STANDING CROP NUTRIENT BIOMASS FOR TWO EVERGREEN BOTTOMLAND HARDWOOD FORESTS

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Abstract.--Estimates of standing crop nutrient biomass were made for an Atlantic white cedar (*Chamaecyparis thyoides* L.) and an American holly (*Ilex opaca* Ait.) swamp located within the New Jersey Pinelands near Atlantic City. Other major tree species included red maple (*Acer rubrum* L.), tupelo (*Nyssa sylvatica* Marsh.) and sweetbay magnolia (*Magnolia virginiana* L.). Aboveground standing crop biomass for the two forests is 268.4 t/ha (cedar) and 312.6 t/ha (holly). Standing crop biomass for the two dominant species, cedar and holly, is 181.9 and 39.6 t/ha respectively. Standing crop nutrient biomass (kg/ha) for the cedar (629 N; 55 P; 216 K; 458 Ca; 56 Mg) and holly (692 N; 62 P; 341 K; 1,139 Ca; 129 Mg) swamps are compared with other temperate hardwood and coniferous forest ecosystems.

Keywords: Standing crop biomass, standing crop nutrient biomass, swamp forest, bottomland hardwoods, New Jersey Pinelands, Atlantic white cedar, American holly, red maple, tupelo, sweetbay magnolia.

INTRODUCTION

Bottomland hardwoods (the term is inclusive of both hardwood and softwood species and encompasses as many as 70-100 species) constitute a unique and valuable forest resource occupying floodplains in the central, southern and eastern United States (Larson et al., 1981 and Huffman and Forsythe, 1981). Bottomland hardwoods occur in every state cited by Clark (1976) as occurring within the Central Hardwood Forest Region. In recent years, increasing interest in bottomland hardwood forests for both their on-site (indirect ecological) and off-site (direct harvested) values has developed (Langdon et al., 1981). Messina (1980) has commented on the increased off-site utilization of the bottomland hardwood resource and on the need for accurate estimates of nutrient concentrations, nutrient distributions and nutrient standing crops for merchantable stands.

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The present study was completed while the author was Assistant Professor of Forestry at Stockton State College, Pomona, New Jersey. The author wishes to thank Stockton State College and The Columbia Gas System for providing financial support for the study. The assistance of Kenneth Carlson, Thomas Fromm, Kenneth Gigliello and Richard Kaminski in collecting the data is gratefully appreciated. Nutrient analysis was performed in the laboratories of Drs. Lawrence Safford and James Hornbeck (U.S. Forest Service, Durham, New Hampshire). Finally, I thank Tim McDevitt for his assistance in helping with the nutrient analysis work, Renee Ciotti for typing this manuscript, and Deborah Kelly for preparing the illustrations.

These forests include the Atlantic white cedar and lowland red maple forests of the mid-Atlantic Coastal Plain. Despite the off-site value of these forests, little silvicultural research has been conducted which enhances our ability to properly manage these forests. Only a few reports have been published relating to factors (soil, water, nutrients, phytosociology) affecting growth and yield of these forests (Parrott et al., 1981; Reynolds et al., 1978; Reynolds et al., 1979; Reynolds and Parrott, 1980; Reynolds et al., 1981a and b).

At present, only a small percentage of these forests are harvested or silvically treated each year. The potential for silvicultural manipulation of mid-Atlantic bottomland forests, utilizing forest fertilization has not been evaluated. Fertilization field trials need to be initiated.

The present report expands our knowledge of bottomland forests by supplementing previous research concerning these forests. In this paper, data from standing crop nutrient biomass studies for two evergreen bottomland hardwood forests are presented. The data are compared with previously reported data for other types of hardwood forests. The present studies provide a basis for future fertilization trials, allowing for a comparison of unmanaged standing crop nutrient pools with nutrient pools for managed (fertilized) stands.

METHODS

Site Description

The location of both swamp sites within Atlantic County, New Jersey has been previously described (Reynolds et al., 1981a). The cedar swamp is on the Stockton State College campus (latitude 39° 27' N; longitude 74° 33' W). Stockton College is 24 km northwest of Atlantic City. The holly swamp is a part of the Brigantine National Wildlife Refuge (latitude 39° 28' N; longitude 74° 27' W), which is located on the coast due north of Atlantic City and 12 km east of Stockton College.

The cedar swamp is situated along the north end of Cedick Run, a stream which flows northward into a man-made cranberry bog, Lake Fred. The cedar study site varies in width from 10 to 70 m and is 190 m long. The cedar swamp is a part of a larger swamp ecosystem within the Stockton Ecological Preserve which includes a hardwood swamp located at the south end of Cedick Run (Reynolds et al., 1978). The holly swamp is located on an inlet of Great Bay and is bordered by a tidal marsh on the east and a road running through the refuge on the west. The holly study site varies in width from 10 to 110 m and is 220 m long. Both study sites are 1.0 ha in size.

Atlantic white cedar (*Chamaecyparis thyoides*) is the major tree species present in the cedar swamp in terms of stem density, frequency, basal area and biomass (Reynolds et al., 1979; Reynolds et al., 1981a). Other notable tree species growing in the cedar swamp include red maple (*Acer rubrum*), tupelo (*Nyssa sylvatica*) and sweetbay magnolia (*Magnolia virginiana*). An occasional American holly (*Ilex opaca*) sapling is encountered in the forest shrub layer. Important shrub species for the cedar swamp include pepperbush (*Clethra alnifolia*), highbush blueberry (*Vaccinium corymbosum*), mountain laurel (*Kalmia latifolia*) and sheep laurel (*Kalmia angustifolia*). Ferns are generally absent from the forest floor and the herbaceous layer is primarily characterized by various moss species.

Because of high cedar stem density, light penetrating to the forest floor is limited. Limited available light and considerable surface moisture for the forest floor probably help to sustain the lush moss growth while restricting the presence of other herbaceous species.

American holly is the major tree species present in the holly swamp in terms of stem density, frequency and basal area. Other important tree species (red maple, tupelo and sweetbay magnolia) exceed holly in standing crop biomass. Holly is the major woody plant occupant of the forest understory. Other notable tree species (Atlantic cedar, red maple and tupelo) occupy the forest overstory. A limited number of southern red oak (*Quercus falcata*), sweetgum (*Liquidambar styraciflua*), black cherry (*Prunus serotina*), sassafras (*Sassafras albidum*) and persimon (*Diospyros virginiana*) trees occur in the stand. Because of very high holly stem density, limited space exists in the forest shrub layer for the growth of other plants and light penetrating to the forest floor is greatly limited. As a consequence, only a few shrub plants are present. These include pepperbush, highbush blueberry and arrowwood (*Viburnum dentatum*). However, several *Smilax* species are present in the forest shrub layer. No ferns are present and other herbaceous plants are absent from the forest floor with the exception of poison-ivy (*Rhus radicans*) which is abundant.

Topographic, edaphic and hydrologic data for the cedar swamp have been reviewed in previous reports (Reynolds and Parrott, 1980; Parrott et al., 1981; and Reynolds et al., 1981b). Topographically, the holly swamp is positioned very nearly at mean sea level; however, its elevation has not been surveyed. Soils at the holly swamp are physically similar to those for the cedar swamp. In a recent paper (Reynolds et al., 1981a), hypotheses were advanced concerning the possible effects of the seaside location of the site on soil chemical conditions and groundwater fluctuations.

Nutrient Analysis Procedures

Leaf, branch and stem samples were collected prior to autumnal yellowing and replicated as described in Table 1. Tissue samples for the four cedar swamp species and for American holly were collected in conjunction with biomass sampling. All other tissue samples (holly swamp: red maple, tupelo, magnolia and cedar) were collected separate from biomass measurement. Stem and branch tissues were not separated into bark, sapwood and heartwood components.

All tissue samples were ashed and extracted using 0.1 N nitric acid according to the procedures of Likens and Bormann (1970). All solutions were analyzed for Ca, Mg and K using a model 306 Perkin-Elmer digital atomic absorption spectrophotometer equipped with a recorder output. Calcium and magnesium were measured in the presence of lanthanum using absorbance methods. Potassium was measured using emission techniques.

Nitrogen and phosphorus were determined by performing standard Kjeldahl extractions on each of the tissues. All samples were analyzed on a Technicon Autoanalyzer II set up to determine N and P content of each sample simultaneously.

Table 1.--Tissue samples used for nutrient analysis.

Sample	Swamp	Time of Year Collected	Number of Replicates
cedar tissues	cedar	Dec.-March	6-8
cedar tissues	holly	July	2-3
red maple tissues	cedar	Sept.-Oct.	5
red maple tissues	holly	July	2-3
tupelo tissues	cedar	June	3
tupelo tissues	holly	July	1-3
magnolia tissues	cedar	Sept.-Oct.	8-9
magnolia tissues	holly	July	2-3
holly tissues	holly	April	2-3

RESULTS

Tissue Nutrient Concentrations

Figures 1-5 show N, P, K, Ca and Mg concentrations of leaf, branch and stem tissues for the five major tree species composing the two swamp sites. Standard deviations for each of the concentrations are shown in each Figure. When individual variances are considered, cedar leaf concentrations of N, P and K are generally lower than leaf concentrations of N, P and K for the four hardwood species. However, cedar and holly leaf concentrations of P and K do not differ significantly. In several instances, N concentrations for magnolia stem or branch tissues were higher than N concentrations of stem or branch tissues for the other four species. In general, leaf concentration of Ca for cedar was significantly higher than leaf concentrations of Ca for the four hardwood species. Tupelo and holly leaf concentrations of Mg do not differ significantly. However, leaf concentration of Mg for tupelo is significantly higher than leaf concentrations of Mg for cedar, maple and magnolia. Tissue nutrient concentrations for the various tree tissues were slightly higher for the holly swamp.

Standing Crop Nutrient Biomass

Figure 6 illustrates macronutrient standing crop biomass for the two swamp sites. For the cedar swamp, total above-ground P, K and Ca biomass for cedar and maple are nearly equal. This is notable since maple standing crop biomass is 82.4 t/ha as compared with 181.9 t/ha for cedar. By contrast, N and Mg biomass for cedar exceed the biomass of these elements for maple.

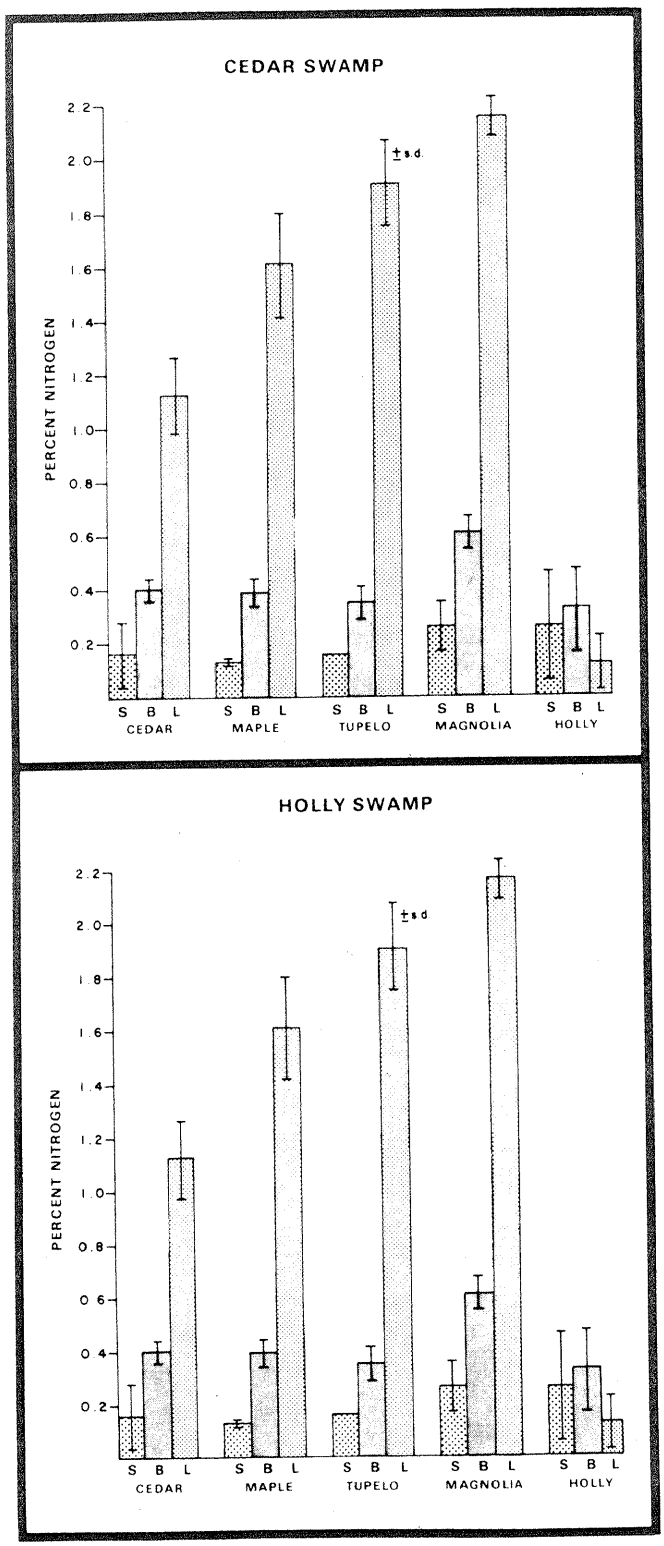

Figure 1.--Percent nitrogen concentration for stem(s), branch (B) and leaf (L) tissues of various tree species for the cedar and holly swamps.

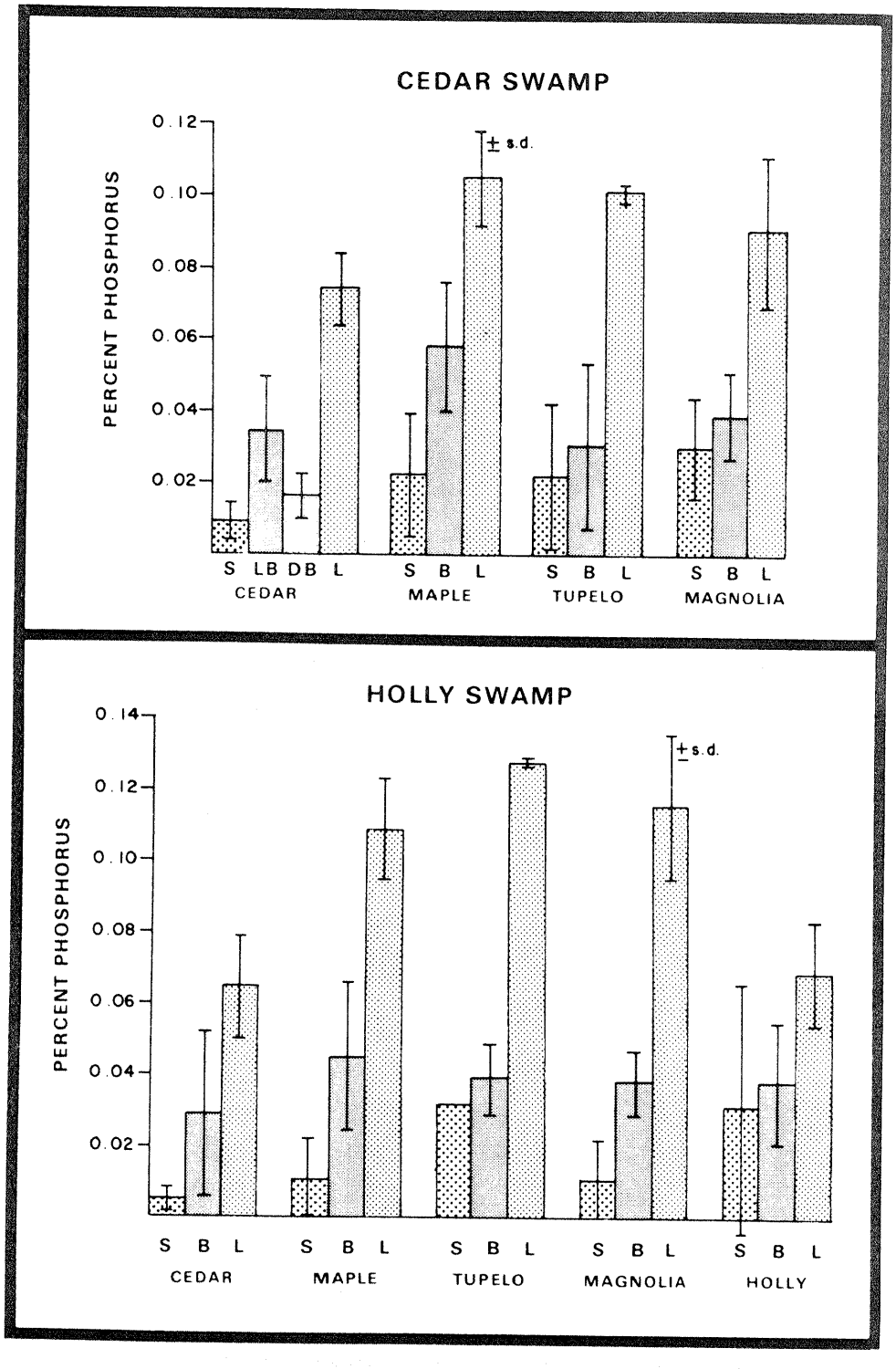

Figure 2.--Percent phorphorus concentration for stem(s), branch (B), live branch (LB), dead branch (DB) and leaf (L) tissues of various tree species for the cedar and holly swamps.

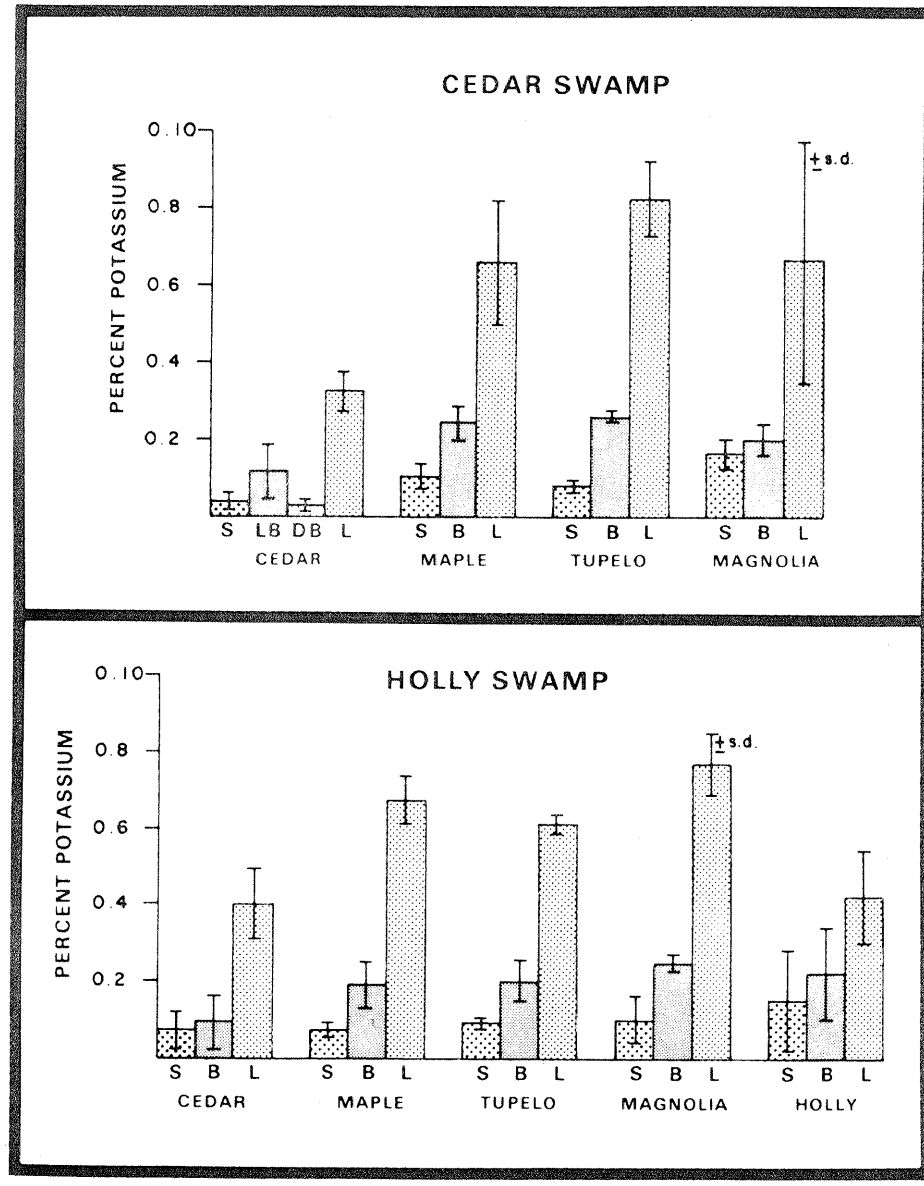

Figure 3.--Percent potassium concentration for stem(s), branch (B), live branch (LB), dead branch (DB) and leaf (L) tissues of various tree species for the cedar and holly swamps.

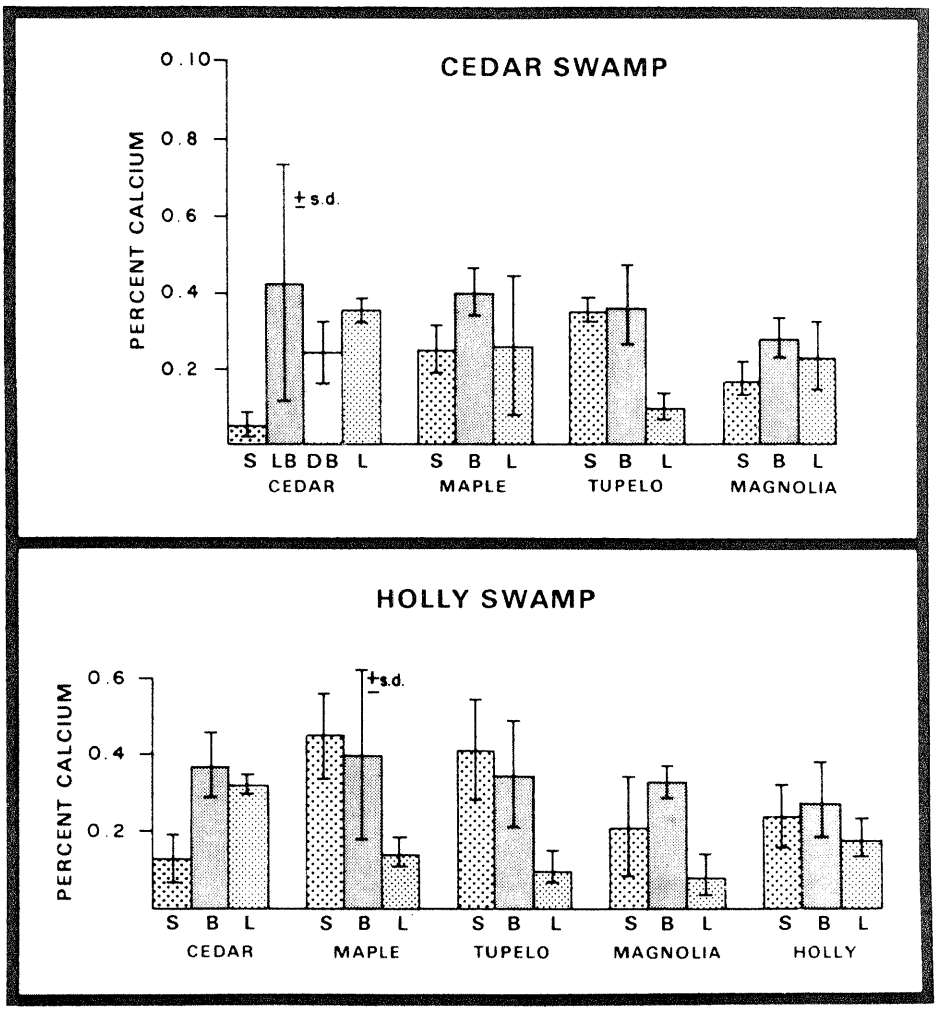

Figure 4.--Percent calcium concentration for stem(s), branch (B), live branch (LB), dead branch (DB) and leaf (L) tissues of various tree species for the cedar and holly swamps.

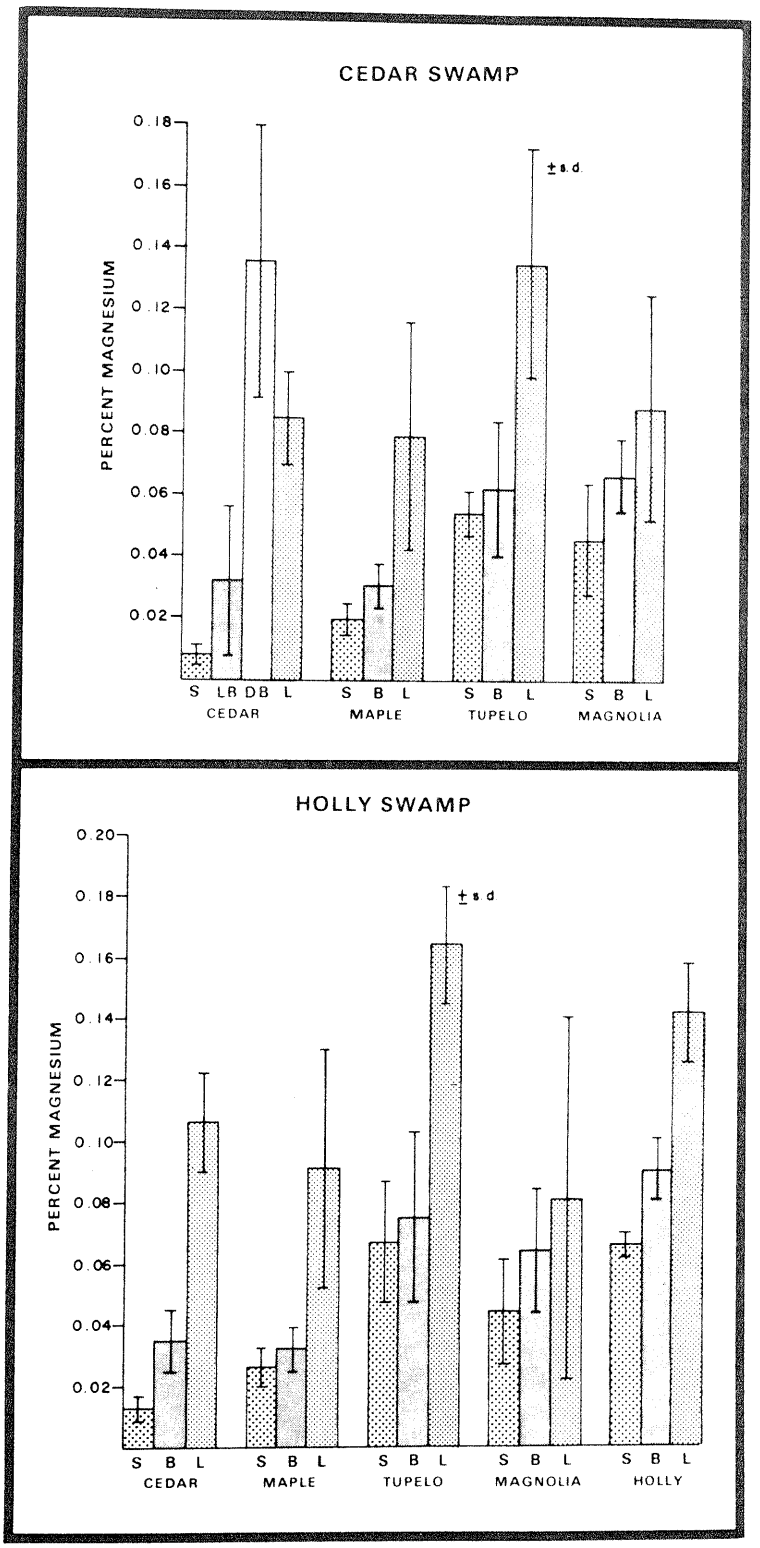

Figure 5.--Percent magnesium concentration for stem(s), branch (B), live branch (LB), dead branch (DB) and leaf (L) tissues of various tree species for the cedar and holly swamps.

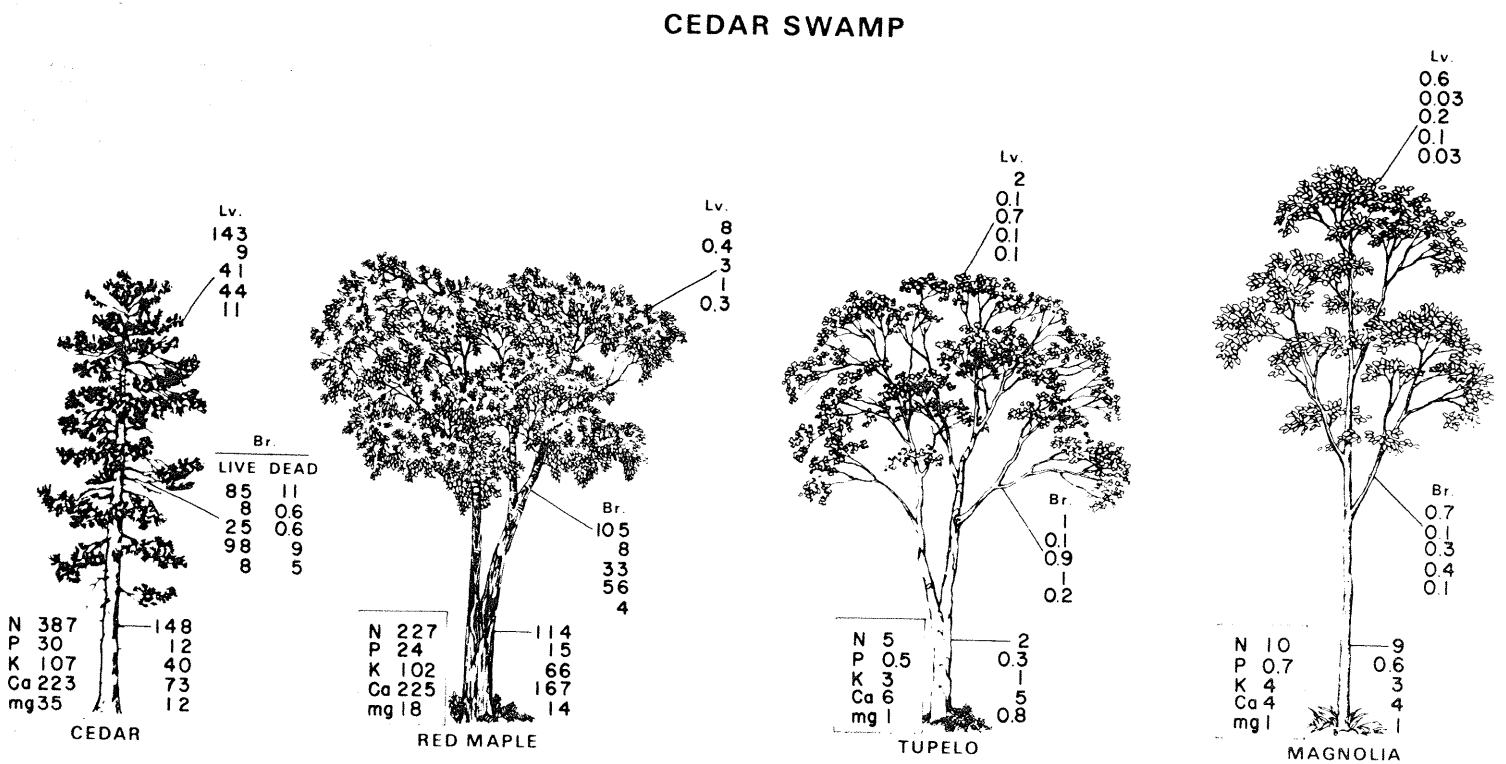

Figure 6A.--Distribution (kg/ha) of N, P, K, Ca and Mg in major tree species of the cedar forest. Values in boxes are for the total tree stand; various subtotals for leaves, branches and stems are shown in individual tree figures.

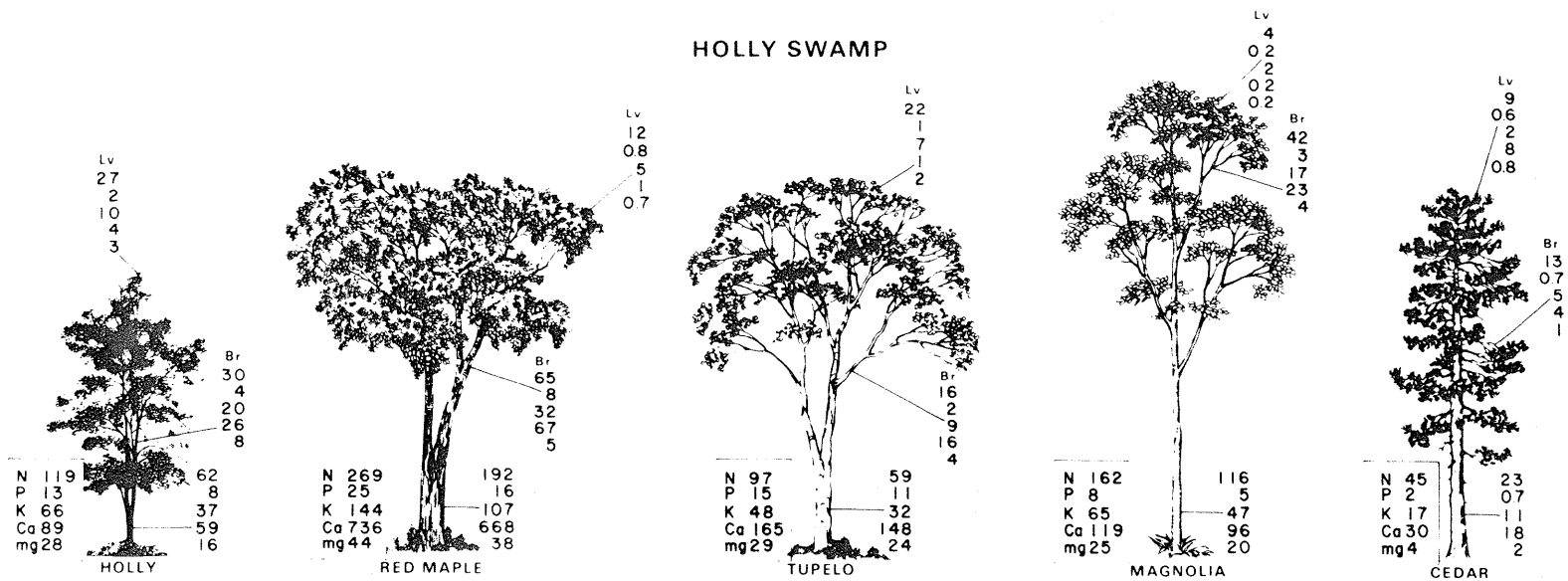

Figure 6B.--Distribution (kg/ha) of N, P, K, Ca and Mg in major tree species of the holly forest. Values in boxes are for the total tree stand; various subtotals for leaves, branches and stems are shown in individual tree figures.

For the holly swamp, standing crop nutrient biomass is greatest for maple for all five macronutrients. Above-ground standing crop biomass of maple (165.4 t/ha) is 53% of the total forest standing crop biomass. P, Ca and Mg biomass for tupelo exceed the biomass of these elements for holly. In addition, N and Ca biomass for magnolia exceed the biomass of these elements for holly. Standing crop biomass for holly, tupelo and magnolia are 35.6, 41.4 and 52.3 t/ha respectively.

DISCUSSION

Tissue Nutrient Concentrations

The present paper demonstrates that a significant difference exists between deciduous and non-deciduous species as evidenced by foliar macronutrient concentrations. Cedar leaf concentrations of N, P and K were observed to be significantly lower than leaf concentrations of these elements for maple, tupelo and magnolia. In addition, the Ca content of cedar leaves was observed to be significantly higher than leaf concentrations of Ca for the three deciduous species. Leaf concentrations of P and K for American holly, another evergreen species, did not differ significantly from foliar concentrations of these nutrients for cedar. These results confirm the findings of previous researchers that non-deciduous forests are more frugal in their use of macronutrients than deciduous forests (Marion, 1979).

Several researchers have shown that nutrient concentrations in hardwoods are often higher than in conifers (Rennie, 1955; Ralston and Prince, 1963; and Voigt, 1968). In addition, it has been noted that nutrient requirements of oak ecosystems are greater than those of other temperate forest ecosystems (i.e., other types of deciduous broadleaf trees and temperate coniferous forest) and may approach those of agricultural ecosystems (Duvigneaud and Denaeyer-DeSmet, 1973 and Johnson and Risser, 1974).

Holly and cedar foliar macronutrient concentrations presented here are somewhat lower than those (1.43% N; 0.98% P; 0.49% K; 1.35% Ca; and 0.3% Mg) reported for cypress (*Taxodium distichum*) by Schlesinger (1978), but are similar to those (1.26% N; 0.1% P; 0.49% K; 0.3% Ca; and 0.06% Mg) reported by Likens and Bormann (1970) for red spruce (*Picea rubens*). They differ from those (0.37% N; 0.01% P; 2.7% Ca; and 0.1% Mg) reported by Reiners and Reiners (1970) for northern white cedar (*Thuja occidentalis*) foliage.

For the above evergreen species (three non-deciduous and one deciduous), N leaf concentration exceeds that of Ca for all species except northern cedar. Marion (1979) has stated that the N/Ca ratio "is probably, to a large extent, site specific." There are many examples of forest types where N exceeds Ca, or where Ca exceeds N, for boreal, temperate and tropical ecosystems. Which nutrient is more abundant is frequently correlated with type of soil parent material and nutrient turnover rates.

High foliar concentrations of Ca for Atlantic cedar as compared with other deciduous species (maple, tupelo and magnolia) is a notable deviation from the observation that macronutrient concentrations in conifers are generally lower than in hardwoods. Why Atlantic cedar and holly (an evergreen hardwood) accumulate Ca in their leaves merits further study. A number of wildlife biologists have noted that white-tail deer prefer to browse on cedar leaves because of their

high nutritional value and Ca content (Gould and Brown, 1961; Little et al., 1958; and Lund, 1972). Lund states that the nutritional value of all evergreens for food is not equal.

Low foliar macronutrient concentrations for cedar and holly are probably correlated with low nutrient turnover rates for the forest floors of the two swamps. High groundwater conditions for both swamps result in anaerobic conditions and retard decomposition and nutrient turnover. Since greater surface moisture exists in the cedar swamp, one should expect slightly lower macronutrient tissue concentrations for this swamp. Macronutrient concentrations for trees growing in the holly swamp are, in fact, slightly higher than those for the cedar swamp. The similarity of macronutrient concentrations for Atlantic cedar and holly with those for other evergreen species growing on wet sites (cypress, red spruce and northern cedar) suggests that low nutrient turnover rates are a major cause of low macronutrient concentrations in the tissues of lowland coniferous or other non-deciduous tree species. As contrasted with other broadleaf deciduous species, showing a preference for upland dry sites, many conifers and other evergreen species grow in lowland, wet habitats because of their ability to tolerate high moisture conditions and limited available nutrients.

Reiners and Reiners (1970) have confirmed that nutrient turnover rates for the Minnesota northern cedar forest floor are low. Additionally, Krause et al. (1978) state that boreal forests vary in their nutrient contents and that their fertility is greatly correlated with how wet or dry the various sites are. Nutrient rich (drier) sites have an abundance of herbaceous vegetation, intermediate sites have an ericaceous ground cover, and poor (wet) sites show a ground cover of spagnum mosses. Krause et al. (1978) reported on jack pine (*Pinus banksiana*) for dry, sandy sites; balsam fir (*Abies balsamea*) and white spruce (*Picea glauca*) for imperfectly drained soils; and black spruce (*Picea mariana*) and tamarack (*Larix laricina*) for poorly drained, organic sites.

Like their non-deciduous counterparts, deciduous species growing on low, wet areas have lower foliar macronutrient concentrations than deciduous broadleaf species growing on upland dry sites. Recently, Messina (1980) reported on foliage macronutrient contents for three bottomland hardwood species: green ash (*Fraxinus pennsylvanica* Marsh.), sweetgum and red maple. Compared with the foliar nutrient contents for maple, tupelo and magnolia considered in this paper, nutrient concentrations presented by Messina were comparable for N and K. P, Ca and Mg concentrations reported by Messina were lower than those for tupelo, sweetbay magnolia and red maple. By contrast, Jones et al. (1980) reported on foliar concentrations of K, Ca and Mg for nine upland central hardwood species. Calcium concentrations reported by Jones et al. (1980) were much higher than for the three deciduous species considered in this paper. Concentrations of K and Mg reported by Jones et al. (1980) were slightly higher for several species.

In the present study, various tissues to be used for macronutrient analysis were collected at differing times of the year. Duvigneaud and Denaeyer-DeSmet (1973) have commented on seasonal variations in foliar macronutrient concentrations. They point out that young leaves are rich in N, P and K and poor in Ca. While leaves are maturing, N, P and K decline until the leaves become mature, whereupon these concentrations remain constant. During autumnal yellowing, N, P and K decline and Ca increases. Throughout leaf development, Mg concentration remains constant. In this study, all tissues for deciduous species were collected prior to autumnal yellowing. The similarity in foliar macronutrient concentrations

for maple and magnolia for the two swamps confirms that macronutrients were in a steady state at the time of collection. If macronutrients were being exported from or accumulated in the leaves at the time of collection, one would expect to see significant variability in macronutrient concentrations for leaves collected in September/October as compared with those collected in July.

Standing Crop Nutrient Biomass

Table 2 shows that macronutrient biomass for the cedar and holly swamps is similar to that observed by previous researchers for other types of non-deciduous forests including *T. distichum*, *C. obtusa*, *P. banksiana*, *A. balsamea*, *P. glauca*, *P. mariana* and *L. laricina* (Harada et al., 1969; Krause et al., 1978; and Schlesinger, 1978). N, P and K biomass for the cedar and holly swamps is nearly equal to median biomass of these elements for temperate coniferous forests (Marion, 1979). However, N, P and K biomass for both swamps is lower than median biomass of these elements for temperate broadleaf forests. These results confirm that non-deciduous forests generally contain less nutrients than deciduous forests.

The three New Jersey swamps cited in Table 2 differ in their percentage of deciduous composition. This variability in deciduous standing crop biomass (100% hardwood, 83% holly and 32% cedar) accounts for differing amounts of N, P and K biomass for the three swamp forests. Biomass of the three nutrients for the holly swamp is intermediate in comparison with the other two swamps. By comparison, N, P and K biomass is highest for the hardwood swamp, which is composed of all deciduous species, and lowest for the cedar swamp, which has the greatest percentage of non-deciduous standing crop biomass (68%, 181.9 t/ha).

Deciduous trees in the holly swamp (259.1 t/ha) account for a greater percentage of the standing crop biomass (83%) than do deciduous trees (86.5 t/ha) in the cedar swamp (32%). This difference accounts for quantitative differences in Ca and Mg biomass observed for the two swamps. Ca biomass for the cedar swamp is lower than median Ca biomass for coniferous forests (Table 2). Although median Mg biomass for coniferous forests was not reported by Marion (1979), Mg biomass for the cedar swamp is much lower than median Mg biomass reported by Marion (1979) for broadleaf forests. By contrast, Ca biomass for the holly swamp is nearly equal to median Ca biomass for broadleaf forests and Mg biomass is slightly higher than median Mg biomass reported for broadleaf forests.

Compared with Ca and Mg biomass for a New Jersey hardwood swamp (Reynolds et al., 1978), biomass of these elements is somewhat higher for the holly swamp. Although deciduous standing crop biomass for the hardwood swamp (100% deciduous; 316.1 t/ha) is slightly higher than that for the holly swamp, the seaside location of the latter probably adequately accounts for the slightly higher Ca and Mg biomass.

Data on Ca biomass for the three swamps may be compared with the findings of Rennie (1955). As related by Duvigneaud and Denaeyer-DeSmet (1973), Rennie (1955) compared standing crop nutrient biomass of Ca for deciduous, non-pine coniferous and coniferous (pine) forests. Rennie concluded that deciduous forests contain approximately four times as much Ca as pine forests and twice as much Ca as non-pine coniferous forests. If the higher Ca biomass for the holly swamp is disregarded, due to the seaside location of the stand, then Ca biomass for the hardwood swamp is nearly twice that for the cedar swamp, a finding in agreement with Rennie (1955).

Table 2

Comparative standing crop nutrient biomass (kg/ha) for various temperate deciduous and non-deciduous forest ecosystems.

Forest Type	Location	Biomass	N	P	K	Ca	Mg	Reference
boreal	Canada	--	80-612	10-52	82-245	54-413	--	Krause et al., 1978
coniferous (range) (median value)	Temperate Zone	274,000-604,000 (291,000)	375-1,327 (664)	-- (47)	-- (263)	-- (717)	-- --	Marion, 1979
broadleaf (range) (median value)	Temperate Zone	147,000-504,000 (338,000)	406-1,608 (1,085)	36-99 (73)	286-531 (463)	644-1,334 (1,142)	93-123 (115)	Marion, 1979
hardwood swamp (red maple-tupelo-magnolia)	New Jersey	316,104	815	86	383	848	76	Reynolds et al., 1978
American holly swamp (*Ilex opaca* only)	New Jersey	312,611 (35,655)	692 (119)	62 (13)	341 (66)	1,139 (89)	129 (28)	this paper
Atlantic white cedar swamp (*Chamaecyparis thyoides* only)	New Jersey	268,423 (181,927)	639 (387)	55 (30)	271 (107)	458 (223)	56 (35)	this paper
Chamaecyparis obtusa	Japan	143,000	391	44	191	619	188	Harada et al., 1969
cypress swamp	Georgia	300,560	967	44	212	646	108	Schlesinger, 1978

Macronutrient biomass for the New Jersey hardwood swamp is slightly below average when compared with median macronutrient biomass for other broadleaf forests (Marion, 1979). Broadleaf forests appear to differ in their macronutrient biomass depending upon whether they grow on upland, dry sites or on lowland, wet sites. Broadleaf forests growing on upland sites generally have higher macronutrient biomass due to greater forest floor nutrient turnover rates, whereas those growing on lowland sites have lower macronutrient biomass due to lower nutrient turnover rates. Low macronutrient biomass for the New Jersey hardwood swamp is thought to result from the availability of fewer nutrients for plant uptake and assimilation.

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