

Decline of Second-Growth Douglas-fir in Relation to Great Blue Heron Nesting

Abstract

The effects that great blue herons (*Ardea herodias*) have upon nesting trees, Douglas-fir (*Pseudotsuga menziesii*), were explored in western Washington. An explanation for the decline and death of nesting trees following use by herons is offered. Excrement deposited on the soil beneath nests was analyzed, and found to contain nutrients in amounts beneficial to Douglas-fir. Although soil pH decreased following the onset of nesting, this decrease was not sufficient to adversely change soil nutrient availability. However, heron excrement on needles beneath the nest probably acted as a physical barrier to photosynthetic and to transpirational processes. It was also caustic to needle tissues and resulted in abnormal needle loss. This needle loss was likely the precursor to tree decline.

Introduction

In the Pacific Northwest, great blue herons (*Ardea herodias*) maintain large nesting colonies in the upper branches of Douglas-fir (*Pseudotsuga menziesii*). When walking through an active heron rookery in spring, one is overwhelmed by the smell of excrement and rotting heron food (fish, shellfish and frogs) which cover the forest floor. Those trees that support nests have lost most of their foliage; they appear diseased and near death. The areas directly beneath nesting trees are void of plant growth, in contrast to the lush understory that surrounds the rookery. The association between the presence of heron excrement and the deterioration of nesting trees and their shrub understory, suggests that excrement has caused the observed changes. Dolesh (1984) suggested this type of deterioration was caused by detrimental changes in soil conditions resulting from heron excrement deposits beneath the nesting trees. The objective of this study was to develop a basis for understanding nesting tree decline using (1) a description of the morphological changes that nesting trees undergo, (2) a chemical examination of heron excrement, and (3) an analysis of soil pH beneath nesting trees.

Study Area

This study was conducted on the Washington State Monroe Management Tract located approximately 3 km southeast of the town of Monroe, Washington. An active rookery was the collection site for heron excrement and soil samples, while trees used for crown reconstruction were

obtained from within and directly adjacent to a rookery that had been abandoned since 1974.

The stand in which the inhabited rookery was located, was composed of a 60-year-old Douglas-fir and western hemlock (*Tsuga heterophylla*) overstory with sword fern (*Polystichum munitum*) in the understory. It is a relatively flat site (sloping 0-5 percent toward the southeast) at about 180 m in elevation. The stand in which the abandoned rookery was located, was composed of a 100-year-old Douglas-fir and western hemlock overstory along the periphery, with young red alder (*Alnus rubra*) and bigleaf maple (*Acer macrophyllum*) filling in the gaps in the canopy in the center of the rookery. Salmonberry (*Rubus spectabilis*), vine maple (*Acer circinatum*) and sword fern were the dominant understory plants. The site slopes to the northeast (10-20 percent) and is at approximately 230 m in elevation.

Methods

To characterize tree growth responses produced in the presence and absence of nesting, breast height increment cores were removed from trees within and directly adjacent to the abandoned rookery site. From these characterizations, two Douglas-fir, each representing typical growth response patterns expressed in the absence of and following nesting, respectively, were felled for analysis of crown development.

An estimation of the time at which nesting began was necessary to relate nesting activity to periods of tree decline. In order to complete the morphological aspects of this study, the following assumptions were made: (1) Since relatively

large branches are needed to support a heron nest, the second node from the apex bud was assumed to be the highest position or the earliest time that a nest could have been built, and (2) Assuming that herons are responsible for causing malformations typically found in association with heron nests, the year preceding the death of the apical shoot and initiation of compression wood on the lower side of the upturning branch could be considered the latest possible construction time. In this way nest initiation was bracketed to within a few years.

The functional crowns of the sample trees were reconstructed from 1935 until 1980. This was done by counting the number of rings contained within all branches formed after 1934 in relation to the number of annual rings contained within the main stem directly above the point of branch insertion. When a branch becomes non-functional, it fails to produce annual rings. The difference between the stem ring count and the branch ring count is the number of years that the branch has been in a nonfunctional state. Functional branches are those branches, generally located in the upper crown, that contribute carbohydrates to the tree stem (Underwood 1967). Changes in this portion of the crown were assumed to represent relevant changes in terms of tree health.

Heron excrement was gathered using three trays (0.6 m x 0.6 m) placed beneath an inhabited tree. The area below the projected crown of the tree was stratified into three horizontal concentric deposition zones, each approximately 0.85 m in width. Each tray was constructed of a corrugated fiberglass base with 2.5-cm fiberglass splash borders, sealed by silicon-based sealer and reinforced by a wooden frame. Inserted in one side of each tray was a garden hose segment that fed into a plastic bag to accommodate rain water. Trays were installed prior to nesting activity in 1982. The contents of each tray was collected and combined at the end of the 1982 nesting season. The excrement was analyzed for nitrogen, phosphorus, potassium, sulfur, calcium, magnesium and sodium content using standard EPA methods (EPA 1979). These values were then expanded from parts per million to grams per square meter.

To assess whether prolonged exposure to heron excrement had altered soil acidity, pH was measured at six depths along five soil profiles

beneath nesting trees and five soil profiles beneath trees without nests. Soil pit location was determined randomly where soil was collected from 0, 10, 20, 30, 40 and 50 cm beneath the soil surface. Soil pH was measured in a 1:1 solution using the glass-electrode method (McLean 1982). Analysis of variance was used to evaluate differences in soil pH associated with nesting.

Results

Functional tree crown reconstructions revealed those changes that were associated with nesting. In contrast to the unaffected tree which supported a uniform crown during the 45-year interval, the nesting tree exhibited two periods of crown decline (Fig. 1).

It was estimated that nests were constructed in 1934 and 1958. Within a few years following nest establishment, branch senescence in the lower crown proceeded at an abnormally high rate. Eventually nest level became the upper limit of branch senescence. The tree continued to grow and developed a healthy crown above nest level. When a second nest was established higher in the crown, this nest became the new upper limit of branch senescence (Fig. 1).

Nutrient analysis of the heron excrement revealed that nitrogen and phosphorus were the primary nutrient constituents. Excrement pH was neutral (Table 1).

TABLE 1. Annual nutrient additions and pH of the excrement deposited in trays.

| Nutrient | Amount ($\text{g m}^{-2}\text{yr}^{-1}$) |
|------------|--------------------------------------------|
| Nitrogen | 47.4 |
| Phosphorus | 7.1 |
| Sulfur | 2.7 |
| Calcium | 2.5 |
| Magnesium | 0.4 |
| Potassium | 0.4 |
| Sodium | 0.2 |
| pH | 7.0 |

Soil beneath nesting trees was statistically more acidic than the soil beneath control trees ($P < 0.05$). Soil pH values ranged from slightly above 3.4 to 5.0 (Fig. 2).

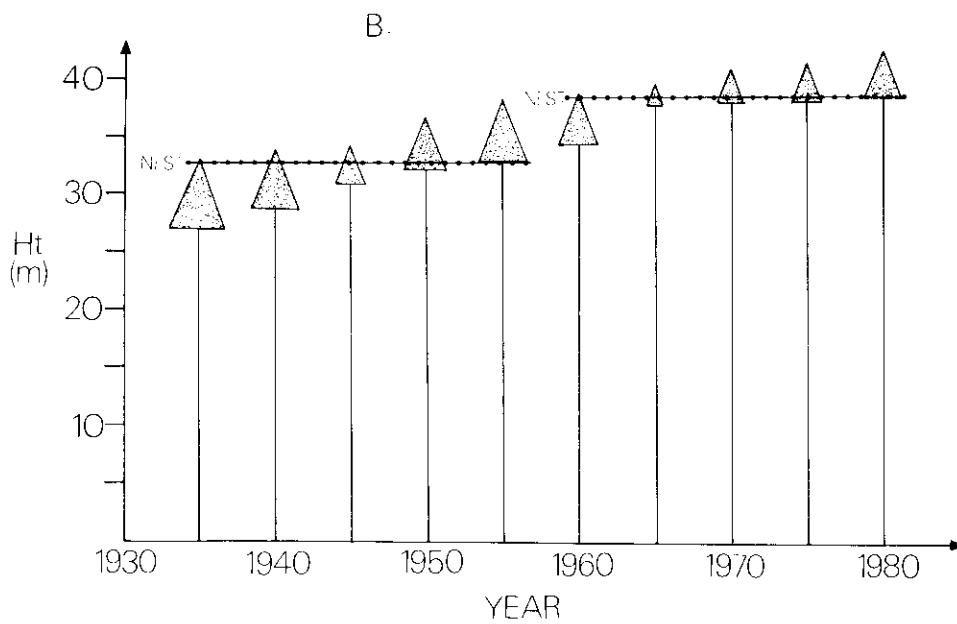
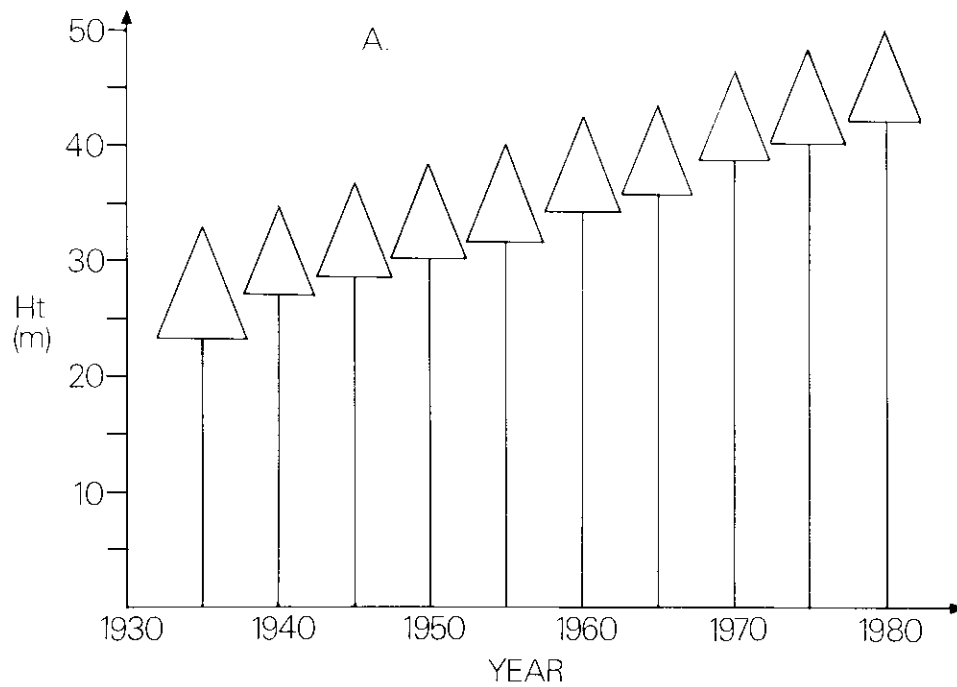


Figure 1. Patterns of crown development for the control tree (A) and the nesting tree (B) at 5-year intervals. Note the relationship between nest height (which remains constant) and the eventual upper limit of branch loss on the nesting tree.

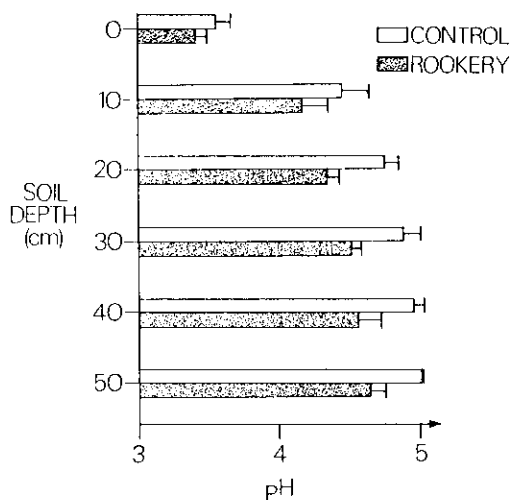


Figure 2. Mean soil pH profiles from beneath nesting trees and from beneath the control trees. The small bars indicate two standard errors of the mean.

Discussion

Tree crown reconstructions showed that within a few years following the establishment of heron nests, branches below each nest died in an ascending direction. The nesting tree exhibited accelerated lower branch senescence following the construction of two heron nests established circa 1934 and 1958. Only those branches in the lower crown were affected; nest level became the upper limit of branch senescence.

Abnormal foliage loss in the lower crown could have been caused by the herons physically debranching the trees while in the process of building their nests. But since herons are relatively awkward when it comes to hovering, it seems unlikely that they would have the opportunity to remove twigs in the lower crown—especially at the branch tips.

Considering the ascending pattern and upper limit of branch senescence, low foliage tolerance to heron excrement is a logical cause for tree decline. Accumulation of heron excrement on foliage would present a physical barrier

to essential physiological processes such as photosynthesis, and could also cause chemical burning.

As the grey excrement coats needle surfaces, the amount of sunlight reaching chloroplasts would substantially decrease. The coating would also clog stomata, reducing both carbon dioxide uptake, thus affecting photosynthesis, and water loss, thus affecting transpirational cooling. Impaired photosynthesis resulting from lower effective light levels and restricted carbon dioxide intake, combined with the likelihood of excessive heating, would act to reduce foliage efficiency and longevity.

Another way in which the excrement could affect the foliage is through chemical burning. When concentrated nutrients are applied directly to foliage in aqueous form, osmotic burning has been reported to result (Miller and Young 1976). Concentrations of total nitrogen alone in the heron excrement were within the range of values that have been shown to be extremely detrimental to the foliage of Douglas-fir (Miller and Wert 1979).

The pattern of needle loss sustained by nesting trees shows that needle damage occurs over several years, for the degree to which needles were damaged increased as the time of exposure increased. Branches beneath recently established nests support chlorotic one-year- and two-year-old needles and a few three-year-old needles speckled with necrotic spots. Unaffected trees in the area and the branches above nest level on nesting trees support six age classes of foliage. This evidence suggests these trees have the capacity to tolerate exposure for at least three years. Foliage abscission and the reduction in foliage quality would eventually cause branch death and lead to overall tree decline.

Heron excrement containing concentrated nutrients reaches the soil surface annually. Those nutrients which were contained within these deposits added during a nesting season, were present in concentrations that have been shown to be beneficial to the growth of Douglas-fir (Steinbrenner 1981, Gessell *et al.* 1979, Rustagi and Gupta 1979, B. C. For. Serv. 1971). Nutrients supplied by the herons would supplement existing soil nutrients and should represent a positive influence on tree growth. It is possible that an accumulation of nutrients in the soil or chemicals

not examined in the excrement caused the demise of nesting trees. This possibility, however, is unlikely since only the foliage beneath the nest level was affected. If the foliage loss had been caused by a soil-related factor, such as nutrient toxicity, symptoms of deterioration would be evident throughout the crowns of nesting trees.

The addition of nutrients to soil, particularly nitrogen, has been reported to elicit changes in soil pH (Otchere-Boateng 1979). Changes in soil pH are important since they can drastically affect plant nutrient availability and toxicity. For example, a lowering of pH may make aluminum toxic to roots (Heilman 1981). Extended nest use was associated with a decrease in soil pH beneath nesting trees. The decrease in soil pH however, was still within the range of values that occur in undisturbed Douglas-fir forests (Heilman 1981, Franklin 1970). A lowering of soil pH to these levels is probably not biologically significant. Symptoms of biologically significant changes in soil pH would have been evident throughout the crown and not confined solely to the lower crown.

Conclusions

Great blue heron nesting in Douglas-fir was associated with significant damage to host trees.

Literature Cited

- B. C. Forest Service. 1976. Five-year growth response of Douglas-fir to fertilization in the Sayward Forest, Vancouver Island. Res. Note No. 77. Victoria, B.C.
- Dolesh, R. J. 1984. Lord of the shallows: the great blue heron. *Nat. Geogr.* 165(4):540-554.
- EPA. 1979. Methods for chemical analysis of water and wastes. EPA-600/4-79-020.
- Franklin, W. T. 1971. Mineralogical and chemical characteristics of western andic soils. Oregon State University, Corvallis. Dissertation.
- Heilman, P. E. 1981. Minerals, chemical properties, and fertility of forest soils of the Douglas-fir Region. Wash. State Univ. Coop. Ext. Serv., Pullman.
- Gessel, S. P., E. C. Steinbrenner, and R. E. Miller. 1979. Response of northwest forests to elements other than nitrogen. *Inst. For. Res.* 40:140-149.
- McLean, E. O. 1982. Soil and lime requirement. *In* A. L. Page, (Ed.) *Methods of soil analysis-Chemical and microbiological properties.* 2:199-209.
- Miller, R. E., and D. C. Young. 1976. Forest fertilization: Foliar application of solutions proves efficient. *Fert. Solutions* 20(2):36-60.
- Miller, R. E., and S. Wert. 1979. Effects of soil and foliar applications of nitrogen fertilizers on a 20-year-old Douglas-fir stand. USDA—For. Serv., Pac. Northw. For. and Rng. Exp. Sta., Res. Note PNW-329, Portland, Oregon.
- Otchere-Boateng, J. K. 1979. Reaction of nitrogen fertilizers in forest soils. *Inst. For. Res.* 40:37-47.
- Rustagi, K., and I. Gupta. 1979. An evaluation response of Douglas-fir stands to multiple nutrient fertilization application. *Interim. Rep. Reg. Fert. Proj.*
- Steinbrenner, E. C. 1981. Growth response of young Douglas-fir to repeated application of nitrogen and phosphorus. *Soil Sci. Soc. Amer. J.* 45:953-955.
- Underwood, R. J. 1967. A study of the effects of pruning on the longitudinal distribution of radial growth in Douglas-fir. University of Washington, Seattle. Thesis.

Received 23 October 1985

Accepted for publication 4 March 1986

Since this damage was confined to foliage beneath nests, low foliage tolerance to excrement would appear to be the destructive mechanism involved. Nutrient additions to the soil beneath nesting trees would have probably acted as a positive rather than a negative influence on tree growth.

In a broad sense, damage to nesting trees by herons represents an interesting yet localized problem. In terms of forest dynamics, heron nesting would act to enhance plant diversity through disturbance, where seral trees and shrubs are given space to invade rookery sites. Nesting tree loss would represent a serious problem if availability of suitable great blue heron habitat ever becomes limited.

Acknowledgments

Don Theoe and Lloyd Emery of the Washington State Department of Natural Resources deserve credit for their interest and enthusiasm during the completion of this project. Efforts made by Jacquelyn Erickson and Ray Lee in the field were greatly appreciated. I would also like to thank two anonymous reviewers for their thoughtful suggestions.