Chapter 3: Disturbance histories for remnant *Pinus palustris* in southeastern Virginia using the boundary-line growth method*

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Abstract

Question: Can boundary-line growth patterns be used to reconstruct dendroecological growth releases in *Pinus palustris*? What are the disturbance histories for remnant *Pinus palustris* populations in southeastern Virginia?

Location: Mid-Atlantic Coastal Plain, southeastern Virginia, USA

Methods: We extracted increment cores from all remnant *Pinus palustris* trees at two sites in southeastern Virginia and constructed their disturbance histories based on boundary-line growth patterns.

Results: The boundary-line release method revealed moderate and major dendroecological releases for *Pinus palustris* at both sites. Everwoods showed the highest percentage of major and moderate releases in the 1950s and 1960s, while most major releases were recorded in Seacock swamp in the 1960s.

Conclusions: The boundary-line release method can be successfully applied to *Pinus palustris* to determine release events and disturbance history. At Seacock Swamp, we were able to correlate major and moderate releases in high percentages of the trees with historical records of selective

logging. Future application of this method to old growth *Pinus palustris* chronologies spanning over 200 years could help to reconstruct long disturbance histories and provide a means to compare the disturbance ecology of *Pinus palustris* ecosystems before and after European settlement.

Keywords: Boundary-line release method; *Pinus palustris*; dendroecology; dendrochronology

Abbreviations: PES = pre-European settlement; DBH = diameter at breast height; ITRDB = International Tree Ring Database; ASL = above sea level; USDA = United States Department of Agriculture; SSURGO = Soil Survey Geographic database

3.1 Introduction

Before European settlement, the southeastern United States was dominated by pure or mixed forests of *Pinus palustris* that were maintained by periodic fire ignited naturally or by Native Americans (Frost 1993; Smith et al. 2000). In pure stands, *Pinus palustris* shared an association with *Aristidia spp.* (wiregrass) and other grasses forming *Pinus palustris*-grass communities that formed the regional vegetation landscape from xeric uplands and mesic flatwoods down to shrub swamps of the southeast (Bridges and Orzell 1989; Noss 1989; Noss et al.1995; Carter et al. 1999). The PES range of the *Pinus palustris* ecosystem was estimated to have once covered 607,000 ha within the ecoregions of the Coastal Plain and Piedmont of Virginia, where this species reaches its northernmost range (Figure 3.1, Frost 1993). In this part of its range, forests were dominated by pure *Pinus palustris* stands or mixed *Pinus palustris*-*Pinus taeda*-hardwoods.

Since the founding of Jamestown in 1607 and over the past four centuries, intense anthropogenic activities in the form of the naval stores industry, silvicultural practices, fire suppression, and conversion of stands to agricultural fields and suburban areas have fragmented this ecosystem and disrupted the presettlement fire regime. These human activities have reduced the aerial extent of this ecosystem to only 81 ha in this state (Figure 2; Frost 1993; Sheridan et al. 1999). In the absence of fire, *Pinus taeda* (loblolly pine) and hardwood species have out-competed *Pinus palustris*, herbaceous ground cover has been eliminated, and the range of presettlement flora and fauna has collapsed (Outcalt 2000; Smith et al. 2000). As a result, *Pinus palustris* has been listed as a species of special concern in Virginia (Terwilliger & Tate 1994) and the endangered *Picoides borealis* (Red-cockaded woodpecker), a keystone faunal species, has almost been eliminated from this part of its range (USFWS 2003). Further studies of the function and dynamics of the *Pinus palustris* ecosystem here in the northernmost part of its range are warranted due to its past abundance on the landscape in southeastern Virginia, its unique species assemblage, and its value as a timber species.

Reconstruction of the disturbance history of southeastern forests, particularly those containing *Pinus palustris*, using dendroecological applications, stand-age structure, and land use history can provide insight into the disturbance ecology of these forests. So far, studies of the disturbance ecology of *Pinus palustris* have focused on, for example, how invasive non-endemic species have altered the fire regimes of these forests in Florida (Lippincott 2000); the effects of a tornado and fire on the composition of a pine savanna in Texas (Liu et al. 1997); and plant response to soil disturbance by *Geomys pinetis* (southeastern pocket gopher; Simkin et al. 2001). However, no published studies to date have investigated the growth releases of this species using a dendroecological approach.

A study of the population dynamics of *Pinus palustris* at the Wade Tract in Georgia investigated the regeneration of this species in an old growth stand and the importance of fire as a disturbance agent in the maintenance of this ecosystem (Platt et al. 1988). Regarding the field of dendrochronology, a handful of studies have investigated the influence of climate on the annual growth of *Pinus palustris* (Lodewick 1930; Coile 1936; Schumacher & Day 1939; Devall 1991; Meldahl et al. 1999; Foster & Brooks 2001), but none of these studies investigated disturbance. Meldahl et al. (1999) was the only study that speculated on the influence of disturbance on the growth of *Pinus palustris* and how dendrochronology could be used to understand the effects of disturbance on annual ring growth.

Dendrochronological analysis can be combined with land use history to shed light on the disturbance history, dynamics, and functions of forests (Lorimer & Frelich 1989; Abrams et al. 1997; Black & Abrams 2001). Dendrochronology is especially useful in the reconstruction of disturbance and growth release events of a stand through analysis of the change in annual ring growth of the tree species in question (Lorimer & Frelich 1989; Abrams et al. 1997). Growth releases occur when forest canopies are opened, such as when individual or small groups of trees die naturally (e.g., windthrow or disease) or are removed by people (e.g., selective logging). Recent canopy disturbances are easily visible in forests and often studied for their important influence on forest structure, composition, and function (Pickett & White 1985). Tree ring analysis provides a means of extending our knowledge of disturbance history back through time and can provide detailed information about the timing and temporal variability of forest canopy disturbances (Frelich & Lorimer 1991; Ziegler 2002; Black & Abrams 2003). The removal of canopy dominant trees allows for releases to occur in the remaining trees, therefore leaving a historical record of the release event that occurred in the annual ring width of the tree. Growth releases are usually defined as events when the percent growth change reaches some minimum threshold, such as 50% for a period of time; however criteria for releases vary greatly depending on the interests of the research (Black & Abrams 2003).

Past dendroecological approaches aimed at the identification of growth releases have sometimes exaggerated or masked the frequency of releases from disturbance events because their methods applied fixed growth change thresholds. It has also been assumed that these methods could be applied equally to all tree species in a stand; however, the release potential from a disturbance event varies interspecifically due to differences in shade tolerance (Lorimer & Frelich 1989; Orwig & Abrams 1994; Nowacki & Abrams 1997) and thus, threshold levels must take into account the release characteristics of each species (Black & Abrams 2003).

The boundary-line growth technique of Black & Abrams (2003) eliminated the ambiguity of these past approaches by determining release events based on percent growth change and prior growth rate of a particular species. Black & Abrams (2003) determined the upper boundary line for growth of a variety of species through examination of their annual tree-ring chronologies and set release events at 50% of the boundary line for major releases and 20% of the boundary line for moderate releases. Their species specific technique eliminates the need to use diameter, age, and crown class because they are possibly artifacts of the relationship between percent growth change and prior growth (Black & Abrams 2003). Using their technique, boundary-line growth patterns and release events can be determined for multiple species in a stand or forest. Having this characteristic, the method has broad applications in defining dendroecological release for multiple species in a stand or forest without skewing the interpretation of release events due to the shade tolerance of a species. Here we present the first application of Black & Abrams (2003) boundary-line growth technique to remnant naturally-occurring *Pinus palustris* Mill. (longleaf pine), where they are found in two successional *Quercus spp.-Pinus taeda* (oak-loblolly pine) stands in southeastern Virginia.

3.2 Materials and Methods

3.2.1 Study area and sites

Everwoods and Seacock Swamp (Figure 3.1) are located in the Mid-Atlantic Flatwoods region of the Middle Atlantic Coastal Plain (Woods et al. 2005). The flatwoods region is a broad plain consisting of mid-elevation terraces, sandy ridges, and broad, shallow valleys ranging in elevation from 0–30 m ASL and with low local relief (Woods et al. 2005). The most extensive soils in this region are the often drained Aquults (Woods et al. 1999). Streams have high values of dissolved organic carbon and are more acidic than those found in the Piedmont and the Southeastern Plains; this characteristic is expressed in the Blackwater River which flows through this region.

Based on the USDA SSURGO database, Everwoods soils (Alaga fine sands, Chipley sands, and Leon-Chipley sands) are very deep and excessively to poorly drained. Soils at Seacock Swamp include Bibb sandy loams, Emporia fine sandy loams, Nansemond loamy fine sands, Slagle fine sandy loams, and Uchee loamy sands. All soils at this site are well drained, with the exception of Bibb sandy loams which are frequently flooded.

The natural vegetation for this region is *Quercus-Carya-Pinus* forest, with *Carya ovata*, *Pinus echinata*, *Pinus taeda*, *Quercus alba,* and *Quercus stellata* as upland dominants and *Nyssa* spp., *Quercus* spp., and *Taxodium distichum* as valley dominants (Woods et al. 1999). Evergreen shrub bogs (pocosins) are also found in this region on flat, poorly-drained uplands between streams (Woods et al. 2005). *Pinus palustris* is secluded here to upland sites that are low-nutrient, well-drained, and sandy. Current land cover comprises a mix of woodland and agricultural land.

The two study sites are located within the National Climatic Data Center's climate Division 1 of Virginia. The average annual temperature for this region is 13.94° C. The warmest months are July and August, while the coldest are January and February. Mean annual precipitation is 930 mm with August the wettest month.

Everwoods (41.7 ha; 76°55'34" W, 36°39'30" N; ~12 m ASL.) is described by International Paper as a "natural pine site" since its establishment. Neither International Paper, nor its predecessor, Union camp, has actively managed this site, excluding application of herbicides and fertilizers, or prescribed fire. Seacock Swamp (312.8 ha; 76°55'2"W, 36°49'45"N; ~12 m ASL), about 48.3 km north of Everwoods in Southampton County, was subject to selective harvesting in 1953 leaving the remaining standing tree species to reseed the site (Personal communication, T.L. Bain, landowner). Canopies at both sites are dominated by successional *Pinus taeda* mixed with a variety of hardwood species. Neither site has any record of natural or prescribed fire.

3.2.2 Field methods

Sheridan et al. (1999) originally surveyed Everwoods in 2002 and Seacock Swamp in 1998. We relocated and measured all *Pinus palustris* surveyed by Sheridan et al. (1999). *Pinus palustris* at Seacock Swamp were geo-referenced by the Virginia Department of Forestry in 1998 and were used as waypoints to relocate all *Pinus palustris* at this site. We identified, geo-referenced with a GPS unit, measured DBH (at 1.4 m) and height of all *Pinus palustris*. We cored all *Pinus palustris* trees over 10.0 cm DBH. Cores were extracted with an increment borer from opposite sides of each tree, perpendicular to the slope (when present), at a height of 20.3 cm (1/2 breast height) above the ground.

3.2.3 Laboratory methods

Cores were dried, mounted, and prepared by sanding with increasingly fine sandpaper following standard techniques (Stokes & Smiley 1968; Phipps 1985). Cores were visually cross-dated using the Yamaguchi marker-year list method (Yamaguchi 1991). We measured ring widths using the Velmex unislide tree-ring measuring system (0.001mm resolution), and then statistically cross-dated the cores using the computer program COFECHA (Holmes 1983; Grissino-Mayer et al. 1997). Raw ring chronologies were used in determining the boundary-line and disturbance history for *Pinus palustris* for graphing out age-class distributions.

We constructed the disturbance history for *Pinus palustris* at both sites by employing the Black & Abrams (2003) boundary-line release method. All annual raw ring-width chronologies for *Pinus palustris* from the ITRDB website in addition to the annual raw ring-width chronologies from my sites (combined total of 32,970 annual ring-width measurements) were used to construct the boundary line. Nowacki & Abrams (1997) method for calculating percent growth change was applied to all *Pinus palustris* from all sites. To calculate percent growth change, the ten year mean for prior growth (M_1) was subtracted from the ten year mean for subsequent growth (M_2) and divided by the ten year mean of prior growth (M_1) for each year of every series: $(M_2-M_1)/M_1$. Mean raw growth was calculated next using M_1. The first and last ten years for each series were excluded from the calculations because ten years is needed to calculate mean percent growth change and mean prior growth. We plotted mean prior growth against mean percent growth change for all *Pinus palustris* from our sites and the ITRDB.

Development of the boundary line was calculated by placing mean prior growth into 0.5 mm segment classes. From these segment classes, we sorted mean percent growth change and selected the ten highest values for percent growth change. The mean of the ten highest values from each segment class was calculated and the positive segment values were graphed. Exponential, logarithmic, linear, and power trendlines were fit to segment points, with the exponential trendline returning the highest R^2 value. The equation generated from fitting the exponential curve to the segment points was used to construct the boundary line and was developed to determine annual ring growth that exhibited moderate releases (20–49.9%) and major releases (50–100%) for Everwoods and Seacock Swamp following the criteria of Black & Abrams (2003).

3.3 Results

3.3.1 Pinus palustris population

We found no naturally occurring *Pinus palustris* seedlings or saplings at Seacock Swamp and only a few saplings at Everwoods (Figure 3.2). At Everwoods, we relocated all of the *Pinus palustris* surveyed by Sheridan in 2002 plus an additional 12 trees; seven trees were < 10 cm DBH and cores from two trees were damaged, so our chronology for this site included 39 trees. At Seacock Swamp, of the 41 trees surveyed by Sheridan et al. (1999), we were able to relocate 32 of the *Pinus palustris* using the waypoints provided to us by the Virginia Department of Forestry.

Size-classes (Figure 3.2) are rather evenly distributed at both study sites, with a few classes not being represented. Age-distribution plots (Figure 3.3), however, show that most trees at Everwoods are 26–75 years of age, while at Seacock Swamp most are between 50 and 100 years old. The oldest Pinus palustris found was 175 years, however, the increment borer used in obtaining the core for this tree was not large enough to core to the pith of the tree. There were not any *Pinus palustris* over 100 years old at Everwoods, while Seacock Swamp had seven trees over 100 years old.

3.3.2 Disturbance analysis

Using the Black & Abrams (2003) boundary-line method we created a boundary line for the entire range of *Pinus palustris* based on raw growth data from the ITRDB and our sites (Figure 3.4). The boundary line is represented by an exponential line (e = 2.178) that was fitted to all positive segment class points (R^2 = 0.9628):

$$y = 1728.5e^{-0.9735x}$$

Upon application of the boundary line and release criteria (Black & Abrams 2003) to our sites, we found that of the 2,364 annual rings measured from Everwoods, 90 of the annual rings experienced a major release and 192 of the rings experienced a moderate release. For Seacock Swamp, of the 4,365 annual rings measured, 39 annual rings experienced a major release and 240 annual rings experienced a minor release (Figure 3.4 & 3.5).

Based on the percentage of trees that experienced a major or moderate release at the decadal scale (Figure 3.6), Everwoods experienced major releases in both the 1950s and 1960s, with 41% release and 27% release respectively. Five other major releases at Everwoods were recorded but included less than 33% of the annual rings. Moderate releases were also recorded in the 1940s

(17%), 1950s (27%), 1960s (18%), and 1970s (18%) and were observed in all decades except the 1910s (Table 3.1). Major releases occurred at Seacock Swamp throughout the decades except for the 1930s, 1940s, and 1990s; the majority of the annual rings experienced a major release in the 1950s (18%) and the 1960s (49%). The rest of the annual rings experienced a major release less than 26% throughout the rest of the time scale. Of the annual growth rings with moderate releases, 23% of them occurred in the 1950s and 33% occurred in the 1960s. The rest were distributed throughout the time scale at less than 45% (Table 3.1)

3.4 Discussion

3.4.1 Population distribution

We located a few remnant *Pinus palustris* trees that may have been overlooked in Sheridan et al. (1999) original survey. At Seacock Swamp, however, nine *Pinus palustris* from Sheridan's 1998 survey were missing. These trees, along with a high number of *Pinus taeda* and *Pinus echinata,* were victim to Hurricane Floyd in 1999 and were harvested in 2001; however, no records exist on the number of trees or the species of trees salvaged from this site by the landowner or the individuals or company who harvested the damaged trees (Personal communication with T.L. Seacock Swamp, landowner).

Clearly, recruitment of *Pinus palustris* is low in Everwoods and non-existent in Seacock Swamp (Figure 3.2). At both sites, natural or anthropogenic disturbance events have allowed for the recruitment and release of *Pinus palustris* at different intervals over the past 175 years. There are a number of possible explanations for the behavior of these stands with regard to disturbance events and low/non-existent recruitment levels of *Pinus palustris.* At both of these sites, disturbance events created canopy gaps in these closed canopy forests allowing for tree species in the subcanopy to release. *Pinus palustris* is a shade intolerant species (Smith et al. 2000); however, it appears that at both sites, disturbance events have allowed this species to release into the canopy. Our older chronologies that were over 100 years old at Seacock Swamp showed trees that were suppressed in the subcanopy for over 70 years and did not release into the canopy until the 1900s, indicating that *Pinus palustris* can maintain itself in the subcanopy until a canopy gap is created from silvicultural operations or natural disturbances (Lorimer 1985). We also assert that competition from fire-intolerant species from overhead and below the canopy were responsible for the suppression of *Pinus palustris* at our sites Meldahl et al. (1999), in a study of Flomaton Natural Area in Alabama, suggested that competition with fire-intolerant species increased due to fire suppression and may have lead to a decline in growth of *Pinus palustris*. Canopy suppression could not be determined as a causal factor for growth declines in the trees they studied; however, the authors recommended further studies on growth declines of *Pinus palustris*. Application of the Black & Abrams (2003) boundary-line growth method to the Flomaton Natural Area site could help to verify speculations by Meldhal et al. (1999) on disturbance and competition at that site.

Fire suppression at our sites is surely responsible for the low levels of recruitment because it allows for succession by competitive fire-intolerant species such as *Quercus spp.* and other hardwood species, and *Pinus taeda.* In the absence of fire, these species can dominate the canopy and decrease the growth of *Pinus palustris* (Outcalt 2000; Smith et al. 2000). Our examination of individual chronologies of *Pinus palustris* from both sites show incidences of release events that support this idea. Use of the boundary-line growth method confirmed that disturbance events have contributed to the release of *Pinus palustris* via canopy gaps or thinning at both sites.

Our boundary-line analysis indicated that *Pinus palustris* trees at both the Everwoods and Seacock Swamp sites have experienced moderate to major releases, which we assume were caused by the disturbance of the *Pinus taeda* canopy by silvicultural operations throughout the past century. Neither site shows any present evidence of natural disturbance, nor are there any written records of natural disturbance influencing either site according to land managers (Personal communication with International Paper, Union Camp, T.L. Baine, and P. Sheridan). To further validate our assumptions on this matter, we examined the history of hurricanes that might have impacted the sites over the past century. The record of historical hurricane tracks from the National Oceanic and Atmospheric Administration yielded no evidence of past events that could be linked to canopy disturbance at either site. Future research at Seacock Swamp may reveal growth releases over the next decade from the impacts of Hurricane Floyd in 1999 and the silvicultural salvage operations that took place after that hurricane. We think that the absence of records for fire, prescribed or natural, in the area eliminates fire as a cause of release for *Pinus palustris*.

At Seacock Swamp, the 1953 diameter-limit cut of the stand appears to be responsible for the release of *Pinus palustris* at this site. During the 1960s, 87% of the annual rings indicated significant major and moderate releases. Unfortunately, we cannot account for the other minor release events at either site due to the lack of historical land use or management records for either stand. Intense land use, however, is historically documented for the region and we suspect that selective thinning and other silvicultural operations at these sites in the past probably caused the releases.

3.5 Conclusions

Most major studies on the *Pinus palustris* ecosystem in Virginia have focused on the following themes: vegetation composition and history of the Blackwater Ecological Preserve (Frost & Mussleman 1987); the historical decline of longleaf pine in the state (Frost 1993); a survey estimating the population of longleaf pine in the state (Sheridan et al. 1999); and the reproduction, harvesting, development of a seed orchard for, and restoration of longleaf pine in Virginia (Sheridan 2001). No published study has reconstructed the disturbance history of *Pinus palustris* using dendroecological methods, nor has the boundary-line technique been applied to *Pinus palustris* throughout its range. This study shows that the boundary-line release method (Black & Abrams 2003) can be applied to *Pinus palustris* successfully and can yield valuable information on the disturbance history of *Pinus palustris* stands. Mature stands of Pinus palustris are located throughout the southeastern United States and provide chronologies that span over 200 years (ITRB). The boundary-line release technique could be applied to such old growth *Pinus palustris* stands to reconstruct both pre- and post-European colonization disturbance regimes, especially in the interior coastal plains of Mississippi, Alabama, and Georgia, which were not heavily impacted until after the 1850's (Frost 1993).

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Chapter 3 Figures

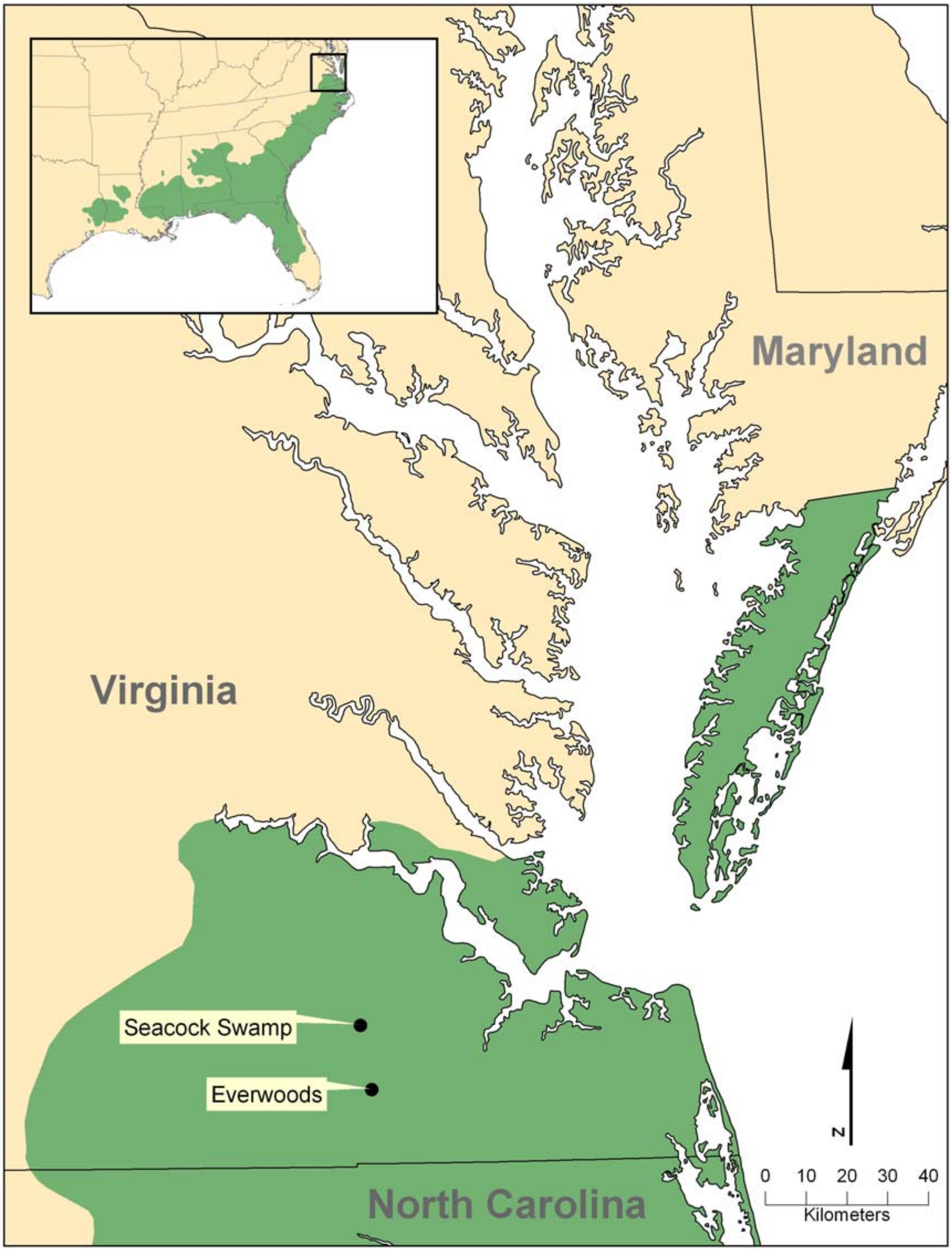

Figure 3.1. Location of the Seacock Swamp and Everwoods study sites in southeastern Virginia. Modeled after Frost (1993).

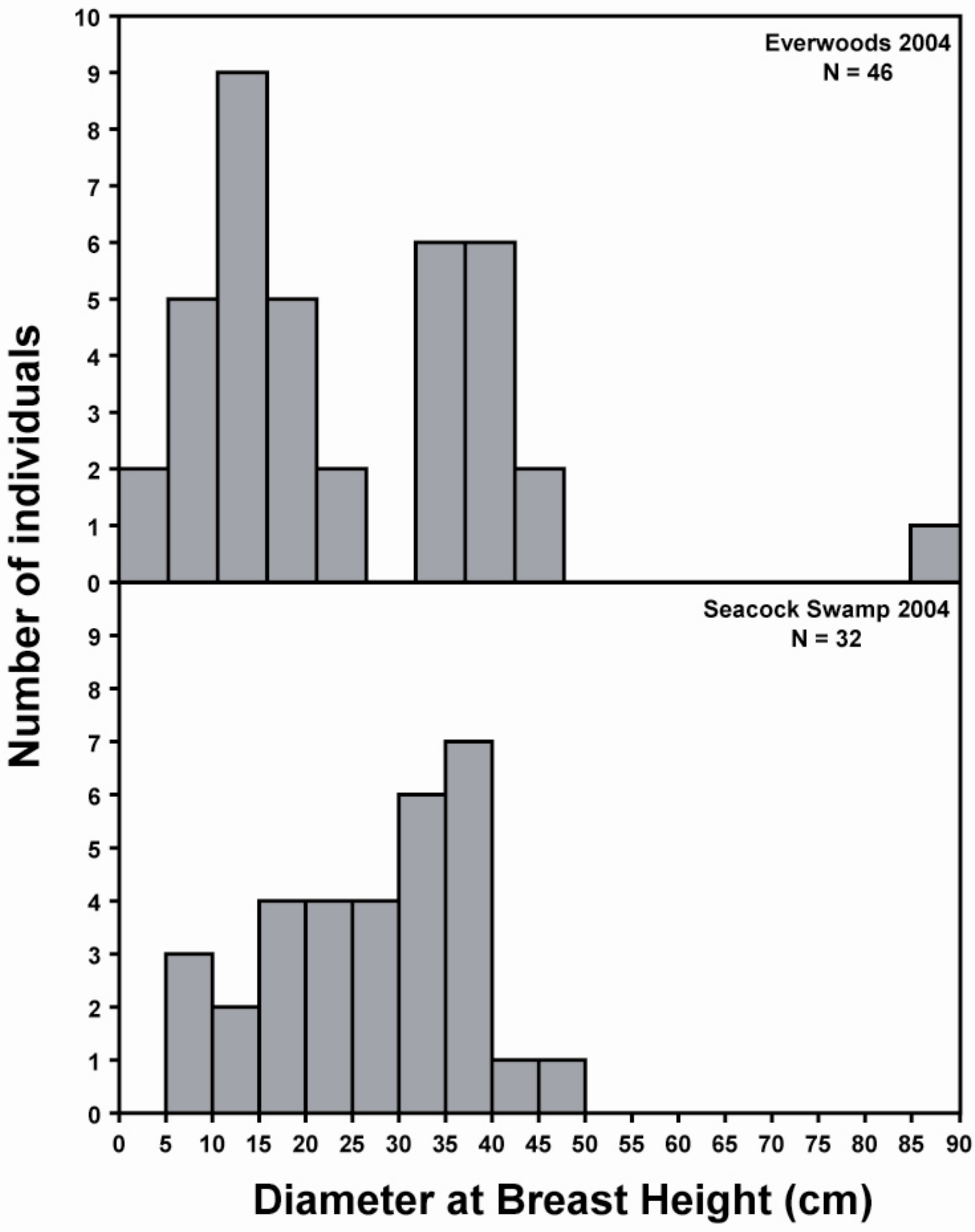

Figure 3.2. Size-class distribution of Pinus palustris at Everwoods and Seacock Swamp in southeastern Virginia in 2004.

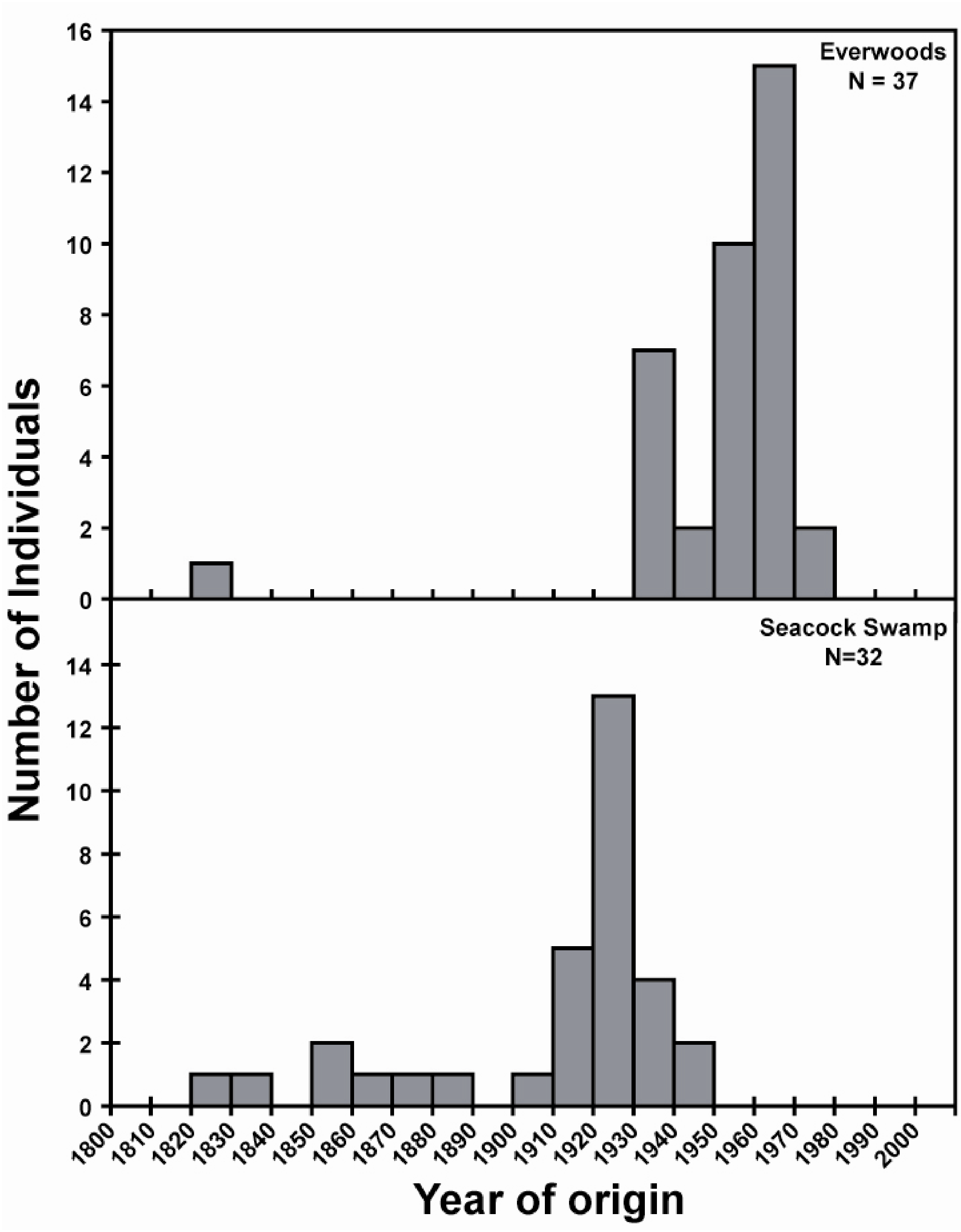

Figure 3.3. Age-Class distribution of longleaf pines at Everwoods and Seacock Swamp.

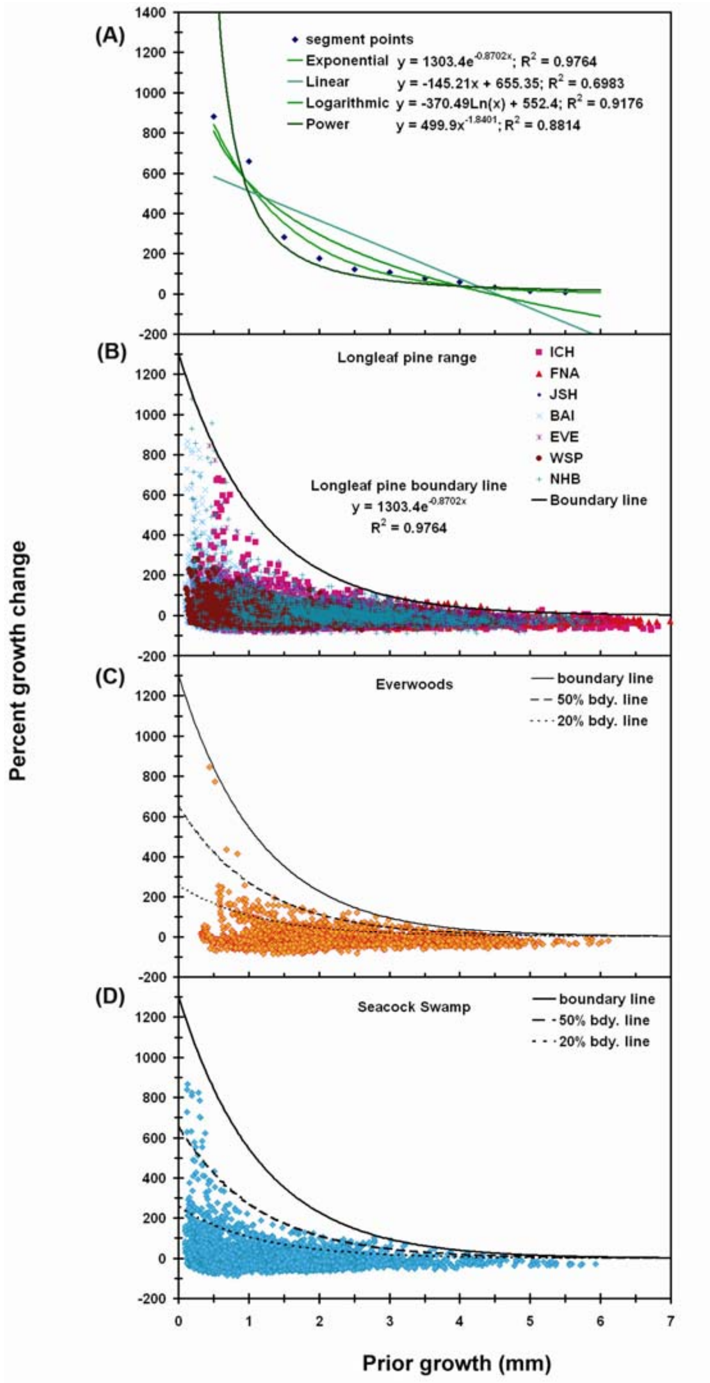

Figure 3.4. **Calculation of the boundary line for longleaf pine and its application to all sites with longleaf pine found in the ITRDB and for the two study sites Everwoods and Seacock Swamp.** (A) Determination of the boundary line by fitting linear, logarithmic, power, and exponential curves to segment classes. Application of the boundary line to (B) all *Pinus palustris* records from the ITRDB plus the two study sites with 100%, 50%,and 20% of the boundary line (C) at Everwoods and (D) at Seacock Swamp.

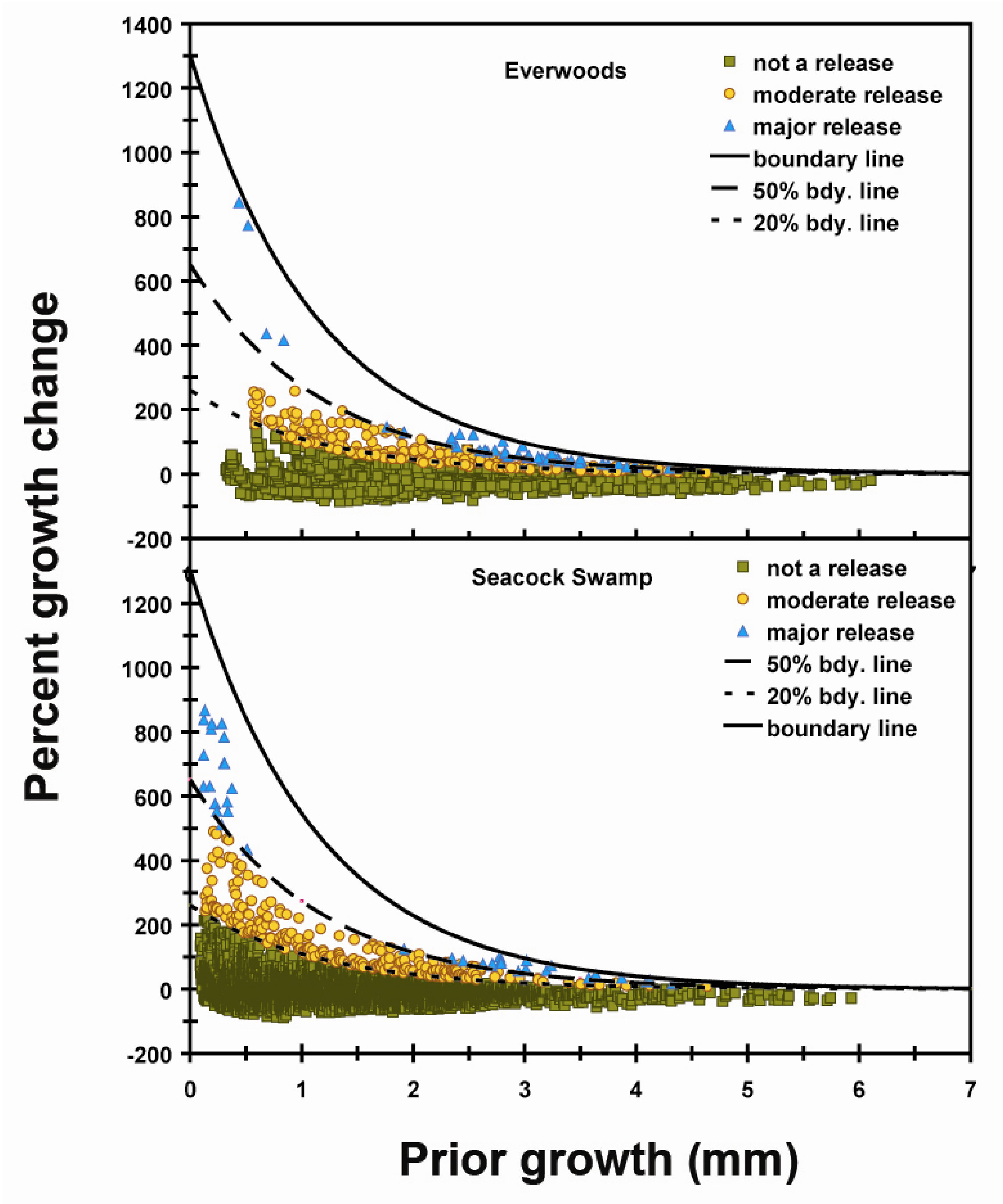

Figure 3.5. Major, moderate, and no release events for Everwoods and Seacock Swamp. Major releases occur between the boundary line and the 50% boundary line, moderate releases occur between the 50% boundary line and the 20% boundary line, no releases are those that fall below the 20% boundary line.

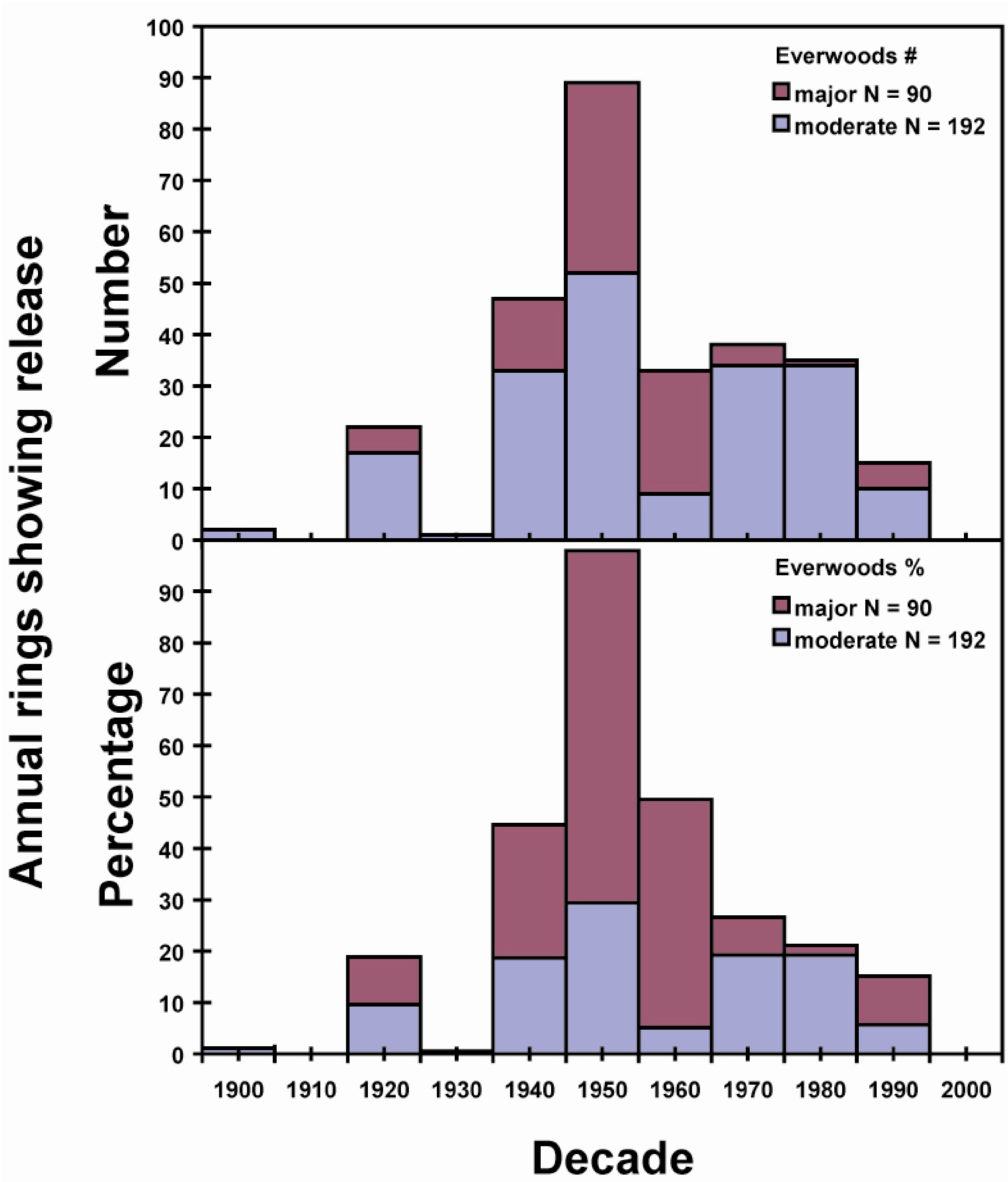

Figure 3.6. Major and moderate releases of annual rings for longleaf pine at Everwoods based on boundary line method (Black & Abrams 2003) at the decadal scale. The top graph shows the number of annual rings that experienced a release and the bottom graph shows the percentage of those annual rings that experienced a release.

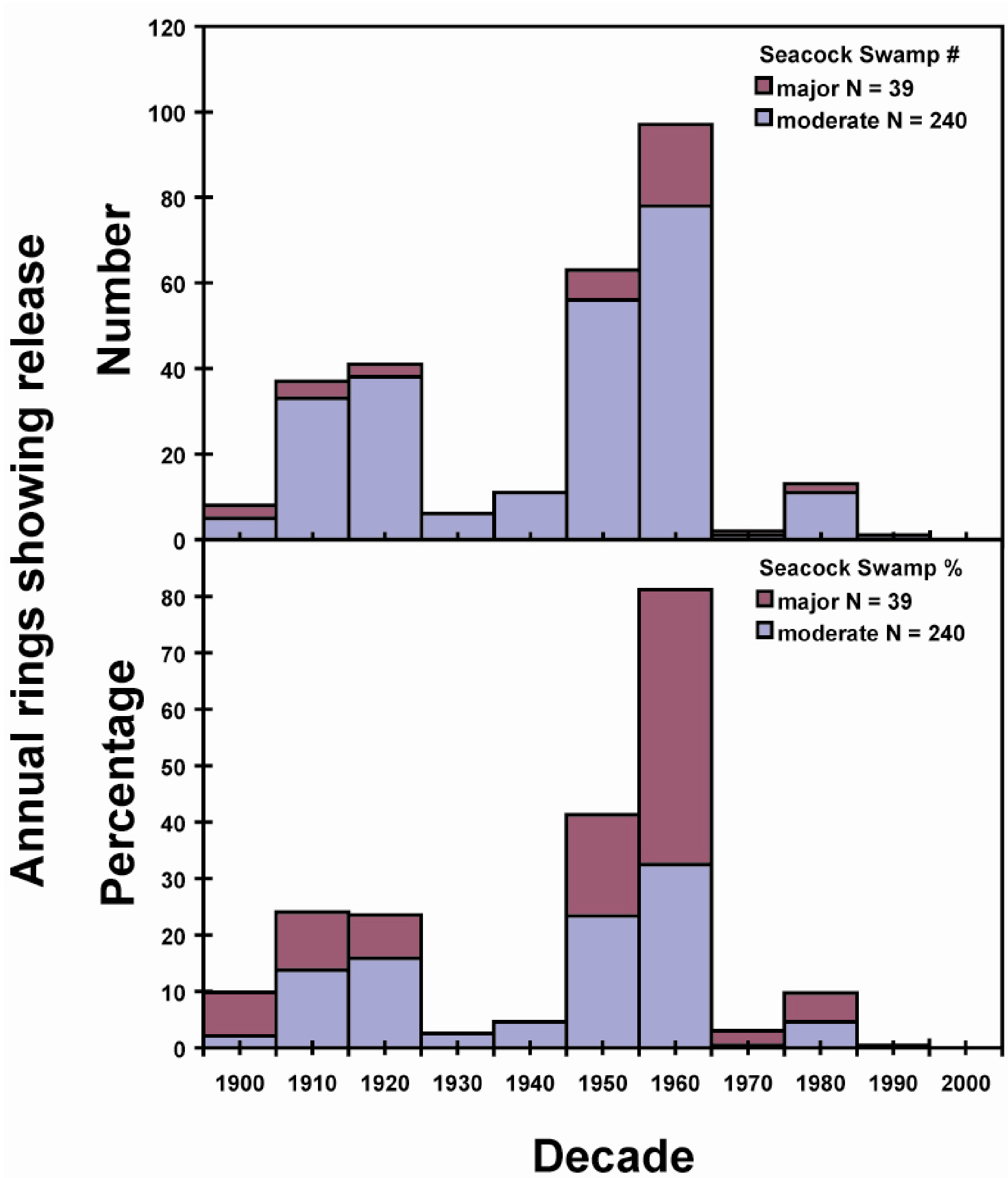

Figure 3.7. Major and moderate releases of annual rings for longleaf pine at Seacock Swamp based on boundary line method (Black & Abrams 2003) at the decadal scale. The top graph shows the number of annual rings that experienced a release and the bottom graph shows the percentage of those annual rings that experienced a release.

A)

EVERWOODS				
DECADE	# at 50%	# at 20%	% at 50%	% at 20%
1900	0	2	0	1
1910	0	0	0	0
1920	5	17	6	9
1930	0	1	0	1
1940	14	33	16	17
1950	37	52	41	27
1960	24	9	27	5
1970	4	34	4	18
1980	1	34	1	18
1990	5	10	6	5
2000	0	0	0	0
Sum	90	192	100	100

B)

SEACOCK SWAMP				
DECADE	# at 50%	# at 20%	% at 50%	% at 20%
1900	3	5	8	2
1910	4	33	10	14
1920	3	38	8	16
1930	0	6	0	3
1940	0	11	0	5
1950	7	56	18	23
1960	19	78	49	33
1970	1	1	3	0
1980	2	11	5	5
1990	0	1	0	0
2000	0	0	0	0
Sum	39	240	100	100

Table 3.1. A) Everwoods and B) Seacock Swamp. Table shows release by decade in number and percentage for both sites from 1900-2000.