RIDGE SENESCENCE OF *CLADIUM JAMAICENCE* IN THE RIDGE AND SLOUGH MOSAIC OF THE FLORIDA EVERGLADES

Taegoo Oh

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Advisor: Dr. Mark Clark

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Abstract

Low level aerial surveys and ground investigations indicates that ridge senescence of sawgrass (*Cladium jamaicence*), either active or evidenced in the recent past, occurs to varying degrees throughout the Shark Slough region, Water Conservation Area (WCA)-3A and WCA-3B. During the survey we observed several distinct types of ridge senescence that can be identified and that can be used to differentiate types of ridge senescence by both size and pattern of die-off. From this survey, we can also suggest that for Type III ridge senescence, the event that caused the die-off we observed in low level aerial surveys was Hurricane Wilma, which deposited a wrack line of periphyton and other debris in what appears to be the area of present day Type III ridge senescence. Therefore, it is likely that Type III ridge senescence is the result of extreme events and deposition of periphyton and other debris in a wrack line along the ridge edge.

Findings also indicate that it is possible to use photointerpretation keys to detect ridge senescence at a high degree of confidence, which can then be used to evaluate spatial and temporal occurrence. Using these interpretation keys, we found a high frequency of Type I ridge senescence in southern regions of WCA-3A over 50 % of ridge area in some Probabilistic Sampling Units (PSUs). Type I ridge senescence was also prevalent within Everglades National Park (ENP) with 35% or more of ridge areas impacted. Type III ridge senescence was also commonly observed with six out of 12 PSU's surveyed having some Type III ridge senescence with 3.3% of the ridge area impacted in those PSU's where Type III ridge senescence occurred. It is likely that the occurrence of Type III ridge senescence increased significantly after Hurricane Wilma which was not document in this spatial quantification since the aerial image was taken in January 2005 and Hurricane Wilma did not occurred until October 2005.

Efforts to relate hydrologic characteristics to ridge senescence showed mixed results. There was a relatively strong positive relationship between all PSU's and water depth with an R^2 value of 0.45 to 0.53 depending on month of the year when average water depths were taken. This relationship was much stronger (often greater than 0.900) when PSU's in WCA-3A and ENP

were analyzed separately.   However, when analyzing the data separately for each water region; the relationship, although almost equally strong, was in two opposite directions with WCA-3A data showing a positive trend and ENP data showing a negative trend between ridge senescence and water depths.

These findings support the fact that ridge senescence is a prominent feature in the Everglades system and may be a factor in ridge development or maintenance. It also suggest that the causal mechanisms of at least Type I ridge senescence are not clear and will require further investigation to determine what factors may be leading to the extensive die-back of sawgrass on ridges throughout much of the southern Everglades

Chapter 1. Definition and Types of Ridge Senescence

INTRODUCTION

Sawgrass ridge senescence has been periodically and widely observed in the southern Everglades. In 1975, Hofstetter and Parson found that dead sawgrass stands were most extensive in Everglades National Park portions of Shark River Slough, in Water Conservation Area 2B (WCA 2B), Taylor Slough, and WCA 3 and 2A. Werner in 1975 found that entire stands in Shark River Slough had died in less than 2 years except for a narrow fringe around the edge. The senescent condition was most obvious in pure stands of dense sawgrass, where living sawgrass was almost eradicated from the interior of the stand although the edge appeared to be healthy and near normal. Some sawgrass plants were stunted with more than the usual numbers of the outer leaves dead. Also, these plants had small circular holes through the outer leaves and channels down to the meristerm. Caterpillars (*Scirpophaga perstrialis*) were found in some of these plants. Also, P. J. Gleason photographed small patches of dying and dead sawgrass in Taylor Slough in April 1971 and in 1977, Wade observed that sawgrass was again gaining in stature and density but nobody could understand the reasons for initial die-off.

More recently in 1999, Les Vilchek, Sr. Environmental Scientist in South Florida Water Management District, found sawgrass senescence in the southern 1/3 of WCA 3B and in the area close to Tamiami trail. He reported “Many areas were fairly large, covering tens of acres or more. Other dead sawgrass areas, not seemingly associated with tree islands (no teardrop shape, no live or dead shrubs and or ferns), were also in abundance especially in the area of the old agricultural ditches/canals extending north from Tamiami Trail. These dead zones are a prominent feature in the landscape there.” (Les Vilchek, 1999). They also noticed a number of small circular features only a few meters in diameter which looked to be pockets of dead sawgrass in WCA 3A.

Although ridge senescence, sawgrass die-off or decadence has been widely observed in the Water Conservation Areas and Shark River Slough of the Florida Everglades for quite some time, only limited quantitative and sparse observational data exists. Furthermore, a universally accepted definition for this loss of sawgrass cover has not been adopted. Since this event results in a significant reduction in plant biomass, it is hypothesized that the accretion rate of organic matter on the ridges (thought to be a critical component maintaining the elevation difference between ridges and sloughs) may be reduced and thereby negatively affect the long-term viability of the ridge slough mosaic system. This report consists of findings from aerial reconnaissance of 12 Probabilistic Sampling Units (PSUs) selected to represent areas with prominent ridge slough landscapes. Aerial photography, Digital Orthophoto Quarter Quadrangles (DOQQs), and ground truthing were employed to classify several types of ridge senescence, and qualitatively evaluate the extent of this die-off. We also related hydrologic characteristics of each PSU with frequency of senesced sawgrass to begin investigating possible causal mechanisms.

Study Objectives

The major objective of this study was to develop a more quantitative definition of sawgrass mortality events to evaluate their temporal and spatial frequency of occurrence. We also investigated possible hydrologic conditions under which ridge senescence may be more likely to occur. Although there is not a definitive cause and effect, narrowing down or removing hydrology as a causal factor will be helpful in understanding how management activities may be related to the occurrence of ridge senescence.

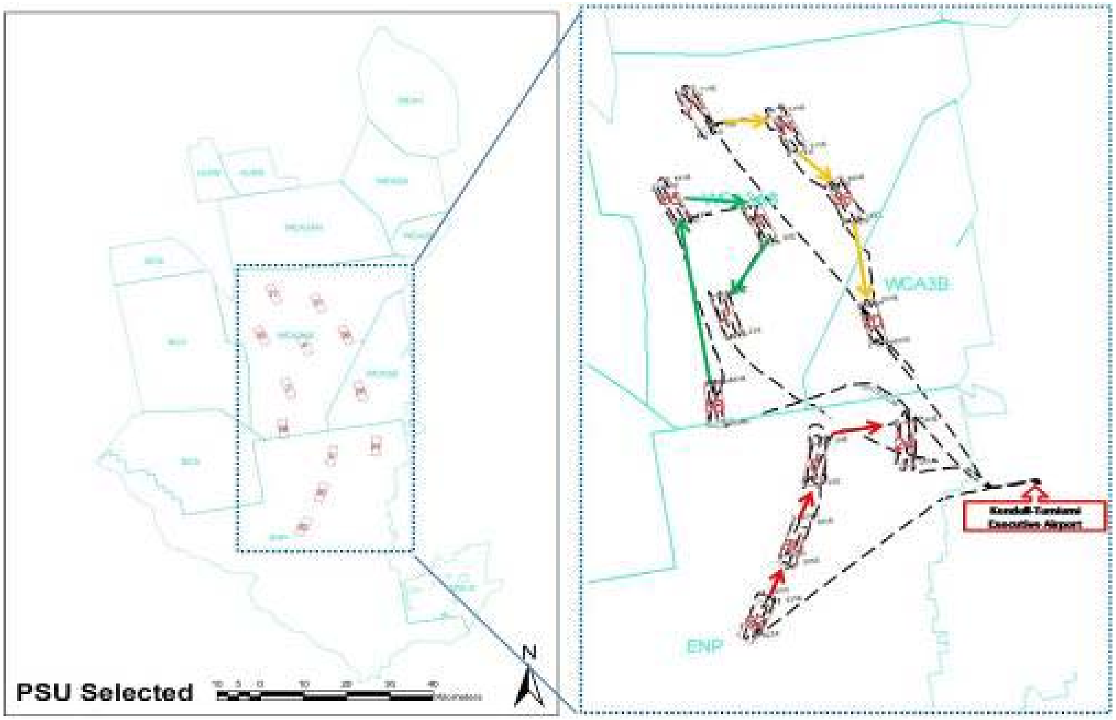
This section of the report is focused on a more quantitative definition of sawgrass senescence based on observations made on the ground, at low altitude and with remote sensing platforms. The principal purpose of this effort is to establish a working classification scheme for types of sawgrass senescence so that future observations can be better quantified and communicated.

METHODS

As an initial assessment of the prevalence and types of ridge, a low level (50-250m altitude) helicopter survey of the region was conducted. For this survey, we selected 12 PSUs that had a ridge slough vegetative community type and that extended from southern ENP to central and eastern WCA-3A and WCA-3B. The PSUs sampled for this survey were 0, 2, 4, 20, 24, 31, 36, 50, 55, 58, 62, and 71. To guide and spatially reference the low altitude aerial survey, 2004 DOQQs (Digital Orthophoto Quarter Quandrangles) images of the PSU's were used (Figure 1-1). After identification of certain senescence types from the aerial surveys (Figure 1-2), a ground truthing survey in PSU 2 on March 6th, 2009, PSU 4 on June 5th, 2008 and PSU 71 on May 28th, 2008 was conducted.

(a) (b)

Figure 1-1. Probabilistic Sampling Units in Everglades (a) and an example of 2004 DOQQ image from PSU 02 (b) used for spatial referencing during low level aerial survey.



(a) (b)

Figure 1-2. Selected PSUs (a) and flight path during low level aerial survey (b): April 05, 2008 (red and yellow arrows, April 06, 2008: green arrows)

RESULTS AND DISCUSSION

Aerial Survey Results and Definition of Ridge Senescence

In our aerial survey of 12 PSUs, ridge senescence was identified to varying degrees at all locations. The degree of occurrence appeared to be a factor of region and time since the senescence event. This survey also recognized not just one type of senescence, but at least three distinct types of ridge senescence principally identified by size and morphology of the senesced area. As a result of the survey we propose the following working definition for “ridge senescence” and outline definitions for three types of senescence that are easily recognized and differentiated.

Definition of Ridge Senescence

We propose the following working definition for ridge senescence:

A contiguous area on a ridge at least 10 m^2 in size and within which 75% or more of the sawgrass has died.

Types of Ridge Senescence

We propose the following classification scheme for ridge senescence that can be used to better communicate and characterized the type of occurrence, the degree of affect and at some point possibly suggest the causal mechanism. The classification is principally based on size and shape of contiguous senesced patches. Terminology for the classification is simply; Type I, Type II and Type III ridge senescence.

Type I ridge senescence is defined as:

Large areas (>100m^2) of ridge senescence that typically occur on the upper most elevations of the ridge.

This type of ridge senescence is clearly the most extensive and relative to an individual ridge has the greatest spatial impact. On those ridges affected, the top of the ridge often has 80-90% sawgrass mortality with healthy sawgrass often surrounding the margin of the ridge forming a buffer or halo between the slough and the ridge top (Figure 1-3). In the area of greatest mortality, however, there are often tussocks of living sawgrass that remain along with other vegetative species such as *Cephalanthus occidentalis*. Although not extensively investigated, vegetation in areas previously dominated by sawgrass where a Type I ridge senescence has occurred appear to be colonizing with slough type species specifically *Nymphaea odorata* (Figure 1-3c). This was most prevalent in PSU 2 and PSU 58 located in southern WCA-3A.

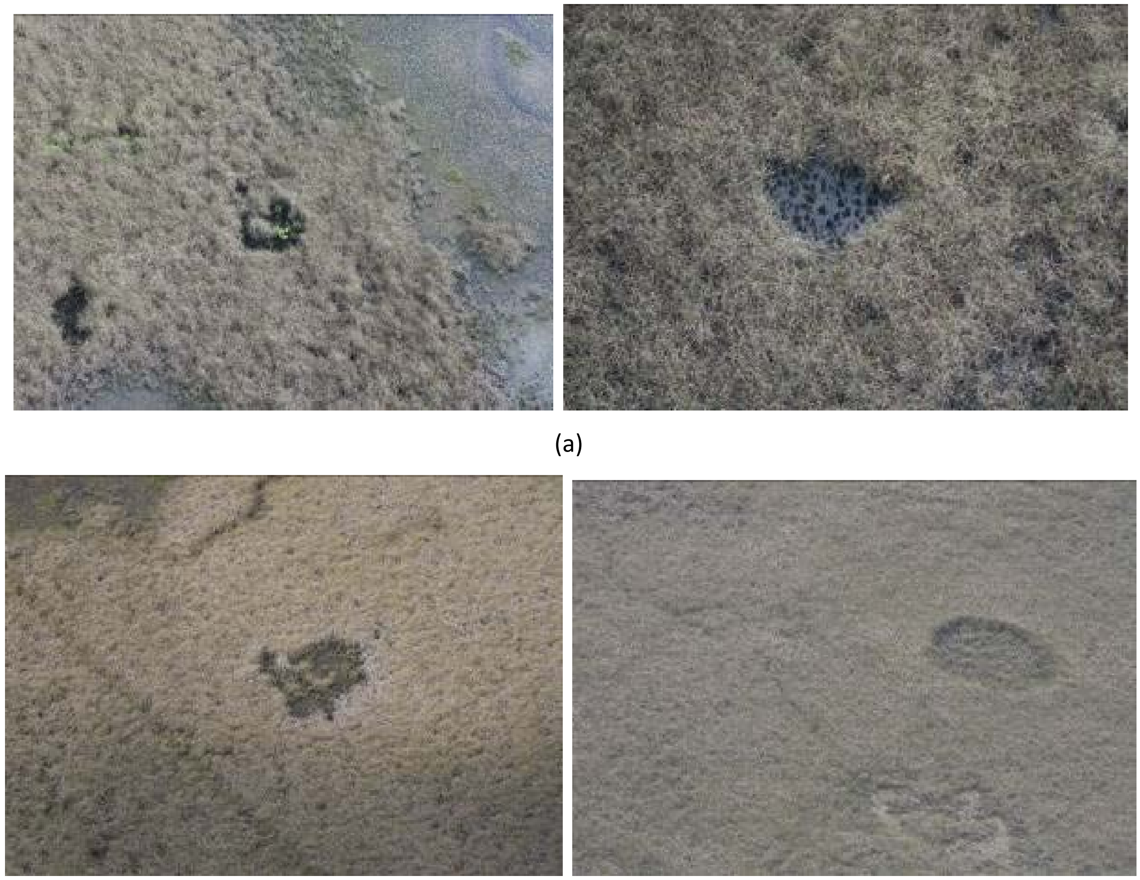
(a)

(b) (c)

Figure 1-3. Type I Ridge Senescence in PSU 2 (a), PSU 58 (b), and PSU 4 (c)

Type II ridge senescence: *Small areas (<100m^2) of ridge senescence that are typically isolated within an otherwise healthy stand of sawgrass on the upper elevation of the ridge.*

This type of senescence is mainly based on the size of the contiguous patch of dead sawgrass. This type of senescence is characterized by a patch of dead sawgrass in an area surrounded by what appears to be an otherwise healthy stand of sawgrass (Figure 1-4). Type II patches occur on ridge tops, but seem more prevalent in the more extensive sawgrass ridges with minimal slough habitat in WCA-3B (PSU 20) and in northeastern Shark River Slough, south of Tamiami Trail (PSU 24). The shapes of senesced areas are amorphous, but generally circular.



(a)

(b) (c)

Figure 1-4. Type II Ridge Senescence in PSU 4(a), PSU 71(b), PSU 24(c)

Type III ridge senescence: *Linear areas of ridge senescence near the edge of the ridge slough boundary and often paralleling the outer edge of a ridge.*

The width of the linear die-off often varies, but is rarely wider than a few meters. The linear die-off in some instances extends almost completely around the full perimeter of the ridge with occasional breaks in the line where healthy sawgrass is present (Figure 1-5).

(a)

(b)

(c)

Figure 1-5. Type III Ridge Senescence in PSU 0(a), PSU 62(b), and PSU 20(c)

Although we have not postulated causal mechanisms for Type I or Type II ridge senescence, we believe that there is strong anecdotal evidence that the Type III ridge senescence observed during aerial surveys is the result of wrack lines generated from hurricane Wilma, which passed over this area in 2005. Photographs taken shortly after hurricane Wilma (Figure 1-6) show spatial patterns of wrack lines composed of periphyton and other debris very similar to the patterns characterized in this study as Type III ridge senescence. Therefore, although the causal mechanism of mortality has not been determined, the similarity between spatial patterns of wrack lines and Type III ridge senescence is quite compelling.

Figure 1-6. Wrack lines of periphyton and other debris (white along edge of ridge) photographed shortly after hurricane Wilma passed over the area in 2005. Photos are from north central WCA-3A. (Photos courtesy of Scott Hagerthey & Sue Newman, SFWMD)

CONCLUSION

This survey indicates that ridge senescence, either active or evidenced in the recent past, occurs to varying degrees throughout the Shark Slough region, WCA-3A and WCA-3B. During the survey we observed several distinct types of ridge senescence that can be identified and that can be used to differentiate types of ridge senescence by both size and pattern of die-off. From this survey we can also suggest that for Type III ridge senescence, the event that caused the die-off we observed in low level aerial surveys was Hurricane Wilma, which deposited a wrack line of periphyton and other debris in what appears to be the area of present day Type III ridge senescence.

Chapter 2. Spatial Occurrence of Ridge Senescence in Water Conservation Areas 3A, 3B, and Everglades National Park in 2004

INTRODUCTION

The Everglades, one of the most unique subtropical wetland ecosystems in the world, evolved in a low-nutrient environment and is unique in that its formation is the result of the accumulation of organic matter over a limestone depression (Reddy and DeLaune 2008). Sawgrass (*Cladium jamaisence)* is arguable the most commonly occuring plant species throughout much of the freshwater system and establishes monodominant stands in the sawgrass prairies north of Alligator Alley and on ridges in the ridge slough vegetative mosaic in much of the area south of the Alley.

A phenomenon described as sawgrass (*Cladium jamaicense*) die-off, senescence, or decadence has been widely observed in the Water Conservation Areas (WCAs) and Shark River Slough of the Florida Everglades at various times in the last 30 years. Even though our previous survey and scientific observations from other agencies have been reported, only limited quantitative data exist. One implication of ridge senescence is a reduction in organic matter input to ridge soils which may cause a critical change in soil accretion rates on ridges relative to slough habitat and maintenance of the ridge and slough mosaic in the Everglades. Therefore, spatial and temporal information about ridge senescence is important to predict the change of these two habitats in the central Everglades.

The main objectives of this component of the study are;

1) to develop photointerpretation keys which allows evaluation of ridge senescence using aerial imagery or other remote spectral platforms.

2) to quantify occurrence of ridge senescence using 2004 ortho-rectified images

3) to find relationships between occurrence of ridge senescence and hydrologic factors

MATERIAL AND METHODS

Characteristics of Sawgrass

Sawgrass is a rhizomatous, perennial sedge, rather than a grass (Davis and Ogden 1994). Sawgrass grows to 2-3m in height on deep peat but only 0.5m on shallow peat. The optimum condition for growth of sawgrass is the area with low to moderate levels and is quite tolerant to drought conditions (Steward and Ornes 1975, Richardson et al. 2008). Sawgrass does not survive well in highly variable deep (>30cm) water regimes.

The current diking and flooding in portions WCA 2 as well as in other parts of the Everglades has resulted in the loss of this community due to deep and fluctuating water levels (Richardson 2009). Sawgrass also requires low nutrients, which promotes its dominance in the oligotrophic waters of the Everglades. Within the ridge slough vegetative mosaic there are often two statures of sawgrass; tall statue (dense marsh often reaching 1.5 meters or more) and short statue (less dens stands and heights of 1.5 meters or less). The stature of sawgrass is often determined by the depth of peat accumulation (Davis and Ogden 1994).

Analysis of the occurrence of ridge senescence

We selected 12 Probabilistic Sampling Units (PSUs); four in WCA 3A (PSU 2, 4, 71, and 58), one in WCA 3B (PSU 20), and four in ENP (PSU 24, 0, 50, and 62) (Figure 2-1). DOQQs in 2004, and ground truthing were employed to classify several types of ridge senescence. We digitally overlaid 200 random points on the DOQQ within each PSU using ArcGIS 9.3. We then classified each point into four major classes (Ridge, Slough, Tree island, or Disturbed) and seven subclasses (Healthy, Type I ridge senescence (Severity 1, 2, and 3), Type II ridge senescence, Type III ridge senescence, Periphyton, Open water, or Floating-leaved plant) (Table 2-1).

To evaluate the relationship between hydrology and occurrence of ridge senescence, we compared certain components of hydopattern within each PSU from EDEN with frequency of ridge senescence based on 2004 aerial images.

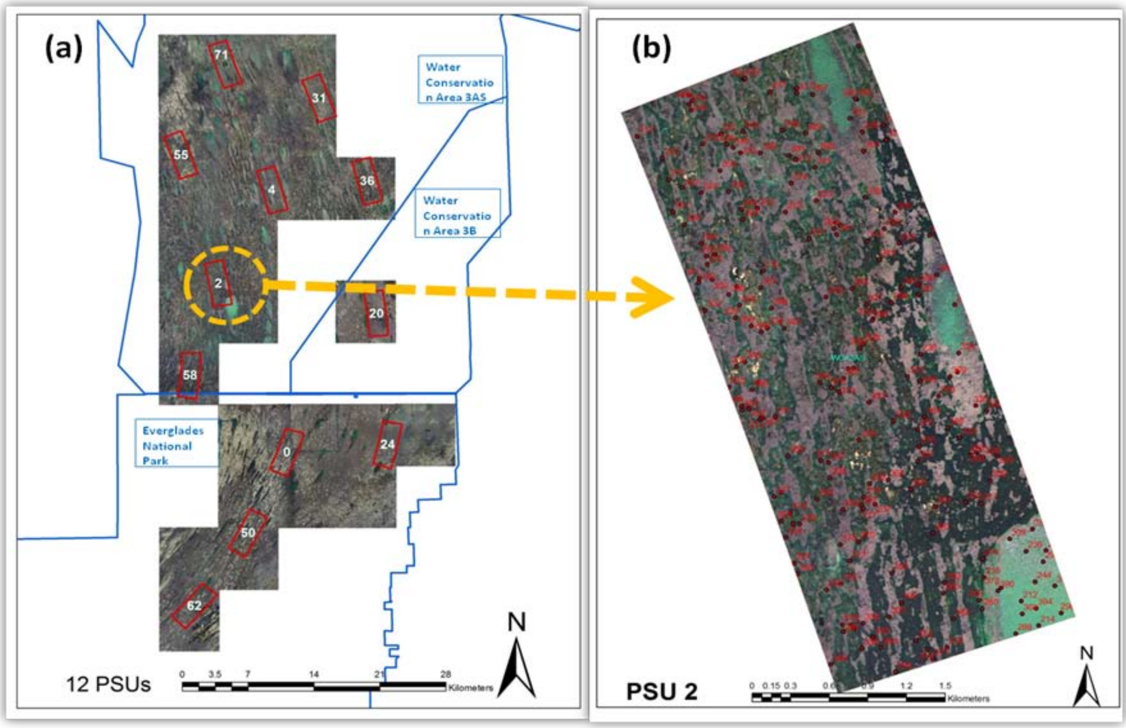


Figure 2-1. Probabilistic Sampling Units (PSUs) in (a) WCA 3A, WCA 3B, and ENP and (b) PSU 2 with randomly generated 200 points (red dots)

Table 2-1. Classification Scheme for Photointerpretation

Major Class	Subclass	Remark
Ridge	Healthy Ridge	
	Type I Ridge Senescence	Severity 1, 2, and 3
	Type II Ridge Senescence	
	Type III Ridge Senescence	
Slough	Periphyton	
	Open Water	

	Floating-leaved Plants
Tree Island	
Disturbed Area	

Hydrologic Data Collection

For this study, we used hydrologic data from the Everglades Depth Estimation Network (EDEN) developed by Palaseanu and Pearlstine (2008) using radial basis function interpolation and the multi-quadric method in ArcGIS 9.1 (ESRI) (Palaseanu and Pearlstine 2008). EDEN is an integrated network of real-time water level monitoring, ground elevation modeling, and water surface modeling that provides scientists and managers with current(1999-present), on-line water depth information for the entire freshwater portion of the Greater Everglades with 400m x 400m resolution (Telis et al. 2006). In order to develop Digital Elevation Model (DEM) for EDEN, the USGS developed a helicopter-based instrument, known as the Airborne Height Finder (AHF), which is able to measure the terrain surface elevation in a noninvasive, nondestructive manner (Desmond 2003). The water level network consists of hourly water level data from 253 gaging stations which have telemetry equipment that provides data on a daily basis. In addition to interpolated water level data, the EDEN provides water depth data which is the difference between the water surface elevation and the ground surface elevation.

Since EDEN dataset with 400m x 400m resolution was not sufficient to differentiate microtopographic differences between ridge and slough, we applied an offset value based on the average elevation differences between ridge and slough from previous studies (Jorczak 2006) as well as other data collected in this study. Due to limited available dataset, we were only able to calculate these offset elevations with any degree of certainty for 9 PSUs. The offset values were added to DEM elevations in order to estimate realistic ground elevation for ridge communities within the study area (Table 2-2). Water depths were estimated by subtracting the offset ground elevation from EDEN water level data. Offset values in WCA-3A and WCA-3B were slightly higher than the 15cm which was reported by Givnish et al. (2008), but slightly lower for PSU 71 reported by Min et al. (2010)(Givnish et al. 2008, Min et al. 2010).

Table 2-2. Offset elevation values applied to EDEN DEM as a means to more accurately predict hydrologic conditions on ridges.

PSU	Area	Offset Elevation Difference (cm)	Source of Data
71	WCA3A	16.3	Within PSU measurements, this report
31	WCA3A	N/A	Insufficient information
55	WCA3A	N/A	Insufficient information
36	WCA3A	N/A	Insufficient information
4	WCA3A	18.2	Within PSU measurements, this report
2	WCA3A	21.5	Within PSU measurements, this report
58	WCA3A	22.3	Linear interpolation using PSU 71, 4, and 2
20	WCA3B	6.1	Within PSU measurements, this report
24	ENP	5.0	Estimated from nearest point of Jorczak (2006) sample station SS1S, 1.99 km from PSU
0	ENP	14.1	Estimated from nearest point of Jorczak (2006) sample station SS1N, 3.93 km from PSU
50	ENP	15.2	Linear interpolation from PSU 24, 0 and 62
62	ENP	16.2	Within PSU measurements, this report

RESULT AND DISCUSSION

Photointerpretation Keys for Ridge Senescence

The first step to quantify the occurrence of ridge senescence was to develop the photointerpretation keys. For the purpose of this study, we have four major classes; 1) Ridge, 2) Slough, 3) Tree island, or 4) Disturbed based on our aerial and ground survey. Ridge class is further divided into Healthy, Type I ridge senescence, Type II ridge senescence, Type III ridge senescence and slough class is also divided three sub classes; periphyton, open water, or floating-leaved plant. Type I ridge senescence was further categorized into three degrees of severity which are based on the visual expression of the Type I condition in the aerial image (Table 2-1).

There is a high degree of certainty that Type I ridge senescence with severity class 1 is present and is extensive on the ridge. Type I ridge senescence with severity class 2 would indicate that the condition is present, but may be in an early stages of recovery. Type I ridge senescence with severity class 3 would indicate that the condition is likely present, but may be in a later stage of recover or that conditions at the time of the aerial photograph were not as definitive in allowing a distinction between Type I and other interpretation categories.

The photointerpretation keys can be applied to aerial imagery or other remote spectral platforms to evaluate the extent of ridge senescence in Everglades. Each class has different visual signatures that allow interpretation of community types and are visualized below in figures 2-2 to 2-10 from perspective of the DOQQ, low altitude aerial survey and ground level.

Figure 2-2. Ridge - Healthy Sawgrass: DOQQ (left), aerial survey (center), ground level image (right). The characteristics of this class are slightly purple or pink color, fine to very fine and homogenous texture

Figure 2-3. Ridge - Type I Ridge Senescence: This class often shows light purple or pink color in the 2004 DOQQ and coarse texture but there are patches (living sawgrass tussocks) inside of ridge along with other vegetative communities (green color) such as *Cephalanthus occidentalis* or *Nymphaea odorata* with dark color (open water).

Figure 2-4. Ridge - Type II Ridge Senescence: This class shows a patchy (dark color) with distinct boundary surrounded by relatively healthy sawgrass community with purple or pink color and medium to coarse texture. The shape is small and amorphous, but generally circular rather than linear

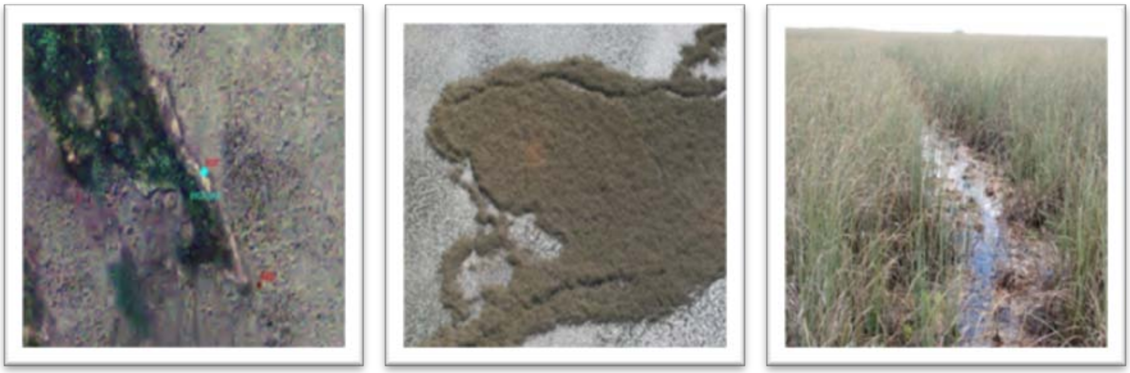


Figure 2-5. Ridge - Type III Ridge Senescence: The representative pattern of this class is distinct linear shape with dark color paralleling the boundary of ridge.

Figure 2-6. Slough - Periphyton: The background color is typically dark but periphyton community shows white or light yellow color with amorphous pattern. The texture is relatively smooth and fine.

Figure 2-7. Slough – Open Water: Open water is characterized by black color, fine and smooth texture without green dots

Figure 2-8. Slough – Floating-Leaved plant: green dots with black background

Figure 2-9. Tree Island: The color is light green to dark green and texture is coarse. This show tear- drop patter paralleling to hydrologic gradient

Figure 2-10. Disturbed: This class shows non-directional distinct line with dark color due to airboat trail, or water control structure and buildings

For the validation of photointerpretation key in this study, we compared our data to existing vegetation cover data. Givnish et al. (2008) visually assigned local patches of vegetation to eight a priori categories: (1) flooded slough (open water with *Nymphaea, Utricularia* and periphyton dominant); (2) emergent slough (*Eleocharis* spp. often dominant); (3) slough–ridge transition; (4) short-sawgrass ridge (dominated by *Cladium jamaicense* < 125 cm tall); (5) tall-sawgrass ridge (*Cladium* > 125 cm tall); (6) ridge–tree island transition; (7) low tree island (fringes and tails of tree islands, dominated by *Annona glabra, Cephalanthus occidentalis* and *Salix caroliniana*); and (8) tall tree island (raised cores and bayheads dominated by a variety of subtropical trees, including *Chrysobalanus icaco, Ficus aurea, Myrica cerifera* and *Persea palustris*) (Givnish et al. 2008). Since we used different classification scheme, we have to assume flooded slough, emergent slough, slough-ridge transition as a slough community and short sawgrass ridge, tall sawgrass ridge, and ridge-tree island transition as a ridge community based on our classification. The percent coverage of slough vegetation and ridge community were 50.1% and 45.1%, respectively, which were very close to Givnish's data, 44.8% for slough and 47.6% for ridge. We also found that there is only a slight discrepancy in tree island community, which may be a result of different classification schemes (Table 2-3).

Table 2-3 Comparison of percent coverage of vegetation between our data and Givnish et al.'s data

Study Area	Community Type					
	Flooded Slough	Emergent Slough	Slough-Ridge Transition	Short-Sawgrass Ridge	Tall-Sawgrass Ridge	Ridge-Tree Island Transition
Central WCA-3A	21	25	13	1	21	28
Southern WCA-SA	47	35	17	12	42	64
Coverage (%)		44.8			47.6	
WCA-3A		Slough			Ridge	
		45.1			50.1	

Frequency Analysis of Ridge Senescence

Ridge senescence as a percentage of total ridge area occurred to varying degrees throughout WCA 3A, 3B, and ENP in 2004 (Table 2-4). The proportion of healthy ridge decreased from northern WCA (66.7 %) to southern WCA (19.7%). The occurrence of all types of ridge senescence (that is, Type I, II, and III) increases from northern part of WCA 3A to southern part (Figure 2-11). Type I ridge senescence was the most frequently observed type of ridge senescence in all PSUs.

Table 2-4. Frequency Analysis of Ridge Senescence in WCA 3A, WCA 3B, and ENP. PSU's are listed from north to south within each water region. Values represent the % of ridge within a particular PSU.

			PSU											
			71	31	55	36	4	2	58	20	24	0	50	62
Ridge	Healthy		66.7	48.0	53.7	44.8	41.9	35.5	19.7	66.2	52.7	61.2	51.9	46.9
	Type I by intensity class	1	28.3	33.3	36.8	36.8	43.4	26.3	31.0	15.5	31.5	25.6	17.0	35.4
		2	5.0	17.9	8.4	10.3	10.1	25.0	29.6	12.8	9.7	7.4	13.3	12.3
		3	0.0	0.0	1.1	0.0	1.6	10.5	18.3	5.4	3.0	5.0	7.4	2.3
	Total Type I		33.3	51.2	46.3	47.1	55.1	61.8	78.9	33.7	44.2	38.0	37.7	50.0
	Type II		0.0	0.8	0.0	8.0	1.6	1.3	1.4	0.0	0.0	0.0	0.0	0.0
	Type III		0.0	0.0	0.0	0.0	1.6	1.3	0.0	0.0	3.0	0.8	10.4	3.1
	Total		100											

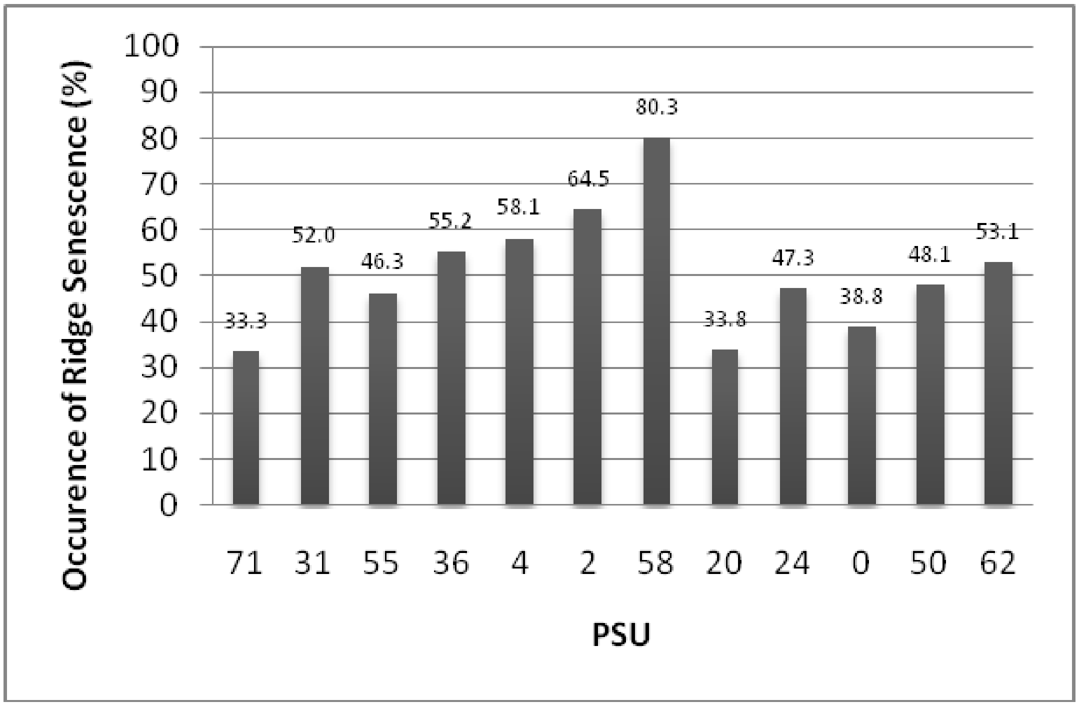


Figure 2-11. The occurrence of all types of ridge senescence with hydrologic gradient from northern WCA 3A to ENP

Relationship between Ridge Senescence and Hydrology

From our previous survey on occurrence of ridge senescence, it is apparent that Type I ridge senescence is quite prominent in some areas of the southern Everglades and that Type III ridge senescence, although of significantly lower percent cover is also prominent especially in southern WCA-3A and within ENP. As we can see in Figure 2-11, we found a spatial gradient in the occurrence of ridge senescence from north to south, but this pattern does not seem to be contiguous. Instead, there appears to be two separate gradients, one for PSU's in WCA-3A (71, 31, 55, 36, 4, 2 and 58), and the other for PSU's in ENP (24, 0, 50 and 62) and WCA-3B (20).

Although causal mechanisms of Type I ridge senescence are still unknown, we wanted to investigate the possible connection between ridge senescence and hydrology as a starting point to narrow hypothesis involving Type I ridge senescence. We found that water depths were most strongly related to the occurrence of ridge senescence during the fall and early winter (from September to February) with an R^2 value of 0.415 to 0.539 (Table 2-5 and Figure 2-12).

Table 2-5. R^2 values from Linear Regression of Occurrence of Ridge Senescence and monthly average water depth (Type I, II, and III)

	R^2		
	All	WCA-3A	ENP
January 2004	0.446	0.946	0.969
February 2004	0.415	0.930	0.361
March 2004	0.097	0.894	0.385
April 2004	0.003	0.849	0.582
May 2004	0.029	0.729	0.631
June 2004	0.196	0.027	0.496
July 2004	0.241	0.434	0.479
August 2004	0.010	0.003	0.305
September 2004	0.196	0.910	0.886
October 2004	0.267	0.577	0.958
November 2004	0.425	0.925	0.855
December 2004	0.455	0.937	0.968
January 2005	0.539	0.938	0.938

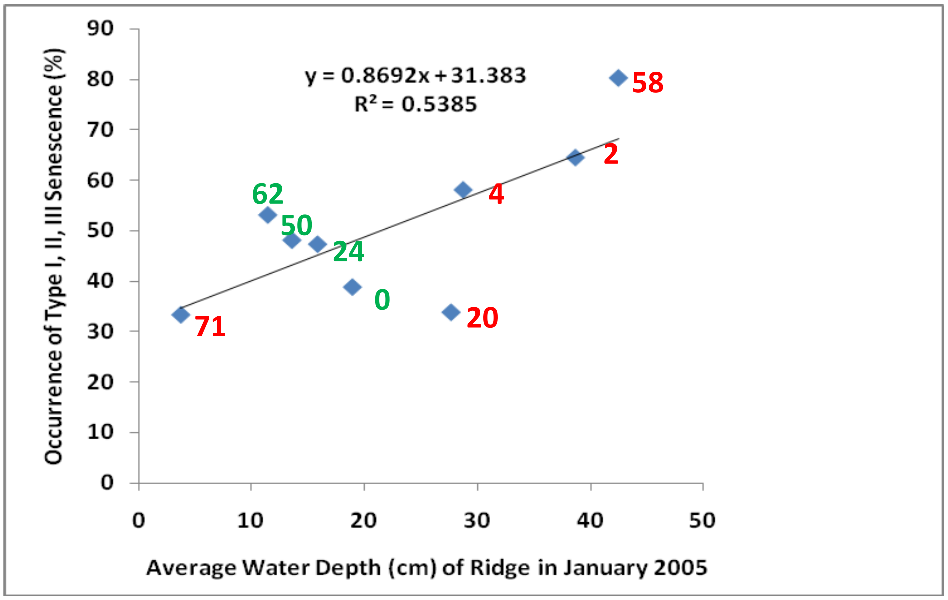


Figure 2-12. Regression of ridge senescence with water depth in January 2005, the same month the aerial photograph used in ridge senescence interpretation was taken (Green numbers and Red numbers represent PSUs in ENP and WCA 3A and 3B, respectively).

This relationship was much stronger (often greater than 0.900) when PSU's in WCA-3A and ENP were analyzed separately (Figure 2-13). However, when analyzing the data separately for each water region; the relationship, although almost equally strong, was in two opposite directions with WCA-3A data showing a positive trend and ENP data showing a negative trend between ridge senescence and water depths. Therefore, proper explanations are required to explain this relationship.

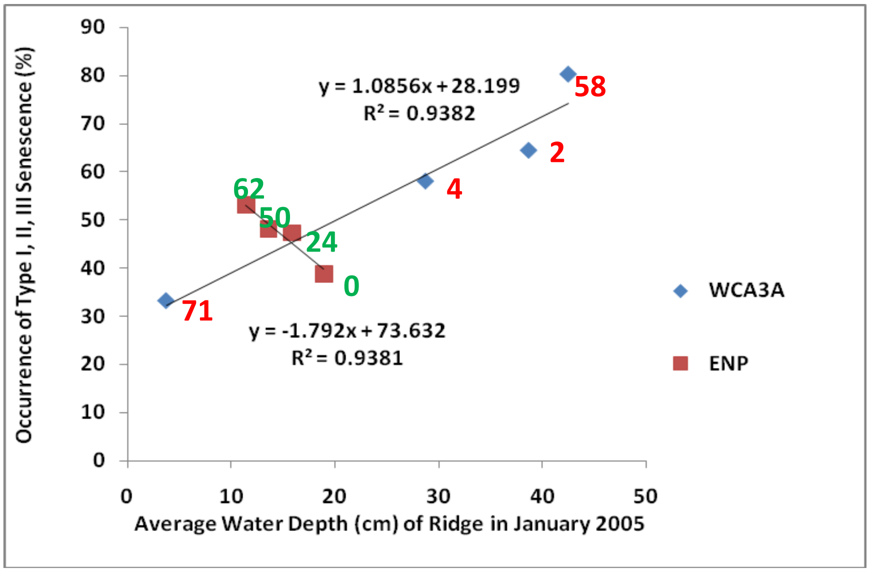


Figure 2-13. Independent regression of ridge senescence with January 2005 water depth for PSU's in WCA-3A and ENP (Green numbers and Red numbers represent PSUs in ENP and WCA 3A, respectively).

As shown in Figure 2-13, average water depth of ridge in January 2005 for PSU 71 has quite different value from others in WCA 3A considering same hydrologic unit. Since this value strongly affects our regression model, we have to verify that water depth in PSU 71 is appropriate to find the relationship between occurrence of ridge senescence and hydrologic factor. In order to test this hypothesis, we calculated additional hydrologic factors that can possibly affect photointerpretation of ridge senescence.

The percent of ridge points with water depth higher than 0 cm was calculated by; (The number of ridge points with water depth higher than 0 cm) / (Total ridge points) *100 on January 24, 2005 which is actual flight date to take DOQQs used in this study. Ridge water depth and slough water depth represent calculated water depth using offsets on January 24, 2005.

As shown in Table 2-6, percent of ridge point with water depth > 0 for PSU 71 was significantly lower value (49.2 %) compared to other PSUs, which indicates that approximately half of ridges in PSU 71 were exposed to the air. Furthermore, ridge and slough water depth indicates 1.7 cm and 18.1 cm, which are lower than other PSUs. The EDEN water depth model on same day also showed that PSU 71 is located in relatively low water depth condition (Figure 2-14). Based on these results, we may expect that photointerpretation methodology could be limited under extremely low depth condition since this method was mainly based on the visual characteristics of ridge such as colors, texture, and pattern. Especially, it is highly likely that texture could be misunderstood due to reduction of contrast. Exposed soil surface can be seen same texture like sawgrass whereas open water shown in black color enhances texture differences.

Table2-6. The percent of ridge point with water depth higher than 0, ridge water depth, slough water depth on January 24, 2005

	PSU								
	71	4	2	58	20	24	0	50	62
The percent of ridge point with water depth >0 cm (%)	49.2	100.0	100.0	88.7	100.0	100.0	100.0	100.0	100.0
Ridge water depth (cm)	1.7	26.3	36.5	40.9	26.3	13.1	14.1	9.5	7.6
Slough water depth (cm)	18.1	43.7	58.7	70.8	33.1	15.2	29.0	23.9	24.2

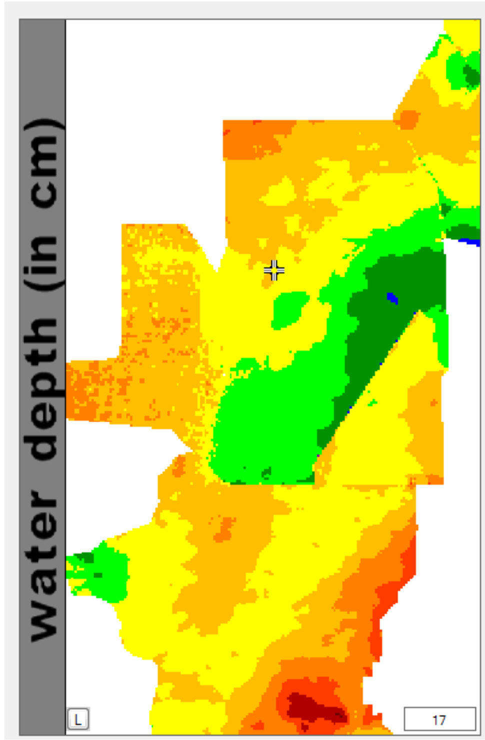


Figure 2-14. EDEN water depth model on January 24, 2005 (Cross indicates the center point of PSU 71)

Thus, assuming that we can exclude PSU 71, two types of regression analysis were conducted. Linear regression result showed that there was a relatively strong positive relationship between all PSU's except PSU 71 with R^2 value of 0.436 even though R^2 value is slightly less than 0.539 (Figure 2-15). However, second degree polynomial regression showed better fitting curve with high R^2 value with 0.809 (Figure 2-16).

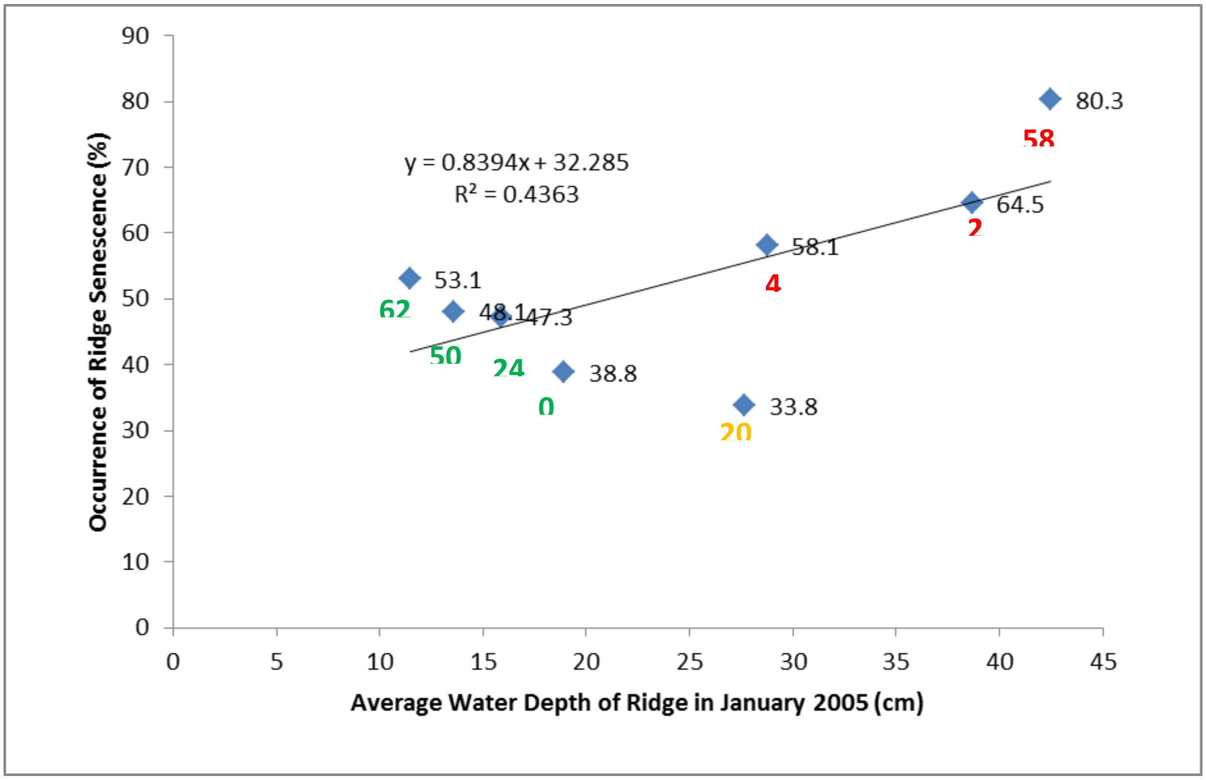


Figure 2-15. Linear Regression of ridge senescence with water depth in January 2005, excluding PSU 71 (Green numbers, Red numbers, and Orange numbers represent PSUs in ENP, WCA 3A, and WCA 3B, respectively)

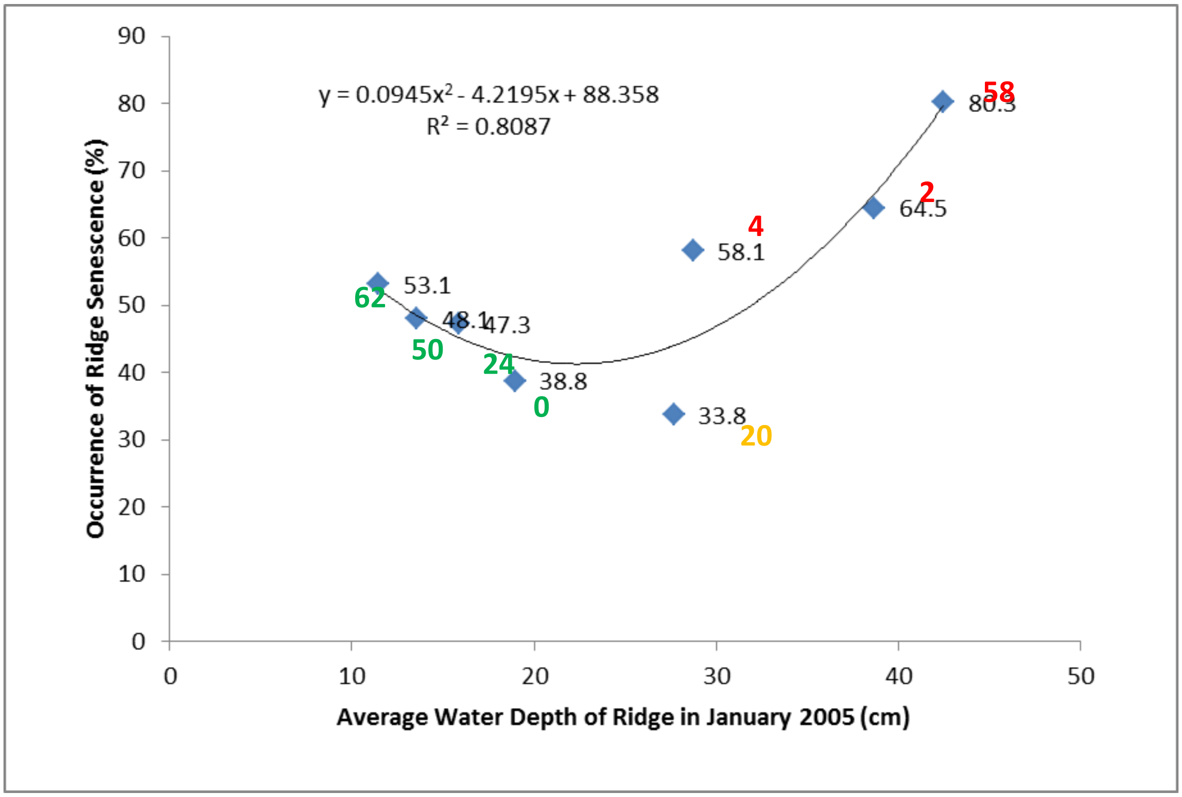


Figure 2-16. Second Degree Polynomial Regression of ridge senescence with water depth in January 2005, excluding PSU 71 (Green numbers, Red numbers, and Orange numbers represent PSUs in ENP, WCA 3A, and WCA 3B, respectively)

Conclusion

From previous investigation, we found that it is possible to use photointerpretation keys to detect ridge senescence at a high degree of confidence, which can then be used to evaluate spatial and temporal occurrence. We also found a high frequency of Type I ridge senescence in southern regions of WCA-3A. Type I ridge senescence was also prevalent within Everglades National Park with 35% or more of ridge areas impacted. Type III ridge senescence was also commonly observed with six out of 12 PSU's surveyed having some Type III ridge senescence with 3.3% of the ridge area impacted in those PSU's where Type III ridge senescence occurred.

Efforts to relate hydrologic characteristics to ridge senescence showed mixed results. There was a relatively strong positive relationship between all PSU's and water depth with an R^2 value of 0.415 to 0.539 depending on month of the year when average water depths were taken. This relationship was much stronger (often greater than 0.900) when PSU's in WCA-3A and ENP were analyzed separately. However, when analyzing the data separately for each water region; the relationship, although almost equally strong, was in two opposite directions with WCA-3A data showing a positive trend and ENP data showing a negative trend between ridge senescence and water depths. Considering extremely dry condition in PSU 71, we might found a relatively strong positive relationship between all PSU's except PSU 71 although R^2 value is slightly less than 0.539. Also, second degree polynomial regression model can be a better model rather than linear model. However, the causal mechanisms of at least Type I ridge senescence are not clear and will require further investigation to determine what factors may be leading to the extensive die-back of sawgrass on ridges throughout much of the southern Everglades

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