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Influence of Flooding Duration on the Biomass Growth of Alder and Willow

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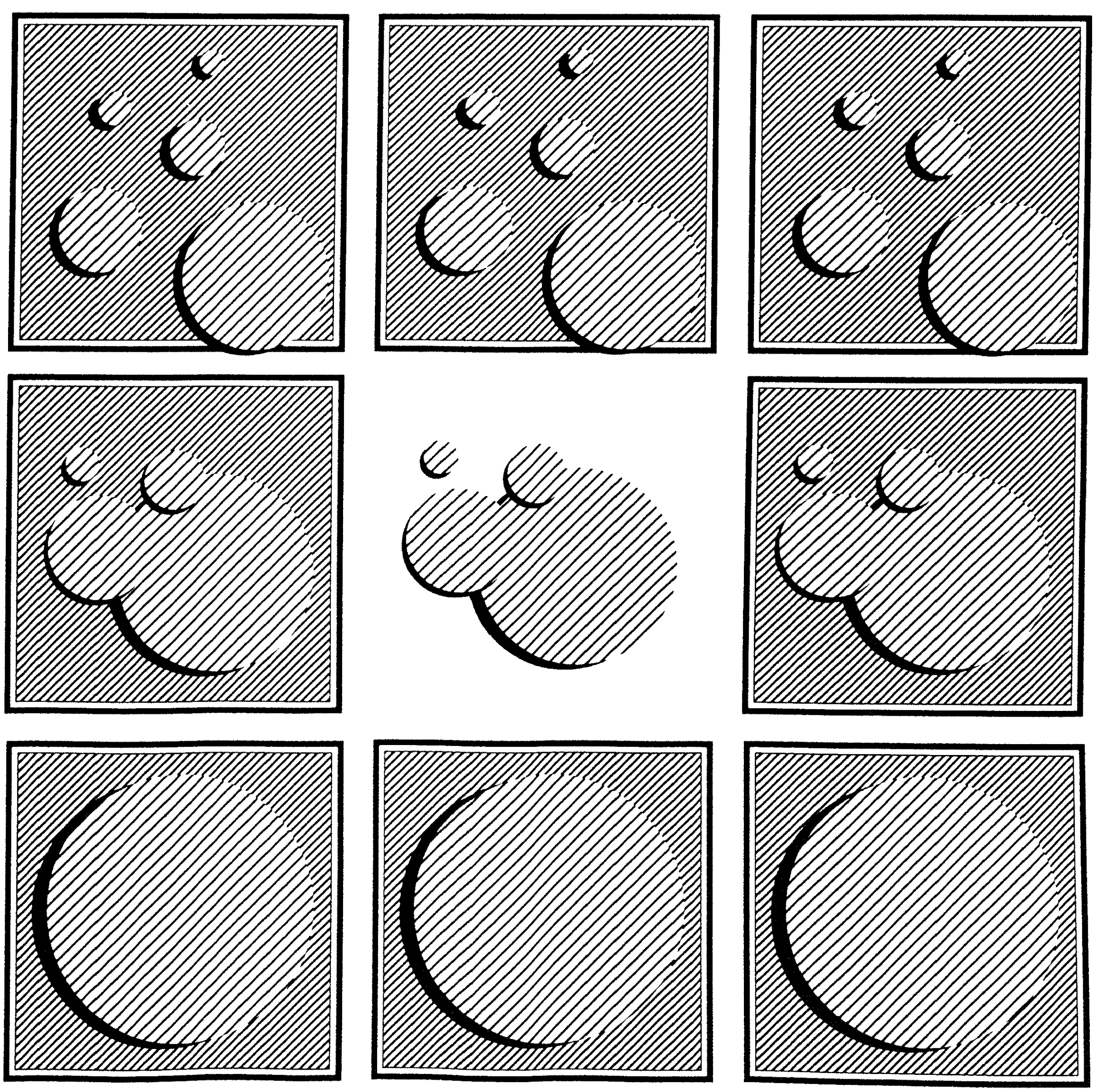

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Simple second-order (quadratic) polynomials were used to model the relationship between 3-year biomass increase (net ovendry weight in grams) and flooding duration (days) for four combinations of shrub type (alder, willow) and soil type (fine-sand, clay-loam).

KEY WORDS: *Alnus rugosa*, *Salix*, inundation, flooding, growth, biomass.

North Central Forest Experiment Station
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Influence Of Flooding Duration On The Biomass Growth Of Alder And Willow

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INTRODUCTION

Speckled alder (*Alnus rugosa* (Du Roi) Spreng.) and willow (*Salix* L.) are dominant species in wetland communities throughout North America (Parker and Schneider 1974, White 1965). They are especially important in human-made impoundments in the North Central States that have been established to increase the amount of deep marsh and other wetland habitats for wildlife (Mathisen 1970, 1985). Managers have traditionally manipulated water levels in these impoundments through flooding and drawdowns in an attempt to duplicate natural water fluctuations, thus providing suitable growing conditions for shrubs and other wetland species (Fredrickson 1985; Knighton 1981, 1985).

Alder and willow are generally adapted to periodic flooding, principally during spring runoff. Willow has the ability to produce adventitious roots in response to flooding (Krasny *et al.* 1988), while alder often persists through stump sprouting. Alder does not tolerate silt deposition as well as willow (Walker *et al.* 1986), however, and long periods of flooding will usually kill both plants (Gill 1970).

An earlier study on the growth and survival of speckled alder and willows for two growing seasons under continuous flooding at varying water depths showed growth to be at least four times greater when water levels were below the shrub root crown than when they were 15 cm above the crown (Knighton 1981). Mortality of alder and willow increased with flooding depth, and mortality was greater for alder than for willows (Knighton 1981). This pointed to a need for more basic information on the response of alder and willow to water level changes, so that impoundment managers can plan water fluctuations to better meet the needs of these important species. The objective of the current study was to determine the influence of partial flooding over several growing seasons on the growth (biomass) of alder and willow.

Lewis F. Ohmann is a Principal Ecologist with the North Central Forest Experiment Station, Grand Rapids, MN; **M. Dean Knighton** is a Watershed Specialist with the USDA Forest Service, Washington, DC; and **Ronald McRoberts** is a Mathematical Statistician, with the North Central Forest Experiment Station, St. Paul, MN.

METHODS

Rooted stems of speckled alder and willow were collected from three wildlife impoundments in northern Minnesota and were grown in tanks for three growing seasons under five water regimes. Shrub response was measured by net biomass increase over the 3 years of treatment. Water chemistry and temperature were routinely monitored and maintained at levels comparable to those in Bear Brook Impoundment, the water source. Volunteer competing vegetation was permitted to grow without interference to simulate field conditions.

Six galvanized stock-watering tanks (3.0 m long by 90 cm wide by 60 cm deep) were buried to within 5 cm of their tops within a fenced enclosure near the Forestry Sciences Laboratory, Grand Rapids, Minnesota (approximately 47° 32'N, 93°28'W). Five smaller tanks (60 cm long by 45 cm wide by 40 cm deep) fabricated from 16-gauge galvanized sheet metal were inserted into each stock tank. Holes 6.4 mm in diameter were drilled into the sides (on 5-cm centers) and bottom (on 10-cm centers) of each smaller tank to permit ready movement of water. All metal surfaces were coated with Sherwin-Williams Primer Green (Catalog No. P60 G2) mixed with Catalyst Reducer (Catalog No. R7 K44), followed by one coat of Sherwin-Williams C + M enamel[1]. This provided a stabilized chlorinated rubber finish recommended by the manufacturer for surfaces

[1] *Mention of trade names does not constitute endorsement of products by the USDA Forest Service.*

exposed to excessive moisture. The coating was intended to prevent zinc toxicity that might develop from the galvanized metal.

In May 1979 the smaller tanks were filled with either Swatara fine-sand from Ketchum Impoundment or Beltrami clay-loam from Beaver Lodge Impoundment. All five smaller tanks in an individual stock tank were filled with one soil in a manner that reconstructed the natural horizons. Each of the soils was randomly assigned to three of the six stock tanks. A 200-liter drum adjacent to each stock tank was used for a reserve supply of water. The drum was connected to the stock tank through a float-valve that maintained a constant water level in the stock tank.

The stock tanks were filled with water from Bear Brook Impoundment. The chemical composition of the water in this impoundment was known from a previous study (Knighton 1981). Water conductivity, pH, and total phosphorus concentrations were monitored in the stock tanks at 2- to 3-week intervals through each growing season. When the chemistry changed substantially from values measured concurrently in the source impoundment, water in the tanks was exchanged for fresh water from the impoundment. Water was added several times each year.

Water temperature and dissolved oxygen (DO) concentration were also measured at 2- to 3-week intervals in the stock tanks. DO was controlled by aerating twice each week for 4 hours using a water pump, garden hose, and nozzle to circulate water through the nozzle and back into the tank under pressure. This procedure saturated the water with oxygen in less than 3 hours.

Willow transplants were collected in April 1979 from the seasonally flooded edge of three wildlife impoundments to ensure an assortment of individuals of *S. bebbiana*, *S. discolor*, *S. interior*, and *S. rigida*; they could not be readily identified at the time of collection. Although willow stems were identified to species after leafing out, data were analyzed at the generic level. All alder stems were collected at the seasonally flooded edge of Bear Brook Impoundment in April 1979. For both shrubs, the roots were usually less than 15 cm deep and the plants were 1 to 1.5 m tall. The transplants were kept in plastic bags at 2 to 4°C until they were planted in the smaller tanks. Prior to planting, stems were pruned to 50-60 cm in height, weighed, and tagged. Pruning was done to give more uniform initial weights, to reduce initial leaf area as an aid in establishment, and to encourage branching.

Four shrub stems, one from each of the three willow sites and one from the alder site, were randomly assigned and planted in the corners of each smaller tank. To allow the transplants to become established, all smaller tanks were held at a water level 15 cm below the shrub root crown for the first growing season. All transplants leafed out and appeared to undergo a normal season of growth.

In October 1979, after a full season of establishment and growth at a water level 15 cm below the root crown, four of the five smaller tanks in each stock tank were lowered into the water to a level 15 cm above the shrub root crown, and frozen at that level over winter.

Within each stock tank, the treatment was applied by raising one randomly assigned smaller tank to a water level 15 cm below the root crown on 15 May, another on 15 June, a third on 15 July, and the fourth on 15 August, 1980. The control tank was maintained at a water level 15 cm below the root crown. In October 1980 all four smaller tanks were again lowered to a water level 15 cm above the root crown, and frozen at that level over winter. The treatment sequence—the same tank raised at the same date—was repeated through the 1981 and 1982 growing seasons. At the end of September 1982, all shrub stems were counted, removed from the soil, washed, separated into root and stem components, ovendried (48 hours at 80°C), and weighed.

Branches that died during the experiment were collected and their weights were added to the final weight of the individual. Some dead branches that died and sloughed off were not found, however, resulting in negative biomass increases for individual shrubs despite prolific adventitious rooting. The negative values were maintained in the regression analysis. As a result, the models that we used to analyze the data did not have horizontal asymptotes of zero as flooding duration increased.

All nonshrub vegetation was harvested at the soil surface, ovendried, and weighed just prior to collection of the shrubs.

ANALYSES

Mean 3-year ovendry weight biomass increase was used as the estimate of growth in all analyses. Pretreatment ovendry biomass of each shrub was estimated using regression equations relating harvest wet weight to ovendry weight (Knighton 1981). Net ovendry weight biomass increases were determined by subtracting estimated pretreatment ovendry weights from posttreatment ovendry weights.

A test for correlation between original shrub weight and final shrub weight was made to determine if covariance analysis was needed to adjust for disparities in original shrub weights.

The data on which the analyses were based differed slightly; for alder, the analyses used the weight of the single stem in each treatment tank, whereas for willows, the analyses used the mean of the three stems in each treatment tank. The relationship between net ovendry weight biomass increase (grams) over the 3-year study and flooding duration (days) was modeled for the four combinations of shrub type (alder, willows) and soil type (fine-sand, clay-loam). An assumption underlying the analysis was that differences due to individual tanks could be ignored and that the experiment could be considered to be completely randomized with three replications of each combination of soil type, shrub type, and flooding duration. For each shrub type-soil type combination, the variances of the biomass observations for the different flooding duration levels were approximately proportional to the mean or the square of the mean of the biomass observations. Thus, weighted regressions analyses, with weights proportional to the inverse of the mean or square of the mean, were used to estimate model parameters. After considering both linear and nonlinear model forms, simple second-order (quadratic) polynomials were selected to model the relationship between net ovendry weight biomass increase and flooding duration.

RESULTS AND DISCUSSION

Based on the lack of correlation between original and final weights (r= 0.36), original shrub size did not alter the biomass response to flooding duration. Apparently, treatment effects were sufficiently large, or the pretreatment establishment and growth adjustment period was sufficiently long, to mask any effect due to original size.

Mean biomass of the nonshrub vegetation was highest in the control tanks (fig. 1). This suggests that the nonshrub vegetation may even have suppressed shrub growth to some degree. Although nonshrub biomass decreased with flooding, the decrease was without pattern and showed a high degree of variability with both duration of flooding and soil type (fig. 1).

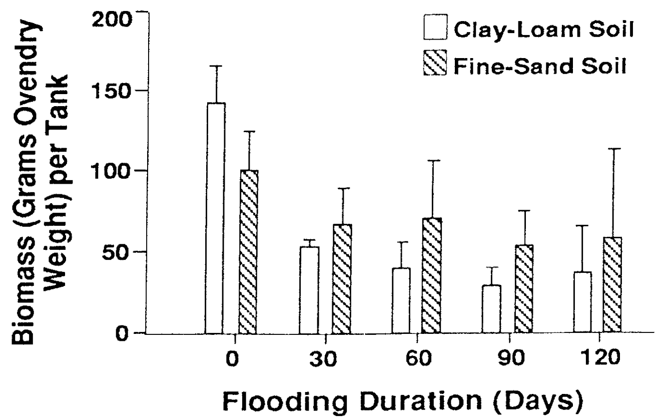

Figure 1.—*Mean (and standard error) ovendry weight of nonshrub biomass after the third growing season on fine-sand and clay-loam soils under five flooding regimes.*

For both shrubs and soil types, the models for the relationships between biomass increase and flooding duration were significant ($P<.05$), were significantly ($P<.05$) curvilinear, and were significantly ($P<.05$) different from each other (figs. 2 and 3).

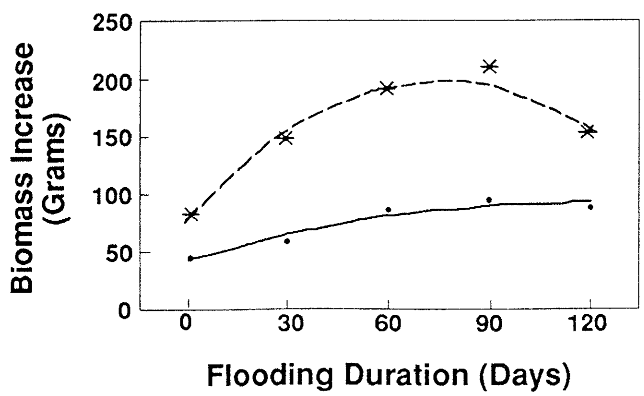

Figure 2.—*Mean ovendry weight biomass increase of willow after three growing seasons on fine-sand (•) and clay-loam (*) soils under five flooding regimes. Lines represent best-fit models weighted by square root of the means. Dashed line represents the model for clay-loam, $y= 79.9 + 3.1x - 0.020x^2$, $R^2=0.71$. Solid line represents the model for fine-sand, $y = 43.7 + 0.8x - 0.004x^2$, $R^2=0.76$.*

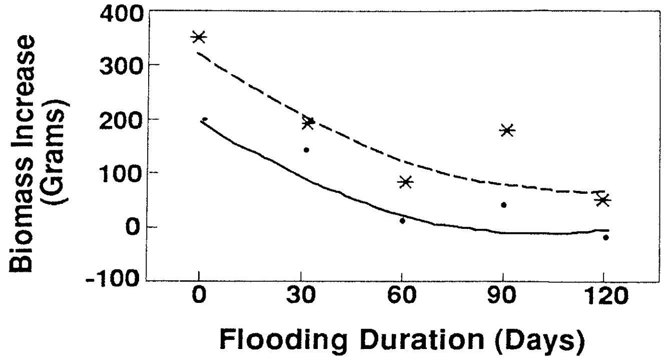

Figure 3.—*Mean ovendry weight biomass increase of alder after three growing seasons on fine-sand (•) and clay-loam (*) soils under five flooding regimes. Lines represent best-fit models weighted by square root of the means. Dashed line represents the model for clay-loam,* $y = 316.8 - 4.3x + 0.019x^2$, $R^2=0.44$. *Solid line represents the model for fine-sand,* $y = 193.8 - 4.0x + 0.019x^2$, $R^2=0.47$.

Even though alder and willow are tolerant of temporary flooding (Hall and Smith 1955), growth stops and mortality increases after two seasons of flooding above shrub root crowns (Knighton 1981). Our results suggest that alder is sensitive to flooding of even short duration, while willow, at least in terms of biomass production, is more productive under a flooding regime of up to 60 days per growing season than under a regime of no flooding. The ability of willow to adapt to flooding is probably due to its prolific capability to produce adventitious roots (Krasny *et al.* 1988).

The vegetative regeneration strategies of these two shrubs may also enable them to compete more effectively under somewhat different environments. Willow seems to do better in colonizing and persisting on floodplains and other environments characterized by fluctuating water tables (Levitt 1972, Hook 1984, Krasny *et al* 1988). Alder initially colonizes and persists on riparian zones or other environments where soil water tables are more stable, with perhaps only short-term seasonal flooding. Once established, alder can persist and expand through stump sprouting (Walker *et al.* 1986).

These results indicate that if the objective of impoundment management is to encourage willow persistence and biomass production, then flooding should not exceed 60 days during the growing season. If the objective is to maintain alder, the riparian zone should not be flooded for even as long as 1 month. The flooding effects on biomass growth of willow and alder that we found in this study support Knighton's (1985) recommendations (page 46) for management of shrub biomass in water impoundments.

ACKNOWLEDGMENTS

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