Journal of Coastal Research	8	1	99–104	Fort Lauderdale, Florida	Winter 1992

Variation in Tree Ring Width in Relation to Storm Activity for Mid-Atlantic Barrier Island Populations of *Pinus taeda*

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ABSTRACT

JOHNSON, S.R. and YOUNG, D.R., 1992. Variation in tree ring width in relation to storm activity for Mid-Atlantic barrier island populations of *Pinus taeda*. *Journal of Coastal Research*, 8(1), 99–104. Fort Lauderdale (Florida), ISSN 0749-0208.

Tree cores were collected from coastal populations of *Pinus taeda* (loblolly pine) on Hog and Parramore Islands of the Eastern Shore of Virginia, Bodie Island (North Carolina) and at North Inlet (South Carolina) for a comparative analysis of growth ring width with storm occurrence. All four sites showed some association between ring width and occurrence of coastal tracking hurricanes and northeasters, with reduced width during the year of the storm or the following year. In addition, ring width increased with decreasing latitude, possibly indicating a relationship between ring width and length of growing season. The difference in variability around the mean ring width between the two Virginia barrier islands was in agreement with suggested differences in island stability. Although a clear relationship between ring width and storm occurrence was not evident, tree ring analysis may be a useful tool in the determination of storm impact on barrier island plant communities, of storm frequency over long time periods, and of differences in stability among barrier islands.

ADDITIONAL INDEX WORDS: *Dendroecology, hurricanes, winter storms, island stability.*

INTRODUCTION

Many recent dendroecological studies have focused on variations in the growth ring widths of boreal or alpine tree species in relation to insect defoliation (ARQUILLIERE *et al.*, 1990; MORIN, 1990; MORIN and LAPRISE, 1990), on stress due to soil acidification (LEBLANC, 1990a; LEBLANC and RAYNAL, 1990) or on reconstructions of past climates (GARFINKEL and BRUBAKER, 1980; STAHLE *et al.*, 1988). Other studies have developed new methods of dendrochronological analysis or statistical re-interpretation of data (NORTON and OGDEN, 1987; JORDAN and LOCKABY, 1990; COOK, 1990; LEBLANC, 1990b). However, no dendroecological studies have focused on the dynamic environment characteristic of barrier islands.

The barrier islands and coastal areas of the Mid-Atlantic United States are frequently affected by strong winds, salt spray or overwash from oceanic storms (DOLAN *et al.*, 1988; 1990). These storms may inflict physical and/or or physiological damage on trees leading to variations in tree growth that are evident in varied tree ring widths (OOSTING, 1945; FRITTS, 1976; MEDINA *et al.*, 1990). Although reductions in ring width from storm effects are not readily distinguishable from regional drought or other localized factors, simultaneous reductions in ring widths in trees from more than one coastal area in years following coastline tracking hurricanes or northeasters would indicate that some relationship may exist. The widespread distribution of *Pinus taeda* in coastal areas of the southeastern United States, including barrier islands from Virginia to Florida (MIROV, 1967; SILBERHORN, 1982), facilitates a variety of dendroecological analyses on local and regional scales (OOSTING, 1954). The purpose of this study was to relate variations in ring width of barrier island populations of *P. taeda* with a history of Mid-Atlantic northeaster and hurricane occurrences.

METHODS

The principle study sites were Parramore Island and Hog Island, off the coast of Virginia's Eastern Shore, and which are included within the Virginia Coast Reserve, a group of more than a dozen barrier islands protected by the Nature Conservancy and designated by the National Science Foundation as a Long Term Ecological Research site. The Parramore Island (37°33′N, 75°48′W) *Pinus taeda* population was extensive with trees occurring within 20 m of the ocean on

91050 received 30 May 1991; accepted in revision 4 September 1991.

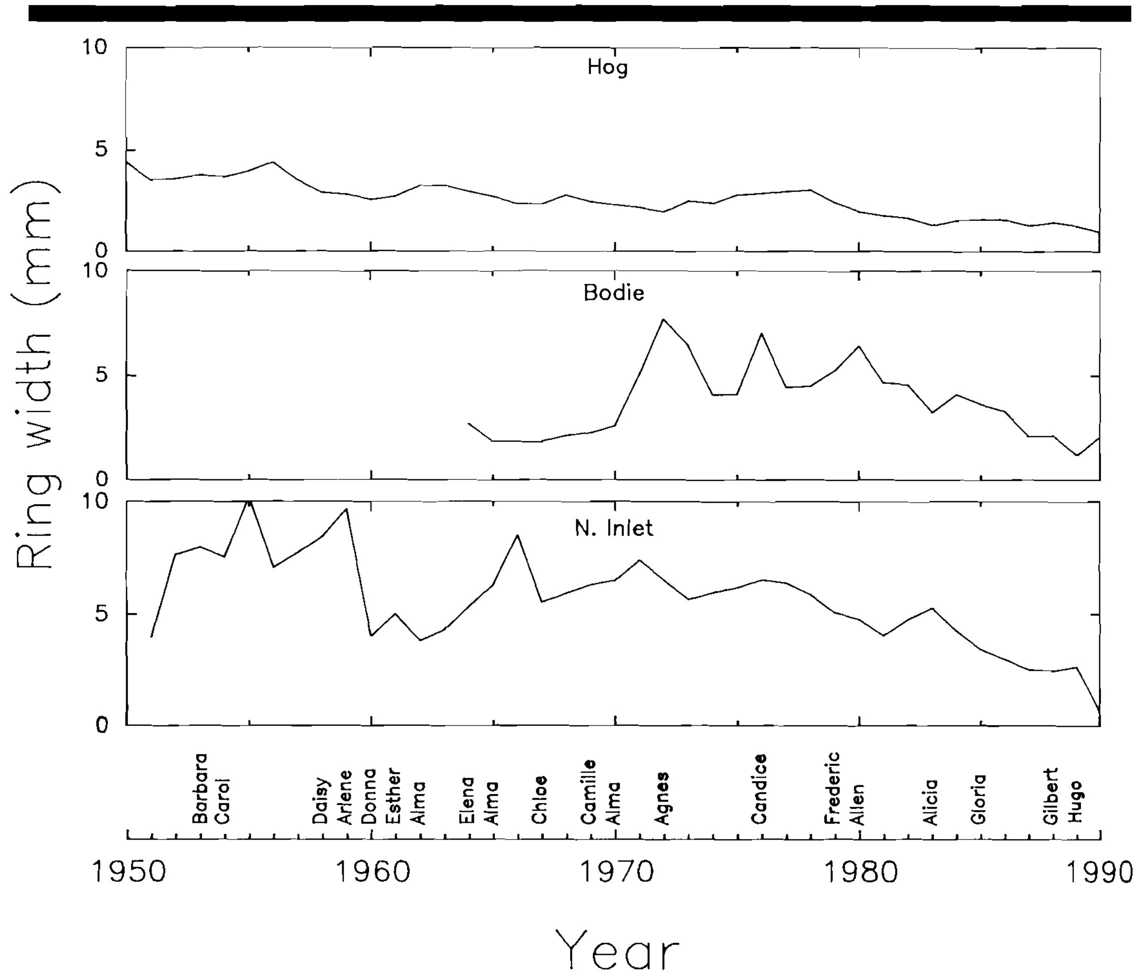

Figure 1. Tree ring series of *Pinus taeda* from Hog Island (Virginia), Bodie Island (North Carolina) and North Inlet (South Carolina) and the occurrence of coastal tracking hurricanes between 1950 and 1990.

the Atlantic side and 10 m of the bay on the west side. A well developed, mature forest was located near the bay side on a relict dune ridge known as Italian Hills. In contrast, the relatively low relief of Hog Island (37°29′N, 75°40′W) supported a much smaller and more sparse *P. taeda* population that was oriented in a narrow, north to south belt on the bay side of the island. Secondary study sites included a small stand growing 15 m from the ocean on Bodie Island, North Carolina (35°50′N, 75°30′W) and a coastal bottomland forest at North Inlet (33°22′N, 79°30′W) on the mainland just north of Georgetown, South Carolina.

To investigate possible relationships between tree growth and large storms, 40 core samples were taken from *P. taeda* trees on Parramore Island and 24 from Hog Island in late summer and fall of 1989. Ten trees were sampled at the Bodie Island site and 20 trees were sampled at the North Inlet site in the fall of 1990. All trees had a diameter at breast height of 20 cm or greater and were sampled approximately 1.4 m from the base using an increment corer. Trees showing evidence of rotting wood or insect damage were eliminated. Cores collected from the seven oldest trees at each of the four sites were used to quantify mean yearly ring width which was measured with a micrometer to within 0.02 mm.

The tree core data were then related to storm data (*i.e.* type and date of land fall) from 1930 to the present, which was acquired from the Virginia Coast Reserve, Long Term Ecological Research data archive at the University of Virginia. To separate the effects of periods of regional drought or increased rainfall from coastal storm activity, the Virginia barrier island data were compared with additional core samples from an inland, mid-successional forest near Richmond, Virginia (37°32′N, 77°33′W). Also, to identify possible age related reductions in ring widths, cores were compared for individual *P. taeda* trees aged to approximately 70, 50 and 20 years.

RESULTS AND DISCUSSION

From 1930 through 1989 more than 470 storms, approximately 8 per year, have influenced the barrier islands of Virginia's Eastern Shore. Twelve major hurricanes have directly affected these islands over the past 170 years, with the most recent occurring in 1933 (LEVY, 1990). A number of northeaster storms during the winter months have also had a strong impact on island biological and physical processes. Hurricanes and northeasters not only subject coastal areas to salt spray and overwash but also to temporary, sharp increases in rainfall and wind. Tree growth may be slowed by an alteration of water relations from salt inundation and by reduced photosynthetic capacity from wind pruning of limbs, resulting in narrower growth rings.

A general decrease in ring width of *Pinus taeda* occurred for Hog Island and North Inlet in the years following hurricanes Barbara (1953) and Daisy (1958), and at Bodie Island in addition to these locations in the years following hurricanes Chloe (1967) and Agnes (1972) (Figure 1). Repeated overwash events during four to five year periods with yearly coastal tracking hurricanes may have contributed to the reduced ring widths in the period of 1958 to 1962. The direct effects of Hugo (1989) at North Inlet are evident in the decrease in ring width for 1990 (Figure 1). The center of that storm passed just to the south of this area. Several site visits have revealed initial physical damage to the trees and later physiological damage from salt water uptake and increased attacks from pine bark beetles. No hurricanes have directly affected (*i.e.* storm center passed nearby) Hog or Parramore Islands of Virginia's Eastern Shore since 1933.

The relatively lengthy chronology for *P. taeda* from Hog Island and the short ring width series from Bodie Island may indicate a similar response to the northeaster of 1962 which resulted in severe overwash at both locations (STEWART, 1962). Hog Island showed a plateau in ring widths from 1962 to 1963 and the earliest tree ring for Bodie Island dates to 1963 (Figure 1). Establishment of the current population on Bodie Island obviously occurred after 1962 and may be related to the storm. The 1963 decrease in ring widths was also evident for Parramore Island and resembled a similar decrease in 1943 (Figure 2). The 1943 decrease in ring widths may reflect the effects of a northeaster that occurred in 1942. The series from the two Virginia barrier islands indicated large fluctuations in growth from 1930 to 1955 and reduced variability and steady decline following peak storm activity during the late 1950's and 1960's (Figure 2). By comparison, the width of growth rings from the inland population decreased sharply from the mid 1950's to the mid 1960's and gradually declined from 1970 to 1980. All three growth ring sequences were narrowest for the 1980's (Figure 2).

A comparison of the 20, 50 and 70 year old *P. taeda* trees on Hog Island indicated that the decreased ring width for the 1980's was not related to tree aging (Figure 3). Ring widths for the 50 and 20 year old trees revealed initial high growth rates, but all three ages showed an equally low growth rate in the 1980's. Yet, variations in ring width did not always coincide for the three trees. For example, in 1954 ring width decreased for the 70 year old tree but increased for the 50 year old *P. taeda* (Figure 3). Similarly, in 1986 ring width increased for both the 20 and 50 year old trees, but decreased for the 70 year old tree. Obviously, genetic differences among the trees, as well as microsite variations in exposure and edaphic factors, strongly influence temporal variation in growth ring width for barrier island trees.

Site differences most likely contributed to variations in the average growth ring width among the four populations sampled. The average ring widths for Hog and Parramore Islands were 3.05 ± 0.95 mm and 2.57 ± 0.25 mm, respectively. For the relatively young population from Bodie Island, growth rings averaged 3.75 ± 1.05 mm, while the mainland population at North Inlet was 5.63 ± 1.19 mm. Ring widths increased with decreasing latitude which may indicate differences in length of growing season among sites. This may not only be related to temperature differences but also to the availability of soil moisture. North Inlet had the largest growth rings and this site

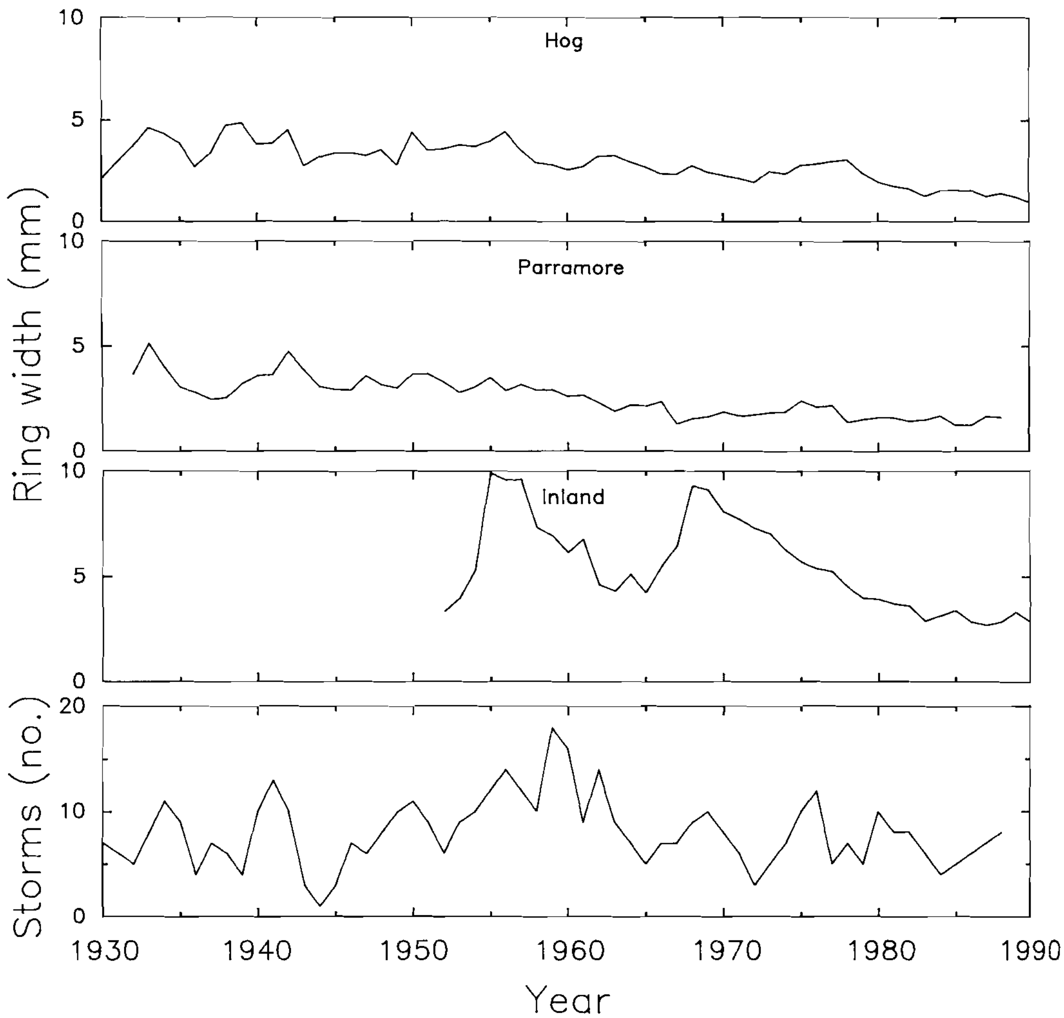

Figure 2. Tree ring series of *Pinus taeda* from Hog Island and Parramore Island and Richmond (inland comparison), Virginia and the total number of storms per year from 1930 to 1988.

can be characterized as a very mesic bottomland forest with almost no interruption in available soil moisture throughout the year.

The magnitude of variability in ring width from year to year at each site may have been related to environmental stability. For the Virginia barrier islands the coefficient of variation (ZAR, 1984) was 0.81 for Hog Island and 0.25 for Parramore Island. Hog Island is considered to be less stable than Parramore (LEVY, 1990; MCCAFFREY and DUESER, 1990; HAYDEN *et al.*, 1991). In the early 1900's, the south end of Hog Island included an extensive *P. taeda* forest as well as the small town of Broadwater. Both have since been washed away as this portion of the island has narrowed from erosion (HAYDEN *et al.*, 1991). The current *P. taeda* population on Hog Island occurs in a very exposed environment with very little relief and is therefore relatively unprotected from storms. In contrast, the Parramore Island *P. taeda* population was sampled in the Italian Hills section which is a relatively high elevation relict dune of considerable distance (> 800 m) from the ocean. Trees from this region of Parramore are relatively well protected from the influence of coastal storm events. By comparison, the Bodie Island popu-

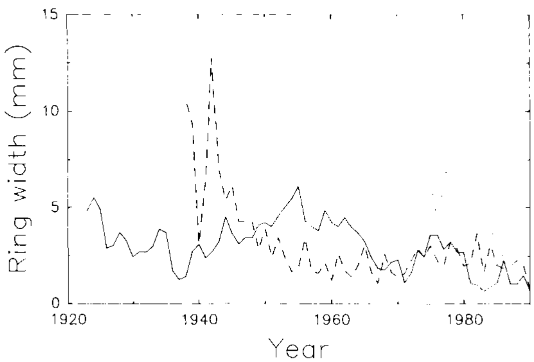

Figure 3. Comparison of tree ring series from a 70 year old (——), a 50 year old (– – –) and a 20 year old (·····) *Pinus taeda* from Hog Island, Virginia.

lation coefficient of variation was 0.73 and North Inlet was 0.55. Variability at the mainland site may also be influenced by biotic factors such as competition from associated hardwood species. The coefficient of variation may be a useful indicator of island stability and suitability for tree growth.

In summary, there is considerable variation in the width of growth rings of *Pinus taeda* from barrier island populations. This variability occurs both through time as well as among the islands. Variation from year to year may reflect the periodic influence of large coastal tracking storms as well as the general favorability of climatic conditions. Most likely, the timing and amount of precipitation are also important. The variability in ring widths among the islands may reflect the stability of the island population as influenced by environmental stability. The larger islands and those with greater relief should provide a more stable environment for the growth of *Pinus taeda* after establishment.

ACKNOWLEDGEMENTS

The staff of the Nature Conservancy and the L. T. E. R. lab, particularly Mr. Randy Carlson, minimized logistical problems associated with field work at the Virginia Coast Reserve. Dr. Bruce Hayden and Dr. John Porter of the University of Virginia graciously provided the coastal storm data. This work was supported in part by a graduate assistantship from Virginia Commonwealth University, a Research Opportunity Award to DRY from NSF grant BSR-870233 to the University of Virginia, Dr. Raymond Deuser, principle investigator, and a grant to DRY from the National Geographic Society.

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□ RÉSUMÉ □

On a collecté des échantillons parmi les populations de *Pinus taeda* sur les Iles Hog et Parramore (côte Est de la Virginier), sur l'Ile Bodie (Caroline du Nord), et à North Inlet (Caroline du Sud) pour comparer la largeur des anneaux de croissance et l'occurence des tempêtes. Les quatres sites présentent une corrélation entre la largeur des stries d'accroissement et les déplacement des ouragans et des vents du Nord Est: la largeur des anneaux est réduite les années de tempête ou l'année suivante. De plus, la largeur des anneaux augmente à mesure que décroit la latitude, ce qui indique une relation probable entre la largeur des anneaux et la durée de la saison de croissance. La variabilité des largeurs moyennes des anneaux des deux iles barrière de Virginie confirment les différences de stabilité des îles. Pourtant aucune corrélation entre tempêtes et largeur des stries d'accroissement n'est évidente. L'analyses des anneaux de croissance peut être un bon outil pour déterminer la fréquence des tempêtes sur de larges périodes et des différences de stabilité entre différentes barrières.—*Catherine Bousquet-Bressolier, Géomorphologie EPHE, Montrouge, France.*

□ RESUMEN □

De las poblaciones de *Pinus taeda* localizadas en las islas de Hog y Parramore de la costa Este de Virginia, en Bodie Island en Carolina del Norte y en North Inlet de Carolina del Sur, se tomaron muestras de arboles para realizar un análisis comparativo del ancho de los anillos de crecimiento con la presentación de las tormentas. Los cuatro sitios mostraron cierta relación entre el ancho de los anillos, la ocurrencia de huracanes costeros y los vientos del noreste, el ancho era reducido durante el año de la tormenta o el año siguiente. Además, el ancho del anillo aumentó con las latitudes decrecientes, indicando, posiblemente, la existencia de una relación entre el ancho del anillo y la longitud media de la estación de crecimiento. La diferencia en la variación alrededor de la media, del ancho del anillo, entre las dos barreras de las islas de Virginia estaban en concordancia con las diferencias sugeridas en la estabilidad de la isla. Aun cuando no existe una clara relación entre el ancho de los anillos y la ocurrencia de la tormenta, el análisis de los anillos puede ser una herramienta útil en la determinación del efecto de las tormentas sobre las comunidades de plantas existentes en las barreras de islas, en la frecuencia de la tormenta sobre largos períodos de tiempo, y de diferencias en estabilidad entre las barreras de islas.—*Néstor W. Lanfredi, CIC-UNLP, La Plata, Argentina.*