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Mapping the Distribution of Barrier Island Slash Pine Woodland and Determining Growth Responses of Pinus elliottii to Hurricane Katrina (2005) on Cat Island, Mississippi

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MAPPING THE DISTRIBUTION OF BARRIER ISLAND SLASH PINE WOODLAND AND DETERMINING GROWTH RESPONSES OF *PINUS ELLIOTTII* TO HURRICANE KATRINA (2005) ON CAT ISLAND, MISSISSIPPI

by

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ABSTRACT

MAPPING THE DISTRIBUTION OF BARRIER ISLAND SLASH PINE WOODLAND AND DETERMINING GROWTH RESPONSES OF *PINUS ELLIOTTII* TO HURRICANE KATRINA (2005) ON CAT ISLAND, MISSISSIPPI

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Barrier islands are ubiquitous features along the Atlantic and Gulf of Mexico North American coastline and are subjected disturbances such as extreme episodic events. The wind, waves, and storm surges of Hurricane Katrina heavily impacted the Mississippi–Alabama barrier island chain on August 29, 2005. Cat Island experienced a 7-m storm surge, the highest wind energy in the chain, but was estimated to have the least amount of forest mortality. The purpose of this study was to investigate the distribution of *Pinus elliottii* on Cat Island Mississippi and evaluate relationships of elevation with mean radial growth rate (mm y^{-1}), stem diameter (cm), and change in radial growth rate (% change) five years post Hurricane Katrina. The overarching hypothesis is that growth rate in *P. elliottii* on Cat Island, is a function of elevation. The two sub-hypotheses tested were 1) mean radial growth and stem diameter are functions of elevation and 2) growth response to Hurricane Katrina (% change) is a function of elevation. Remotely sensed data was used in conjunction with tree core and ground data to assess these relationships. Trees were selected for sampling using a point-centered quarter distance method. At each sample site, two to four radii were extracted from each tree then the stem diameter was measured. The GPS location and elevation were recorded. Decreased radial growth from Hurricane Katrina was observed in 92% of the sample population. Regression analysis

shows no relationship of radial growth and stem diameter versus elevation. The hypotheses were rejected and an alternate proposed.

DEDICATION

This thesis is dedicated to my wife, Casey, for her unconditional love and support; my daughter Allyson for teaching me the beauty of innocence and curiosity; to my parents for never giving up on me and instilling in me a strong work ethic and commitment to my passion; my grandfather Henry T. Woodyard for teaching me to love the wonder and mystery of nature, and to my friends for their love, support, and humor.

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TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF ILLUSTRATIONS

Figure

LIST OF ABBREVIATIONS

MRGR..Mean Radial Growth Rate (mm y^{-1})

GPS...Global Positioning System

MS-AL .... Mississippi–Alabama

NGOM...Northern Gulf of Mexico

RTK...Real-Time Kinematic

RTN...Real-Time Network

UAVSAR..Uninhabited Aerial Vehicle Synthetic Aperture Radar

CORS..Continually Operating Reference Station

GCGC...Gulf Coast Geospatial Center

ML.. Maximum Likelihood

NOAA...National Oceanic and Atmospheric Administration

MSL…... Mean Sea-Level

CHAPTER I

INTRODUCTION

Barrier island ecosystems are key indicators of climate change and sea level rise (Pilkey, 2003). They offer mainland protection from extreme weather phenomena and open wave and wind energies (Snyder and Boss, 2002; Stive and Hammer-Klose, 2004). Along the Atlantic and Gulf of Mexico coasts of the United States, barrier islands constitute approximately 85% of the open-ocean shoreline (Stauble, 1989). Alterations in the elevations of the land, sea, and water table appear to be primary determinants of vegetation change on barrier islands (Hayden *et al*., 1995). Biota modify geomorphic processes and landforms, and the interactions between geomorphic and ecological components are developmentally intertwined (Stallins, 2006). Bare sand is colonized by pioneer species that give rise to foredunes which are followed by transition to shrub thickets and possibly maritime forest with increasing distance from the ocean and decreasing frequency and severity of disturbance (Doing, 1985; Ehrenfeld, 1990). Saline water flooding adversely affects the distribution of many woody plants because it inhibits seed germination as well as vegetative and reproductive growth, alters plant anatomy, and induces plant mortality (Kozlowski, 1997). Plants inhabiting barrier islands tend to be highly adapted to salt spray, saltwater and freshwater flooding, drought, burial under sand, and low soil nutrient content (Lee and Ignaciuk, 1985; Oosting, 1954; Shao, Shugart, and Hayden, 1996).

Relatively little attention has been given to woody species on barrier islands; thus mechanisms controlling spatial patterns are poorly understood (Tolliver *et al*., 1997). The resiliency barrier island Slash pine woodland ecosystems (Mississippi Natural Heritage Program, 2006) exhibit to the current 21st century climate regime is uncertain. These ecosystems have adapted to open wave, wind, and current energies, as well as extreme episodic events such as hurricanes and nor'easters. The existence of barrier island slash-pine woodlands or maritime flat-wood savanna (Mississippi Natural Heritage Program, 2006) requires decadal scale environmental stability (Lucas and Carter, 2010). It has been recently discovered in the Florida Keys that Slash pine produces consistently annual growth rings and can be a useful species for various dendrochronological applications (Harley *et al.,* 2011). Tree-ring records from these areas are important because these data provide rare opportunities for understanding the ecological dynamics of tropical and sub - tropical areas (Brienen *et al*., 2009). By investigating barrier island Slash pine woodland we can gain knowledge about previous effects of historic meteoric events and climate regime. We can also expand our understanding of the spatial pattern processes in the current 21st century climate regime, including hurricane impact, sea level rise, and subsidence which all affect barrier island forest ecosystems.

During Hurricane Katrina in 2005, Cat Island (Figure 1) experienced a seven meter storm surge and received the highest wind energy of all the islands along the MS-AL barrier island chain (Figure 2) (Otvos and Carter, 2008). Mysteriously, post-Hurricane Katrina tree mortality rates were estimated to be lower on Cat Island in comparison to Ship and Horn Islands (Otvos and Carter, 2008). Casual field observations during post-storm recovery investigations led to the belief that micro-differences in elevation were driving growth and resiliency in Slash pine. The purpose of this study was to investigate *Pinus elliottii* (Slash pine) on Cat Island Mississippi after Hurricane Katrina, by evaluating the relationship between elevation related to mean radial growth rate (mm y^{-1}), stem diameter (cm), and change in radial growth rate (% change). The overarching hypothesis is that growth rate in *P. elliottii* on Cat Island is a function of elevation. The two sub-hypotheses tested were 1) mean radial growth and stem diameter are a function of elevation and 2) growth response to Hurricane Katrina (% change) is a function of elevation.

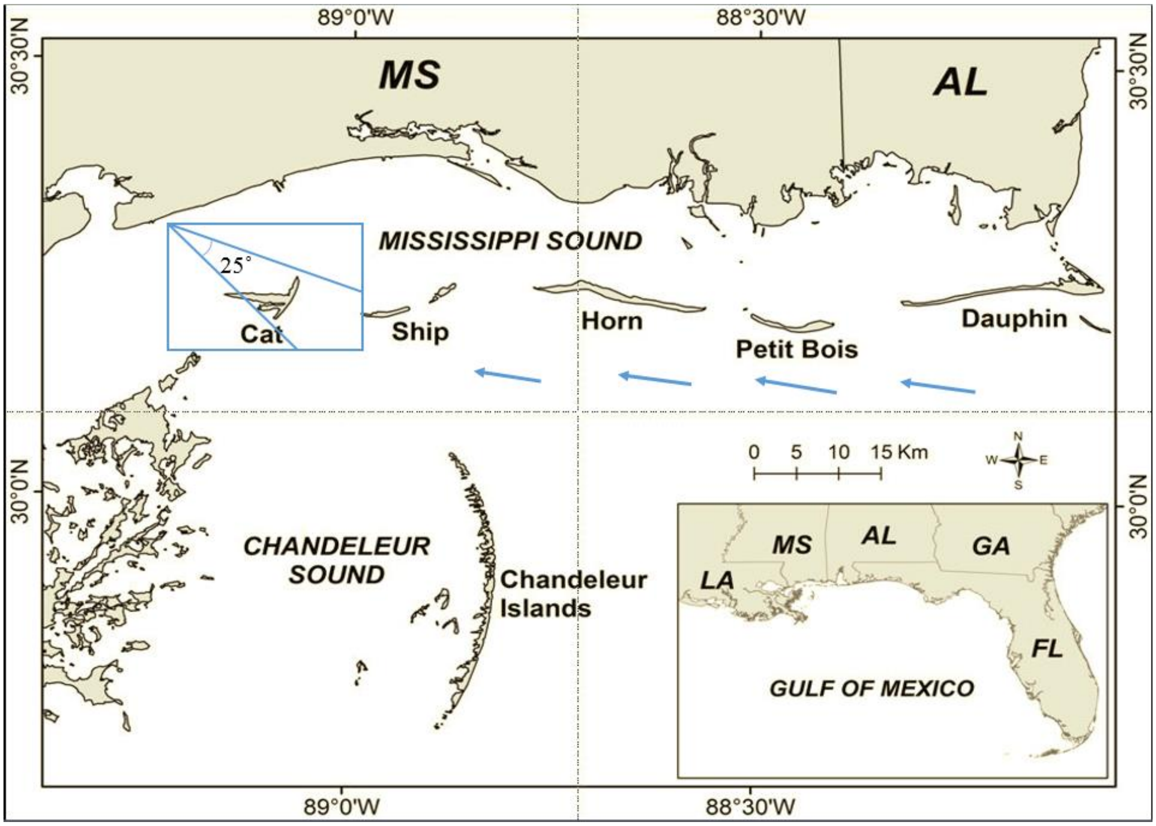

Figure 1. Map showing the Mississippi–Alabama barrier Island Chain. The blue directional arrows indicate dominant wind and wave approach as well as the 25 degree directional restriction of wave approach. The restrictive wave approach resulted in reworking the east shore, resulting in Cat Island's unique "T" shape. (After Carter *et al.,* 2010; Rucker and Snowden 1989).

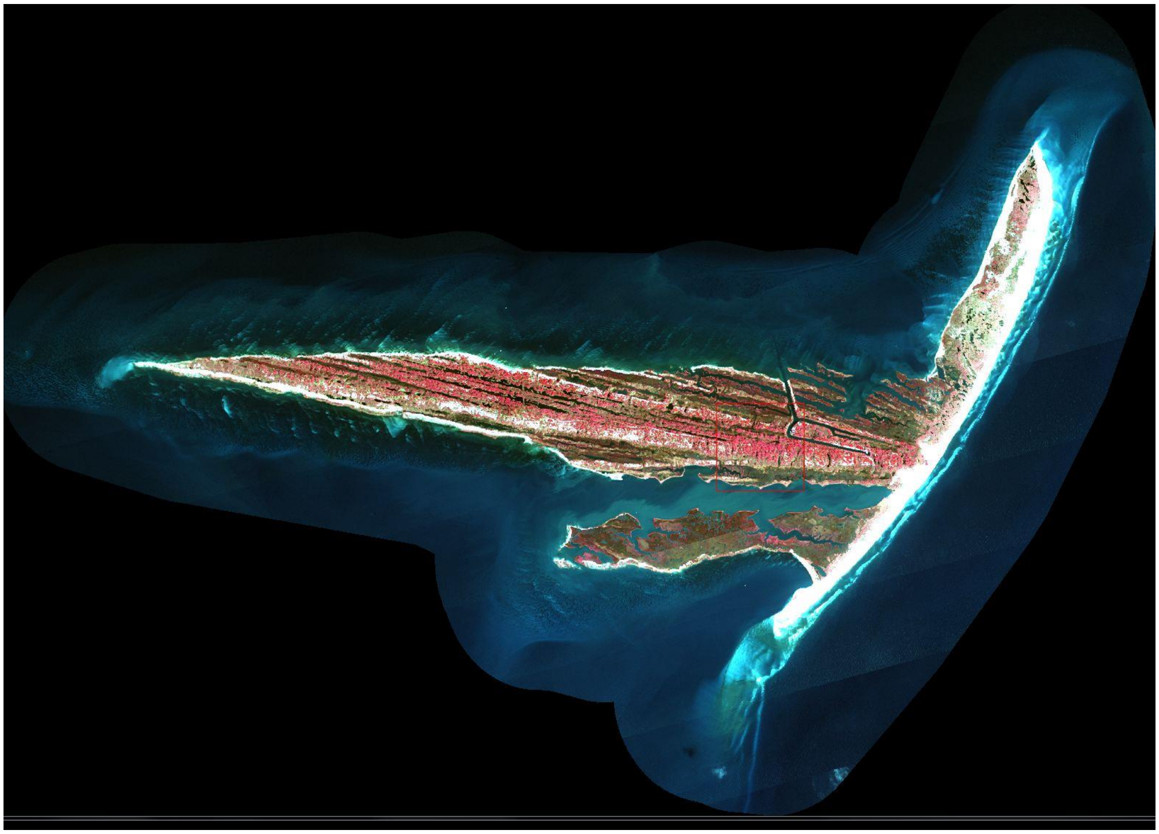

Figure 2. False color image of Cat Island. The red is accentuating Slash pine woodland habitat-type. Image produced from 2-m spatial resolution, 4.6nm spectral resolution, AISA EAGLE visible near-infrared (VNIR) sensor. This imagery was collected in October 2012 as part of an ongoing study.

Significance of Study

In the late 1700's the father of biogeography, Alexander Von Humbolt, began investigating the relationship of elevation and its influence on species distribution, growth, and biodiversity on terrigenous landscapes. Since then, macro-change elevation studies have become a familiar topic within biogeography and ecology. However, examining microtopographic differences driving growth and resiliency within forest communities on low-lying islands is much more difficult, requiring the capability of accurately and precisely measuring micro differences in elevation on the magnitude of centimeters. Cat Island, is a siliciclastic barrier island consisting primarily of alluvial

Appalachian quartz sand (Otvos and Carter 2008), while the Pine Rocklands of the Florida Keys are limestone rock-lands (Harley *et al.,* 2011).Through plot level data, the relationship of stem diameter and elevation in *Pinus elliottii* Var. *densa* was identified in the Pine-Rockland forests of the Florida Keys. The largest diameter trees are found at the highest elevation (Saha *et al.,* 2011).

Research identifies barrier island ecosystems as key indicators of global climate change and sea-level-rise. The ecosystems of different plant communities and corresponding ecotones are sensitive to increased salinities from salt spray, sea-level rise, and increasing occurrence and strength of extreme episodic events. However, understanding forest species and their ability to adapt to changing environmental conditions is important because of the likelihood that barrier island Slash pine woodland contributes to the slowing of erosion and slowing or reversal of sediment loss following heavy storms and hurricane impact. Understanding these natural processes and synergistic relationships is critical to the preservation of barrier island forest stands and barrier islands themselves. The long life and variables trees ameliorate to their island maritime landscapes affect the ecological adaptive strategies of associated plants and animals as well as aid in the islands' geomorphic stability. A better understanding of biogeomorphic relationships will aid in barrier island protection and conservation efforts.

Conservation of barrier islands is beneficial because barrier islands contribute as valuable economic coastal assets affecting tourism, fishing, and shipping. Results gathered from this work can be applied and compared to other biogeographic studies at local, regional, and global scales and would be advantageous in any biomass stress or change detection analysis with respect to extreme episodic events, global climate change, subsidence, and sea-level rise. *Pinus elliottii* will be referred to hereafter as Slash pine.

Geologic Background of the Northern Gulf of Mexico

The Northern Gulf of Mexico's geologic evolution has been controlled by eustatic glacial-interglacial cycles and corresponding changes in sea level (Boyd *et al*., 1989; Curray, 1960; Fisk, 1947; Fisk, *et al.*, 1954; Kindinger, 1988, 1989; Kindinger *et al.*, 1989; Kulp *et al*., 2002; Otvos, 2005; Wilkinson, 1975). Sea level fluctuation is a principal mechanism responsible for erosional and depositional cycles that affect the geomorphology of marginal–marine and marine sedimentary environments. The re-working and re-distribution of surficial sediment within the basin is primarily a product and function of transgressing and regressing shorelines. Fluctuating sea-levels influence sedimentary depocenters of marginal-marine environments to migrate landward or seaward and laterally. The resulting sediments found in the Northern Gulf are the product of the interactions among sea level fluctuation, sediment supply, and the underlying receiving basin geometry (Fisk, 1947; Fisk *et al*., 1954; Morton and Suter, 1996). Throughout the late Quaternary, Northern Gulf of Mexico geology has been dominated by the Mississippi and Mobile River system, which, by means of delta switching, deposited multiple overlapping deltas across the continental shelf out to the shelf break. River avulsion, forced by changes in the gradient of the coastal plain, provides more favorable paths to the basin and shifts sedimentary depocenters to new locations. As active distributaries became progressively abandoned, vertically stacked units of deltaic sediments formed (Fisk *et al*., 1954). A series of basin-ward sloping, stepped terraces across the coastal plain indicate faulting of the basin margin that occurred in response to regional sediment loading (Fisk, 1947; Otvos, 2005; Saucier, 1963). These terraces constitute the Plio-Pliestocene Prairie Formation extending across the continent above the northern Gulf, downwarping at the seaward margin where it is onlapped by recent

Holocene deposits in the Gulf basin. The downwarping occurred in response to Quaternary sediment loading of the basin, prior to the Holocene Mississippi River deltaic phases and construction of the southern Louisiana land mass (Otvos 2005 b; Saucier, 1963). The Gulf of Mexico encompasses six depositional provinces based on sediment mineralogy and texture, used to identify provenance and age, and amount of weathering and erosive re-working. Transition zones occur between provinces where type minerologies can be mixed vertically and laterally (Hsu, 1960; Isphording, 1989). The Mississippi River sediments are composed of amphiboles, dolomite, pyroxenes, epidote, ilmenite and biotite, abundant feldspar, and a montmorillonite-illite-kaolinite suite of clays (Hsu, 1960; Isphording, 1989).

Barrier Islands

Holocene barriers occur worldwide on tectonically active and passive margin coasts with wide, gently sloping continental shelves (Hayes, 1979; Stutz and Pilkey, 2002). The genesis and fate of Holocene coastal barrier islands along the Gulf of Mexico and Atlantic coasts have been the subject of ongoing debate in scientific literature (Curray and Moore, 1963; Field and Duane, 1976, 1977; Hoyt, 1967, 1968, 1970; Johnson 1919; Kwon 1969; Leont'yev and Nikiforov 1965; Otvos, 1970; Otvos 1981 Otvos and Giardino, 2004; Schwartz, 1971; Swift, 1975; Tanner, 1990). Investigation of barriers' geologic evolution provides insight as to previous environmental conditions, such as sea level, during barrier formation (Rodriguez *et al.*, 2004; Schwartz, 1971). Barrier Islands are separated from the mainland by a shallow bay, sound, or lagoon that differs markedly in hydrodynamics and ecology from the open ocean and so have a profound effect on the mainland coasts they fringe (Johnson, 1919; Shepard, 1960 a; Hoyt, 1967; Otvos, 1970). Geologist Elie de Beaumont (1845) is credited with developing and advocating the first theory of barrier island formation. This theory suggested that submarine banks can aggrade above sea level by shore-normal wave action in the nearshore swash zone. He postulated that the aforementioned criteria coupled with the shallowing of water leads to barrier formation. Douglas W. Johnson published his 1919 *Shore Processes and Shoreline Development* which favored de Beaumont's (1845) hypothesis because it named a mechanism responsible for maintaining sedimentary nourishment, trans-location, and growth. Johnson believed de Beaumont's (1845) hypothesis lacked field evidence and advocated that the creation of barrier islands is a product of shoreline submergence, emergence, and beach ridge engulfment (Johnson 1919; Kwon 1969; Otvos 1981). Currently, barrier islands are recognized as having a multitude of factors that influence development and evolution (Schwartz, 1971; Swift, 1975). Due to their widespread distribution across varying climates and geologic settings, however, they are subject to a spectrum of modifying physical processes (Field and Duane, 1976; Hayes, 1979; Hoyt, 1967, 1970; Hoyt and Henry, 1967; Otvos, 1970, 1977; Schwartz, 1971; Shepard, 1960; Swift, 1975). Barrier islands are distinguished from offshore barrier bars, which are submerged at high tides, and from coral reefs, which are composed of carbonates (Hoyt, 1967). The current local climatic, hydrologic conditions, and underlying geology are, therefore, the dominant factors in continuing barrier evolution and survival (Field and Duane, 1976; Rosati and Stone, 2009).

Otvos and Giardino (2004) proposed an evolutionary model for the Mississippi Alabama Barrier Island Chain that incorporates ridge engulfment in the eastern Sound and an emergent bar model in the central Sound. In the central Mississippi Sound the underlying barrier island platform was constructed by nearshore sediment aggradation over muddy-sandy Holocene nearshore deposits (Otvos, 1981, 1985, 2005a; Otvos and

Giardino, 2004). This interpretation was supported by core interpretations showing increased sorting and decreased silt and clay concentrations upward in the 3-12 m thick muddy, brackish Holocene layer (Otvos, 1981, 1985, 2005). Open nearshore, inner shelf fauna assemblages were present throughout the unit over the muddy layer which lie in the barrier platform. This assemblage was composed of 7-12 m of poorly to moderately sorted sandy-to-muddy deposits with few fauna (Otvos, 1985). Interspersed lenses of moderate to well-sorted sands in this unit were interpreted as transient intertidal shoals (Otvos, 1981). The stabilizing barrier platform began to enclose the Sound, protecting the backbarrier environment from the high-energy waves of the open Gulf. Transition to a restricted bay hydrodynamic regime allowed fine-grained sediment to settle and accumulate as lagoonal facies. A low-salinity nearshore marine environment was maintained by high levels of freshwater influx from estuaries along the mainland prior to the enclosing of the Sound and was reinforced by the newly restricted exchange with the open Gulf waters, explaining the absence of open marine fauna (Otvos, 1985, 2005a; Otvos and Giardino, 2004).

Barrier Island Beach Ridges

Beach ridge strandplains form where abundant fine to medium sandy sediment is available in the nearshore swash zone of a shallow, gently sloping shoreface (Otvos, 2000; Tanner, 1995). Beach ridges are formed from accretion on moderate to low energy coasts. Beach ridges usually occur in sets of successive ridges, normally constructed over decades, forming a beach ridge strandplain (Otvos, 2000; Taylor and Stone, 1996; Tanner, 1995). Beach ridge strandplains exhibit a dune-swale topography characterized by sandy, vegetated ridges, often less than a meter high, interspersed by swales that can be flooded, intertidal, or subaerial (Otvos, 2000; Taylor and Stone, 1996; Tanner, 1995). Ridge construction provides a mechanism for shoreline progradation and vertical aggradation of coasts and barriers (Hine, 1979; Otvos, 2000; Rodriguez and Meyer, 2006; Rodriguez *et al*., 2004; Tanner, 1995; Taylor and Stone, 1996). Straight-crested ridge sets are constructed perpendicular to dominant shorenormal wave approach, while the ridges formed by longshore transport and recurved spit development exhibit recurved ridge crests (Otvos, 2000). The berms aggrade vertically as sediment eroded from the seaward slope of the berm is transported and deposited up the berm seaward slope face. Lateral aggradation of the berms occurs during higher tides as sediment is transported over the berm crest and deposited down the berm shoreward slope (Hine, 1979). Over several tidal cycles during extended fair weather periods, the berms aggrade to a permanently subaerial height. Continued deposition of sediment landward of the berm crest infills the zone between the berm and the previous shoreline, establishing a new, seaward shoreline (Hine, 1979). As the ridge construction cycle repeats, successive ridges weld to the shoreface, ultimately removing the inland ridges from the nearshore environment. Inland ridges are essentially relict shorelines (Otvos 2000). Offshore winds enable landward eolian sediment transport and deposition over the ridges, developing dunes deposits over the ridges (Otvos, 2000; Tanner, 1995). Colonization of ridges and dunes by vegetation enhances ridge stability and preservation (Otvos, 2000; Tanner, 1995). The orientation of beach ridges to each other and to the shoreline is principally determined by sediment supply and dominant wave approach (Lopez and Rink, 2008; Otvos, 2000; Rodriguez and Meyer, 2006; Rodriguez *et al*., 2004; Tanner, 1995; Taylor and Stone, 1996). Beach ridge orientation has been used to infer the direction of historical shifts in dominant incident wave approach intervals (Otvos, 2000; Rodriguez and Meyer, 2006; Rodriguez *et al*., 2004; Tanner, 1995; Taylor and Stone, 1996). Abundant sediment supply is crucial to the development of beach ridge sets and must be able to sustain the multiple cycles of ridge formation over multi-decadal intervals (Otvos, 2000; Tanner, 1995; Taylor and Stone, 1996).

Barrier Island Vegetation Research

The well-developed Slash pine (*P. elliotii*, Engelm.) forests that occur on a chain of barrier islands in the Gulf of Mexico have been considered to be the result of sporadic fires (Penfound and O'Neill, 1934). Ecologists have eagerly seized the opportunity to study plant succession on relatively barren areas where the changes are rapid and plainly evident. Such an opportunity is provided at Cat Island (Penfound and O'Neil 1934). Penfound and O'Neil (1934) conducted a vegetation survey using a quadrat method and frequency index to compute type and amount of vegetation inhabiting the island. The aforementioned study gives insight to historic physiographic features as well as the type and amount of vegetation inhabiting the island. Furthermore, the study gives important information on climax communities, successional pathways, and plant relationships, such as those sympatric and symbiotic relationships among *Serenoa repens* (saw-palmetto), *Quercus geminata,* (sand live oak), *Q. virginiana* (live oak), and *P. elliottii* (Slash pine).

Stoneburner (1978) tested the hypothesis that hurricane impact maintained the pure pine forest stands on barrier islands. The study collected tree core samples from four islands in the chain that had trees at that time: Petit Bois, Horn, East Ship, and Cat Islands. Stoneburner (1978) sampled 16 Slash pine on Cat Island extracting duplicate cores from each tree. Stoneburner did not cross-date the samples, test for elevation and growth, nor mention where or how the trees were selected for coring. Instead of cross-dating the cores, which is currently the standard practice in dendrochronological analyses (Holmes, 1983; Grissino-Mayer, 2001), he used an analysis of variance (ANOVA) based upon three groups of ring widths claimed to be attributed to hurricane impacts. Although the methods of Stoneburner's paper are not in practice with today's, the study provides insight to the effects hurricanes have on ring growth in Slash pine on Cat Island, revealing that there is a 1 to 2 year lag in growth response to hurricane impacts (Stoneburner, 1978).

The recovery of all vegetated, terrestrial habitats on barrier islands following tropical storms has not commonly been examined (Otvos and Carter, 2008). Otvos and Carter's (2008) study shows that through the comparison of geologic charts, aerial photography and satellite imagery, one can quantify geomorphic and vegetative responses and changes that occur post hurricane. Although this study is examining all habitat types in relation to hurricane impact, the aforementioned study gives insight to the devastating effects historical hurricanes have had on the Mississippi Gulf Coast Barrier island's genesis cycle and will contribute to furthering the understanding of the biogeomorphic patterns and processes pre and post hurricane on barrier islands.

Remotely sensed image interpretation is becoming an important tool in defining parameters of plant species and classifying habitats on barrier islands (Lucas and Carter, 2010). Lucas and Carter (2010) conducted a study using ground data in conjunction with hyperspectral data, Light Detection and Ranging (LIDAR), and historical data to successfully classify, map, and study vegetation on Horn Island Mississippi. The aforementioned study is important because Horn Island and Cat Island are both located off the coast of Mississippi within the same immediate geographic location (approximately 30 km). This research allows inferences to be made about vegetation routines on Cat Island. The study shows vegetation changes on a decadal scale and a similar methodological approach will be taken on the Cat Island study with determining growth response after Hurricane Katrina.

The environment on the barrier islands is harsh, so vegetation is ever-changing, resilient, and morphologically adapted to survive in harsh environments (Lucas and Carter, 2012). Lucas and Carter (2012) evaluated changes and distributions of vegetation on Horn Island Mississippi five years post-hurricane Katrina. The study states that the majority of habitat change post-hurricane occurred close to the shoreline in areas of over wash where elevation changes occurred. This study contributed to the understanding of habitat change on the barrier island after hurricane disturbance as well as to the understanding of native vegetation growth response time on barrier islands.

Relatively little attention has been given to woody species on barrier islands; thus, mechanisms controlling spatial patterns are poorly understood. Moreover, the impact of short-term flooding and salinity to small-scale distribution patterns of these woody species has not been thoroughly investigated (Tolliver *et al*., 1997). Tolliver *et al*. (1997) examined the rate of stomatal conductance in relation to low, medium, and high treatments of saline water. This study shows that at low salinity treatments (2 and 5g L) for a duration of 30 days significantly reduced stomatal conductance in *Pinus taeda* (loblolly pine). Although growth was reduced, all samples recovered at this range of salinity. The experiment also shows *P. taeda* could also withstand medium treatments of salinity (10 g L^{-1}) for more than 25 days and recover. Furthermore, *P. taeda* withstood high salinity treatments (20, 30 g L^{-1}) for as long as approximately 1 to 5 days, after which 100% mortality occurred. Although this was a controlled experiment rather than a natural one, this research provides valuable understanding of the effects a hurricane induced storm surge as well as frequent salt and fresh water flooding likely has on growth in *P. elliottii* on Cat Island, Mississippi.

Although not a barrier island by definition, the relationship of stem diameter and elevation in *Pinus elliottii* Var. *densa* was identified in the Pine-Rockland forests of the Florida Keys. The largest diameter trees are found at the highest elevation (Saha *et al.,* 2011). The science of dendrochronology has generally been restricted to temperate regions where guaranteed anatomically distinct growth rings are produced in response to temperature and precipitation. High quality dendrochronological data has been produced for soft wood conifers such as Slash pine (*Pinus elliottii* var. densa) in southern Florida (Harley, 2011). The mentioned study demonstrates that Slash pine forms anatomically distinct annual growth rings necessary for disturbance and climate analysis. Harley (2011) proved that *Pinus elliottii* can be used as a climate proxy showing that tree ring analysis is not limited to temperate regions and can be used in the subtropical, coastal, and island settings. Although the Florida Keys are not by definition barrier islands, they are low-lying islands in within a marginal marine setting. The ecosystems are not exactly same, but they are very similar allowing inferences to be made on like habitat-types. Harley and Saha (2011) studies provide insight to the behavior of the same species in a dynamic, resource constrained, hurricane-prone ecosystem.

Although there have been numerous studies investigating habitat-types, species richness, and effects of hurricane impacts upon barrier islands, this study is unique because it is investigating micro-differences in elevation of one habitat-type, Slash pine woodland, including driving growth and resiliency throughout the lifespan of the tree in relation to hurricane impact. Although Cat Island's ecosystem has been studied holistically on the island, forest stands and climax community species have not been individually studied in relation to their respective elevations. Studying the climax community Slash pine woodland provide insight to the historic effects hurricane impacts have had and historical vegetative patterns that occurred within that specific location. Standard inferences can be made such as what the forest looked like, what vegetation has been there, and what will be there in the coming years if left undisturbed.

Study Area

Spanning 105-km-long, the Mississippi–Alabama Barrier Island Chain (Figure 1) begins at the mouth of Mobile Bay, Alabama, and along with East Dauphin Island, Alabama, forms the southern border of the Mississippi Sound, and ends with the most western, Cat Island, Mississippi (Figure 2). Located 14 km (3346161.242 N, 298830.6424 E, mean - 26.86 meters h.a.e.) seaward of the Mississippi mainland shore, Cat Island (Figures 2-3), approximately 730 hectares in size, was formed on a Holocene sand platform approximately 3800 years ago (Otvos and Giardino, 2004; Otvos and Carter, 2008). The soil type is primarily St. Lucie sand, St. Lucie sand, and hummocky with a high rate of drainage and infiltration (U.S.D.A. 1975). Cat Island is one of more than 50 barrier islands that border the Northern Gulf of Mexico, and it contains a variety of habitat types. These include: beach dunes, swales, lagoons, ponds, freshwater and saltwater marshes, and maritime forest (Lucas and Carter, 2010). The climate is humid and subtropical with an approximate average air temperature of 12°C in the winter and 27°C in the summer. Average annual precipitation is approximately 140 cm, with a peak in July due mainly to thunderstorms. The western portion of the east-west trending dune-swale system was placed under the jurisdiction of the Gulf Islands National Seashore, U.S. National Park Service (USNPS) in 1984. British Petroleum (BP) purchased a small portion of the shoreline on the North Spit after the 2010 Gulf oil spill. The remainder of private land (all but 60 acres) was sold to the state of Mississippi in 2013 (Boddie, *personal communication*). Cat Island is unique in comparison to its sister islands because of its geomorphology and biogeography. It has a large number of forested beach ridges populated by century old stands of Sand live oak and Slash pine (Funderburk, *unpublished data*). The Cat Island ridge complex is composed of three distinct sets of sub-parallel east-west trending ridges. The ridge set on the south side of the island is younger and less well developed than the older two sets (Rucker and Snowden 1989). The ridges which form the main body of Cat Island are densely vegetated by pine forest and live oak with an understory characterized by sawtooth palmetto. The series of robust ridges on Cat Island, at the downdrift end of a long barrier island chain, seem enigmatic since updrift islands to the east generally do not display these prominent linear features (Rucker and Snowden, 1989).The other barrier islands do not currently exhibit dune swale systems or ridge complexes, nor such densely forested areas. Its shape and location make it unique within its chain. The relative lateral stability of Cat Island has been largely attributed to the protective environment sustained by the active St. Bernard Delta for a ~2000 year period (Otvos, 1985, 2005; Otvos and Carter, 2008; Otvos and Giardino, 2004; Rucker and Snowden, 1989, 1990). The geographic location of the island allows much more protection than the other islands receive: protection from the erosional effects of currents, waves, and swells of the open Gulf of Mexico (Rucker and Snowden, 1989; Otvos, 2005). Cat Island is vulnerable to open-ocean-wave activity only through a narrow 25 degree southeastern window between Ship Island to the east and the Chandeleur Islands to the south (Figure 1). This directional restriction of wave approach resulted in the reworking of the eastern shores thus giving it its unique “T” shape (Rucker and Snowden, 1989). Finally, Cat Island stands out by having a distinct land use history. Cat Island is the only island in the MS chain to have been privately owned since the original government geographic land survey in 1821. The Slash pine on the island were tapped and their sap was harvested in the late 1800's and early 1900's (Funderburk, *unpublished data*; Boddie, *personal info*). A specific growth signature caused from the extraction process is evident and occurs throughout the stands of Slash pine on the island (Funderburk, *unpublished data*).

CHAPTER II

MATERIALS AND METHODS

Vegetation Mapping

Coastal vegetation communities have been successfully mapped using airborne and satellite spectral sensors; however, improvements to classification accuracy have been achieved when spectral data were combined with additional information, such as elevation, vegetation maps, ground reference data, or in situ spectral data (Bachmann *et al*., 2002; Lee and Shan, 2003; Wang *et al*., 2007). Using 2010 habitat–type GPS locations and 2010 fused multispectral and radar data sets, a supervised maximum likelihood habitat-type classification was produced. Habitat types include: beach dune, low, marsh, high marsh, estuarine shrubland, and maritime woodland (Figure 3).

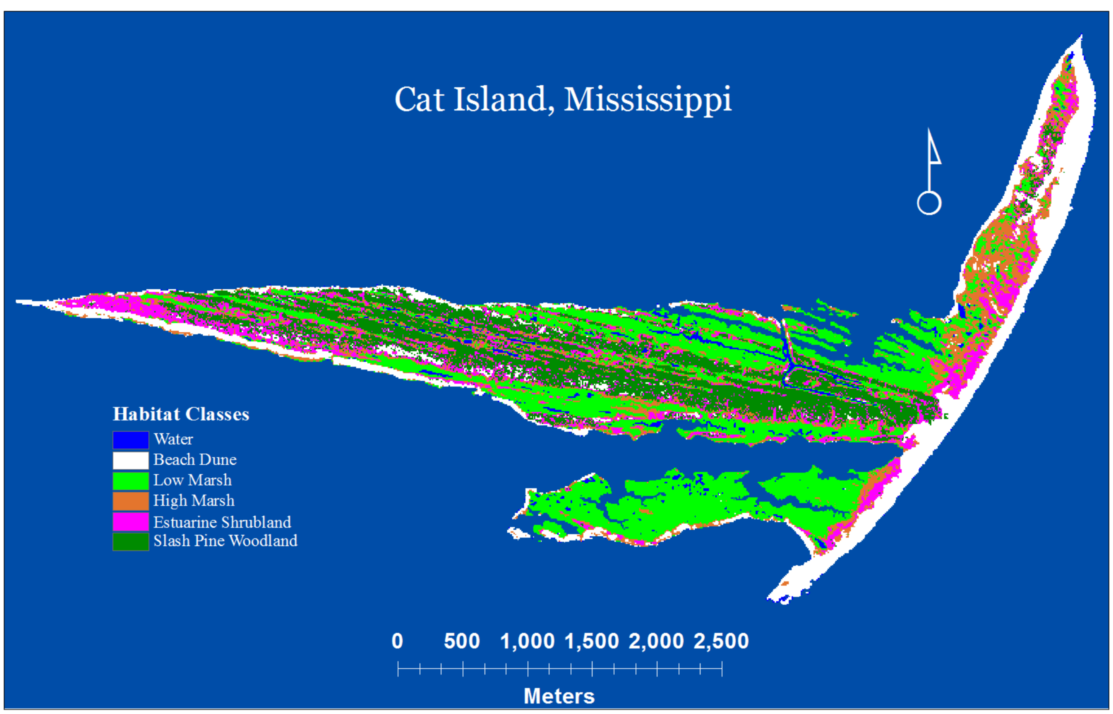

Figure 3. Hyperspectral-Radar fused, supervised maximum likelihood habitat-type classification of Cat Island MS, depicting 6 habitat-types.

Remotely Sensed Data

Remotely sensed data products for this project include: SPOT 5, high resolution visible infrared (HRVIR), 10 m multispectral coverage (April-July 2010 image acquisitions, North American Data Purchase, USGS EROS Data Center, Sioux Falls, SD), and unmanned aerial vehicle synthetic aperture radar (UAVSAR), horizontal send, vertical receive (HV), cross-polarized, L-band, radio detection and ranging (radar) collected in May 2010 and provided by NASA's Jet Propulsion Laboratory (JPL). UAVSAR data came pre-geocoded as a cross-polarimetric product. Spot 5 is a multispectral electronic scanning radiometer operating at optical wavelengths with a separate objective lens and sensor for each of the four spectral bands: (blue = 0.43 – 0.47 µm used primarily for atmospheric correction; red = 0.61 – 0.68 µm; near-infrared = 0.78 – 0.89 µm; and SWIR = 1.58 – 1.75 µm). Spot 5 utilizes a pushbroom, linear array sensor; each sensor is a 1,728 CCD linear array located at the focal plane of the corresponding objective lens (Jensen, 2007). Radar is an active microwave remote sensing system which is based on the transmission of long wavelength microwaves (e.g., 3–25 cm) through the atmosphere and then records the amount of energy backscattered from the terrain. L-band radar, which was used in this project, has a wavelength of approximately 23.5 cm and a frequency of 2.0–1.0 GHz (Jensen, 2007).

Ground Data Sets

Ground data sets include: 2010 GPS habitat-type database that contained primary and secondary species information, cardinal directional photos, and a fiberglass range pole with alternating 0.3 m (1 ft.) orange and white segments. Collected as part of this study, tree data set containing core samples from each tree (2–4), stem diameter measurements at breast height, GPS location taken at the base of each tree and measured with a Trimble real-time-kinematic (RTK). The RTK allowed for the collection of precise (+ or – 2 cm) orthometric, geoidal, and ellipsoidal location and height. The RTK or real-time-system was equipped with a Trimble R-8 dome/antennae mounted atop 2 m carbon fiber pole with TSC3 handheld data logger attached. The Geoid model 2012A was used for acquisition of positional information. The Trimble system ties into a real-time-network of over 50 continually operating reference stations (CORS). This CORS system was emplaced and is currently managed by the Gulf Coast Geospatial Center (GCGC) (David Mooneyhan *personal communication*). The GCGC serves as the spatial reference center for the National Oceanic and Atmospheric Administration (NOAA). Both vertical and horizontal accuracy and precision reports of point data collected for this study are located in Appendix A. Nothing measured had an error of higher than 2 cm.

Habitat-Type Classification

Maximum likelihood (ML) was selected as the supervised classification method because it is widely accepted and generally provides the greatest accuracy among various supervised classification procedures (Jensen, 2005). The 2010 GPS habitat-type database, collected as part of a previous study, served as ground sample training points in the construction of a 6 class, supervised, maximum likelihood habitat-type classification map of Cat Island (Figure 3). Maximum likelihood computes the probability that a given pixel belongs to one of a predefined number of classes, taking into account the variability in each defined ROI and assuming that training data in each band for each class are normally distributed. The pixel is then assigned to the class to which it most likely belongs (Jensen, 2007). Using ENVI 4.8 image processing software, band 2 (red = 0.61 – 0.68 μm) and 3 (near-infrared = 0.78 – 0.89 μm) of SPOT 5 were used in combination with an L-band (23.5 cm) of synthetic aperture radar to produce a habitat-type classification of Cat Island. Habitat types mapped included: beach dune, low, marsh, high marsh, estuarine shrubland, and Slash pine woodland. Classification accuracy was determined by an error matrix and coefficient of agreement (Jensen, 2005).The ML classification of the fused multispectral and radar data indicated an overall accuracy of 88% (Appendix B). This allowed the Slash pine habitat-type to be isolated and its distribution to be visualized. Visualizing the distribution of Slash pine woodland facilitated the selection of a nonbiased sampling design. Slash pine woodland habitat-type coverage was approximately 20%, or 150.75 hectares, of the island's 738 hectare total land area.

Ground Sampling

Increment cores were collected during late August and early September of 2013. This was done because the impact of Hurricane Katrina occurred on August 29, 2005. Sampling within the same relative time frame allows inferences to be made as well as gives insight to the behavior of the tree rings during that time of year. Trees were sampled using a proportional systematically aligned spatial sampling method (Figure 4) (McGrew and Monroe, 2000). Using geographical informational systems (GIS), a fishnet with centroids was created and projected onto the classified image of the island. This entire sampling scheme was installed onto the GPS unit (Trimble Geo-6000 transmitter/receiver) as a raster image was visible, and it was used in the field during sampling. Each complete cell of the fishnet is 250 m^2 (Figure 4) and was divided into four quadrants based upon cardinal direction.

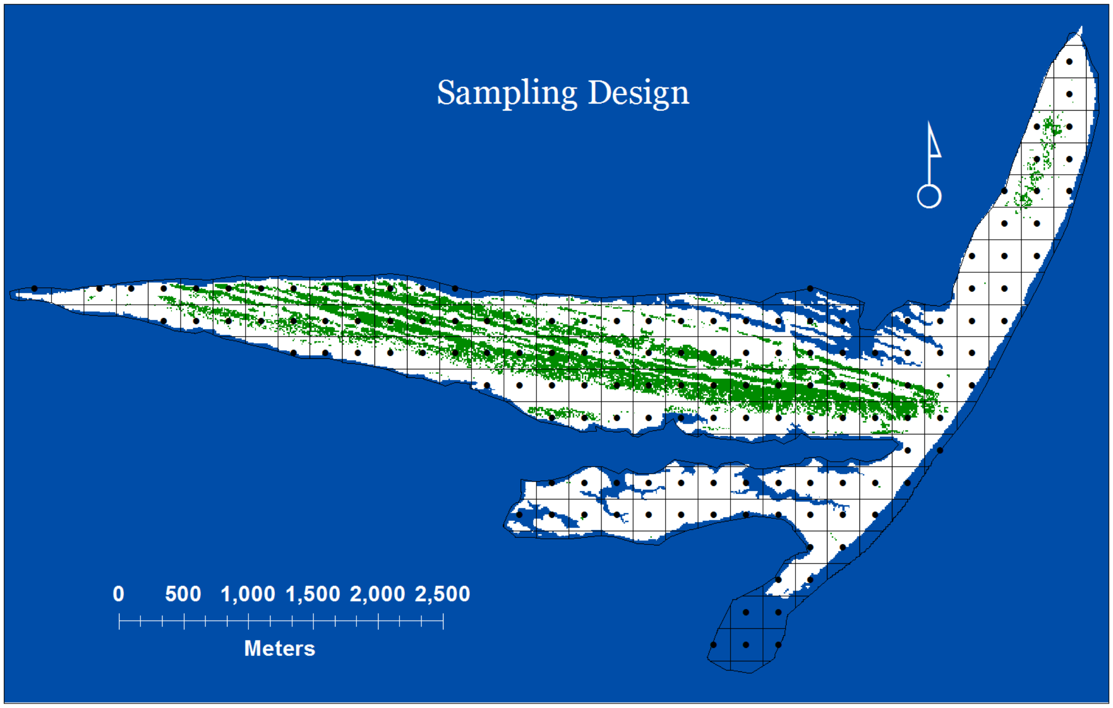

Figure 4. Point-centered quarter distance sampling design. 250 m² fishnet overlain the island. This map is depicting the distribution of Slash pine woodland habitat-type only; all other habitat-types have been whited out.

The nearest tree to the centroid in each quadrant was cored. There was a potential four sample maximum from each cell. Recorded at each sample site were: stem diameter at breast height, GPS location, and elevation. Mississippi State plane E (FIPS) NAD 1983 was used for all map projection, coordinate systems, and units (ft) converted to meters. GPS location and elevation were recorded at the base of each tree with RTK. Cores were extracted from trees if the cell contained a centroid and there could be a sample taken in any of the four quadrants. Cores were taken with a 5.15mm diameter Haglof increment borer. Two to four cores were extracted from each tree at no less than a 30cm height. Trees with less than 15-cm stem diameter were not sampled. Tree core samples were labeled and stored in plastic tubes until they were prepared for sanding and reading.

Dendrochronology Laboratory Methods

Tree core samples were dried, mounted, then sanded using progressively finer sandpaper, beginning with ANSI 100-grit (125–149 mm) and ending with ANSI 400-grit (20.6–23.6 mm) (Orvis and Grissino-Mayer, 2002). Cores were read from the bark-cambium interface, which was interpreted as the most recent year of full growth, to the pith which was interpreted as the first year of growth. The samples were visually cross-dated, then scanned with a high resolution digital scanner (EPSON, Expression 10000XL) at 1,200 dpi then measured and using the WinDENDRO™ system (version 2009C, Canada). Visual cross-dating was used to statistically confirm with COFECHA (Holmes, 1983; Grissino-Mayer, 2001). The computer program ARSTAN was used to cross-check manually computed mean radial growth rates and ages. The computer program JOLTS was run to check for suppression in growth. JOLTS was run to validate the manual technique discussed in the statistical analysis section.

Statistical Analyses

Linear regression was used to examine all relationships between the independent variable, elevation, and dependent variables; mean radial growth rate (mm y^{-1}), stem diameter (cm), and change in radial growth rate following Hurricane Katrina (% change). Change in radial growth rate (% change) was measured within a 10 year window: 2001–2010. Windows were split equally temporally; the first five years was 2001–2005 and the second five years are 2006–2010. The sum of five years pre – Katrina radial growth served as the base for comparing change in radial growth (Table 3). Percent change was derived for each sample by subtracting the sum of five years post-Katrina radial growth (2006–2010), from the sum of five years pre-Katrina radial growth (2001–2005), then dividing the difference by five years pre-Katrina radial growth (2001–2005) and finally multiplying that product by 100, thus, arriving at percent change ((post-pre)/(pre)*100)). All statistical data were processed in Excel ver. 2012 and Sigma Plot ver. 12.5.

Results and Discussion

Through a series of eight trips from late August to September 2013, 55 Slash pine were sampled and cross-dated; eight preliminary tree cores, two cross-cut sections, and 45 grid sampled tree cores. The tree ring chronology extends from 2012 to 1883 and has an interseries correlation of .406 (Appendix C.); eight preliminary cores were retrieved on the first trip to assess the plausibility of the project and did not contain horizontal or vertical data. Neither did the cross cut sections. Only 45 trees contained core, stem diameter, and elevation data. These were the only samples used in the analysis of mean radial growth rate, stem diameter, and change in radial growth rate following post-Katrina versus elevation.

The relationship of mean radial growth rate (mm y^{-1}) (Figure 5), stem diameter (cm) (Figure 6), and change in radial growth rate (% change) following Hurricane Katrina (Figure 7) versus elevation proved to be statistically insignificant; r^2 = .09 .06, and .02, respectively. Although insignificant, showing these relationships is critical to accepting or rejecting the tested hypotheses. Furthermore, there is valuable information that can be interpreted from the data sets.

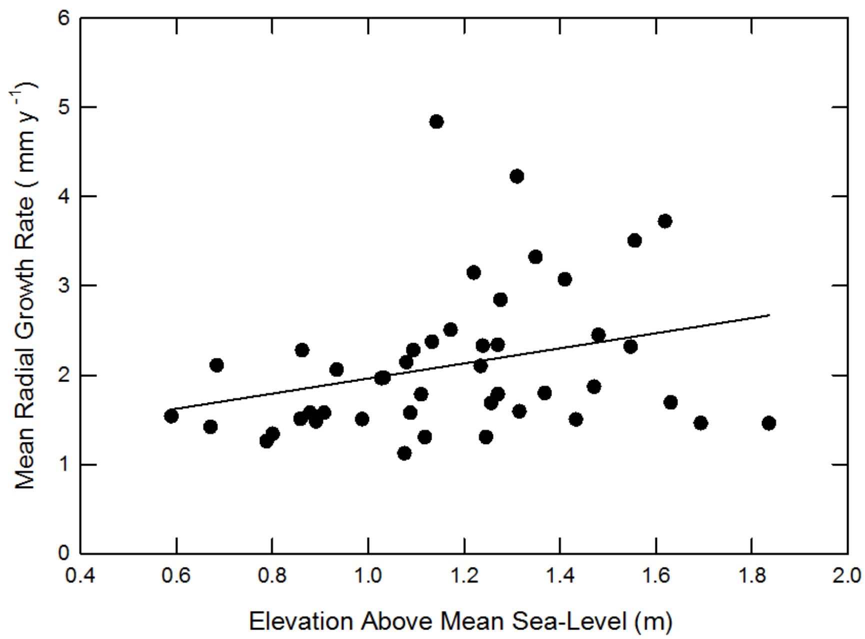

Figure 5. Linear regression of mean radial growth rate versus elevation above mean sea-level. Graph shows no relationship between the two variables; $r^2 = .09$.

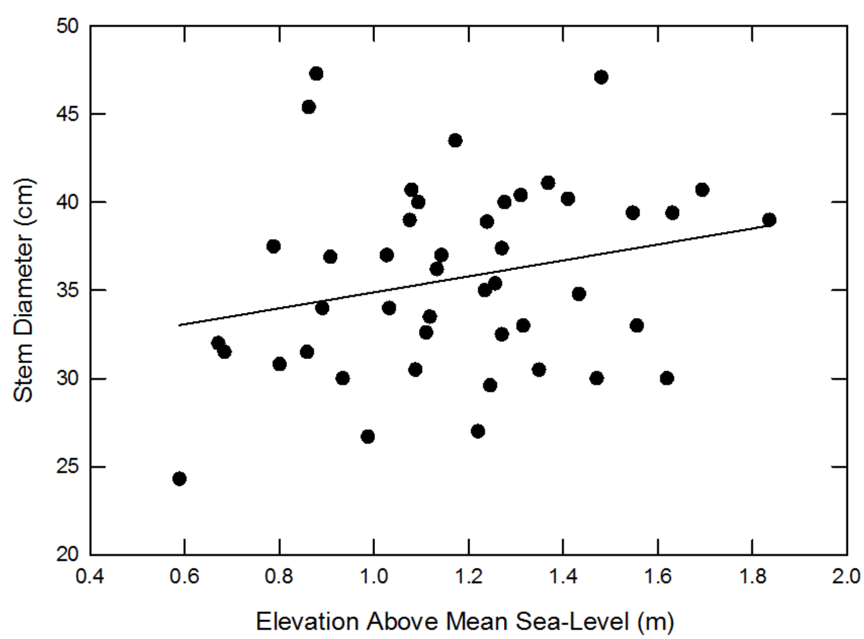

Figure 6. Linear Regression between stem diameter and elevation above mean sea-level. Graph shows no relationship between the two variables; $r^2 = .06$.

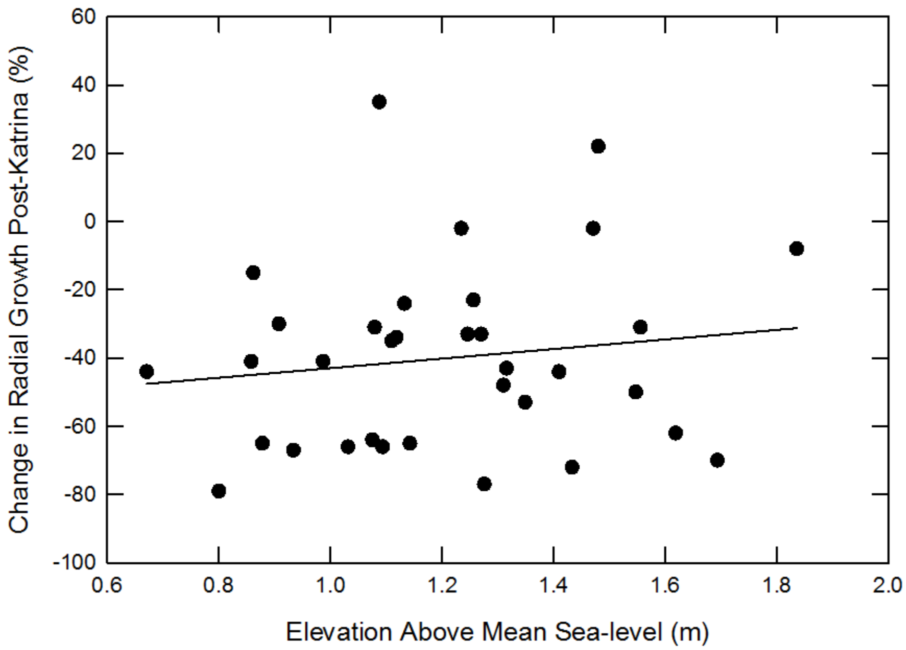

Figure 7. Linear regression between change in radial growth post-Katrina and elevation above mean sea-level. Graph shows no relationship between the two variables; $r^2 = .02$.

Elevation proved unsuccessful as a predictor of mean radial growth rate; however, there were significant results using age to model radial growth. For example, mean radial growth rate (mm y^{-1}) versus age (y) (Figure 8) produced a strong coefficient of determination ($r^2 = .6$). Furthermore, using the same linear equation ($y = ax + b$) and plotting mean radial growth rate (mm y^{-1}) versus inverse age (1/age y^{-1}), radial growth is predicted and modeled even better ($r^2 = .72$) (Figure 9). Radial growth rate is modeled better using the inverse age because the inversely proportional relationship of age and growth rate is taken into account; as age increases, growth rate decreases.

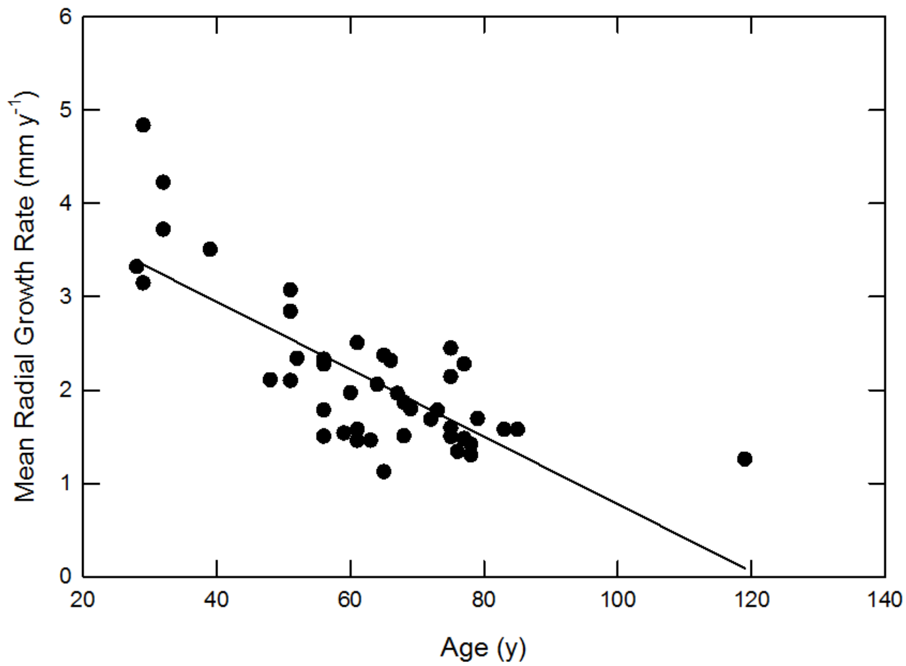

Figure 8. Linear regression between mean radial growth rate and age. Radial growth is predicted very well using age as the independent variable:$r^2 = .6$.

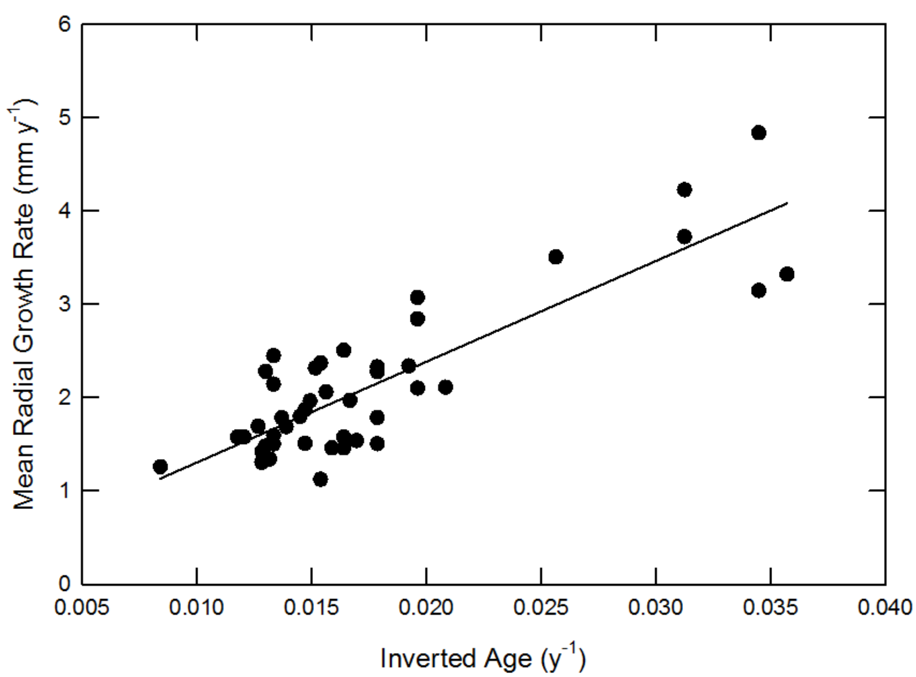

Figure 9. Linear regression between mean radial growth rate and inverted age (1/age). Among the variable measured, radial growth is modeled best here; $r^2 = .72$.

Although there was no relationship between change in radial growth rate following hurricane Katrina, Figure 7 shows that only two samples had an increased radial growth rate after the impact of Hurricane Katrina (2006–2010). One sample showed no change in radial growth, and the other 92% of the sample population (n=33) showed a decrease in radial growth rate following the impact of Hurricane Katrina. Growth response to Hurricane Katrina was cross-checked through the open-sourced dendrochronological software analysis package JOLTS (Table 1).

Table 1

JOLTS software output for Katrina suppression

Tree ID	Suppression Duration (y)	Years Suppressed	Max Year Suppression	Suppression (%)
Cat004	1	2005	2005	101
Cat006	6	2005-10	2005	117
Cat008	No Kat SUP	No Kat SUP	No Kat SUP	No Kat SUP
Cat011	7	2005-11	2006	134
Cat013	1	2005	2005	106
Cat014	5	2006-10	2006	119
Cat017	7	2005-11	2005	181
Cat018	No Kat SUP	No Kat SUP	No Kat SUP	No Kat SUP
cat019	2	2006-07	2006	121
Cat022	1	2005	2005	100

Table 1 (continued).

Cat023	No Kat SUP	No Kat SUP	No Kat SUP	No Kat SUP
Cat024	1	2005	2005	100
Cat032	3	2005-07	2005	134
Cat033	5	2006-10	2006	144
Cat034	3	2005-07	2005	114
Cat035	3	2005-07	2005	109
Cat038	6	2005-10	2005	144
Cat040	5	2005-09	2006	157
Cat043	3	2005-07	2005	122
Cat044	8	2005-12	2006	182
Cat045	3	2005-07	2006	131
Cat047	4	2006-09	2006	107
Cat049	3	2006-08	2006	116
Cat055	9	2004-11	2005	132
Cat062	1	2006	2006	101
Cat064	2	2005-06	2005	128
Cat065	2	2006-07	2006	141
Cat067	4	2004-07	2005	136
Cat069	2	2006-07	2006	160
Cat070	2	2006-07	2006	109

Table 1 (continued).

Cat071	2	2005-06	2006	100
Cat072	1	2006	2006	100
Cat077	6	2004-09	2005	140
Cat078	5	2005-09	2005	170

Table 1 shows 92% of the sample population experienced a suppression in growth due to the impact of Hurricane Katrina. The use of JOLTS software reinforces the results pertaining to growth response of Hurricane Katrina and reinforces the manually computed findings. In this case, the reinforcement between JOLTS and manually computed change in radial growth solidifies the findings of this research. Based on these results, utilizing the sum of radial growth within a five year moving window appears to be a small enough window of time where the mandation to geometrically correct for the same amount of volume being put on to an ever increasing cylinder becomes unnecessary. More research and manipulation of window size needs to be done to determine the true nature of this technique. Elevation was not a part of the JOLTS analysis which resulted in one more samples than the manually computed change in radial growth analysis. Sample size was 34 for JOLTS software analysis whereas sample size was 33 for manual computations. The total sample population was not used in either analysis because the core samples' timeline did not extend to the impact of Hurricane Katrina or fit within the five year pre-and-post-analysis window.

Retardation in growth to the majority of the sample population was attributed to the 7 m storm surge Cat Island experienced during Hurricane Katrina. Storm surge from the Gulf of Mexico inundated the Slash pine throughout the island, infiltrating the soil, breaching the fresh water lens, causing its salinity to increase and temporarily retarding growth in Slash pine. The exact salinity measurement the Slash pine community experienced during the impact of Hurricane Katrina can only be speculated upon and is actually insignificant. As indicated from Tolliver *et al.* (1997), it is the amount of time beyond the tolerable salinity threshold that determines the growth response to salt water flooding (Tolliver *et al.,* 1997). Tolliver *et al.* (1997) shows *Pinus taeda* able to withstand high treatments of salinity (20–30 g L^{-1}) for a duration of one to five days but then was able to recover. Exposure to high salinity treatments (20–30 g L^{-1}) longer than the aforementioned time frame (one to five days) resulted in mortality. Tolliver *et al.* (1997) show tolerance or resiliency to salt water being a unique characteristic of *P. taeda* in comparison to the other woody stemmed vegetation commonly found on barrier islands and used in the experiment: *Baccharis halimifolia*, and *Myrica cerifera.* The aforementioned woody shrub species could tolerate medium salinity treatment (10 g L^{-1}) for 11–16 days before immanent mortality. Whereas *P. taeda* could withstand medium salinity treatments (10 g L^{-1}) for more than 25 days before immanent mortality. Through this experimental data we can infer to the ability of Slash pine to withstand similar if not higher salinity treatments. It is probable that the inhabiting Slash pine would only experience salinity ranging between 20–30 g L^{-1} and for only a short amount of time (< 3 days). However, damage and recovery was not uniform throughout the population. Some trees showed the most disruption in radial growth in 2005, and some display the most disruption in radial growth in 2006. This is a result of a combination of factors and can be explained.

Observations from increment cores taken during field sampling in late August and early September of 2013 indicated that some samples had not completed the formation of their late wood ring, and some had. Thus, late wood cell growth may not have been complete when Katrina impacted. The aforementioned field evidence coupled with an eight month post-Katrina drought (Otvos and Carter, 2008) explains the variability in damage and recovery. The fact that terminal parenchyma of late-wood ring growth was not complete in all samples on the date Katrina impacted explain why some trees show the most disruption of radial growth in 2005 and some in 2006. According to the JOLTS output, the sample population experienced an average suppression time of 3.7 years. Moreover, throughout the sample population there appears to be a threshold of elevation where trees do not occur. Slash pine do not exist below the elevation of ~ .5 m (msl). Below this elevation threshold, it is probable that frequent salt or fresh water flooding, near the shoreline or interior ponds, inhibit germination of seedlings as well as retard growth in any mature tree that had been previously established. Hypothetically, if a seed were to germinate below this elevation, it has to contend with extreme forces of nature such as salt water and tidal flooding, meteoric flooding, and storm surge from extreme episodic events. The likelihood of survival to a mature tree is speculated to be very low.

Conclusions

This investigation was part of an ongoing study to assess post-Katrina change in geomorphic features and vegetation on the Mississippi–Alabama barrier island chain. All data have been stored and backed up with the Gulf Coast Geospatial Center and can serve as a benchmark for comparison in future studies of change and resiliency on Cat Island following storms and in response to continued sea-level rise and subsidence. Hypothesis one, mean radial growth rate and stem diameter are a function of elevation, was rejected. Using the current sample design and population, within the 1.25 m range of elevation sampled, there was no observable statistical relationship of mean radial growth rate (mm y^{-1}) or stem diameter vs. elevation. Hypothesis two, growth response to Hurricane Katrina (% change) is a function of elevation, was also rejected. Within the 1.25 m range of elevation sampled, the observed post-Katrina change in radial growth rate was not related to elevation. In fact, among the variables measured, radial growth rate appeared to be most directly a function of tree age. The Slash pine population on Cat Island experienced a 3.7 year average suppression in growth from the impact of Hurricane Katrina. Furthermore, some trees are still exhibiting suppression from the impact of Katrina. Interestingly, 9% of trees remained unaffected showing no suppression to the impact of Hurricane Katrina; which is quite remarkable in terms of tolerance and resilience.

It was observed throughout the sample population that no samples fell below approximately .5 m (msl). This appears to be the threshold of elevation where germination and establishment occurs. Below the threshold elevation of ~ .5 m, Slash pine do not exist likely due to frequent flooding from salt, brackish, or fresh water; all of which affect germination in seeds. Although both hypotheses were rejected, this study facilitates the necessity for a more broad and in-depth investigation. Future research will likely reveal that radial growth rate may be modeled best using two or more independent variables. For example, growth may be heavily influenced by elevation and distance to nearest body of water (salt or fresh). Given the relationship of mean radial growth rate versus elevation was on the cusp of being statistically significant (p-value = .066), it is probable the relationship of radial growth versus elevation will change with an increased sample size. It is also likely that with a larger sample size the relationship of elevation and mean radial growth rates may be established. Under the premise that above an elevation threshold of approximately .5 m mean sea-level, there is less frequent flooding and below the converse. The final conclusion of this thesis is the proposal of two alternate hypotheses: 1) seedling survival and establishment of *P. elliottii* on Cat Island, Mississippi, are dependent upon an elevation threshold of ~ .5 m and 2) Elevational dependence of growth rate in mature Slash pine (> 15 yrs.) on Cat Island, Mississippi, may be observed given a greater sample size.

APPENDIX A

VERTICAL AND HORIZONTAL ACCURACY AND PRECISION REPORTS OF ALL 45 SAMPLES

Point	North	East	Elev	Code	Hz Prec	Vt Prec	PDOP	Sats
Gulfport, MS	314761.768	894838.145	57.050		?	?	?	?
040114.52	270224.747	910236.341	4.087		0.028	0.046	1.4	17
040114.53	270518.976	910302.673	3.748		0.032	0.055	1.3	17
040114.54	270327.743	909979.279	3.541		0.037	0.063	1.5	16
040114.55	270281.916	909898.295	3.368		0.036	0.063	1.5	15
040114.56	270269.937	909779.493	3.844		0.040	0.065	1.8	15
040114.57	270238.921	909759.344	3.641		0.036	0.064	1.5	15
040114.58	270204.377	909899.290	3.668		0.059	0.076	2.2	12
040114.59	269520.757	909741.875	4.065		0.037	0.063	1.3	16
040114.60	269388.834	909768.952	4.856		0.043	0.071	1.3	16
040114.61	269342.223	909789.929	5.351		0.046	0.077	1.8	15
040114.62	268843.965	909496.442	4.003		0.041	0.077	1.5	16
040114.63	268462.197	909410.787	5.312		0.042	0.077	1.9	15
040114.64	268467.485	909308.803	3.588		0.036	0.066	1.4	16
040114.65	268361.529	909230.877	3.528		0.044	0.087	1.7	16
040114.66	268545.350	909166.018	4.121		0.047	0.097	1.8	14
040114.67	268565.942	909141.987	4.702		0.060	0.127	1.8	15
040114.68	268591.627	909068.411	4.426		0.056	0.115	1.9	13
040114.69	268591.635	909068.394	4.427		0.073	0.129	1.9	15
040114.70	265590.631	884772.656	3.760		0.045	0.063	1.7	15
040114.71	265876.797	889844.259	2.626		0.035	0.078	2.7	12
040114.72	265886.422	889176.465	2.978		0.062	0.108	1.7	15
040114.73	265900.910	889042.678	4.316		0.062	0.119	2.2	13
040114.74	265907.310	888859.235	4.167		0.059	0.101	1.8	14
040114.75	265837.749	890689.957	2.922		0.032	0.053	1.5	15
040114.76	265754.702	893939.916	2.881		0.037	0.060	1.8	12
040114.77	265581.736	894105.997	2.201		0.047	0.087	2.5	10
040114.78	263700.827	904523.078	5.556		0.069	0.103	1.3	16
040114.79	263634.983	904741.802	4.489		0.076	0.103	1.4	15
040114.80	263752.168	904804.787	4.299		0.073	0.130	1.9	12
040114.81	263569.054	905427.102	3.385		0.073	0.104		

1.3	17				
040114.82	263628.400	905566.976	2.244	0.059	0.098
1.5	15				
040114.83	263300.953	906070.536	6.023	0.084	0.132
1.9	11				
040114.84	263285.129	906235.926	4.186	0.101	0.125
1.5	14				
040114.85	263281.635	906291.502	4.167	0.062	0.096
1.6	14				
040114.86	263359.312	906501.424	2.584	0.044	0.076
1.8	14				
040114.87	262960.508	905543.731	3.064	0.052	0.080
1.5	14				
040114.88	263289.202	903815.608	5.077	0.070	0.118
2.2	12				
040114.89	263540.970	903906.289	2.816	0.060	0.113
1.9	12				
040114.90	263602.115	903843.116	5.104	0.066	0.126
1.9	12				
040114.91	263587.384	903847.535	4.826	0.062	0.116
1.9	12				
040114.92	263651.344	903249.160	3.568	0.058	0.096
1.3	14				
040114.93	263505.831	903062.694	2.828	0.039	0.070
1.4	16				
040114.94	263395.802	902837.303	3.238	0.089	0.160
1.6	13				
040114.95	263448.331	902392.475	3.716	0.038	0.068
1.5	15				
040114.96	263548.381	902033.772	4.050	0.052	0.090
1.6	15				
040114.97	263725.361	905579.094	1.799	0.061	0.093
1.5	13				
040114.98	263240.810	905637.266	3.898	0.055	0.087
1.4	14				

APPENDIX B

CONFUSION MATRIX OUTPUT FOR CAT ISLAND MAXIMUM LIKELIHOOD HABITAT-TYPE CLASSIFICATION AND CLASS STATISTICS

Confusion Matrix: C:\Barrier Islands\cat classifications\Cat_Island_classified_image

Overall Accuracy = (208/236) 88.1356%
Kappa Coefficient = 0.8341

Ground Truth (Pixels)

Class	EVF: Beach_du	Esturine_shru	High_marsh_ac	Low_marsh_acc	Water_accurac
Unclassified	0	0	0	0	0
EVF: Layer: B	61	0	0	0	0
EVF: Layer: E	0	11	3	0	0
EVF: Layer: H	0	8	24	2	0
EVF: Layer: L	0	0	14	92	0
water_sample_	0	0	0	1	20
Total	61	19	41	95	20

Ground Truth (Pixels)

Class	Total
Unclassified	0
EVF: Layer: B	61
EVF: Layer: E	14
EVF: Layer: H	34
EVF: Layer: L	106
water_sample_	21
Total	236

Ground Truth (Percent)

Class	EVF: Beach_du	Esturine_shru	High_marsh_ac	Low_marsh_acc	Water_accurac
Unclassified	0.00	0.00	0.00	0.00	0.00
EVF: Layer: B	100.00	0.00	0.00	0.00	0.00
EVF: Layer: E	0.00	57.89	7.32	0.00	0.00
EVF: Layer: H	0.00	42.11	58.54	2.11	0.00
EVF: Layer: L	0.00	0.00	34.15	96.84	0.00
water_sample_	0.00	0.00	0.00	1.05	100.00
Total	100.00	100.00	100.00	100.00	100.00

Ground Truth (Percent)

Class	Total
Unclassified	0.00
EVF: Layer: B	25.85
EVF: Layer: E	5.93
EVF: Layer: H	14.41
EVF: Layer: L	44.92
water_sample_	8.90
Total	100.00

Class	Commission (Percent)	Omission (Percent)	Commission (Pixels)	Omission (Pixels)
EVF: Layer: B	0.00	0.00	0/61	0/61
EVF: Layer: E	21.43	42.11	3/14	8/19
EVF: Layer: H	29.41	41.46	10/34	17/41
EVF: Layer: L	13.21	3.16	14/106	3/95
water_sample_	4.76	0.00	1/21	0/20

Class	Prod. Acc. (Percent)	User Acc. (Percent)	Prod. Acc. (Pixels)	User Acc. (Pixels)
EVF: Layer: B	100.00	100.00	61/61	61/61

```
EVF: Layer: E        57.89        78.57              11/19              11/14
EVF: Layer: H        58.54        70.59              24/41              24/34
EVF: Layer: L        96.84        86.79              92/95              92/106
water_sample_       100.00        95.24              20/20              20/21

------------------------------------------------------------------------------------------
--------------------------------------------------

Filename: C:\Barrier Islands\cat classifications\Cat_Island_classified_image
Dims: Full Scene (505,197 points)

Class Distribution Summary
Unclassified: 0 points (0.000%) (0.0000 Meters²)
EVF: Layer: Beach_dune.shp [White] 15 points: 13,483 points (2.669%) (1,348,300.0000
Meters²)
EVF: Layer: Estuarine_shrubland.shp [White] 9 points: 9,364 points (1.854%) (936,400.0000
Meters²)
EVF: Layer: High_marsh.shp [White] 16 points: 10,735 points (2.125%) (1,073,500.0000
Meters²)
EVF: Layer: Low_marsh.shp [White] 35 points: 23,288 points (4.610%) (2,328,800.0000
Meters²)
water_sample_points [Maroon] 11 points: 1,855 points (0.367%) (185,500.0000 Meters²)
EVF: Layer: Slash_pine_woodland_flatwood_savanna_combo.shp [White] 22 points: 15,075
points (2.984%) (1,507,500.0000 Meters²)

Stats for Class: Unclassified
Basic Stats      Min    Max      Mean         Stdev
     Band 1        0      0  0.000000      0.000000


Stats for Class: EVF: Layer: Beach_dune.shp [White] 15 points
Basic Stats      Min    Max      Mean         Stdev
     Band 1        1      1  1.000000      0.000000

Histogram         DN     Npts  Total  Percent       Acc Pct
Band 1             1    13483  13483 100.0000      100.0000

Stats for Class: EVF: Layer: Estuarine_shrubland.shp [White] 9 points
Basic Stats      Min    Max      Mean         Stdev
     Band 1        2      2  2.000000      0.000000

Histogram         DN     Npts  Total  Percent       Acc Pct
Band 1             2     9364   9364 100.0000      100.0000

Stats for Class: EVF: Layer: High_marsh.shp [White] 16 points
Basic Stats      Min    Max      Mean         Stdev
     Band 1        3      3  3.000000      0.000000

Histogram         DN     Npts  Total  Percent       Acc Pct
Band 1             3    10735  10735 100.0000      100.0000

Stats for Class: EVF: Layer: Low_marsh.shp [White] 35 points
Basic Stats      Min    Max      Mean         Stdev
     Band 1        4      4  4.000000      0.000000

Histogram         DN     Npts  Total  Percent       Acc Pct
Band 1             4    23288  23288 100.0000      100.0000

Stats for Class: water_sample_points [Maroon] 11 points
Basic Stats      Min    Max      Mean         Stdev
     Band 1        5      5  5.000000      0.000000

Histogram         DN     Npts  Total  Percent       Acc Pct
Band 1             5     1855   1855 100.0000      100.0000

Stats for Class: EVF: Layer: Slash_pine_woodland_flatwood_savanna_combo.shp [White] 22
points
Basic Stats      Min    Max      Mean         Stdev
     Band 1        6      6  6.000000      0.000000

Histogram         DN     Npts  Total  Percent       Acc Pct
Band 1             6    15075  15075 100.0000      100.0000
```

APPENDIX C

COFECHA OUTPUT FOR SITE CHRONOLOGY, CAT ISLAND, MISSISSIPPI

```
  P R O G R A M      C O F E C H A
Version 6.06P    29045

-----------------------------------------------------------------------------------------
-------------------------------------------


 QUALITY CONTROL AND DATING CHECK OF TREE-RING MEASUREMENTS


 File of DATED series:   dated.txt


 File of UNDATED series: undated.txt


                                        ****************************************
                                        *C* Number of dated series        55 *C*
                                        *O* Master series 1883 2012  130 yrs *O*
                                        *F* Total rings in all series   3418 *F*
                                        *E* Total dated rings checked   3385 *E*
                                        *C* Series intercorrelation     .406 *C*
                                        *H* Average mean sensitivity    .396 *H*
                                        *A* Segments, possible problems   35 *A*
                                        *** Mean length of series       62.1 ***
                                        ****************************************


 ABSENT RINGS listed by SERIES:            (See Master Dating Series for absent rings
listed by year)

 Cat033      1 absent rings:   2001
 Cat035      2 absent rings:   2005  2006
 Cat044      1 absent rings:   2007
 Cat049      1 absent rings:   2007
             5 absent rings    .146%


PART 2:  TIME PLOT OF TREE-RING SERIES:
15:15  Tue 08 Jul 2014  Page   2
-----------------------------------------------------------------------------------------
-------------------------------------------
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850
1900 1950 2000 2050 Ident   Seq Time-span  Yrs
   :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :
    :    :    : -------- --- ---- ---- ----
```

```
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
<===>    .    . CIS001     1 1916 1959   44
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
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   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
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   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
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    .  <==>   . Cat038    28 1981 2012   32
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```

```
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
    .<====>   . Cat049    37 1962 2012   51
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   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
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1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900
1950 2000 2050
PART 2:  TIME PLOT OF TREE-RING SERIES:
15:15  Tue 08 Jul 2014  Page   3
------------------------------------------------------------------------------------------
-------------------------------------------
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850
1900 1950 2000 2050 Ident   Seq Time-span  Yrs
   :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :
    :    :    : -------- --- ---- ---- ----
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
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   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
<=======>   . Cat090    55 1930 2012   83
   :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :
    :    :    :
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850
1900 1950 2000 2050
   :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :
    :    :    :
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850
1900 1950 2000 2050

PART 3:  Master Dating Series:
15:15  Tue 08 Jul 2014  Page   4
------------------------------------------------------------------------------------------
-------------------------------------------
  Year  Value  No Ab    Year  Value  No Ab    Year  Value  No Ab    Year  Value  No Ab
Year  Value  No Ab    Year  Value  No Ab
  ------------------    ------------------    ------------------    ------------------
------------------    ------------------
                        1900   .236   1       1950 -1.063  36       2000 -1.347  47
                        1901   .168   1       1951  -.995  37       2001 -1.006  47  1
                        1902  -.859   1       1952  -.085  39       2002   .568  45
                        1903 -3.535   1       1953  -.390  40       2003   .794  45
                        1904   .129   1       1954   .178  40       2004   .597  44
                        1905  2.108   1       1955   .096  41       2005  -.286  43  1<<
                        1906   .013   1       1956   .186  41       2006  -.509  43  1
```

```
                        1907   .726   1       1957   .645  45       2007 -1.148  42  2
                        1908  2.425   1       1958   .693  45       2008   .050  42
                        1909  2.124   1       1959   .607  45       2009  -.023  40

                        1910  -.006   1       1960  1.001  44       2010   .597  40
                        1911  -.041   1       1961  1.277  45       2011   .537  36
                        1912  1.591   1       1962   .730  47       2012  1.448  32
                        1913 -1.084   1       1963 -1.265  47
                        1914 -1.483   1       1964  -.397  47
                        1915  -.495   1       1965   .539  47
                        1916  -.377   2       1966   .312  47
                        1917  1.512   3       1967  -.254  47
                        1918   .726   4       1968  -.366  47
                        1919   .627   4       1969 -1.568  46

                        1920 -1.525   4       1970  -.260  46
                        1921 -1.236   4       1971 -1.066  46
                        1922   .744   4       1972  -.661  46
                        1923  -.002   4       1973  -.312  46
                        1924   .221   4       1974   .107  47
                        1925   .211   4       1975  -.985  47
                        1926  -.020   4       1976  1.072  47
                        1927   .426   4       1977  -.106  47
                        1928 -2.358   5       1978  1.248  48
                        1929  -.860   5       1979   .664  49

                        1930   .341   7       1980   .564  49
                        1931   .246   9       1981   .022  50
                        1932   .725   9       1982 -1.108  50
  1883  -.031   1       1933   .508  10       1983   .085  50
  1884  1.442   1       1934  -.032  10       1984   .926  51
  1885  1.626   1       1935   .101  16       1985   .202  52
  1886  1.580   1       1936   .263  18       1986   .145  52
  1887 -4.031   1       1937  -.619  20       1987 -1.586  52
  1888 -1.399   1       1938   .490  22       1988  -.806  52
  1889   .044   1       1939   .922  23       1989   .496  52

  1890 -1.435   1       1940   .590  25       1990  -.097  52
  1891   .048   1       1941   .382  26       1991   .348  52
  1892   .726   1       1942   .007  26       1992   .101  51
  1893 -1.568   1       1943  -.348  27       1993   .338  50
  1894   .827   1       1944  -.868  27       1994   .838  50
  1895  1.153   1       1945  -.810  29       1995   .223  49
  1896  2.617   1       1946  -.452  30       1996   .358  49
  PART 3:  Master Dating Series (cont):
  1897  -.591   1       1947  -.133  31       1997  -.205  49
  1898 -1.016   1       1948  -.066  33       1998  -.117  49
  1899 -1.456   1       1949  -.325  34       1999  -.146  49


PART 4:  Master Bar Plot:
15:15  Tue 08 Jul 2014  Page   5
-----------------------------------------------------------------------------------------
-------------------------------------------
   Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year Rel value  Year
Rel value  Year Rel value  Year Rel value
                   1900------A     1950-d          2000e
                   1901------A     1951-d          2001-d
                   1902-c          1952----@       2002--------B
                   1903n           1953---b        2003---------C
                   1904-----A      1954------A     2004--------B
                   1905----------H 1955-----@      2005---a
                   1906----@       1956------A     2006--b
                   1907--------C   1957--------C   2007-e
                   1908----------J 1958--------C   2008-----@
                   1909----------H 1959--------B   2009----@
                   1910----@       1960---------D  2010--------B
                   1911----@       1961----------E 2011-------B
                   1912----------F 1962--------C   2012----------F
                   1913-d          1963-e
                   1914f           1964---b
                   1915--b         1965-------B
```

```
                   1916---b        1966------A
                   1917----------F 1967---a
                   1918--------C   1968---a
                   1919--------C   1969f
                   1920f           1970---a
                   1921-e          1971-d
                   1922---------C  1972--c
                   1923----@       1973---a
                   1924------A     1974-----@
                   1925------A     1975-d
                   1926----@       1976---------D
                   1927-------B    1977----@
                   1928i           1978----------E
                   1929-c          1979--------C
                   1930------A     1980--------B
                   1931------A     1981----@
                   1932--------C   1982-d
   1883----@       1933-------B    1983-----@
   1884----------F 1934----@       1984---------D
   1885----------G 1935-----@      1985------A
   1886----------F 1936------A     1986-----A
   1887p           1937--b         1987f
   1888f           1938-------B    1988--c
   1889-----@      1939---------D  1989-------B
   1890f           1940--------B   1990----@
   1891-----@      1941-------B    1991------A
   1892--------C   1942----@       1992-----@
   1893f           1943---a        1993------A
   1894---------C  1944-c          1994---------C
   1895---------E  1945--c         1995------A
   1896----------J 1946--b         1996-------A
   1897--b         1947----a       1997---a
   1898-d          1948----@       1998----@
   1899f           1949---a        1999----a
```

```
CORRELATION OF SERIES BY SEGMENTS:
15:15 Tue 08 Jul 2014 Page   5
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-------------------------------------------
 Correlations of 50-year dated segments, lagged 25 years
 Flags:  A = correlation under   .3281 but highest as dated; B = correlation higher at
other than dated position

 Seq Series Time_span   1900 1925 1950 1975
                         1949 1974 1999 2024
 --- -------- ---------  ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
---- ---- ---- ---- ---- ---- ----
   1 CIS001   1916 1959   .50
   2 CIS002   1951 1991             .36
   3 Cat003   1936 1980        .23B
   4 Cat004   1940 2012        .39  .42  .46
   5 Cat006   1935 2012        .42B .49  .62
   6 Cat008   1946 2012        .25A .29A .34
   7 Cat009   1945 2003        .34  .36  .37
   8 Cat010   1957 2004             .29B
   9 Cat011   1952 2011             .37  .42
  10 Cat012   1931 1999        .41  .33
  11 Cat013   1931 2010        .51  .71  .71
  12 Cat014   1981 2012                  .27A
  13 Cat017   1950 2012             .44  .42
  14 Cat018   1928 2012        .29B .30A .32A
  15 cat019   1935 2012        .60  .64  .55
  16 Cat022   1930 2008        .50  .65  .47
  17 Cat023   1937 2011        .30B .45  .46
  18 Cat024   1953 2008             .41  .38
  19 Cat026   1939 1999        .39  .52
  20 Cat027   1935 2001        .36  .46  .47
  21 Cat029   1936 2010        .64  .66  .71
  22 Cat031   1984 2012                  .56
  23 Cat032   1935 2012        .68  .73  .74
  24 Cat033   1979 2012                  .38
```

```
  25 Cat034   1935 2012        .68  .73  .75
  26 Cat035   1940 2012        .63  .66  .62
  27 Cat037   1978 2006                  .50
  28 Cat038   1981 2012                  .53
  29 Cat039   1935 2011        .32A .58  .66
  30 Cat040   1948 2012        .46  .48  .50
  31 Cat042   1933 1992        .44  .60
  32 Cat043   1941 2012        .30A .29B .42
  33 Cat044   1938 2012        .46  .49  .41
  34 Cat045   1985 2012                  .54
  35 Cat046   1883 2001   .35  .26B .44  .45
  36 Cat047   1950 2010             .60  .45
  37 Cat049   1962 2012             .39  .42
  38 Cat051   1917 1968   .39  .35
  39 Cat054   1961 2011             .46  .43
  40 Cat055   1949 2012        .35  .37  .42
  41 Cat062   1962 2012             .44  .47
  42 Cat064   1948 2012        .31B .31B .32A
  43 Cat065   1957 2012             .22B .25B
  44 Cat067   1947 2012        .23A .22B .28A
  45 Cat069   1945 2012        .57  .57  .53
  46 Cat070   1974 2012             .19B
  47 Cat071   1943 2010        .54  .55  .45
  Part   5: CORRELATION OF SERIES BY SEGMENTS (cont)
  48 Cat072   1955 2012             .40  .35
  49 Cat074   1957 2012             .32A .34
  50 Cat076   1952 2012             .46  .49
  51 Cat077   1938 2012        .25B .37  .31A
  52 Cat078   1937 2012        .21B .13B .25A
  53 Cat080   1957 2012             .11B .15B
  54 Cat081   1918 1994   .28A .27A .21B
  55 Cat090   1930 2012        .25A .49  .50
 Av segment correlation   .38  .40  .43  .45


PART 6:  POTENTIAL PROBLEMS:
15:15  Tue 08 Jul 2014  Page   6
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-------------------------------------------

 For each series with potential problems the following diagnostics may appear:

 [A] Correlations with master dating series of flagged  50-year segments of series
filtered with  32-year spline,
     at every point from ten years earlier (-10) to ten years later (+10) than dated

 [B] Effect of those data values which most lower or raise correlation with master series
     Symbol following year indicates value in series is greater (>) or lesser (<) than
master series value

 [C] Year-to-year changes very different from the mean change in other series

 [D] Absent rings (zero values)

 [E] Values which are statistical outliers from mean for the year
=========================================================================================
===========================================

 CIS001    1916 to  1959      44 years
Series   1

 [B] Entire series, effect on correlation (  .500) is:
       Lower   1948< -.077   1950> -.038   1916> -.033   1940< -.032   1937> -.026   1951>
-.023  Higher   1928  .206   1920  .049

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1948 -4.6 SD
=========================================================================================
===========================================

 CIS002    1951 to  1991      41 years
Series   2
```

```
 [B] Entire series, effect on correlation (  .359) is:
       Lower   1969> -.089   1963> -.039   1954< -.037   1957< -.037   1971> -.030
1984< -.025  Higher   1987  .135   1975  .045

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1969 +3.1 SD;    1975 -5.6 SD
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 Cat003    1936 to  1980      45 years
Series   3

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1936 1980    2   -.10  .03 -.12 -.29  .01 -.02  .03  .22  .09  .16  .23|-
.09  .27* .13  .07  .13 -.01 -.28 -.06  .01 -.09

 [B] Entire series, effect on correlation (  .232) is:
       Lower   1963> -.053   1954< -.049   1975> -.032   1944> -.031   1947< -.022   1950>
-.019  Higher   1969  .072   1976  .046
     1936 to 1980 segment:
       Lower   1963> -.053   1954< -.049   1975> -.032   1944> -.031   1947< -.022   1950>
-.019  Higher   1969  .072   1976  .046

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 Cat004    1940 to  2012      73 years
Series   4

 [B] Entire series, effect on correlation (  .376) is:
       Lower   1963> -.051   1950> -.027   1947< -.026   2010< -.022   1972> -.016   2006>
-.015  Higher   1969  .052   1987  .052

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 Cat006    1935 to  2012      78 years
Series   5

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1935 1984   -9   -.19  .42* .00 -.08  .13 -.01  .05  .19  .00  .00  .42|-.14 -.22 -
.17 -.09  .05  .01 -.18  .09 -.14  .13

 [B] Entire series, effect on correlation (  .462) is:
       Lower   1937< -.056   1976< -.031   1994< -.016   1959< -.014   1951> -.013   1949>
-.011  Higher   1963  .030   2012  .025
     1935 to 1984 segment:
       Lower   1937< -.059   1976< -.044   1951> -.020   1959< -.018   1949> -.016   1950>
-.016  Higher   1963  .044   1969  .025

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 Cat008    1946 to  2012      67 years
Series   6

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1946 1995    0   -.22 -.06  .00 -.18 -.02 -.43 -.11  .04  .19  .06  .25*-
.01  .11  .12  .14  .12  .02 -.11 -.12 -.10  .12
    1950 1999    0   -.22 -.17  .05 -.13  .00 -.47 -.12  .04  .16  .03  .29*-
.01  .14  .10  .04  .06  .06 -.17 -.11 -.12  .13
```

```
 [B] Entire series, effect on correlation (  .215) is:
       Lower   1989< -.042   1982> -.029   1950> -.029   1959< -.024   1946< -.021
1966< -.017  Higher   1969  .049   1987  .046
     1946 to 1995 segment:
       Lower   1989< -.052   1982> -.038   1950> -.038   1959< -.030   1946< -.030
1966< -.021  Higher   1969  .056   1987  .051
     1950 to 1999 segment:
       Lower   1989< -.066   1982> -.044   1950> -.043   1959< -.038   1966< -.029   1951>
-.022  Higher   1969  .066   1987  .062

 [C] Year-to-year changes diverging by over 4.0 std deviations:
       1946 1947   4.1 SD

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1946 -5.4 SD
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 Cat009    1945 to  2003      59 years
Series   7

 [B] Entire series, effect on correlation (  .355) is:
       Lower   1959< -.132   1963> -.035   1981< -.034   2001> -.017   1945> -.016   1977>
-.013  Higher   1969  .059   1975  .025

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1959 -6.2 SD
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 Cat010    1957 to  2004      48 years
Series   8

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1957 2004    7   -.10 -.19 -.32 -.15  .11 -.01  .15 -.14 -.07  .35  .29| .08  .20 -
.29 -.19  .14 -.10  .37* .07    -    -

 [B] Entire series, effect on correlation (  .286) is:
       Lower   1971> -.084   1963> -.045   1990> -.031   1964< -.031   1999< -.020
1970< -.017  Higher   1975  .051   2000  .037
     1957 to 2004 segment:
       Lower   1971> -.084   1963> -.045   1990> -.031   1964< -.031   1999< -.020
1970< -.017  Higher   1975  .051   2000  .037

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1971 +4.0 SD;    1990 +3.2 SD
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 Cat011    1952 to  2011      60 years
Series   9

 [B] Entire series, effect on correlation (  .430) is:
       Lower   1966< -.079   1990> -.038   1997> -.026   1963> -.025   1957< -.024   1971>
-.014  Higher   1969  .048   1976  .035

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1966 -4.6 SD;    1990 +3.2 SD
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 Cat012    1931 to  1999      69 years
Series  10

 [B] Entire series, effect on correlation (  .345) is:
       Lower   1961< -.028   1956< -.027   1997> -.020   1990> -.014   1993< -.014
1933< -.013  Higher   1971  .062   1937  .014

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
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       1971 -6.2 SD
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 Cat013    1931 to  2010      80 years
Series  11

 [B] Entire series, effect on correlation (  .594) is:
       Lower   1934< -.051   1936< -.029   2006> -.014   1995< -.010   1971> -.009
1983< -.009  Higher   1987  .053   1982  .018

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 Cat014    1981 to  2012      32 years
Series  12

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1981 2012    0   -.07  .16  .21 -.08 -.04 -.14 -.33  .21 -.08  .11  .27*   -    -
-    -    -    -    -    -    -    -

 [B] Entire series, effect on correlation (  .273) is:
       Lower   1987> -.208   1993< -.045   1996< -.038   2007> -.031   2005> -.023   2001>
-.023  Higher   2000  .156   2012  .068
     1981 to 2012 segment:
       Lower   1987> -.208   1993< -.045   1996< -.038   2007> -.031   2005> -.023   2001>
-.023  Higher   2000  .156   2012  .068

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1987 +3.9 SD
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 Cat017    1950 to  2012      63 years
Series  13

 [B] Entire series, effect on correlation (  .441) is:
       Lower   1987> -.049   2000> -.040   1969> -.027   1971> -.027   2008< -.012   1967>
-.012  Higher   1963  .055   2007  .020

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1975 -5.0 SD
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 Cat018    1928 to  2012      85 years
Series  14

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1928 1977    1   -.18 -.09 -.16 -.03  .12  .04 -.19  .04  .25 -
.15  .29|  .39* .16  .19 -.11 -.28  .09  .13 -.06 -.04 -.20
    1950 1999    0   -.15 -.01 -.32 -.26  .18  .10 -
.07  .11  .00  .07  .30* .25  .08  .00 -.09 -.13 -.04 -.02 -.04 -.02 -.13
    1963 2012    0   -.09  .09 -.17 -.16  .23  .08 -.08  .02 -.03  .18  .32*   -    -
-    -    -    -    -    -    -    -

 [B] Entire series, effect on correlation (  .298) is:
       Lower   1996< -.048   2000> -.032   1962< -.028   1929> -.020   1977> -.018
1930< -.012  Higher   1969  .035   2012  .022
     1928 to 1977 segment:
       Lower   1962< -.053   1929> -.032   1977> -.029   1930< -.023   1967> -.017
1974< -.014  Higher   1969  .058   1976  .030
     1950 to 1999 segment:
       Lower   1996< -.082   1962< -.047   1977> -.033   1967> -.020   1995> -.018
1974< -.011  Higher   1969  .067   1978  .035
     1963 to 2012 segment:
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      Lower   1996< -.088   2000> -.057   1977> -.031   1967> -.018   2008< -.018   1995>
-.016  Higher   1969  .060   2012  .038

 [C] Year-to-year changes diverging by over 4.0 std deviations:
      1929 1930  -4.0 SD

 [E] Outliers     4   3.0 SD above or -4.5 SD below mean for year
      1929 +3.7 SD;    1938 +3.0 SD;    1995 +3.0 SD;    2000 +3.2 SD
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 cat019    1935 to  2012      78 years
Series  15

 [B] Entire series, effect on correlation (  .512) is:
      Lower   2012< -.059   1976< -.024   1949< -.021   1989< -.017   2005> -.013   1990>
-.009  Higher   1969  .030   1971  .028

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 Cat022    1930 to  2008      79 years
Series  16

 [B] Entire series, effect on correlation (  .394) is:
      Lower   2000> -.040   1930< -.029   2006> -.027   2003< -.022   1992< -.021   1937>
-.018  Higher   1950  .028   1976  .022

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
      1950 -5.3 SD;    2006 +3.1 SD
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 Cat023    1937 to  2011      75 years
Series  17

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1937 1986   -1   -.08 -.23 -.07 -.21  .02  .04 -.06 -.08  .30  .34* .30|-
.07  .15  .08  .15  .17 -.10  .17  .00 -.25 -.22

 [B] Entire series, effect on correlation (  .383) is:
      Lower   1946< -.038   1963> -.037   1937> -.026   2006> -.019   1989< -.016
2011< -.012  Higher   1987  .039   1976  .029
    1937 to 1986 segment:
      Lower   1963> -.049   1946< -.049   1937> -.037   1938< -.013   1944> -.012
1965< -.011  Higher   1976  .049   1978  .046

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1946 -6.4 SD
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 Cat024    1953 to  2008      56 years
Series  18

 [B] Entire series, effect on correlation (  .395) is:
      Lower   1994< -.150   2002< -.026   2006> -.021   1977> -.016   2003< -.016
1970< -.013  Higher   1969  .064   1963  .040

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 Cat026    1939 to  1999      61 years
Series  19

 [B] Entire series, effect on correlation (  .397) is:
      Lower   1940< -.123   1987> -.053   1979< -.021   1971> -.015   1953> -.014
1991< -.012  Higher   1982  .043   1976  .040
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 Cat027    1935 to  2001      67 years
Series  20

 [B] Entire series, effect on correlation (  .443) is:
       Lower   1963> -.049   1937> -.034   1952< -.024   1942< -.012   1991< -.011   1967>
-.010  Higher   2000  .044   1978  .032

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       2000 -5.1 SD
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 Cat029    1936 to  2010      75 years
Series  21

 [B] Entire series, effect on correlation (  .650) is:
       Lower   1958< -.019   2003< -.016   1955< -.015   1999> -.013   1969> -.013   1953>
-.011  Higher   1987  .047   1963  .027

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 Cat031    1984 to  2012      29 years
Series  22

 [B] Entire series, effect on correlation (  .561) is:
       Lower   2000> -.074   2001> -.041   2008< -.039   1997> -.031   1996< -.022   1995>
-.012  Higher   1987  .222   2007  .056

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 Cat032    1935 to  2012      78 years
Series  23

 [B] Entire series, effect on correlation (  .707) is:
       Lower   1963> -.013   1995< -.013   1937> -.010   1945< -.009   1949> -.009   1998>
-.008  Higher   1987  .036   1969  .013

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 Cat033    1979 to  2012      34 years
Series  24

 [B] Entire series, effect on correlation (  .409) is:
       Lower   2007> -.059   2008< -.049   2005> -.038   1987> -.027   1983< -.025
2012< -.019  Higher   2000  .128   1982  .085

 [D]    1 Absent rings:  Year   Master  N series Absent
                         2001   -1.006      47       1

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       2001 -4.9 SD
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 Cat034    1935 to  2012      78 years
Series  25

 [B] Entire series, effect on correlation (  .709) is:
       Lower   1963> -.013   1995< -.012   1937> -.010   1945< -.009   1949> -.009   1998>
-.008  Higher   1987  .036   1969  .013

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 Cat035    1940 to  2012      73 years
Series  26
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 [B] Entire series, effect on correlation (  .543) is:
       Lower   2005< -.035   1949> -.027   2007> -.019   2000> -.015   1975> -.012   1953>
-.012  Higher   1963  .029   1976  .028

 [D]    2 Absent rings:  Year   Master  N series Absent
                         2005    -.286      43       1  >> WARNING:  Ring is not usually
narrow
                         2006    -.509      43       1

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       2005 -4.9 SD
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 Cat037    1978 to  2006      29 years
Series  27

 [B] Entire series, effect on correlation (  .505) is:
       Lower   1988< -.060   1979< -.051   1999> -.030   2001> -.021   2000> -.019   2006>
-.017  Higher   1987  .124   1978  .039

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1999 +3.3 SD
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 Cat038    1981 to  2012      32 years
Series  28

 [B] Entire series, effect on correlation (  .531) is:
       Lower   1987> -.048   1988> -.026   2011< -.024   1983< -.021   1990> -.019
2008< -.017  Higher   2000  .088   1982  .059

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 Cat039    1935 to  2011      77 years
Series  29

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1935 1984    0   -.01 -.30 -.02 -.21  .03  .00  .26 -.07  .03 -.05  .32*-
.10  .10  .01  .05  .28  .15 -.18  .02 -.27  .08

 [B] Entire series, effect on correlation (  .440) is:
       Lower   1938< -.044   1957< -.041   1948< -.034   2003< -.023   1951> -.020
1939< -.019  Higher   1987  .050   2000  .028
     1935 to 1984 segment:
       Lower   1938< -.057   1957< -.053   1948< -.036   1951> -.029   1939< -.024   1953>
-.021  Higher   1978  .036   1961  .033

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1948 -5.5 SD
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 Cat040    1948 to  2012      65 years
Series  30

 [B] Entire series, effect on correlation (  .500) is:
       Lower   1987> -.058   1971> -.048   1983< -.040   1988> -.019   1948> -.016   1972>
-.012  Higher   1963  .032   1982  .031

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1983 -5.4 SD
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 Cat042    1933 to  1992      60 years
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Series  31

 [B] Entire series, effect on correlation (  .482) is:
       Lower   1939< -.066   1992< -.039   1938< -.029   1955< -.027   1946> -.019
1954< -.017  Higher   1987  .067   1976  .033

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1939 -4.8 SD
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 Cat043    1941 to  2012      72 years
Series  32

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1941 1990    0    .17 -.04  .25 -.17 -.01 -.21  .05 -.18  .04 -.20  .30*-.06  .03 -
.10  .22  .13  .26 -.08  .02  .05  .04
    1950 1999   -8    .13 -.05  .32*-.14 -.03 -.10  .05 -.24  .00 -.29  .29|-.05  .10 -
.01  .26  .14  .21 -.18 -.03  .04  .08

 [B] Entire series, effect on correlation (  .373) is:
       Lower   1987> -.042   1962< -.029   1949> -.023   1994< -.017   1954< -.016   2006>
-.012  Higher   2007  .031   1971  .025
     1941 to 1990 segment:
       Lower   1962< -.050   1987> -.049   1949> -.030   1954< -.029   1983< -.019
1979< -.009  Higher   1971  .044   1976  .031
     1950 to 1999 segment:
       Lower   1987> -.058   1962< -.043   1994< -.024   1954< -.023   1983< -.015
1995< -.014  Higher   1971  .047   1976  .035

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1949 +3.0 SD;    1987 +3.5 SD
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 Cat044    1938 to  2012      75 years
Series  33

 [B] Entire series, effect on correlation (  .425) is:
       Lower   2010< -.054   1946> -.022   1975> -.019   1944> -.014   1980< -.013
1978< -.012  Higher   2007  .032   1976  .029

 [D]    1 Absent rings:  Year   Master  N series Absent
                         2007   -1.148      42       2

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       2007 -6.1 SD
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 Cat045    1985 to  2012      28 years
Series  34

 [B] Entire series, effect on correlation (  .536) is:
       Lower   1992< -.099   1998< -.041   2005> -.030   1988> -.026   1990> -.015
1991< -.010  Higher   1987  .162   2000  .059

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1992 -4.8 SD
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 Cat046    1883 to  2001     119 years
Series  35

 [*] Early part of series cannot be checked from 1883 to 1915 -- not matched by another
series

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
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+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1925 1974    8   -.20 -.01  .19  .09  .04 -.18 -.13  .03 -.33 -.10  .26| .09  .04 -
.12 -.13  .05  .01  .01  .28* .09  .02

 [B] Entire series, effect on correlation (  .353) is:
      Lower   1969> -.041   1945> -.015   1990< -.012   1947> -.011   1926< -.011
1918< -.010  Higher   1963  .056   2000  .027
     1925 to 1974 segment:
      Lower   1969> -.070   1945> -.023   1926< -.018   1936< -.017   1974< -.015   1947>
-.015  Higher   1963  .132   1957  .023

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1969 +3.8 SD
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 Cat047    1950 to  2010      61 years
Series  36

 [B] Entire series, effect on correlation (  .483) is:
      Lower   2008< -.092   1985< -.036   1982> -.026   2007> -.022   1967> -.011   2005>
-.011  Higher   1987  .045   1978  .025

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 Cat049    1962 to  2012      51 years
Series  37

 [B] Entire series, effect on correlation (  .431) is:
      Lower   1971> -.093   1984< -.090   1994< -.039   1986< -.019   2005> -.015
1981< -.014  Higher   1987  .102   1963  .048

 [D]    1 Absent rings:  Year   Master  N series Absent
                         2007   -1.148      42      2

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1971 +3.9 SD
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 Cat051    1917 to  1968      52 years
Series  38

 [B] Entire series, effect on correlation (  .372) is:
      Lower   1925< -.072   1950> -.049   1931< -.027   1926> -.024   1927> -.019   1949>
-.019  Higher   1928  .207   1917  .017

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
      1927 +3.6 SD;    1950 +3.5 SD
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 Cat054    1961 to  2011      51 years
Series  39

 [B] Entire series, effect on correlation (  .461) is:
      Lower   1988< -.049   1975> -.039   2003< -.034   1998> -.018   1962< -.017
1989< -.017  Higher   1961  .028   2000  .028

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1988 -5.1 SD
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 Cat055    1949 to  2012      64 years
Series  40

 [B] Entire series, effect on correlation (  .323) is:
      Lower   1954< -.065   1969> -.027   1971> -.022   2004< -.018   2001> -.018   2000>
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-.017  Higher   1987  .080   1975  .031

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1954 -5.3 SD
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 Cat062    1962 to  2012      51 years
Series  41

 [B] Entire series, effect on correlation (  .473) is:
       Lower   1963> -.028   2007> -.026   1977> -.021   2002< -.020   1983< -.019
2010< -.015  Higher   1987  .031   2012  .029

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 Cat064    1948 to  2012      65 years
Series  42

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1948 1997    1   -.27  .06 -.01 -.02 -.02 -.01 -.02 -.03  .11  .16  .31| .38*-.04 -
.12  .21 -.20  .06 -.27 -.24 -.12 -.07
    1950 1999    1   -.29  .05 -.02 -.01 -.02  .00  .01 -.02  .13  .15  .31| .36*-.06 -
.11  .21 -.17  .06 -.29 -.25 -.15 -.06
    1963 2012    0   -.20  .06  .05  .07 -.09 -.04  .03 -.08  .06  .05  .32*   -    -
-    -    -    -    -    -    -    -

 [B] Entire series, effect on correlation (  .297) is:
       Lower   1996< -.034   2006> -.025   1952< -.022   1977> -.019   2004< -.017   1975>
-.016  Higher   1971  .064   1969  .031
     1948 to 1997 segment:
       Lower   1996< -.042   1952< -.027   1977> -.025   1975> -.021   1963> -.021
1962< -.016  Higher   1971  .080   1969  .037
     1950 to 1999 segment:
       Lower   1996< -.042   1952< -.027   1977> -.025   1975> -.021   1963> -.021
1962< -.016  Higher   1971  .082   1969  .038
     1963 to 2012 segment:
       Lower   1996< -.047   2006> -.030   2004< -.023   1977> -.023   1975> -.019   1963>
-.017  Higher   1971  .068   1969  .036

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       2006 +3.2 SD
==========================================================================================
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 Cat065    1957 to  2012      56 years
Series  43

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1957 2006    1   -.07  .31  .01 -.03 -.08  .06 -.23 -.14 -.18  .15  .22| .32*-.24 -
.09 -.10  .02  .06    -    -    -    -
    1963 2012   -9   -.01  .37*-.02 -.04 -.06  .00 -.23 -.19 -.20  .11  .25|   -    -
-    -    -    -    -    -    -    -

 [B] Entire series, effect on correlation (  .261) is:
       Lower   1969> -.042   1987> -.036   1984< -.030   1977> -.029   1978< -.018
1996< -.017  Higher   1963  .052   2000  .033
     1957 to 2006 segment:
       Lower   1969> -.044   1987> -.037   1984< -.032   1977> -.030   1978< -.019
1996< -.018  Higher   1963  .059   2000  .037
     1963 to 2012 segment:
       Lower   1969> -.044   1987> -.038   1984< -.035   1977> -.029   1996< -.021
2006< -.021  Higher   1963  .054   2000  .033

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
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       2006 -4.9 SD
==========================================================================================
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 Cat067    1947 to  2012      66 years
Series  44

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1947 1996    0    .10 -.12  .07 -.29 -.03 -.01  .02 -.16 -.22 -.18  .23* .03  .15 -
.11  .12  .06  .13  .03  .22  .01  .02
    1950 1999    8    .08 -.11  .09 -.30 -.03 -.03  .00 -.15 -.22 -.17  .22| .02  .13 -
.15  .10  .06  .17  .05  .23* .03  .00
    1963 2012    0    .09 -.04  .22 -.17  .04  .00  .07 -.19 -.27 -.16  .28*   -    -
-    -    -    -    -    -    -    -

 [B] Entire series, effect on correlation (  .243) is:
       Lower   1969> -.041   2000> -.033   1960< -.022   1982> -.019   1961< -.018
1986< -.017  Higher   1963  .128   1984  .030
     1947 to 1996 segment:
       Lower   1969> -.054   1960< -.027   1982> -.026   1961< -.022   1971> -.022
1986< -.020  Higher   1963  .175   1984  .040
     1950 to 1999 segment:
       Lower   1969> -.053   1960< -.027   1982> -.024   1961< -.022   1971> -.020
1986< -.020  Higher   1963  .184   1984  .040
     1963 to 2012 segment:
       Lower   1969> -.051   2000> -.041   1982> -.024   1986< -.022   1971> -.021
1983< -.020  Higher   1963  .137   1984  .036

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1963 -5.8 SD;    1969 +3.0 SD
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 Cat069    1945 to  2012      68 years
Series  45

 [B] Entire series, effect on correlation (  .541) is:
       Lower   2000> -.020   1987> -.019   1976< -.018   2005> -.017   1960< -.015
1971< -.012  Higher   1963  .038   1950  .018

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 Cat070    1974 to  2012      39 years
Series  46

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1974 2012   -6    .14  .09  .23  .05  .27*-.12  .09 -.41  .13 -.27  .19|   -    -
-    -    -    -    -    -    -    -

 [B] Entire series, effect on correlation (  .190) is:
       Lower   1982> -.065   1979< -.047   1975> -.045   2005> -.044   1988> -.017
1999< -.015  Higher   2007  .058   1977  .040
     1974 to 2012 segment:
       Lower   1982> -.065   1979< -.047   1975> -.045   2005> -.044   1988> -.017
1999< -.015  Higher   2007  .058   1977  .040

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       2005 +3.2 SD
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 Cat071    1943 to  2010      68 years
Series  47

 [B] Entire series, effect on correlation (  .447) is:
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       Lower   2007> -.038   1989< -.031   1949> -.027   1998< -.017   1995< -.017   2001>
-.016  Higher   1963  .054   1976  .026

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
       1949 +3.2 SD
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 Cat072    1955 to  2012      58 years
Series  48

 [B] Entire series, effect on correlation (  .321) is:
       Lower   2012< -.084   1960< -.046   1975> -.040   2005> -.029   2001> -.020
2004< -.014  Higher   1987  .088   1963  .031

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 Cat074    1957 to  2012      56 years
Series  49

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1957 2006    0    -.08 -.23 -.08 -.05 -.20 -.11 -.05 -.14 -.02  .05  .32* .17 -.02 -
.04  .22 -.22  .13    -    -    -    -

 [B] Entire series, effect on correlation (  .337) is:
       Lower   1972> -.053   1977> -.030   1983< -.025   1969> -.022   1984< -.019
1960< -.013  Higher   1963  .116   1971  .042
     1957 to 2006 segment:
       Lower   1972> -.057   1977> -.032   1983< -.028   1969> -.025   1984< -.021
1960< -.014  Higher   1963  .132   1971  .046

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1963 -5.1 SD;    1972 +4.1 SD
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 Cat076    1952 to  2012      61 years
Series  50

 [B] Entire series, effect on correlation (  .443) is:
       Lower   1978< -.031   1962< -.029   2002< -.021   1957< -.019   1992< -.016   1981>
-.010  Higher   1963  .036   1975  .027

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 Cat077    1938 to  2012      75 years
Series  51

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1938 1987   -4     .21  .09 -.06  .16  .10  .21  .28*-.09  .13 -.02  .25|-.11 -.07 -
.21  .00 -.15 -.03 -.23  .09  .09  .10
    1963 2012    0     .19  .16  .06  .03  .04  .17  .18 -.10  .04 -.21  .31*   -    -
-    -    -    -    -    -    -    -

 [B] Entire series, effect on correlation (  .264) is:
       Lower   1973< -.039   1978< -.027   1941< -.025   1938< -.023   2012< -.014   1985>
-.013  Higher   1982  .044   1960  .016
     1938 to 1987 segment:
       Lower   1973< -.053   1978< -.035   1941< -.033   1938< -.031   1969> -.017   1985>
-.016  Higher   1982  .057   1960  .025
     1963 to 2012 segment:
       Lower   1973< -.068   1978< -.035   1969> -.020   1985> -.018   1988> -.017
2012< -.017  Higher   1982  .051   1994  .021
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 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1973 -6.4 SD;    1985 +3.1 SD
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 Cat078    1937 to  2012      76 years
Series  52

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1937 1986    2   -.17 -.38 -.12 -.18  .12  .05  .03  .15  .13 -
.04  .21| .18  .35* .21 -.22 -.05 -.02 -.21  .21 -.32 -.22
    1950 1999    2   -.09 -.32 -.12 -.16 -.01 -.08 -
.04  .10  .28  .01  .13| .21  .33* .19 -.18 -.07  .00 -.23  .24 -.30 -.20
    1963 2012    0   -.02 -.24 -.01 -.11  .00 -.14 -.08  .06  .20  .01  .25*   -    -
-    -    -    -    -    -    -    -

 [B] Entire series, effect on correlation (  .208) is:
       Lower   1987> -.075   1963> -.044   1989< -.017   1955< -.016   1974< -.015
1962< -.013  Higher   1969  .085   2012  .035
     1937 to 1986 segment:
       Lower   1963> -.072   1955< -.020   1974< -.019   1951> -.019   1982> -.017
1962< -.017  Higher   1969  .126   1978  .050
     1950 to 1999 segment:
       Lower   1987> -.100   1963> -.058   1989< -.021   1974< -.017   1955< -.016   1951>
-.016  Higher   1969  .137   1978  .049
     1963 to 2012 segment:
       Lower   1987> -.109   1963> -.063   1989< -.026   1974< -.024   1985< -.016
1976< -.014  Higher   1969  .111   2012  .050

 [C] Year-to-year changes diverging by over 4.0 std deviations:
       1986 1987   5.3 SD

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1985 -5.3 SD;    1987 +3.3 SD
=========================================================================================
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 Cat080    1957 to  2012      56 years
Series  53

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1957 2006    2   -.09 -.03 -.35 -.39  .09 -.04 -.06 -
.04  .00  .18  .11| .23  .30* .06  .04 -.22  .00    -    -    -    -
    1963 2012   -1   -.08  .05 -.26 -.33  .09 -.10 -.07 -.09  .01  .15* .15|   -    -
-    -    -    -    -    -    -    -

 [B] Entire series, effect on correlation (  .169) is:
       Lower   1965< -.119   1971> -.049   1982> -.048   1977> -.032   1988> -.016
1961< -.015  Higher   1969  .065   2012  .035
     1957 to 2006 segment:
       Lower   1965< -.119   1971> -.052   1982> -.051   1977> -.033   1988> -.016
1961< -.014  Higher   1969  .074   1987  .038
     1963 to 2012 segment:
       Lower   1965< -.134   1971> -.052   1982> -.051   1977> -.032   1986< -.017   1988>
-.015  Higher   1969  .067   2012  .044

 [C] Year-to-year changes diverging by over 4.0 std deviations:
       1964 1965  -4.3 SD

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
       1965 -6.4 SD;    1971 +3.2 SD
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 Cat081    1918 to  1994      77 years
Series  54
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 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1918 1967    0   -.07  .14  .15  .15  .11 -.24 -.09 -.05 -.08  .27  .28* .09 -.14 -
.23 -.05  .16  .13 -.03  .08 -.18 -.18
    1925 1974    0   -.23  .21  .20 -.01  .08 -.15 -.06  .02 -.09  .26  .27* .12 -.09 -
.16 -.13  .08  .14 -.12  .01 -.18 -.04
    1945 1994   -5   -.15  .06  .11  .07  .21  .26*-.05  .07 -.07 -.04  .21|-.02 -.20 -
.10 -.14  .03  .21  .02 -.02 -.17  .00

 [B] Entire series, effect on correlation (  .191) is:
      Lower   1958< -.036   1929< -.029   1976< -.029   1993< -.028   1982> -.027   1928>
-.017  Higher   1963  .060   1950  .030
     1918 to 1967 segment:
      Lower   1958< -.059   1928> -.057   1929< -.047   1945> -.014   1965< -.013
1932< -.013  Higher   1963  .082   1950  .039
     1925 to 1974 segment:
      Lower   1928> -.064   1958< -.062   1929< -.049   1965< -.014   1932< -.014   1945>
-.013  Higher   1963  .080   1950  .037
     1945 to 1994 segment:
      Lower   1958< -.062   1976< -.050   1982> -.049   1993< -.048   1945> -.017   1987>
-.017  Higher   1963  .106   1950  .052

 [C] Year-to-year changes diverging by over 4.0 std deviations:
      1928 1929  -4.5 SD

 [E] Outliers     1   3.0 SD above or -4.5 SD below mean for year
      1993 -4.6 SD
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 Cat090    1930 to  2012      83 years
Series  55

 [A] Segment   High   -10   -9   -8   -7   -6   -5   -4   -3   -2   -1   +0   +1   +2
+3   +4   +5   +6   +7   +8   +9  +10
    ---------  ----   ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  --
-  ---  ---  ---  ---  ---  ---  ---
    1930 1979    0   -.09  .05 -.12 -.08  .21 -.03 -.27 -.08 -.19 -.07  .25*-.15 -.07 -
.05  .05  .04  .17  .06  .21 -.03  .06

 [B] Entire series, effect on correlation (.377) is:
      Lower   1995< -.026   1939< -.021   1945> -.019   1938< -.019   1977> -.019
1958< -.018  Higher   1987  .072   1969  .045
     1930 to 1979 segment:
      Lower   1939< -.037   1938< -.034   1945> -.033   1977> -.032   1958< -.032   1944>
-.027  Higher   1969  .107   1963  .088

 [E] Outliers     2   3.0 SD above or -4.5 SD below mean for year
      1945 +3.1 SD;    1952 +3.8 SD
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PART 7:  DESCRIPTIVE STATISTICS:
15:15  Tue 08 Jul 2014  Page   7
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-------------------------------------------
                                                Corr   //-------- Unfiltered --------\\
//---- Filtered -----\\
                                No.    No.    No.    with   Mean   Max     Std   Auto   Mean
Max     Std   Auto  AR
 Seq Series   Interval   Years  Segmt  Flags   Master  msmt   msmt    dev   corr   sens
value    dev   corr  ()
 --- -------- ---------  -----  -----  -----   ------ -----  -----  -----  -----  -----
-----  -----  -----  --
   1 CIS001   1916 1959     44      1      0    .500   1.25   3.64   .712   .777   .369
2.56   .529   .058   1
   2 CIS002   1951 1991     41      1      0    .359   2.00   5.78  1.536   .762   .452
2.45   .526  -.026   3
   3 Cat003   1936 1980     45      1      1    .232   1.33   3.14   .650   .263   .488
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												2.73	.610	-.022	2
4	Cat004	1940	2012	73	3	0	.376	1.44	4.76	.830	.571	.396	2.86	.579	.045	3
5	Cat006	1935	2012	78	3	1	.462	1.80	7.10	1.620	.560	.530	2.55	.373	-.108	2
6	Cat008	1946	2012	67	3	2	.215	2.01	8.49	1.523	.609	.442	2.73	.482	-.039	2
7	Cat009	1945	2003	59	3	0	.355	1.54	3.79	.825	.443	.437	2.60	.489	-.079	1
8	Cat010	1957	2004	48	1	1	.286	2.11	5.18	1.035	.376	.360	2.82	.611	.006	1
9	Cat011	1952	2011	60	2	0	.430	1.97	5.40	1.179	.755	.372	2.85	.520	.039	1
10	Cat012	1931	1999	69	2	0	.345	1.80	4.53	.966	.651	.316	2.50	.399	-.081	1
11	Cat013	1931	2010	80	3	0	.594	1.86	9.03	1.902	.881	.500	2.62	.547	.007	1
12	Cat014	1981	2012	32	1	1	.273	4.23	11.93	3.060	.843	.256	2.68	.622	-.036	1
13	Cat017	1950	2012	63	2	0	.441	1.46	2.66	.622	.469	.369	2.42	.450	-.032	1
14	Cat018	1928	2012	85	3	3	.298	1.58	10.79	1.601	.136	.693	3.11	.543	-.019	1
15	cat019	1935	2012	78	3	0	.512	1.42	4.51	.811	.792	.323	2.65	.573	-.035	1
16	Cat022	1930	2008	79	3	0	.394	1.69	8.18	1.915	.884	.481	2.75	.554	.126	1
17	Cat023	1937	2011	75	3	1	.383	2.45	10.30	2.085	.877	.377	2.66	.488	.104	1
18	Cat024	1953	2008	56	2	0	.395	2.33	8.74	1.927	.769	.522	2.76	.528	.008	1
19	Cat026	1939	1999	61	2	0	.397	2.51	5.59	1.147	.634	.306	2.75	.476	-.046	1
20	Cat027	1935	2001	67	3	0	.443	1.96	6.96	1.467	.619	.450	2.59	.381	-.063	1
21	Cat029	1936	2010	75	3	0	.650	2.14	11.35	2.025	.706	.453	2.68	.533	-.049	3
22	Cat031	1984	2012	29	1	0	.561	4.84	10.61	2.873	.620	.424	2.47	.519	.114	2
23	Cat032	1935	2012	78	3	0	.707	1.31	6.75	1.228	.858	.448	2.72	.577	.016	1
24	Cat033	1979	2012	34	1	0	.409	2.27	4.97	1.416	.694	.485	2.41	.582	.089	2
25	Cat034	1935	2012	78	3	0	.709	1.31	6.75	1.229	.857	.453	2.67	.570	.016	1
26	Cat035	1940	2012	73	3	0	.543	1.78	7.06	1.399	.564	.447	2.85	.451	.067	1
27	Cat037	1978	2006	29	1	0	.505	3.15	9.84	2.057	.673	.337	2.68	.590	.118	2
28	Cat038	1981	2012	32	1	0	.531	3.72	7.79	1.994	.808	.356	2.52	.573	.008	2
29	Cat039	1935	2011	77	3	1	.440	2.28	9.16	1.628	.816	.359	2.74	.555	-.087	1
30	Cat040	1948	2012	65	3	0	.500	1.12	3.73	.706	.679	.429	2.72	.541	.073	1
31	Cat042	1933	1992	60	2	0	.482	2.11	7.14	1.538	.689	.472	2.98	.690	.007	1
32	Cat043	1941	2012	72	3	2	.373	1.69	4.65	.902	.557	.405	2.69	.495	-.053	2
33	Cat044	1938	2012	75	3	0	.425	1.50	5.99	.944	.743	.343	2.67	.434	-.036	1
34	Cat045	1985	2012	28	1	0	.536	3.32	8.54	2.187	.777	.402	2.61	.697	-.126	2
35	Cat046	1883	2001	119	4	1	.353	1.26	3.70	.772	.734	.328	2.68	.454	-.032	2
36	Cat047	1950	2010	61	2	0	.483	1.46	3.07	.518	.489	.292	2.66	.559	-.045	1
37	Cat049	1962	2012	51	2	0	.431	2.84	9.67	2.161	.798	.410	2.79	.563	.039	2
38	Cat051	1917	1968	52	2	0	.372	2.34	6.26	1.301	.715	.268	2.52	.433	-.084	2
39	Cat054	1961	2011	51	2	0	.461	3.07	28.70	4.073	.409	.464				

```
2.78   .511   .090   1
  40 Cat055   1949 2012     64      3      0    .323   2.06   8.73  1.420   .808   .297
2.71   .547   .121   1
  41 Cat062   1962 2012     51      2      0    .473   2.10   4.50   .980   .834   .231
2.49   .425   .047   1
  42 Cat064   1948 2012     65      3      3    .297   2.37   5.36   .925   .375   .326
2.54   .453  -.008   1
  43 Cat065   1957 2012     56      2      2    .261   1.50   2.38   .453   .304   .318
2.44   .444   .059   1
  44 Cat067   1947 2012     66      3      3    .243   2.32   6.37  1.492   .636   .403
2.75   .409   .002   1
  45 Cat069   1945 2012     68      3      0    .541   1.51   3.05   .529   .552   .294
2.56   .371  -.025   2
  46 Cat070   1974 2012     39      1      1    .190   3.51  12.37  2.931   .780   .392
2.85   .737   .020   1
  47 Cat071   1943 2010     68      3      0    .447   1.87   4.87  1.099   .759   .291
2.71   .537  -.002   1
  48 Cat072   1955 2012     58      2      0    .321   2.03   6.77  1.673   .882   .314
3.06   .682   .011   2
PART 7:  DESCRIPTIVE STATISTICS (cont)
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-------------------------------------------
                                                Corr   //-------- Unfiltered --------\\
//---- Filtered -----\\
                          No.    No.    No.    with   Mean   Max     Std   Auto   Mean
Max     Std   Auto  AR
 Seq Series   Interval   Years  Segmt  Flags   Master  msmt   msmt    dev   corr   sens
value    dev   corr  ()
 --- -------- ---------  -----  -----  -----   ------ -----  -----  -----  -----  -----
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  49 Cat074   1957 2012     56      2      1    .337   2.28   7.52  1.506   .505   .399
2.86   .437  -.060   1
  50 Cat076   1952 2012     61      2      0    .443   1.58   4.20   .905   .359   .491
2.80   .585   .010   1
  51 Cat077   1938 2012     75      3      2    .264   1.59   3.80   .851   .618   .382
2.64   .455   .044   4
  52 Cat078   1937 2012     76      3      3    .208   1.34   4.70   .958   .788   .381
2.69   .479  -.054   2
  53 Cat080   1957 2012     56      2      2    .169   1.78   4.59   .990   .663   .337
2.58   .475  -.038   2
  54 Cat081   1918 1994     77      3      3    .191   1.48   5.57  1.010   .687   .391
3.07   .641   .032   1
  55 Cat090   1930 2012     83      3      1    .377   1.58   7.55  1.334   .753   .360
3.08   .581   .070   1
 --- -------- ---------  -----  -----  -----   ------ -----  -----  -----  -----  -----
-----  -----  -----  --
 Total or mean:           3418    128     35    .406   1.92  28.70  1.334   .659   .396
3.11   .517   .001
```

APPENDIX D

JOLTS OUTPUT FOR SUPPRESSION IN TREE GROWTH OF SITE CHRONOLOGY ON CAT ISLAND, MISSISSIPPI

```
SUPPRESSIONS IN TREE GROWTH
Version 6.01P    29132
-------------------------------------------------------------------------------------------
-------------------------------------------

 File of tree-ring measurements: dated.txt
Menu of run control parameters:                     Values
 1  Find occurrences of                                  SUP
    by method                                      RUNNING MEAN
                            (Search for SUPPRESSIONS)
 2  RUNNING MEAN SUP factor                            1.000
 3  RUNNING MEAN window                             5 yrs before
                                                    5 yrs after

 RUNNING MEAN method:
        5 years running mean prior to each year tested, and
        5 years running mean starting at each year tested
 4  Min years between reported SUP events           1
 5  ENTIRE TIME SPAN analyzed
 6  Tree age span analyzed                          0       0
 7  File types created                     Out  Sum  Gra  Fhx
 8  Run title:

 Columns of spreadsheet files contain:
  1, 2, 3, 4:     Year, Count of trees, Count of trees recording, Mean tree radius
  5, 6, 7, 8, 9:  Trees in first year of SUP, Mean SUP value, Std dev of SUP value,
                    Mean tree radius at first year of SUP, Percent of trees recording
 10,11,12,13:     Trees in maximum year of SUP, Mean SUP value, Std dev of SUP value,
Percent of trees recording
 14,15,16,17:     Trees within SUP, Mean SUP value, Std dev of SUP value, Percent of
trees recording

 File ZZ   SUP.GRM is in column format

 File ZZ   SUP.FHM is in Fire History (FHX2) format
-------------------------------------------------------------------------------------------
-------------------------------------------
   Series   1   CIS001      1916 to  1959    44 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1916    1923       8    1922   4.173    -.32       1
    1925    1929       5    1926   2.121    2.71      10
    1932    1932       1    1932   1.109   11.95      17
    1934    1938       5    1934   1.305   14.55      19
    1940    1941       2    1940   1.093   24.13      25
    1943    1948       6    1944   1.321   28.38      28
-------------------------------------------------------------------------------------------
-------------------------------------------
   Series   2   CIS002      1951 to  1991    41 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1951    1955       5    1951   1.000    3.05       1
    1957    1957       1    1957   1.000   18.05       7
    1963    1968       6    1967  13.824   13.39      13
    1970    1970       1    1970   2.159   19.80      20
    1972    1977       6    1972   2.472   23.42      22
    1981    1984       4    1981   1.121   50.40      31
    1987    1988       2    1987   1.030   69.71      37
-------------------------------------------------------------------------------------------
-------------------------------------------
   Series   3   Cat003      1936 to  1980    45 years
```

```
   ____SUP_time_span____     Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years     Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1936    1943       8     1941   1.307     .31       1
    1945    1945       1     1945   1.218   14.98      10
    1947    1947       1     1947   1.047   18.88      12
    1954    1955       2     1954   1.488   28.96      19
    1963    1966       4     1965   2.100   38.22      28
    1969    1969       1     1969   1.239   47.13      34
R    1977    1980       4     1977   1.000   55.30      42
----------------------------------------------------------------------------------------
------------------------------------------
   Series   4   Cat004      1940 to  2012    73 years
   ____SUP_time_span____     Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years     Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1940    1948       9     1945   3.437    -.81       1
    1953    1955       3     1953   1.170   17.36      14
    1964    1967       4     1966   1.566   31.56      25
    1981    1983       3     1981  15.225   49.25      42
    1986    1988       3     1987   1.781   53.39      47
    1991    1994       4     1991   1.333   60.77      52
    1997    2001       5     1998   1.409   70.85      58
    2005    2005       1     2005   1.012   89.32      66
    2007    2007       1     2007   1.043   93.78      68
    2009    2010       2     2009   1.000   98.02      70
----------------------------------------------------------------------------------------
------------------------------------------
   Series   5   Cat006      1935 to  2012    78 years
   ____SUP_time_span____     Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years     Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1935    1945      11     1945   1.703   -1.51       1
    1952    1955       4     1952   2.645    7.45      18
    1963    1963       1     1963   1.049   27.03      29
    1967    1967       1     1967   3.715   31.05      33
    1969    1973       5     1969   2.676   35.06      35
    1981    1983       3     1982   1.981   59.82      47
    1987    1990       4     1987   1.632   70.10      53
    1994    1994       1     1994   1.121   86.19      60
    1997    2001       5     1998   1.518   91.81      63
    2005    2010       6     2005   1.173  113.29      70
    2011    2011       1     2011   1.000  137.25      77
----------------------------------------------------------------------------------------
------------------------------------------
   Series   6   Cat008      1946 to  2012    67 years
   ____SUP_time_span____     Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years     Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1946    1950       5     1946   1.000    1.41       1
    1952    1954       3     1952   1.465    7.80       7
    1957    1959       3     1957   1.590   15.35      12
    1966    1967       2     1966   1.326   35.22      21
    1969    1969       1     1969   1.686   42.22      24
    1977    1977       1     1977   1.000   49.58      32
    1979    1979       1     1979   1.000   48.42      34
    1981    1985       5     1984   4.109   48.34      36
    1987    1989       3     1987   1.767   57.89      42
    1994    2001       8     1996   1.607   73.61      49
    2007    2010       4     2007   1.149  116.10      62
----------------------------------------------------------------------------------------
------------------------------------------
   Series   7   Cat009      1945 to  2003    59 years
   ____SUP_time_span____     Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years     Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1945    1950       6     1950   1.247    1.21       1
    1952    1952       1     1952   1.093   14.63       8
    1962    1963       2     1962   1.243   30.38      18
    1965    1969       5     1965   1.647   35.03      21
    1981    1982       2     1981  19.712   56.58      37
    1986    1988       3     1987   1.764   59.80      42
```

```
    1990    1993       4    1993   1.588   64.18      46
    1995    2000       6    1996   1.663   71.57      51
R    2003    2003       1    2003   1.000   90.80      59
-------------------------------------------------------------------------------------------
-------------------------------------------
   Series   8   Cat010      1957 to  2004    48 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1957    1964       8    1964   1.542    1.19       1
    1967    1968       2    1967   1.151   17.28      11
    1972    1973       2    1972   1.184   26.87      16
    1981    1982       2    1981   1.130   44.28      25
    1985    1987       3    1985   1.552   50.46      29
    1991    1994       4    1991   1.397   62.09      35
    1997    2003       7    1998   1.617   76.15      41
-------------------------------------------------------------------------------------------
-------------------------------------------
   Series   9   Cat011      1952 to  2011    60 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1952    1957       6    1952   1.000     .39       1
    1962    1970       9    1965  10.316     .96      11
    1977    1977       1    1977   1.038   31.14      26
    1979    1983       5    1981   1.396   34.52      28
    1985    1985       1    1985   1.207   48.16      34
    1992    1996       5    1992   1.295   63.70      41
    1999    2001       3    1999   1.292   81.08      48
R    2005    2011       7    2006   1.339   97.30      54
-------------------------------------------------------------------------------------------
-------------------------------------------
   Series  10   Cat012      1931 to  1999    69 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1931    1935       5    1931   1.000    2.20       1
    1942    1947       6    1942   4.435    8.26      12
    1949    1950       2    1949   1.457   18.44      19
    1952    1952       1    1952   1.056   23.60      22
    1963    1963       1    1963   1.068   38.92      33
    1967    1971       5    1967   2.667   42.65      37
    1973    1973       1    1973   1.054   55.26      43
    1977    1977       1    1977   1.046   63.81      47
    1981    1985       5    1981   1.272   72.37      51
    1992    1996       5    1992   1.247  101.69      62
R    1998    1999       2    1998   1.000  120.73      68
-------------------------------------------------------------------------------------------
-------------------------------------------
   Series  11   Cat013      1931 to  2010    80 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1931    1937       7    1931   1.000   -5.31       1
    1940    1946       7    1945   8.668  -22.23      10
    1950    1953       4    1951   1.609   -9.12      20
    1962    1964       3    1962   1.480   17.70      32
    1967    1971       5    1967   1.375   29.56      37
    1980    1984       5    1981   1.869   61.36      50
    1991    1991       1    1991   1.019   89.42      61
    1993    2003      11    1995   1.295   93.94      63
    2005    2005       1    2005   1.061  131.23      75
R    2007    2010       4    2007   1.000  138.16      77
-------------------------------------------------------------------------------------------
-------------------------------------------
   Series  12   Cat014      1981 to  2012    32 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1981    1986       6    1981   1.000    1.75       1
    1988    2002      15    1990   5.192     .07       8
    2006    2010       5    2006   1.189   92.64      26
```

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-----------------------------------------------------------------------------------------
-------------------------------------------
   Series  13   Cat017      1950 to  2012    63 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1950    1954       5    1950   1.000    1.21       1
    1957    1959       3    1957   1.189    8.16       8
    1962    1965       4    1962   1.662   13.41      13
    1972    1973       2    1972   1.175   29.45      23
    1975    1975       1    1975   1.100   35.17      26
    1982    1983       2    1982   1.210   43.48      33
    1985    1985       1    1985   1.497   47.91      36
    1988    1989       2    1988   1.400   51.53      39
    1996    1999       4    1997   2.100   60.97      47
    2005    2011       7    2005   1.807   74.64      56
-----------------------------------------------------------------------------------------
-------------------------------------------
   Series  14   Cat018      1928 to  2012    85 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1928    1937      10    1933   7.117    2.35       1
    1940    1944       5    1944   2.713    4.57      13
    1946    1947       2    1946   1.453   16.08      19
    1961    1964       4    1962   2.172   42.48      34
    1968    1969       2    1969   1.416   56.22      41
    1971    1972       2    1971   1.287   62.92      44
    1980    1982       3    1981   2.384   76.50      53
    1985    1988       4    1986   1.549   84.61      58
    1999    1999       1    1999   5.258  105.79      72
    2001    2008       8    2002   2.996  107.93      74
-----------------------------------------------------------------------------------------
-------------------------------------------
   Series  15   cat019      1935 to  2012    78 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1935    1946      12    1942   7.964   -1.45       1
    1948    1950       3    1948   1.319    7.53      14
    1960    1960       1    1960   1.672   22.37      26
    1962    1964       3    1963   1.568   23.94      28
    1967    1969       3    1969   1.651   29.85      33
    1971    1973       3    1971   1.328   37.11      37
    1981    1982       2    1981   1.102   54.86      47
    1985    1985       1    1985   1.109   62.09      51
    1995    1995       1    1995   1.588   75.55      61
    1997    2001       5    1997   2.108   78.48      63
    2006    2007       2    2006   1.212   96.38      72
R    2009    2012       4    2009   1.000  103.29      75
-----------------------------------------------------------------------------------------
-------------------------------------------
   Series  16   Cat022      1930 to  2008    79 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1930    1934       5    1930   1.000    2.20       1
    1939    1946       8    1939   1.000  -16.76      10
    1948    1952       5    1950   4.591  -20.23      19
    1959    1959       1    1959   1.065    3.26      30
    1962    1963       2    1963   1.274    7.45      33
    1966    1971       6    1966   1.674   14.60      37
    1980    1983       4    1983   1.201   51.96      51
    1985    1988       4    1985   1.136   65.25      56
    1990    1990       1    1990   1.015   79.98      61
    1992    1992       1    1992   1.008   86.01      63
    1995    1998       4    1997   1.017   94.64      66
    2001    2001       1    2001   1.045  112.64      72
    2003    2003       1    2003   1.008  118.74      74
    2005    2005       1    2005   1.000  125.00      76
R    2008    2008       1    2008   1.000  133.72      79
-----------------------------------------------------------------------------------------
```

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-------------------------------------------
   Series  17   Cat023      1937 to  2011    75 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1937    1948      12    1947   2.387   -5.41       1
    1956    1956       1    1956   1.192    2.04      20
    1963    1966       4    1964   2.530   10.96      27
    1968    1971       4    1968   1.293   25.66      32
    1973    1973       1    1973   1.003   42.93      37
    1979    1980       2    1980   1.200   60.39      43
    1982    1983       2    1983   1.288   69.74      46
    1986    1990       5    1986   1.272   83.22      50
    1997    2001       5    1997   1.184  125.77      61
    2007    2007       1    2007   1.038  167.01      71
    2009    2009       1    2009   1.000  175.11      73
R    2011    2011       1    2011   1.000  183.61      75
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  18   Cat024      1953 to  2008    56 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1953    1957       5    1953   1.000    -.03       1
    1959    1966       8    1965   4.596   -9.24       7
    1968    1971       4    1969   1.828    1.09      16
    1981    1987       7    1982   1.681   40.00      29
    1997    1997       1    1997   1.153   94.51      45
    2000    2003       4    2001   1.625  102.65      48
    2005    2005       1    2005   1.000  121.97      53
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  19   Cat026      1939 to  1999    61 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1939    1944       6    1944   1.026    2.20       1
    1946    1946       1    1946   1.095   27.76       8
    1958    1958       1    1958   1.038   60.75      20
    1962    1968       7    1962   1.928   67.53      24
    1978    1979       2    1979   1.461  112.52      40
    1988    1991       4    1989   2.234  128.20      50
R    1995    1999       5    1995   1.455  141.37      57
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  20   Cat027      1935 to  2001    67 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1935    1945      11    1943   7.836    -.77       1
    1950    1951       2    1950   1.122   21.06      16
    1959    1961       3    1960   1.112   43.76      25
    1964    1964       1    1964   1.010   55.01      30
    1968    1971       4    1968   1.482   63.09      34
    1980    1983       4    1980  82.341   81.91      46
    1987    1988       2    1988   1.610   94.94      53
    1990    1993       4    1990   1.667  101.09      56
    1995    1995       1    1995   1.106  113.71      61
R    1997    2001       5    1997   1.244  119.18      63
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  21   Cat029      1936 to  2010    75 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1936    1951      16    1946  19.827   -2.55       1
    1955    1958       4    1955   1.811   -1.69      20
    1967    1971       5    1969   1.559   25.25      32
    1975    1975       1    1975   1.004   48.48      40
    1977    1977       1    1977   1.087   53.56      42
    1979    1979       1    1979   1.126   58.66      44
    1982    1983       2    1983   1.072   67.13      47
```

```
    1985    1985       1    1985   1.113   75.40      50
    1987    1988       2    1987   1.147   81.68      52
    1995    1998       4    1995   1.336  104.24      60
    2000    2005       6    2001   1.153  121.16      65
R    2007    2010       4    2007   1.000  148.65      72
-----------------------------------------------------------------------------------------
-------------------------------------------
   Series  22   Cat031      1984 to  2012    29 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1984    1988       5    1984   1.000    5.12       1
    1996    1997       2    1996   2.064   47.18      13
    1999    2000       2    1999   2.229   55.08      16
    2003    2009       7    2003   2.037   70.49      20
R    2011    2012       2    2011   1.000  131.63      28
-----------------------------------------------------------------------------------------
-------------------------------------------
   Series  23   Cat032      1935 to  2012    78 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1935    1939       5    1935   1.000   -2.24       1
    1941    1947       7    1945 100.896  -14.78       7
    1950    1953       4    1951   1.383   -1.74      16
    1963    1964       2    1964   1.070   21.75      29
    1967    1969       3    1967   1.371   27.97      33
    1977    1977       1    1977   1.094   44.40      43
    1979    1980       2    1979   1.350   46.64      45
    1986    1987       2    1986   1.212   55.55      52
    1994    1997       4    1994   1.532   66.21      60
    2000    2003       4    2001   1.359   75.88      66
    2005    2007       3    2005   1.134   86.33      71
    2009    2009       1    2009   1.000   95.44      75
    2011    2011       1    2011   1.000  100.09      77
-----------------------------------------------------------------------------------------
-------------------------------------------
   Series  24   Cat033      1979 to  2012    34 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1979    1983       5    1979   1.000    -.42       1
    1991    1991       1    1991   1.374   16.43      13
    1993    2001       9    1995   3.080   18.42      15
    2006    2010       5    2008   1.442   53.68      28
R    2012    2012       1    2012   1.000   77.34      34
-----------------------------------------------------------------------------------------
-------------------------------------------
   Series  25   Cat034      1935 to  2012    78 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1935    1939       5    1935   1.000   -2.24       1
    1941    1947       7    1945 101.216  -14.78       7
    1950    1953       4    1951   1.383   -1.75      16
    1963    1964       2    1964   1.070   21.74      29
    1967    1969       3    1967   1.372   27.97      33
    1977    1977       1    1977   1.094   44.40      43
    1979    1980       2    1979   1.350   46.64      45
    1986    1987       2    1986   1.212   55.55      52
    1994    1997       4    1994   1.532   66.21      60
    2000    2003       4    2001   1.352   75.92      66
    2005    2007       3    2005   1.139   86.38      71
    2009    2009       1    2009   1.000   95.44      75
    2011    2011       1    2011   1.000  100.11      77
-----------------------------------------------------------------------------------------
-------------------------------------------
   Series  26   Cat035      1940 to  2012    73 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1940    1944       5    1940   1.000     .05       1
```

```
    1955    1956       2    1956   1.780   21.15      16
    1963    1965       3    1963   9.712   25.12      24
    1967    1969       3    1967   2.569   29.06      28
    1977    1981       5    1980   4.366   38.16      38
    1986    1993       8    1987   1.671   52.62      47
    1995    1995       1    1995   1.057   76.32      56
    1997    2002       6    1997   1.138   81.93      58
    2005    2007       3    2005   1.093  106.75      66
    2009    2009       1    2009   1.000  119.95      70
R    2011    2012       2    2011   1.000  126.67      72
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  27   Cat037      1978 to  2006    29 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1978    1983       6    1983  27.408   -3.55       1
    1985    1988       4    1985   5.188    3.72       8
    1990    1990       1    1990   1.160   21.48      13
    1992    1993       2    1993   1.240   28.38      15
    1995    1997       3    1995   1.114   40.95      18
    2000    2001       2    2000   1.165   62.27      23
R    2003    2006       4    2003   1.000   75.88      26
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  28   Cat038      1981 to  2012    32 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1981    1985       5    1981   1.000    2.40       1
    1991    1995       5    1991   1.883   23.14      11
    1997    1998       2    1998   1.663   38.57      17
    2000    2001       2    2000   1.507   50.57      20
    2005    2010       6    2005   1.437   67.90      24
R    2011    2012       2    2011   1.000  111.88      31
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  29   Cat039      1935 to  2011    77 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1935    1942       8    1942   1.767   -3.29       1
    1944    1945       2    1945   1.690   -1.59      10
    1947    1948       2    1947   1.975    2.36      13
    1954    1957       4    1956   1.782   13.43      20
    1963    1970       8    1963   2.006   28.23      29
    1981    1983       3    1981   1.363   73.78      47
    1985    1985       1    1985   1.119   84.44      51
    1987    1988       2    1987   1.153   90.21      53
    1996    2010      15    1997   1.652  113.19      62
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  30   Cat040      1948 to  2012    65 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1948    1953       6    1948   1.000   -1.48       1
    1956    1960       5    1957   1.824    1.41       9
    1967    1970       4    1967   2.447    7.50      20
    1973    1975       3    1973   1.121   14.74      26
    1981    1983       3    1981   1.669   24.18      34
    1989    1993       5    1989   1.270   35.57      42
    1995    1995       1    1995   1.250   44.12      48
    1997    1998       2    1997   1.402   47.27      50
    2005    2009       5    2006   1.574   59.59      58
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  31   Cat042      1933 to  1992    60 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1933    1940       8    1940   1.994   -1.66       1
```

```
    1944    1945       2    1945   1.315    6.71      12
    1948    1951       4    1948   1.457   14.47      16
    1954    1955       2    1954   1.206   28.28      22
    1963    1965       3    1963   1.632   48.12      31
    1967    1970       4    1967   1.328   59.47      35
    1979    1983       5    1981   1.869   90.14      47
    1985    1985       1    1985   1.080  105.52      53
    1987    1988       2    1987   1.111  111.51      55
R    1990    1992       3    1990   1.000  119.87      58
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  32   Cat043      1941 to  2012    72 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1941    1945       5    1941   1.000    1.45       1
    1951    1954       4    1951   1.628   16.30      11
    1962    1964       3    1962   1.549   34.35      22
    1977    1981       5    1977  11.588   53.92      37
    1988    1998      11    1991   3.826   68.31      48
    2005    2007       3    2005   1.216  104.58      65
    2011    2011       1    2011   1.000  119.78      71
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-------------------------------------------
   Series  33   Cat044      1938 to  2012    75 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1938    1945       8    1944   2.450   -2.98       1
    1947    1953       7    1949   1.663    4.49      10
    1968    1971       4    1969   1.553   40.90      31
    1977    1981       5    1979   2.278   54.71      40
    1988    1988       1    1988   1.022   73.60      51
    1995    1999       5    1997   3.416   79.77      58
R    2005    2012       8    2006   1.817   94.58      68
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  34   Cat045      1985 to  2012    28 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1985    2001      17    1991  49.348    -.14       1
    2005    2007       3    2006   1.312   54.69      21
    2009    2011       3    2009   1.000   75.88      25
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  35   Cat046      1883 to  2001   119 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1883    1891       9    1890   3.261    -.12       1
    1893    1894       2    1893   1.229    5.82      11
    1897    1903       7    1897   1.629   10.90      15
    1910    1911       2    1910   1.133   36.77      28
    1913    1914       2    1913   1.105   43.00      31
    1924    1924       1    1924   1.016   63.16      42
    1926    1926       1    1926   1.036   65.64      44
    1934    1936       3    1934   4.258   72.37      52
    1943    1944       2    1943   1.000   80.48      61
    1948    1952       5    1951  31.627   80.03      66
    1958    1964       7    1959   2.563   86.36      76
    1966    1967       2    1966   1.052   97.06      84
    1970    1973       4    1970   1.179  102.79      88
    1981    1982       2    1981   1.105  118.13      99
    1985    1989       5    1985   1.597  122.69     103
R    1996    2001       6    1997   1.217  140.65     114
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  36   Cat047      1950 to  2010    61 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
```

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    1950    1954       5    1950   1.000    1.89       1
    1962    1964       3    1962   2.408   14.79      13
    1966    1966       1    1966   1.205   21.30      17
    1969    1972       4    1970   1.445   25.57      20
    1981    1987       7    1983   1.840   44.20      32
    1997    1998       2    1997   1.548   68.03      48
    2000    2001       2    2000   1.225   72.93      51
    2006    2009       4    2006   1.069   82.29      57
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  37   Cat049      1962 to  2012    51 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1962    1966       5    1962   1.000    -.76       1
    1969    1969       1    1969   1.000    7.44       8
    1974    1977       4    1977   2.785    3.95      13
    1980    1987       8    1981   6.655    9.10      19
    1994    2004      11    1994   1.237   58.52      33
    2006    2008       3    2006   1.157  112.68      45
    2010    2010       1    2010   1.000  134.53      49
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-------------------------------------------
   Series  38   Cat051      1917 to  1968    52 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1917    1921       5    1917   1.000   -1.58       1
    1923    1925       3    1923  24.222    -.06       7
    1928    1931       4    1928   2.690    7.54      12
    1935    1935       1    1935   1.069   25.51      19
    1937    1937       1    1937   1.046   30.64      21
    1943    1945       3    1944   1.341   44.04      27
    1951    1954       4    1951   1.321   65.70      35
    1961    1966       6    1962   1.319   95.67      45
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-------------------------------------------
   Series  39   Cat054      1961 to  2011    51 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1961    1970      10    1969   1.651  -22.55       1
    1977    1977       1    1977   1.195   19.32      17
    1979    1983       5    1979  24.941   20.79      19
    1985    1985       1    1985   1.649   36.59      25
    1987    1989       3    1988   1.396   43.27      27
    1991    1991       1    1991   1.036   59.57      31
    1997    1997       1    1997   1.149   83.71      37
    1999    2005       7    2000   1.381   90.80      39
    2007    2007       1    2007   1.102  133.44      47
R    2009    2011       3    2009   1.000  144.79      49
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  40   Cat055      1949 to  2012    64 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1949    1955       7    1955   2.477   -4.61       1
    1962    1966       5    1963   1.809    8.24      14
    1974    1975       2    1974   1.701   29.80      26
    1981    1988       8    1984   1.373   43.80      33
    1993    1994       2    1994   1.075   71.92      45
    1996    2000       5    1996   1.287   78.83      48
R    2004    2012       9    2005   1.318  101.66      56
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  41   Cat062      1962 to  2012    51 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1962    1974      13    1969  14.647    -.26       1
    1981    1984       4    1982   1.447   27.09      20
```

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   1993    1993       1    1993   1.105   55.75      32
   1996    1997       2    1997   1.233   62.01      35
   1999    2003       5    2000   1.310   69.24      38
   2006    2006       1    2006   1.007   90.03      45
   2009    2011       3    2009   1.000   98.56      48
------------------------------------------------------------------------------------------
-------------------------------------------
  Series  42   Cat064      1948 to  2012    65 years
  ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
  Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
   1948    1952       5    1948   1.000    1.93       1
   1959    1959       1    1959   1.030   28.07      12
   1962    1963       2    1962   1.578   31.22      15
   1966    1971       6    1966   1.872   36.07      19
   1980    1982       3    1980   1.574   64.84      33
   1984    1984       1    1984   1.166   74.75      37
   1986    1988       3    1986   1.174   79.25      39
   1996    1997       2    1996   1.180  105.85      49
   2000    2000       1    2000   1.021  116.52      53
   2005    2006       2    2005   1.275  127.40      57
   2008    2012       5    2008   1.315  136.68      60
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-------------------------------------------
  Series  43   Cat065      1957 to  2012    56 years
  ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
  Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
   1957    1961       5    1957   1.000    1.34       1
   1963    1964       2    1963   1.186    9.79       7
   1971    1972       2    1971   1.454   21.04      15
   1974    1974       1    1974   1.020   26.28      18
   1978    1978       1    1978   1.273   31.44      22
   1980    1981       2    1980   1.457   34.20      24
   1994    1999       6    1996   1.733   52.25      38
   2006    2007       2    2006   1.407   72.95      50
   2009    2009       1    2009   1.000   78.75      53
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-------------------------------------------
  Series  44   Cat067      1947 to  2012    66 years
  ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
  Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
   1947    1951       5    1947   1.000    1.05       1
   1956    1956       1    1956   1.000   11.97      10
   1958    1963       6    1961   8.584   10.71      12
   1972    1975       4    1973   2.742   31.75      26
   1977    1977       1    1977   1.083   44.57      31
   1980    1980       1    1980   1.101   51.70      34
   1983    1983       1    1983   1.096   60.04      37
   1985    1987       3    1986   1.321   63.11      39
   1989    1989       1    1989   1.091   75.46      43
   1993    1996       4    1993   1.196   86.69      47
   2004    2007       4    2005   1.358  121.43      58
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-------------------------------------------
  Series  45   Cat069      1945 to  2012    68 years
  ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
  Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
   1945    1950       6    1950   1.054    1.56       1
   1957    1960       4    1959   1.229   21.23      13
   1963    1964       2    1963   1.171   31.57      19
   1967    1969       3    1969   1.114   38.55      23
   1971    1971       1    1971   1.169   46.52      27
   1982    1983       2    1982   1.138   65.05      38
   1992    1996       5    1994   1.610   75.58      48
   1998    2000       3    1998   1.509   82.32      54
   2006    2007       2    2006   1.590   93.28      62
   2009    2009       1    2009   1.000  100.16      65
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   Series  46   Cat070      1974 to  2012    39 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1974    1979       6    1974   1.000   -4.32       1
    1986    1996      11    1986   6.139    7.22      13
    1999    2001       3    1999   1.154   62.00      26
    2006    2007       2    2006   1.086  101.45      33
    2009    2009       1    2009   1.000  119.76      36
------------------------------------------------------------------------------------------
-------------------------------------------
   Series  47   Cat071      1943 to  2010    68 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1943    1947       5    1943   1.000    1.17       1
    1950    1950       1    1950   1.044   16.14       8
    1960    1960       1    1960   1.099   32.07      18
    1963    1964       2    1963   1.893   35.58      21
    1966    1967       2    1966   1.423   41.34      24
    1979    1983       5    1982  12.839   54.47      37
    1985    2000      16    1985   3.523   58.19      43
    2003    2003       1    2003   1.008  104.60      61
    2005    2006       2    2006   1.003  111.11      63
R    2010    2010       1    2010   1.000  127.15      68
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-------------------------------------------
   Series  48   Cat072      1955 to  2012    58 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1955    1964      10    1960   1.574    2.05       1
    1966    1967       2    1966   1.093   22.60      12
    1972    1972       1    1972   1.000   36.58      18
    1979    1982       4    1979   1.000   29.72      25
    1984    1993      10    1986 351.743   27.08      30
    1995    2000       6    1996   1.133   58.30      41
    2004    2004       1    2004   1.001   90.06      50
    2006    2006       1    2006   1.001   96.98      52
    2009    2009       1    2009   1.000  107.85      55
R    2011    2012       2    2011   1.000  114.19      57
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-------------------------------------------
   Series  49   Cat074      1957 to  2012    56 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1957    1963       7    1962   3.279   -1.15       1
    1966    1967       2    1967   1.903    6.71      10
    1970    1970       1    1970   1.012   13.03      14
    1973    1975       3    1973   2.156   15.08      17
    1980    1984       5    1980   2.174   27.00      24
    1986    1987       2    1986   1.195   44.73      30
    1995    2001       7    1997   1.816   67.48      39
    2003    2006       4    2003   1.077   94.50      47
    2010    2010       1    2010   1.000  121.35      54
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-------------------------------------------
   Series  50   Cat076      1952 to  2012    61 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1952    1958       7    1957   2.037     .35       1
    1960    1960       1    1960   1.939    5.86       9
    1962    1963       2    1962   1.660    8.64      11
    1969    1969       1    1969   1.514   17.93      18
    1971    1973       3    1971   1.660   20.24      20
    1975    1975       1    1975   1.363   27.93      24
    1984    1988       5    1986   2.788   38.59      33
    1990    1990       1    1990   1.125   49.42      39
    1997    1997       1    1997   1.329   59.56      46
    1999    2007       9    2000   2.086   62.25      48
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R     2010    2012       3    2010   1.000   90.32      59
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-------------------------------------------
   Series  51   Cat077      1938 to  2012    75 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1938    1942       5    1938   1.000    1.86       1
    1948    1951       4    1948  29.292    7.03      11
    1959    1959       1    1959   1.958   18.57      22
    1961    1969       9    1963   3.153   19.59      24
    1971    1975       5    1971   1.366   36.24      34
    1986    1990       5    1988   1.416   67.35      49
    1996    1999       4    1997   1.412   84.14      59
    2004    2009       6    2005   1.400  100.10      67
-----------------------------------------------------------------------------------------
-------------------------------------------
   Series  52   Cat078      1937 to  2012    76 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1937    1944       8    1943   7.410     .21       1
    1948    1952       5    1948   1.508    9.52      12
    1961    1967       7    1962   1.469   32.26      25
    1983    1985       3    1983   3.005   66.98      47
    1995    2000       6    1998   6.829   70.44      59
    2005    2009       5    2005   1.703   85.76      69
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-------------------------------------------
   Series  53   Cat080      1957 to  2012    56 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1957    1965       9    1962   1.292    1.73       1
    1979    1980       2    1979   1.653   37.92      23
    1985    1987       3    1986   3.047   42.07      29
    1992    1993       2    1993   1.779   51.69      36
    1996    2001       6    1996   1.735   57.63      40
    2004    2007       4    2004   1.167   77.58      48
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-------------------------------------------
   Series  54   Cat081      1918 to  1994    77 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1918    1923       6    1923   1.122    -.34       1
    1934    1937       4    1935   1.568   21.36      17
    1943    1947       5    1945   8.831   24.56      26
    1950    1953       4    1950   2.022   33.32      33
    1956    1960       5    1957   1.213   43.46      39
    1963    1969       7    1964   1.234   57.42      46
    1971    1972       2    1972   1.049   76.75      54
R     1987    1994       8    1987  15.792  102.59      70
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-------------------------------------------
   Series  55   Cat090      1930 to  2012    83 years
   ____SUP_time_span____    Before/after  Begin_year_SUP Spline_steepest
   Begin     End   Years    Year max_dif  Radius Ring_no    Year   slope
 [] Running mean
    1930    1934       5    1930   1.000    2.91       1
    1949    1950       2    1949   1.000   32.13      20
    1953    1959       7    1953   1.000   28.36      24
    1963    1966       4    1963   7.133   29.23      34
    1968    1971       4    1968   1.368   33.93      39
    1974    1975       2    1975   1.137   41.84      45
    1978    1979       2    1978   1.187   47.08      49
    1981    1987       7    1982   1.679   50.78      52
    1990    1992       3    1992   1.055   70.65      61
    1995    1999       5    1995   1.205   83.13      66
    2004    2004       1    2004   1.011  108.81      75
    2011    2011       1    2011   1.000  128.15      82
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        First year of running mean factor is always smaller than prior mean
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 SUMMARY OF SERIES
       55 ring measurement series in file
       55 ring measurement series analyzed

 RUNNING MEAN method:
       55 series with SUPs
      489 SUPs in all trees
    8.891 SUPs per tree, all trees
    8.891 SUPs per tree with SUPs

 SUP Summary
     Mean   St Dev
    3.534   17.828 SUP factor, Running mean method
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