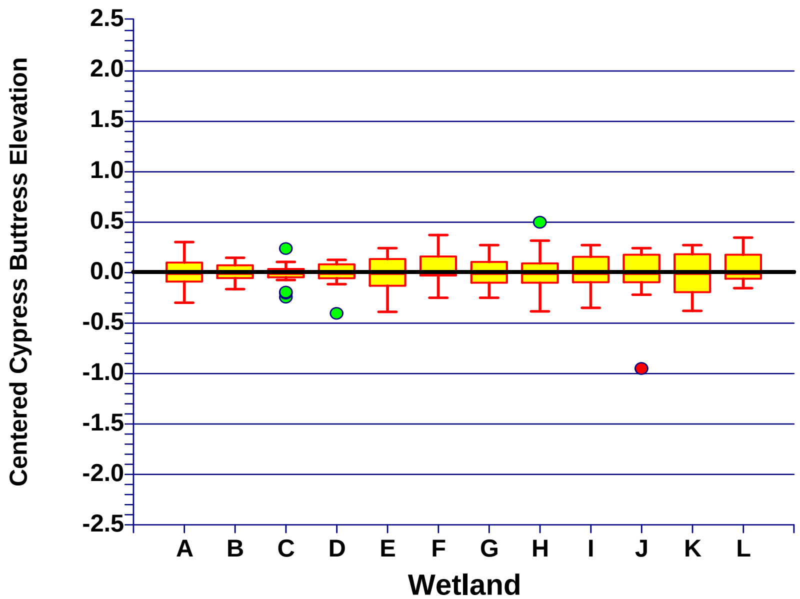
Medians significantly different if z-value > 1.96

[2] The elevation of the base of Lyonia lucida could also have been chosen, since it has also been a common indicator used for normal pool determinations for many years. However, as the results will show, the point is moot.

[3] A Kruskal-Wallis Multiple-Comparison Z-Value Test is a distribution-free multiple comparison test, meaning that the assumption of normality is not necessary. It should be used for testing pairs of MEDIANS following the Kruskal-Wallis test. The test needs sample sizes of at least five (but preferably larger) for each treatment. The error rate is adjusted on a comparison-wise basis to keep the experiment-wise error rate at a specified level. Instead of using means, this test uses average ranks.

Another factor to be assessed is the variability of each of the standardized medians between wetlands. Figure 2 presents a box plot[4] of the centered cypress buttress elevations for each of the 12 wetlands (see Table 2 for the information key to identify each wetland). Because they are centered on themselves, the median for each wetland is zero. However, in terms of variability (as represented by the heights of the boxes) and skewness of the data, there is some noticeable difference between wetlands.

Figure 2. Centered Cypress Buttress Elevations Between Wetlands



[4] The box plots were created using NCSS software with the default settings (Hintze, 2001). Box plots are useful tools because many important aspects of the data distribution for each variable are clearly represented in one graphic. The red horizontal line within each box corresponds to the median, or the 50th percentile, of each biologic indicator. The length of the box is equivalent to the interquartile range (IQR), where the bottom line of the box is equal to the 25th percentile and the top line is equal to the 75th percentile. Therefore, half of the data for each variable fall within the box's outline. Each box is bounded on the top and bottom by a T-shaped symbol. Values within this T-shaped symbol and the top of the box are less than or equal to the 75th percentile plus one and a half times the IQR. Values within the T-shaped symbol and the bottom of the box are greater than or equal to the 25th percentile minus one and a half times the IQR.

Outliers for each biologic indicator are represented by the green and red dots. The green dots are mild outliers, which have been defined for these box plots as values that are within three times the IQR from the 75th and 25th percentiles. Severe outliers are values that are greater than three times the IQR from the 75th and 25th percentiles and are denoted with red dots. The relative lengths of the boxes and relative positions of the dots and T-shaped symbols contain descriptive information on the variance and skewness of the data.

Figures 3-7 present the elevation data for each of the other biological indicators, also centered on the cypress buttress elevations. The medians for the moss collars and lyonia show some variability, but the results of the Kruskal-Wallis Multiple-Comparison Z-Value test showed that they are not statistically different from each other. Therefore, although there is some variability between the medians as compared to the cypress buttresses, it on the range of less than 0.2 feet, and is of no statistical significance. However, the variability of the remaining three biological indicators is greater. It should be noted that these three indicators also show a very large range of stage frequency associated with the different wetlands in Table 2. The frequencies of inundation range from approximately 0 to 37% for saw palmetto, 6 to 35% for hypericum, and 16 to 53% for outermost cypress.

Figure 3. Centered Moss Collar Elevations Between Wetlands

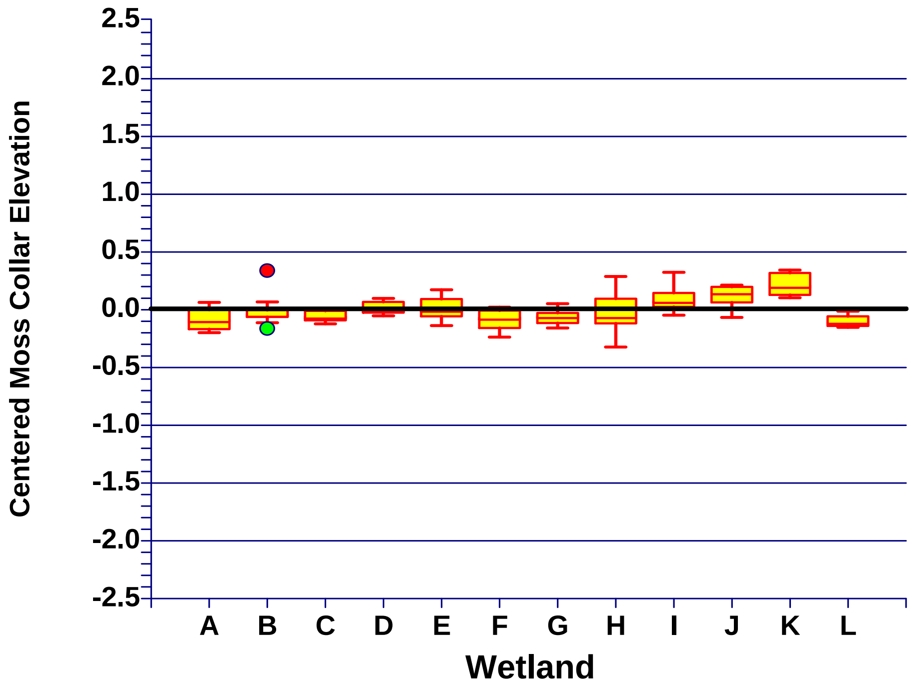


Figure 4. Centered Lyonia Elevations Between Wetlands

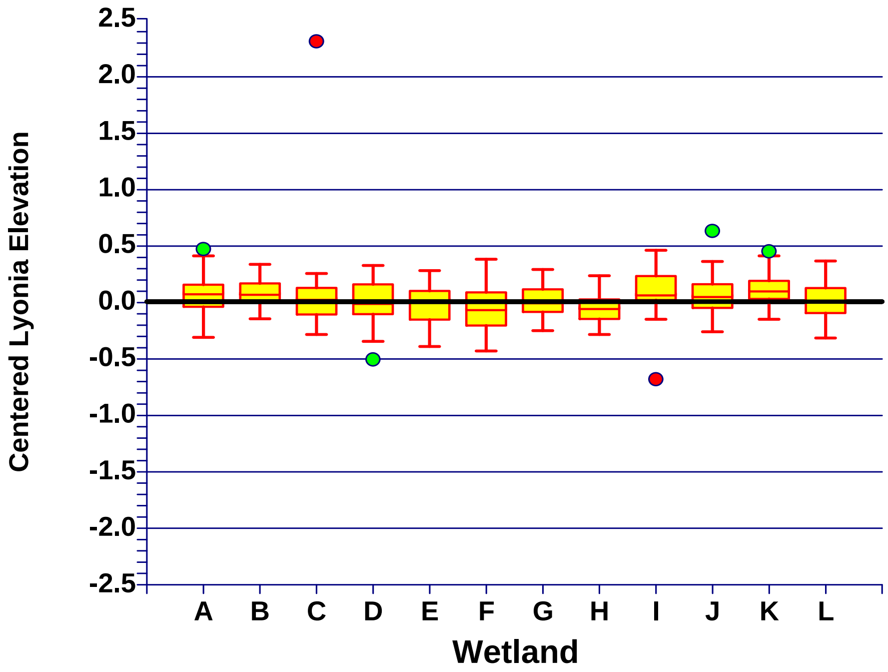


Figure 5. Centered Saw Palmetto Elevations Between Wetlands

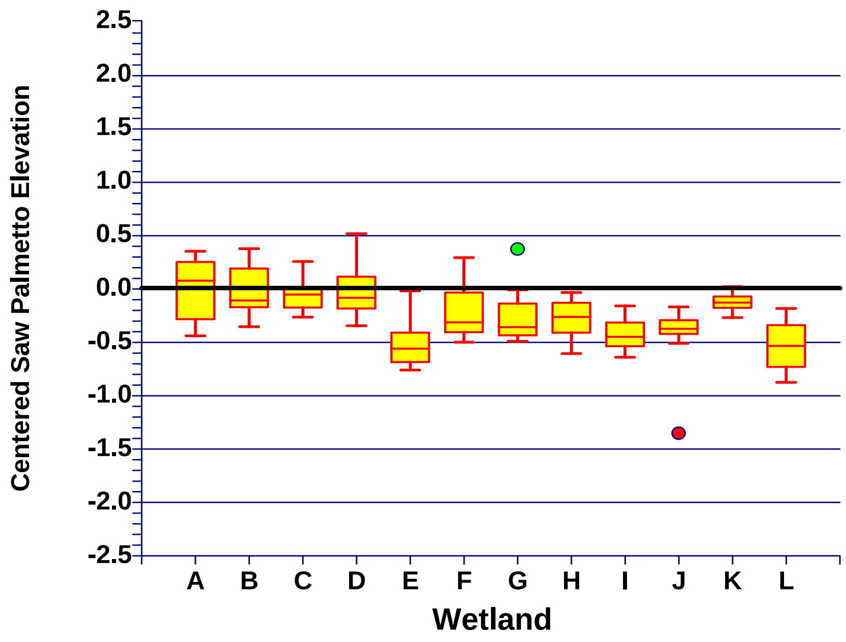


Figure 6. Centered Hypericum Elevations Between Wetlands

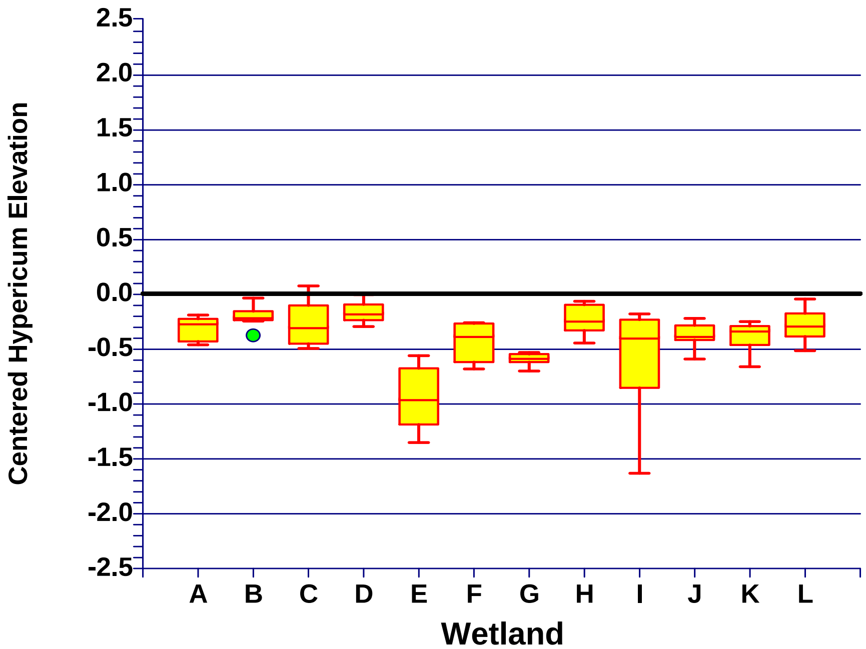
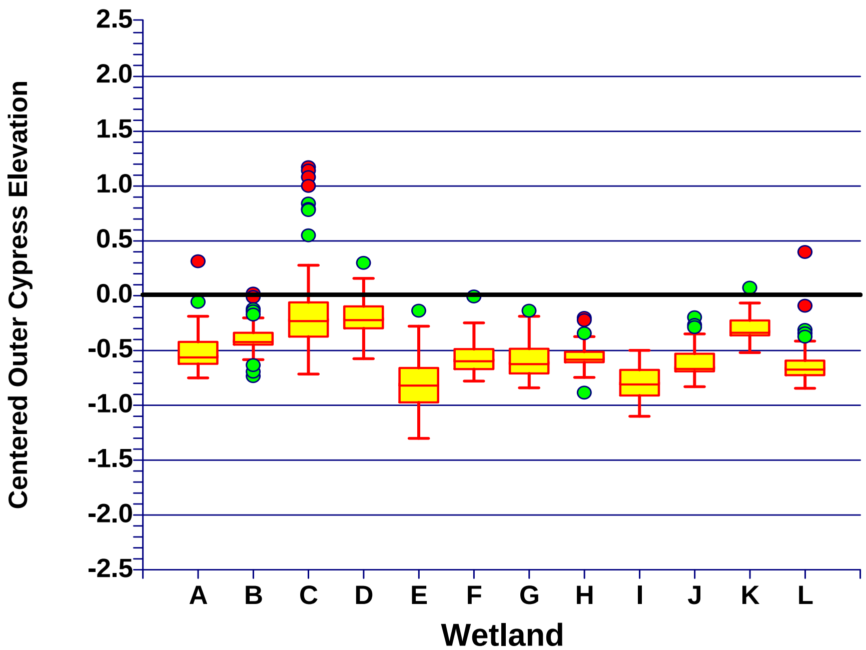


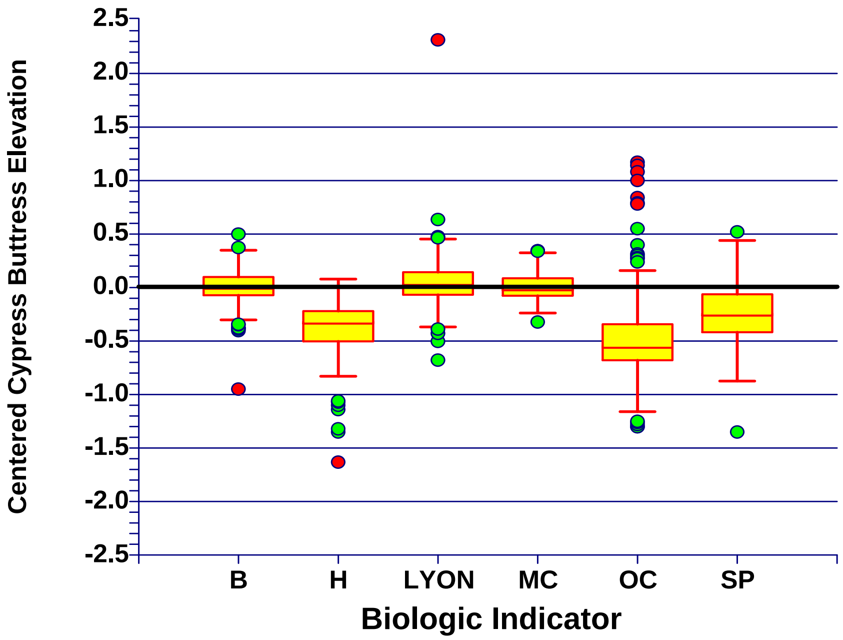
Figure 7. Centered Outermost Cypress Elevations Between Wetlands



An inspection of Figures 2-7 also shows that the standardized medians for saw palmetto, hypericum, and outermost cypress for all but one of the wetlands are below zero (the saw palmetto value for Wetland A, (Green Swamp 1, is above zero). Therefore, the question then becomes "can an adjustment factor be applied to the measured values for hypericum, outermost cypress, or saw palmetto to bring them in line with the other three?" On the assumption that the inflection of the cypress buttress can be considered a reasonably stable feature in wetlands, the next analysis examined the other indicators in terms of their offset from the median buttress inflection point.

Figure 8 presents box plots of the cumulative data (data for all wetlands) for each of the biologic indicators. The saw palmetto, hypericum, and outermost cypress indicators exhibit more variance than the other three indicators (outermost cypress displays the largest number of severe outliers). The median hypericum indicator measurement is 0.33 feet below the buttress inflection. The median of outermost cypress is 0.55 feet and saw palmetto is 0.25 feet below the median buttress inflection point. Therefore, if any of these three indicators are chosen as a tool to determine normal pool, these values can be used to adjust each one to be the equivalent of the elevation of the cypress buttress indicator.

Figure 8. Comparison of Biologic Indicators Centered on Buttress Elevations



Conclusions and Recommendations

For purposes of the WAP, an estimate of historic normal pool is desired. In other words, if the hydrology of a wetland has been altered, the normal pool must be set through biologic indicators that estimate conditions prior to the alteration. Therefore, as each of these six biologic indicators is assessed for use in historic normal pool determinations, other factors besides the above results must be considered. Keeping in mind that the indicators will be regularly used in wetlands that have seen significant hydrologic change (as opposed to the test wetlands that had relatively unimpacted hydrology), how the indicators are expected to react to hydrologic change must be considered. A quantitative assessment of these reactions would require a very long-term test, using data with a period of record ranging several years before and after the hydrologic impact. This data does not exist. However, many wetlands in the northern Tampa Bay area have been monitored for such a period, and the reactions of these indicators have been observed. For instance, the elevations of individual lyonia and cypress buttresses do not appear to change in response to hydrologic impact. Reasons for this may include the nature of the species, age of the species used, and the length of time it takes for these species to mature. In contrast, the elevations of moss collars have been observed to move over years of hydrologic stress, with some moss collars reaching the elevation of the ground in severely dehydrated wetlands. Therefore, although the elevation of these three indicators appears to be relatively consistent in healthy wetlands, the cypress buttress and lyonia indicators may be better choices for use in historic normal pool determinations, when available.

Although saw palmetto shows more variable than cypress buttress, lyonia, and moss collars in the test wetlands, long-term observation has shown its elevation to be highly resistant to change in wetlands with hydrologic impacts. No apparent downward movement is seen in wetlands that have had lowered water levels for decades. Despite its larger variability when compared to cypress buttresses, and the need to apply an offset factor, saw palmetto's stability over time (coupled with the fact that it is often the only biologic indicator available in non-forested wetlands) may make it a very good choice to use for the determination of historic normal pool.

Outermost cypress and hypericum are perhaps the least desirable choices for historic normal pool determination, for different reasons. While outermost cypress may be a relatively stable indicator in wetlands with altered hydrology, it shows a very high level of variability in this assessment, in both median comparisons with cypress buttress, and in stage frequency. Hypericum also shows a high level of variability in the median comparison with cypress buttress, and second highest variability with respect to stage frequency. Hypericum is also the only wetland-dependent shrub assessed as a biologic indicator, and may be much more subject to movement in wetlands with impaired hydrology, or even with annual or seasonal fluctuations. For these reasons, it is recommended that outermost cypress be used cautiously to determine historic normal pool (i.e., used only when other indicators are not present), and the use of hypericum should be avoided.

Despite being based on a different assumption of standardizing data between biological indicators rather than water levels, the results of the work discussed above arrived at very similar conclusions as Carr and Rochow (2004). This is perhaps due to the similar hydrologic fluctuations between the various wetlands in the Northern Tampa Bay area. In any event, the results of each assessment are consistent. Based on these analyses and others, the following recommendations are made concerning the determination of historic normal pool in wetlands within the Northern Tampa Bay area.

1) Based on the assessments discussed in this paper and others, the elevations of cypress buttress inflection and lyonia are well-established and equal indicators of historic normal pool in wetlands. However, soil subsidence, soil oxidation, and karst activity can alter wetland structure, and hence elevations of biologic indicators. Therefore, evaluations of these processes must be taken into account when determining historic normal pool elevations, regardless of the indicator used.

2) Moss collars can be a reliable indicator of normal pool, but are more subject to change as hydrology is altered. Caution should be used when relying on moss collar elevations as the sole indicator of historic normal pool.

3) The saw palmetto indicator appears to be a reliable indicator of historic normal pool when used with an adjustment factor (adding 0.25 feet). The saw palmetto indicator is somewhat more variable than the lyonia indicator, but is a common feature in the landscape, and may be the only choice for non-forested wetlands.

4) The outermost cypress indicator is a less desirable indicator of historic normal pool, due to the high variability with its relationship to cypress buttress and stage frequency. If used, the addition of 0.55 is necessary to approximate historic normal pool.

5) The hypericum indicator is not a recommended indicator for historic normal pool, due to the high variability of its relationship to cypress buttress and stage frequency, and it dependence on wetland hydrology.

6) Regardless of the indicator chosen, the median of multiple samples of biologic indicators should be used, rather than the elevation of a single sample, or small number of samples. The more samples taken, the

more likely the result will be more robust, but for practical purposes, a sample size of five individuals is recommended as a minimum.

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