COMMUNITY ATTRIBUTES OF ATLANTIC WHITE CEDAR (CHAMAECYPARIS THYOIDES) SWAMPS IN DISTURBED AND UNDISTURBED PINELANDS WATERSHEDS

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Abstract: We assessed the effect of regional watershed conditions on plant community attributes, seedbed and seedling density, and environmental conditions in New Jersey Pinelands Atlantic white cedar (Chamaecyparis thyoides) swamps under three disturbance regimes (high, moderate, and low). High regional watershed disturbance, defined by the percentage basin cover of combined residential and agricultural development, was associated with elevated pH, specific conductance, and nutrient concentrations in surface waters adjacent to our study sites. High disturbance sites generally had lower understory species richness and differed from other sites in overall understory species composition. High canopy red maple (Acer rubrum) cover and high canopy closure were also associated with swamps in high disturbance basins. Because other environmental variables did not differ significantly between disturbance types and red maple is a common associate of cedar throughout the Pinelands, differences in species richness and composition may be related to canopy conditions rather than the effects of watershed disturbance. Regional differences in biogeography may also be a factor. We found no exotic species in our study sites. Only one species considered uncharacteristic of the Pinelands was associated with high disturbance basin sites. Unlike previous, similar studies in the Pinelands, the high disturbance sites did not support a unique group of plants. Although Sphagnum cover (typically associated with optimal cedar seedbed conditions) was lowest in disturbed basin sites, there were no significant differences in overall seedbed conditions and cedar seedling density. Cedar swamps located a distance from upgradient watershed disturbances and not affected by overbank flooding seem to be buffered from the impacts of these regional disturbances.

Key Words: New Jersey Pinelands, watershed disturbance, biological invasion, plant species composition, Atlantic white cedar wetlands

INTRODUCTION

Species invasions into regions outside their natural range have altered biological diversity throughout the world (Mooney and Drake 1986, Drake et al. 1989). For successful invasion to occur, the abiotic and biotic barriers that exclude species from an environment must be removed or overcome (Ashton and Mitchell 1989). Resource availability (e.g., nutrients, moisture, space) and physical disturbance are important environmental factors that influence the invasibility of a particular environment (Huenneke et al. 1990, Burke and Grime 1996, Higgins and Richardson 1996). Proximity to altered landscapes, which serve as sources for exotic species (Forman 1995), may be another factor. In the New Jersey Pinelands (Pine Barrens), USA, invasion of aquatic and wetland plant communities by both exotic species and species from adjacent biogeographic regions is associated with human-mediated watershed disturbances related to upland land uses, nutrient enrichment, and decreased acidity (Ehrenfeld 1983, Morgan and Philipp 1986, Zampella and Laidig 1997).

Over the past two decades, discussion of the design of nature reserves to preserve biodiversity focused primarily on the size and dimensions of a reserve and the role of buffers and landscape corridors (Shafer 1990, Forman 1995). More recently, the need for a watershed approach to maintaining sustainable ecosystems has received consideration (Lubchenco et al. 1991, Herrmann 1997). In the Pinelands, large forest reserves are located downgradient from developed and agricultural lands. Because the region's uplands and lowlands act as a single hydrologic unit with water and energy flowing down elevational gradients (Ballard 1979), aquatic and wetland plant communities located on these reserves may not be completely buffered from the effects of distant, upgradient land-use related watershed disturbances.

Atlantic white cedar (Chamaecyparis thyoides) wetlands are a significant component of Pinelands biodiversity. Ehrenfeld and Schneider (1990, 1991, 1993) associated an increase in the occurrence of non-native and upland plant species, loss of native species, in-
increased species richness, and reduced *Sphagnum* cover (i.e., cedar seedbed) and cedar seedling germination with cedar swamps impacted by adjacent residential development and storm water runoff. In this study, we evaluated the regional effect of upstream land-use disturbances on these same Atlantic white cedar community attributes in swamps located within forest reserves. We addressed three main questions. First, is there a difference in species richness and native, non-native, and upland plant species composition between cedar swamps in disturbed and undisturbed watersheds? Second, is there a difference in functional attributes such as *Sphagnum* cover and seedling germination between cedar swamps in disturbed and undisturbed watersheds? Finally, do site-specific environmental conditions differ between cedar swamps in disturbed and undisturbed watersheds?

**METHODS**

**Study Sites**

We selected four closed-canopy cedar stands in each of six drainage basins representing watersheds with a high (Albertson Brook and Pump Branch), moderate (Mullica River and Batsto River), and low (Bass River and Wading River) degree of watershed disturbance associated with agricultural and residential land use (Figure 1). All twenty-four sites, established as permanent, long-term monitoring sites, were on state-owned forest land. The streams associated with the six drainage basins are tributaries of the Mullica River. All owned forest land. The streams associated with the six drainage areas are associated with the Kirkwood-Cohansey aquifer (Rhodehamel 1979) and lie within Stone’s (1911) biogeographic Pine Barrens District. The soils in the study basins are primarily sands, loamy sands, and sandy loams. Upland soils include Typic Quartzipsamments, Haplaquodic Quartzipsamments, Spodic Quartzipsamments, and Typic Hapludults, and dominant wetland soils include Aeric Haplauquods and mucks (Histosols) (Markley 1979).

At each site, we established a single 20 × 50 m permanent macroplot. The long axes of the macroplots paralleled the adjacent stream. We nested three 10 × 10 m plots within each macroplot. Each 100-m² plot contained a single 5 × 5 m subplot and five 1 × 1 m quadrats. We marked each macroplot with two metal stakes and determined its position with a geographic positioning system (GPS). Using a geographic information system and the GPS positional data, we measured the distance between each macroplot and the nearest stream.

**Vegetation Sampling**

We sampled vegetation in 1995 and 1996. We measured the diameter of all trees (dbh > 2.5 cm) within each 100-m² plot and counted saplings (stems > 1 m, dbh < 2.5 cm) in each 25-m² subplot. Using the Braun-Blanquet cover scale (Mueller-Dombois and Ellenberg 1974), where r = rare, + = < 1%, 1 = 1-5%, 2 = 5-25%, 3 = 25-50%, 4 = 50-75%, and 5 = > 75% cover, we estimated the abundance of all canopy and subcanopy (stems 1-3 m tall) tree species in each 100-m² plot and all understory species in each 25-m² subplot. Non-vascular species were merely noted as *Sphagnum* mosses or other bryophyte species. We listed additional species found in the surrounding plot and macroplot and noted new species observed during other visits made throughout the growing season.

We collected voucher specimens of most species found in each watershed. With one exception concerning red maple, taxonomic nomenclature for vascular plants follows Gleason and Cronquist (1991). We identified the trident-leaved form of red maple that we found in our macroplots as *Acer rubrum var. triilobum* Torr. & Gray ex K. Koch because this facultative wetland variety (Reed 1997) is generally associated with Pinelands swamps (McCormick 1979).

Within each 1-m² quadrant, we counted all tree seedlings (stems < 1 m, dbh < 2.5 cm) and estimated the total cover of tall shrubs (> 1 m), medium shrubs (0.25 to 1 m), low shrubs (< 0.25 m), herbs, *Sphagnum* mosses, and other bryophyte species. We counted seedlings over a two-year period. Within a watershed, we made all seedling counts within a one-month period.

Because calculating means from ranked cover data can give misleading results (Jongman et al. 1995), we calculated median macroplot values (n = 3) for all ranked vascular plant cover data. Before calculating median values, we assigned an abundance rank of 0.5 to species considered rare, contributing < 1% cover, or present in only one of three associated plots. We used the same approach to calculate median *Sphagnum* cover values (n = 15) for each macroplot.

Site-Specific Environmental Factors

In the center of each 100-m² plot, we installed a 2.5-cm water-table observation well to a depth of 1 m. The entire length of each well casing was screened with horizontal slots. In October 1995, we began monthly water-table measurements. We made all measurements with a graduated steel tape at least three days after a significant rainfall (> 2.5 cm). Some daily water levels, comprising less than 3% of all values, were estimated due to frozen or vandalized wells. Using a transit and the center wells as reference points, we also measured elevations at 0.5-m intervals along a single transect bisecting the macroplots. We then re-scaled all elevations and water levels relative to the