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Glossy buckthorn (Rhamnus frangula), a threat to the vegetation of the Cedarburg Bog

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GLOSSY BUCKTHORN *(Rhamnus frangula)*, A THREAT TO THE VEGETATION OF THE CEDARBURG BOG

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ABSTRACT

Glossy buckthorn (Rhamnus frangula) is a shrub or small tree which is a native of Eurasia, introduced to North America about the mid-nineteenth century. Escaped from cultivation, Rhamnus frangula is rapidly becoming a serious pest in certain kinds of wetland habitats and has been in the Cedarburg Bog for at least the last thirty years. Glossy buckthorn is most dense in the string bog, the most unique vegetation type in the Bog. Since 1968, the string bog population of Rhamnus frangula has been growing logarithmically at a rate which doubles the population size in less than 4 years. Individual shoots also grow (accumulate woody biomass) logarithmically. The rate of growth of woody dry weight decreases, however, at 11 - 12 years of age, the age at which shoots attain the height of the string bog canopy. As they reach the canopy, shoots become more branched, allocate less biomass to wood, and allocate more biomass to leaves and probably to fruits. The estimated rate of accumulation of R. frangula woody biomass density has also been logarithmic, with a present density of 610 g/m^2. If the current rate of woody biomass accumulation continues as expected, by 1993 the woody strings of the string bog will contain 2.2 kg/m^2 of R. frangula wood. Light intensity in the strings will decrease markedly as shading by R. frangula increases.

At present, there appears to be no hope of controlling the spread of glossy buckthorn on a Bog-wide basis, although it could be removed and then excluded from certain selected areas. A long term research project is required to document the effect of R. frangula on the native vegetation. Its effect on the string bog is expected to be catastrophic.

INTRODUCTION

Much attention has been paid to the values of wetlands to wildlife, and to the role of wetlands in maintaining water quality. Many of Wisconsin's pristine natural areas are wetlands despite the loss of much of Wisconsin's original wetland acreage to drainage or filling. Exotic plant species currently present a severe threat to the quality of our remaining wetland natural areas. Invasions by aggressive exotics can become a problem even in relatively well protected natural areas such as the Cedarburg Bog.

Bazzaz (1986) defines colonizers as those species which colonize open or disturbed habitats, and invaders as those species which enter intact vegetation and, in time, dominate or displace the native vegetation. In the process of growth of the invader population the original vegetation is modified and the invader may eventually usurp much of the supply of available resources in the habitat. Invaders must be competitively superior or competitively competant (Bazzaz, 1986) in the habitats they invade in order to be able to enter an established community. The general characteristics of colonizers and invaders are very different because of the selection of competitive ability in invaders.

Some general characteristics of many invaders and colonizers are: 1) All invasive species have long distance dispersal ability (often provided by either intentional or inadvertent dispersal by humans). 2) Most invasive species have periods of logarithmic population growth once they are established; rates and lag times with intrinsic species characteristics and extrinsic environmental factors. 3) Prolific reproduction and efficient dispersal are the most crucial life history feature of colonizers and invaders. 4) The invasiveness of some species is enhanced by having wide habitat tolerance and high levels of phenotypic plasticity. Control measures for most exotic species are only successful when the pest species population is small. Pest species are often present in small numbers at a site for many years before their populations begin a phase of logarithmic growth.

The aggressiveness of glossy buckthorn in wetlands is due primarily to its prolific reproduction, both vegetatively and by seed, and to its tolerance of a wide variety of environmental conditions. Its fruit is very attractive to birds and it forms abundant sprouts both from stumps and roots. Glossy buckthorn has a very wide moisture tolerance; while only becoming a problem in the wetland areas, it is also found on dry upland sites at the Field Station. Although R. frangula thrives in open, sunny areas it can become well established in dense shade. It is apparently not adversely affected by a poor soil nutrient regime, as evidenced by its vigor in the string bog. Primary productivity of the native species of the string bog is very low because of the low levels of available nutrients in that habitat.

Rhamnus frangula is an unusually aggressive invader of the string bog in the sense that it readily invades an undisturbed native plant community. Most aliens require disturbance to become established in native communities, without which they are presumably excluded by competition from the existing well established vegetation. Perhaps the stunted stature of the string bog vegetation, the openness, high light levels, and natural "forest edges" present R. frangula with a community that it responds to as a disturbance community. The potential destructiveness of Rhamnus frangula to wetland vegetation is enhanced by its growth form and potential dominance of the tall shrub layer. As a tall shrub which casts a very dense shade, it has the potential to alter both the herbaceous and lower shrub layers of a plant community.

We present a brief summary of the growth form and natural history of Rhamnus frangula, a description of the population in the Cedarburg Bog, a discussion of possible control measures, and suggestions for research needed to document the effect of Rhamnus frangula on wetland plant communities.

BIOLOGY OF Rhamnus frangula

Rhamnus frangula is in the Buckthorn Family (Rhamnaceae), which in Wisconsin includes the genera Rhamnus and Ceanothus (New Jersey Tea). Rhamnus frangula has several common names including glossy, alder, and European buckthorn. A tall shrub or small tree up to 7 m high, the young twigs of R. frangula are grayish-brown with a sandy brown pubescence; older twigs are brown or grayish, generally dotted with numerous light-colored silvery lenticels; the leaves are alternate, thin, elliptic to obovate with five to eight pairs of veins and entire to crenate margins. The leaves are bright green and glossy above, somewhat paler beneath and finely pubescent along the veins. The pubescent twigs which tend to have short internodes, arch upwards, and have naked, hairy winter buds (i.e. lack bud scales), give the shrub a distinctive appearance which renders winter identification simple and unambiguous.

Rhamnus frangula flowers over a long period (from May almost to the first frost) and its fruits ripen from July through September. Its flowers are in sessile, axillary umbels of 2-10 flowers. Fruits are 2-seeded drupes which change from red to dark purple as they ripen.

Rhamnus frangula is native to Europe, western Asia, and northern Africa (Rehder, 1927). The species was first cultivated in the late 18th century because of its attractive, lustrous foliage, and has several cultivated varieties. Glossy buckthorn was introduced to North America in the northeastern United States as a cultivated shrub where it has escaped cultivation and become thoroughly naturalized. The North American range of Rhamnus frangula now extends from Quebec, Ontario and Minnesota, south to Nova Scotia, New England, New Jersey, Ohio, Indiana and Illinois (Fernald, 1970).

The invasion of the Great Lakes area by glossy buckthorn is more recent (Howell and Blackwell, 1977). In Michigan, it was first collected as escaped from cultivation in 1934 (Voss, 1985). As of 1943, there had been only two collections of glossy buckthorn in Wisconsin (in Milwaukee and Walworth counties) (Pohl, 1943). Only recently has it become a problem in this area, "becoming a serious pest as a tall shrub in bogs, especially alkaline ones (fens), and other damp places, including tamarack and cedar swamps (particularly in disturbed areas as along new power lines and other clearings), thickets along rivers, lake shores, ditches, fence rows, and low woods" (Voss, 1985).

Rhamnus frangula IN THE CEDARBURG BOG

Over the last three years we have conducted a general survey of the presence of R. frangula in the various plant communities and areas of the Cedarburg Bog. We also conducted a somewhat more detailed survey of the density of R. frangula in the various plant communities along the transect through the Bog formed by the Field Station boardwalk.

We determined that the density of R. frangula was higher in the central, string bog portion of the Bog than in any other plant community. R. frangula density was less than 0.5 stems/m^2 in the boardwalk transect through the conifer swamp, shrub carr and swamp hardwoods, and approximately 30 stems/m^2 in the strings of the string bog. We, therefore, concentrated our studies of the age and size distributions of R. frangula in the string bog area. Glossy buckthorn is found only in the strings and is absent from the flarks (the low, flat, open areas between the strings of stunted woody vegetation). All R. frangula was harvested from two transects (1 m wide) placed perpendicularly through two strings. Two different strings north of the boardwalk loop were chosen as having representative Rhamnus densities and the transects were located randomly within those strings. One transect was approximately 12 m long and the other 11 m.
In order to determine the relationships among the various size measures, and the relationships of the size measures to shoot age, a subsample of 138 shoots was obtained from the total of 684 shoots in studied transects. The height and basal diameter of each shoot in the subsample were measured, and the shoots were aged by counting annual growth rings. Stems (woody biomass only) were then dried to a stable weight at 65^{o}C and weighed. A very close relationship was found to exist between log basal diameter and log dry weight of wood (Fig. 7), log height (Fig. 8), and shoot age (Fig. 9). Log basal diameter was therefore used to estimate dry weight of woody tissue, height and age of the remainder of the shoots.

None of the relationships among shoot size parameters and shoot age differed significantly between the two sampled transects. Likewise, the relationship of log basal diameter to log dry weight and log height did not differ between the two transects. Stem densities per m^2 were also similar (less than 10% difference) in the two transects. Data from the two transects were, therefore, combined for all further analysis.

Population Growth

From maximum stem ages, it was apparent that Rhamnus frangula had been present in the string bog at least since 1955. By 1962 R. frangula was present at low densities throughout much of the string bog. We found very little evidence of mortality of buckthorn in the string bog; only two dead stems were found in the area sampled. Observations over the past five years also indicated that the high density of young shoots in the string bog had not been present prior to the past 3 to 4 years. It was reasonable, therefore, to make the assumption that since 1966, there had been no (or very little) mortality of R. frangula shoots in the string bog after they had reached one year of age. This assumption was required in order to estimate a growth curve for the population from the current age distribution of individuals.

The age distribution of stems in the string bog population indicated a slow, steady recruitment of new individuals to the population from 1966 to 1978 (Fig. 1, shoots 10 to 23 years old) and a much more rapid increase in number of individuals since that time. Using the age distribution of the present population, we estimated stem densities from 1966 to 1988 by using the cumulative number of individuals in the sampled area during each year. From 1968 to 1988, the string bog population grew logarithmically (Fig. 2), at a rate which doubled the population in less than 4 years (multiplies by 1.23/year).

The mean density of the population in 1988 was 29.7 stems/m^2, but this density was not uniform across the strings. Densities varied systematically from approximately 4 stems/m^2 at the string margins (where the strings meet the flarks) to about 52 stems/m^2 at the center of the strings (Fig. 3). Strings in the Cedarburg Bog have primarily a northwest-southeast orientation. In the two

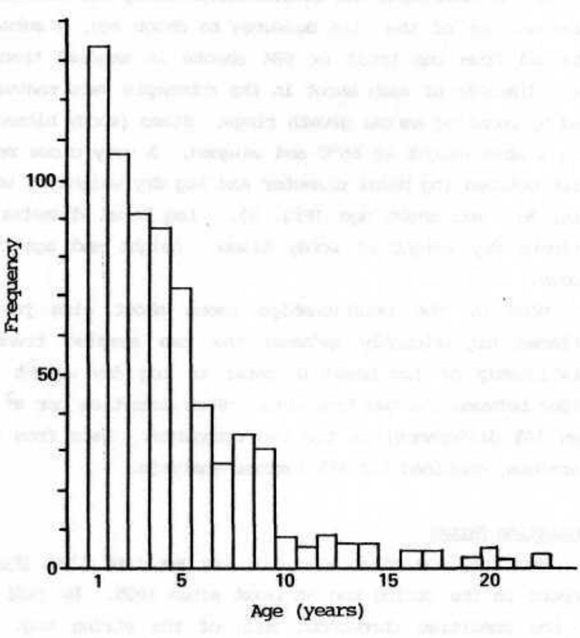

Figure 1. Frequency distribution of stem ages of the string bog population of Rhamnus frangula.

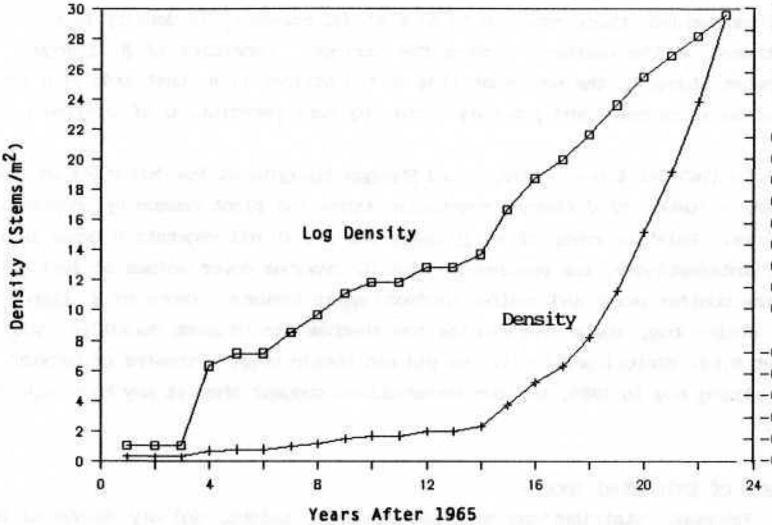

Figure 2. Growth of the density of stems of the Rhamnus frangula population in the string bog from 1966 to 1988. Scale on the left shows densities and on the right shows log-transformed densities. Log densities form roughly a straight line since 1968, indicating logarithmic growth.

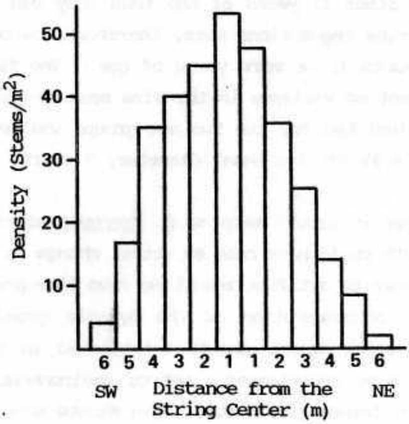

Figure 3. Distribution of Rhamnus frangula in 1 m^2 segments along two transects arranged from the southwest (SW) side of strings to the northeast (NE).

strings sampled, there appeared to be a slight asymmetry in density from the southwest to the northeast across the strings. Densities of R. frangula were somewhat higher on the southwest side of the strings (i.e. that side with more of a southern exposure and probably receiving more penetration of sunlight) (Fig. 3).

In 1968 Grittinger (1969) found Rhamnus frangula at low densities in the Bog across a number of different vegetation types and plant community compositional indices. Relative cover of R. frangula was low in all vegetation types in 1968, but, interestingly, the species reached its maximum cover values of just over 1% in the conifer swamp and conifer-hardwood swamp forests. Cover of R. frangula in the string bog, where the species now reaches its highest densities, was only about 0.02% (Grittinger 1969). We did not obtain cover estimates of buckthorn in the string bog in 1988, but our observations suggest that it may have approached 50%.

Growth of Individual Shoots

Frequency distributions of basal diameter, height, and dry weight of woody tissue were all extremely skewed with a large number of small individuals and few large individuals in the population. Basal diameter, height, and weight were therefore log-transformed before analysis. The frequency distributions of all three log-transformed size measures were approximately normal.

The relationships of all three log transformed size measures to shoot age indicated that individual shoots grew logarithmically (see Fig. 4 and 5, Table 1). The scatter plots of all three size measures suggested, however, that shoots grew at a slower rate after 11 years of age than they did from 1 to 11 years (Fig. 4 and 5). Separate regressions were, therefore, calculated for shoots 1 to 11 years old and shoots 12 or more years of age. The fit of the regression lines to the data (amount of variance in the size measure explained by age) when separate lines were calculated for the two age groups was improved over the fit with a single line by 4.9% for log basal diameter, 7.4% for log dry weight, and 17.8% for log height.

The apparent change in growth rate of R. frangula after about the 11th or 12th year of shoot growth could have been an actual change in growth rate at that age, or it could have been an artifact resulting from interpreting a static size-age relationship as a representation of the dynamic growth over time of an individual shoot. In other words, shoots established in the string bog more than 11 years ago may have experienced a set of environmental conditions which gave them an entirely different growth curve than shoots more recently

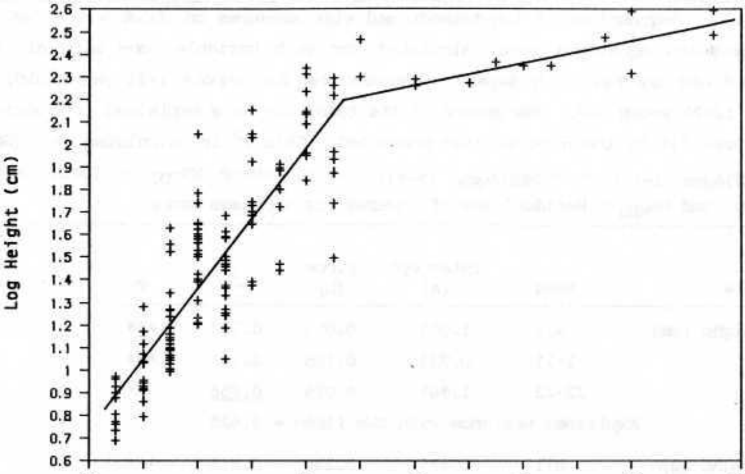

Figure 4. Log height of Rhamnus frangula stems plotted versus shoot age. Equations for a single regression line through the data point, and for the two separate regression lines drawn are presented in Table 1.

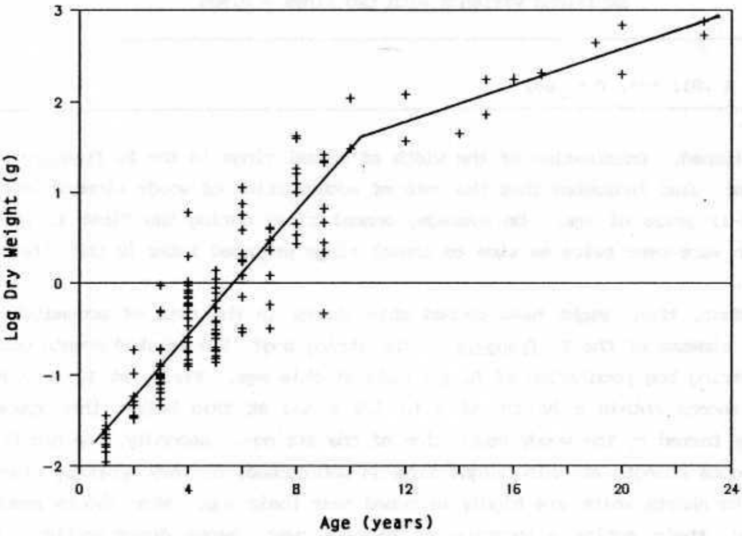

Figure 5. Log dry weight of woody biomass of Rhamnus frangula stems plotted versus shoot age. Equations for a single regression line through the data points and for the two separate regression lines drawn are presented in Table 1.

Table 1. Regressions of log-transformed size measures on shoot age. Two sets of regression equations were calculated for each variable, one with all ages combined and another with separate regressions for shoots 1-11 years old, and shoots 12-23 years old. The amount of the total variance explained (r^2) when two lines were fit to the data is also presented. This r^2 is calculated as: $(SS_{TOT} - SS_{RES(Ages\ 1-11)} - SS_{RES(Ages\ 12-23)})/SS_{TOT}$, where SS_{TOT} = Total Sum of Squares, and SS_{RES} = Residual Sum of Squares for each age group.

Variable	Ages	Intercept (a)	Slope (b)	r^2	P
Log height (cm)	all	1.001	0.093	0.703	***
	1-11	0.733	0.156	0.751	***
	12-23	1.967	0.025	0.656	**
	Explained variance with two lines = 0.828				
Log weight (g)	all	-1.485	0.236	0.814	***
	1-11	-1.907	0.335	0.776	***
	12-23	0.563	0.100	0.758	***
	Explained variance with two lines = 0.874				
Log diameter (mm)	all	-0.065	0.082	0.845	***
	1-11	-0.178	0.108	0.778	***
	12-23	0.648	0.037	0.706	***
	Explained variance with two lines = 0.886				

**, P < .01; ***, P < .001

established. Examination of the width of annual rings in the R. frangula stems, however, also indicated that the rate of accumulation of woody biomass decreased at 11-12 years of age. On average, annual rings during the first 11 years of growth were over twice as wide as annual rings produced later in the life of the shoot.

What, then, might have caused this change in the rate of accumulation of woody biomass of the R. frangula in the string bog? Two related events occur in the string bog population of R. frangula at this age. First, at 10-12 years of age, shoots obtain a height of 2 to 2.5 m and at this height they reach the canopy formed by the woody vegetation of the strings. Secondly, the growth form of shoots changes at this height from an unbranched, or very sparsely branched, stem to shoots which are highly branched near their top. When shoots reach the canopy, their entire allocation of biomass must change dramatically. Woody biomass changes from being allocated entirely to the main axis to being allocated primarily to branches. The proportion of biomass allocated to leaves must increase greatly as the shoots become more branched and the proportion of biomass allocated to fruits must also increase markedly. In fact, R. frangula may not even begin to set fruit until it reaches the height of the canopy.

In light of these observations on the growth of R. frangula in the string bog, it is interesting to reconsider the dynamics of the population since the species first entered the Bog. Recall that maximum stem ages indicated that R. frangula invaded the string bog around 1955 and that the population began to grow logarithmically in 1968. Note that there was a period of about 13 years between the introduction of R. frangula to the Bog and the beginning of logarithmic population growth, and that fruit production by R. frangula in the string bog begins in earnest at 11 to 12 years of age. Shoots established from 1955 to about 1967 may have been primarily immigrants from outside of the string bog, with reproduction within the population beginning about 1967.

From the fitted growth curves of log dry weight regressed on shoot age (Fig. 5) and the estimated density of shoots in the population from 1966 to 1988 (Fig. 2) we could estimate the density of accumulated woody biomass in the community over the same period of time (Fig. 6). Density of woody dry weight of R. frangula in the string bog in 1988 was 610 g/m^2. Woody biomass accumulated logarithmically since 1965, and had different rates of logarithmic accumulation before and after 1976 because of the influence of the change in shoot growth rate at 11 to 12 years. From 1966 to 1976, accumulated woody biomass more than

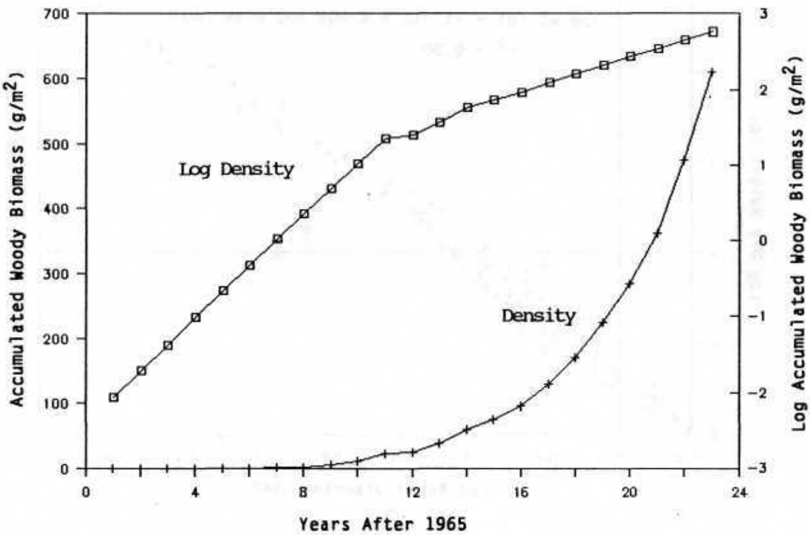

Figure 6. Growth of the density of accumulated dry weight of woody biomass of Rhamnus frangula in the string bog from 1966 to 1988. Scale on the left shows woody biomass density and on the right shows log-transformed biomass densities.

doubled each year (logarithmic growth rate = 2.2); from 1977 to 1988, accumulated woody biomass multiplied by a factor of 1.3 each year.

Finally, we present the relationship between log basal diameter and log height, log dry weight, and age. These relationships were of interest primarily because if shoot size and age could be estimated (or predicted) by measurement of the basal diameter of the shoot, it would provide a great time savings in studies aimed at describing the age structure, or estimating the biomass density of a population. The relationships between size and age of shoots and basal diameter were remarkably close (Fig. 7, 8, and 9). Measurement of log basal diameter accounted for 98% of the variation in log dry weight of woody tissue, 91% of log height, and 92% of age. The accuracy with which these variables can be estimated from simple measurements of basal diameter will greatly facilitate future studies of R. frangula in the string bog. These relationships are, of course, only applicable to R. frangula in the string bog; unique equations would have to be determined to provide size and age estimates from basal diameters of R. frangula in each other plant community in the Bog.

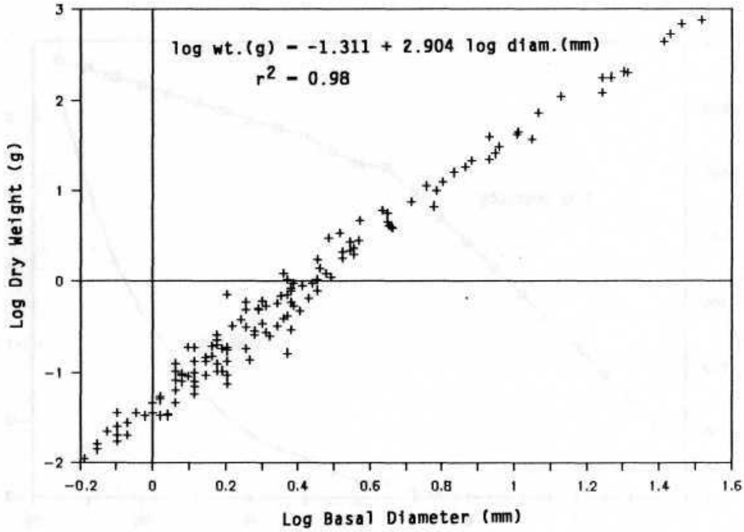

Figure 7. Log dry weight of woody biomass of Rhamnus frangula stems plotted versus log basal diameter of stems. An equation is shown for a least squares linear regression of log dry weight on log basal diameter.

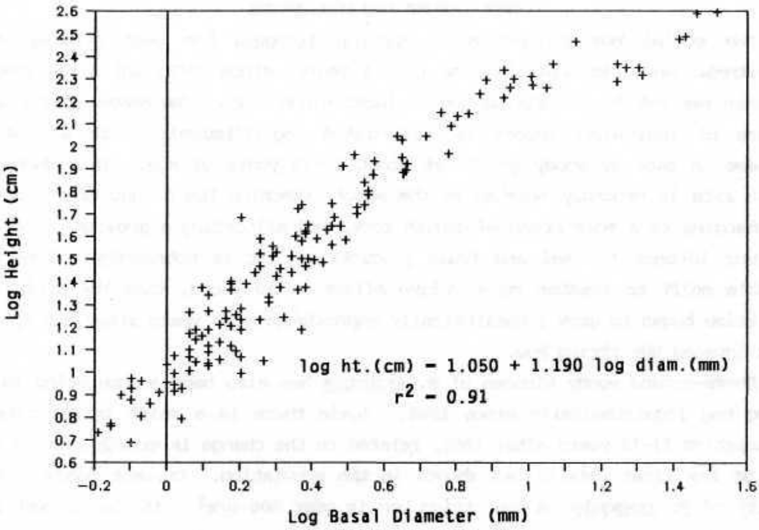

Figure 8. Log height of Rhamnus frangula stems plotted versus log basal diameter of stems. A least squares linear regression of log height on log basal diameter is presented.

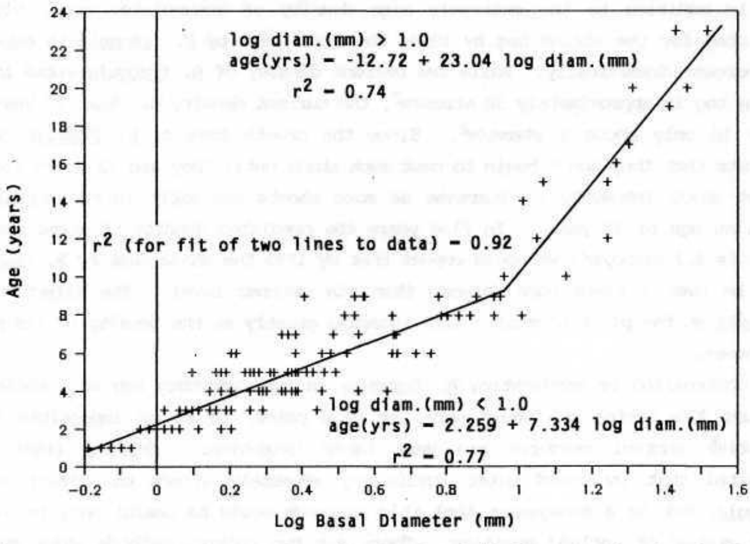

Figure 9. Age of Rhamnus frangula shoots plotted versus log basal diameter of stems. Two separate linear regressions are shown, one for stems with a log basal diameter less than 1.0 and another for larger stems.

CONCLUSIONS AND PROSPECTUS

The string bog population of Rhamnus frangula has been growing at a logarithmic rate (doubling in less than 4 years) since 1968, while the species has been present in the string bog at least since 1955. The above-ground woody biomass of individual shoots is accumulated logarithmically with a distinct decrease in rate of woody growth at about 11-12 years of age. This change in growth rate is probably related to the shoots reaching the height of the canopy and changing to a more branched growth form, and allocating a greater proportion of their biomass to leaf and fruit production. It is noteworthy, given this probable shift to greater reproductive effort at 12 years, that the string bog population began to grow logarithmically approximately 13 years after the species first invaded the string bog.

Above-ground woody biomass of R. frangula has also been accumulating in the string bog logarithmically since 1968. Again there is a shift in the rate of accumulation 11-12 years after 1965, related to the change in growth rate at that time of the first established shoots in the population. Current woody biomass density of R. frangula in the string bog is over 600 g/m^2. If the current rate of woody biomass accumulation (multiplied by 1.3/yr) continues in the string bog for another 5 years, by the end of 1993 there will be over 2.2 kg of woody biomass (dry weight) of R. frangula per square meter in the string bog. The string bog will be essentially transformed from a cedar-tamarack string bog to a Rhamnus string bog.

In addition to the extremely high density of accumulated woody biomass predicted for the string bog by 1993, the shade cast by R. frangula is expected to increase dramatically. While the current density of R. frangula stems in the string bog is approximately 30 stems/m^2, the current density of stems 12 years or older is only about 2 stems/m^2. Since the growth form of R. frangula would indicate that they don't begin to cast much shade until they are 12 years old, we expect shade intensity to increase as more shoots currently in the population reach an age of 12 years. In five years the predicted density of stems over 12 years is 6.3 stems/m^2; we would expect that by 1993 the shade cast by R. frangula will be over 3 times more intense than its current level. The effect of R. frangula on the plant community will increase greatly as the density of its shade increases.

Controlling or eradicating R. frangula in the Cedarburg Bog as a whole, or in just the string bog would seem, at this point, to be an impossible task. Potential control measures are very labor intensive. Zolidis (1988) has suggested that increased water levels may adversely affect the growth of R. frangula, but as a management tool this approach would be useful only in a very small number of wetland habitats. There are two control methods which may be effective for R. frangula. Cutting stems off near ground level and treating the freshly cut stems with glyphosate herbicide would probably kill glossy buckthorn

(Gourley, 1985). This method, which is effective for the control of a wide variety of woody species, is effective only when used during the growing season when access to the string bog is most difficult and the potential of herbicide damage to other vegetation is greatest. Another method which remains untested, but has the potential to kill at least larger shoots of R. frangula, is to completely girdle the stems near the base during the winter. Since girdling removes phloem connection of roots to shoots but leaves the xylem connection of shoots to their roots intact, shoots may continue to grow after girdling and deplete the energy resources of their root systems to the point where they would not re-sprout. The advantages of this method are that it could be used in the winter when string bog access is more feasible and that it does not require herbicide use. This method may, however, be even more labor intensive than cutting and herbiciding. We have girdled some stems of R. frangula in the Bog as a preliminary investigation of the effectiveness of this method.

While elimination of R. frangula from the Bog as a whole may be hopeless, it is absolutely essential that the species be eradicated and then excluded from some rather sizable plots in the string bog. Without this action, the unique plant community of the string bog, the most unusual wetland plant community in southern Wisconsin (Grittinger 1970, Germain 1975), will almost surely be lost entirely. Exclusion plots should be large enough (at least 2 acres) to incorporate and preserve the structural integrity of the string bog, and should be replicated in different parts of the string bog to afford the opportunity to document the impact of R. frangula on the plant community.

Large size of exclusion plots would not only preserve the structure of the string bog, but would slow the ceaseless recolonization of the plots by seeds imported from outside the plots. Replication will allow the diversity of structure in various parts of the string bog to be preserved and enable periodic comparisons of the vegetation within the exclusion plots with the vegetation in paired plots where the R. frangula population was allowed to run its course. The establishment of exclusion plots would also allow valuable experimentation to determine the most effective methods for killing glossy buckthorn.

Exclusion plots should be established as soon as possible and probably should be planned as a two-phase approach: 1) Reproductive size individuals should be killed first, with simultaneous studies of effective control methods and a quantitative description of the vegetation within the exclusion plots and in paired "control" plots. 2) In subsequent years, smaller individuals and individuals reaching reproductive size should be removed with the control methods which have proven to be most effective; the vegetation should be periodically resampled.

In addition to this intensive work which should be undertaken in the string bog, we hope to extend our study of the population and individual growth rates of R. frangula to other plant communities contained in the Cedarburg Bog. It may be that R. frangula reaches reproductive size, and perhaps undergoes a similar shift in growth form at very different ages in the various communities of the Bog. A Bog-wide study of R. frangula will give us the information required to make informed management decisions concerning the Bog as a whole.

The study of Rhamnus frangula in the Cedarburg Bog which has been conducted to date, has important implications for management of R. frangula in other wetlands. The most obvious recommendation is that glossy buckthorn should be removed from wetlands early, before the population enters a logarithmic growth phase. Removal of R. frangula should begin in earnest before it reaches its reproductive growth phase when logarithmic population growth begins and when the change in growth form causes a likely increase in the intensity of shading by R. frangula.

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