# Spatial distribution of wetland vegetation surrounding alligator holes in Everglades National Park, Fl, USA

Danielle E. Ogurcak[1], Jay P. Sah[1], Michael S. Ross[1], Frank J. Mazzotti[2], and Kenneth G. Rice[3]

[1]Florida International University, Miami, FL, USA, [2]IFAS, University of Florida, Davie, FL, USA, [3]USGS, Gainesville, FL, USA

## Introduction

Alligator holes serve an essential role in the Everglades' landscape by functioning as dry-season refugia for many species of invertebrates, fish, amphibians, and reptiles, and also by providing important nursery and foraging areas for many bird species. The American alligator, *Alligator mississippiensis*, maintains these small ponds due to its need for deeper areas of water (e.g., for courtship and mating) in an otherwise shallow marsh environment (Mazzotti and Brandt 1994). Additionally, the disturbance created by resident alligators prevents vegetation succession (holes from becoming overgrown with aquatic and emergent vegetation, Kushlan 1972) and increases habitat heterogeneity as the movement of soil to the edge of the hole creates banks of higher elevation supporting vegetation with different requirements for seed germination and survival (Craighead 1968). Edges of alligator holes are often colonized by woody tree species – with the first colonizer often being willows (*Salix caroliniana* Michx.) (Craighead 1968). Alligator holes are found throughout the Greater Everglades' landscape in a variety of wetland habitats including sawgrass marsh (dominated by *Cladium jamaicense* Crantz), wet prairie (dominated by *Eleocharis* spp. and *Rhynchospora* spp.), and open slough (dominated by floating aquatic plants like *Nuphar advena* (Aiton)Aiton f. and *Nymphaea odorata* Aiton and submerged aquatics (*Utricularia* spp.) (Loveless 1959, Gunderson 1994).

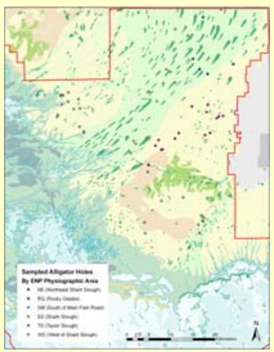
**Above**: picture of alligator hole in a limestone sinkhole (location Rocky Glades) taken May 2006 by Jemeema Carrigan. Note the clear difference in origin between the 2 holes.

**Below**: picture of alligator hole excavated in the peat (location west of Shark Slough) taken May 2007 by Wellington Guzman.

**W**hile the origin of any particular alligator hole on the landscape is not well understood, possible hypotheses include natural depressions in the limerock, excavation by alligators, peat fires, or some combination of these factors. Indeed, there is evidence that many holes were created as a result of peat fires that burned during a period of increased fire frequency and intensity in the Everglades system in the post-drainage era (Bond et al. 1980). Additionally, the edges of many alligator holes are dominated by willows, *Salix caroliniana*, providing increased support for a hypothesis of changes in fire regime contributing to a greater number of alligator holes on the landscape - reports as far back as the late 1950s indicate that willows had become a far more common component of the landscape as a result of the increased frequency of tree island fires (Wade et al. 1980). This line of thinking would suggest that the present-day number of alligator holes in slough habitat is much greater than in the pre-drainage system. Combined with the assertion by F. C. Craighead, that in the early decades of the twentieth century, the preferred habitat of alligators was predominately the freshwater marshes and creeks to the landward side of mangrove zone and marl prairie, it seems very likely that a shift in alligator distribution in the twentieth century has resulted in a landscape and ecosystem that is completely novel.

## Objectives

With the aim of both understanding how the current landscape evolved and how distribution of alligators and their resultant effects on the landscape will shift as a result of proposed changes in water delivery to Everglades National Park (ENP) from CERP, this research attempts to characterize the spatial variation in the current vegetation composition of alligator holes. Specifically, we explore the relationships between vegetation composition and physiographic region, hydrology, and maintenance by resident alligators, and compare the extent of the current distribution and composition of alligator holes to prior conditions (1940s), with the overall goal of forecasting the possible successional trajectories of these holes.




Sixty-two sampled alligator holes in Everglades National Park (ENP). Physiographic layer courtesy of ENP.

## Methodology

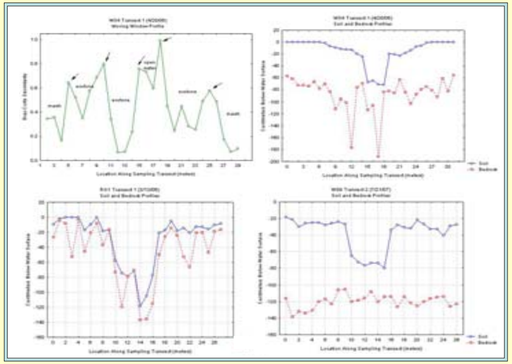
To quantify the current vegetation surrounding alligator holes within ENP, a stratified random sample of alligator holes was selected in physiographic areas in which holes had been mapped from Digital Orthophoto Quarter Quads (DOQQs) and verified by helicopter in 2005. From January 2006 through August 2007, sixty-two alligator holes were visited and sampled in slough and marl prairie habitat within ENP. Sampling was done using two perpendicular transects that extended from the center of each hole, running through the ecotone and into the surrounding marsh. Water depth and muck depth were measured at 1-meter intervals, and vegetation was sampled using the line-intercept method. Additionally, the presence of alligators and other wildlife was noted at each alligator hole.

**Above left**: Alligator hole south of Main Park Road in marl prairie habitat taken July 2006 by Danielle Ogurcak. Note perpendicular transects.
**Above right**: Sampling of water depth at interval start point in alligator hole overgrown by cattail (*Typha* sp.) Picture by Ryan Lynch.

## Data Analysis

*Moving Split-Window Analysis*

Vegetation communities in four zones (marsh, tree island, ecotone, open water) along each transect were characterized by using a moving split-window method (Whitaker 1960, Ludwig and Cornelius 1987, Wierenga et al. 1987). This method involves calculating dissimilarity between two halves of a window, where the window contains data from contiguous sampling units (intervals along a transect), followed by movement of the window one interval further and the process repeated. Windows of both two and four sampling intervals were used. Dissimilarity peaks provided direction for determining break points between zones. Along with the guidance of soil and bedrock profiles from measured water and muck depths, a total of 447 sampling units were aggregated from transect intervals at the 62 alligator holes.



**Top left**: Results of moving split-window analysis for WS4 transect 1. Arrows point to dissimilarity peaks. Compare this with the **top right** graph of soil – bedrock profiles of the same transect. The open water –ecotone transitions are clear in both graphs.

The bottom graphs depict soil-bedrock profiles of alligator holes of two clearly distinct origins. The **bottom left** graph is from a transect through an alligator hole in the Rocky Glades. Notice how the hole occurs in a pre-existing limestone sinkhole. The **bottom right** hole is from a transect through a hole west of Shark Slough. The lack of change in the bedrock depth indicates that this hole could have been created through alligator excavation or a peat fire.

*Non-Metric Multi-Dimensional Scaling*

In order to examine and compare relationships between plant communities surrounding alligator holes, we ordinated relativized species abundances (109 species total) using non-metric multi-dimensional scaling (NMS) (Kruskal 1964) in Primer 6.0. Prior to ordination, outlier analysis was run in PC-ORD (McCune and Medford 1999), and indicated the presence of 1 outlier which was removed before relativization and NMS.

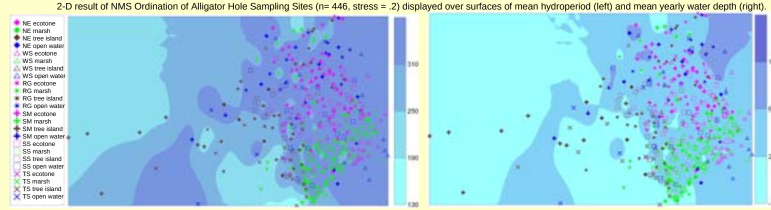
*Hydroperiod and Mean Water Analyses*

Relationships between ordination axes and environmental gradients, including yearly mean water depth, average hydroperiod (00-01 to 06-07), and physiographic location, were examined. EDEN stage data was used to calculate mean water depth per year over a seven-year period from May 1, 2000 to April 30, 2007 for each sampling location (n=446). Average hydroperiod was calculated for the same time period. Interpolation by kriging in Surfer 8.0 was used to create contour maps.

## Results

The NMS ordination clearly shows that ecotone and marsh sampling sites are tightly clumped and aggregated along a definite axis. The ecotone and marsh sites were each characterized by a few dominant species (e.g., *Pontederia cordata* - ecotone, *Cladium jamaicense* – marsh). Within the tree island and open water zones, there is a much larger spread between sampling sites, indicating greater variability . Open water and ecotone are both clearly correlated with longer hydroperiods and larger mean water depths. By physiographic area, Taylor Slough and southern marl prairie sites display the greatest distance from the overall cluster of sites. Shorter hydroperiods and smaller mean yearly water depths define tree islands in marl prairies in the southern part of the park, as well as marsh community in NE Shark Slough. The vegetation surrounding alligator holes is clearly being determined by a combination of hydrologic gradients, the physiographic area of ENP in which they occur, and active maintenance by alligators. Indeed, alligators were observed at more than half of sampled holes. Data needs further investigation to elucidate patterns of variation among sites and their relationship to environmental gradients.

2-D result of NMS Ordination of Alligator Hole Sampling Sites (n= 446, stress = .2) displayed over surfaces of mean hydroperiod (left) and mean yearly water depth (right).




## 1940s Aerial Photo Interpretation

We compared locations of the 62 sampled alligator holes to 1940s aerial photography to determine if alligator holes were present on the landscape at that time. The presence or absence of open water surrounded by vegetation and/or alligator trails was used as an indicator of the presence of an alligator hole. Of the 62 sampled holes, 58 were identified as distinguishable on the 1999 DOQQs. Of those holes, 85% were identified as likely present in the 1940s aerial photos, indicating that the current distribution of alligator holes on the landscape has not changed drastically in the past 60 years. Since 1940s aerials are the oldest photos available, an understanding of the historic (pre-drainage) distribution of alligator holes will require other means of scientific inquiry.

Hole RG6 (below left) is readily discernible in both the 1999 DOQQ and the 1940s aerial photography. TS3 (below right) is quite obvious in the 1999 imagery, but not particularly visible in the 1940s imagery and might not have been a feature on the landscape at that time.

## Discussion

Analysis of the dataset is ongoing. Next steps include the identification of dominant species by sampling site, as well as an investigation of how alligator maintenance and likely origin of an alligator could be influencing vegetation community distribution. As we continue to explore the relationship between hydrology, alligator maintenance, and plant species distribution, we hope to forecast the effects that changes in water regime will have on the community composition of the thousands of alligator holes that pepper the Everglades' landscape. We propose that future research take a systems' view of the landscape, synthesizing work from all physiographic areas within the Everglades where alligators have served as ecosystem engineers.

### Literature Cited

Clarke, K. R. and R. N. Gorley. 2001. PRIMER: Plymouth Routines in Multivariate Ecological Analysis, version 6.0. Primer-E Ltd., Plymouth, UK.
Craighead, F. C. 1968. The role of the alligator in shaping plant communities and maintaining wildlife in the southern Everglades. Florida Naturalist 21:2-7, 69-74, 94.
Gunderson, Lance H. 1994. Vegetation of the Everlgades: Determinants of community composition. P. 323-340. *In* S. M. Davis and J. C. Ogden (eds). Everglades: The Ecosystem and Its Restoration. St. Lucie Press, Delray Beach, FL, USA.
Kruskal, J. B. 1964. N0n-metric multi-dimensional scaling: a numerical method. Psychometicka 29: 115-129.
Kushlan, James A. 1972. An ecological study of an alligator pond in the Big Cypress swamp of southern Florida. M.S. Thesis. University of Miami, Miami, FL, USA.
Kushlan, James A. 1974. Observations of the Role of the American Alligator (Alligator mississippiensis) in the Southern Florida Wetlands. Copeia 1974(4): 993-996.
Loveless, Charles. M. 1959. A study of the vegetation in the Florida Everglades. Ecology 40 (1): 1-9.
Ludwig, J. A. and J. M. Cornelius. 1987. Locating discontinuities along ecological gradients. Ecology 68: 448-450.
Mazzotti, F. J. and L. A. Brandt. 1994. Ecology of the American alligator in a seasonally fluctuating environment. P. 485-505. *In* S. M. Davis and J. C. Ogden (eds). Everglades: The Ecosystem and Its Restoration. St. Lucie Press, Delray Beach, FL, USA.
McCune, B. and M. J. Medford. 1999. PC-ORD: Multivariate Analysis of Ecological Data, version 5.0. MjM Software, Gleneden Beach, Oregon, U.S.A.
Wade, D., J. Ewel, and R. Hofstetter. 1980. Fire in South Florida Ecosystems. Forest Service General Technical Report S E-17. Southeastern Forest Experiment Station, Asheville, NC.
Whitaker, R. H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30: 270-338.
Wierenga, P. J., J. M. H. Hendrickz, M. H. Nash, J. Ludwig, and L. A. Daugherty. 1987. Variation of soil and vegetation with distance along a transect in the Chihuahuan Desert. Journal of Arid Environments 13: 53-63.

**Acknowledgements:** Everglades National Park, South Florida Water Management District, and U.S. Army Corps of Engineers for funding and/or logistical support; South Florida Terrestrial Ecosystem Lab at FIU for data analysis support; Ryan Lynch, Jemeema Carrigan, Mike Rochford, Wellington Guzman, Deborah Kramp, and many others for tireless and fearless hours of field work in alligator holes.