Visual Estimation of Biomass and Application of Three White-tailed Deer HSI Models in Suburban Habitats

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Abstract: We describe a new, non-destructive procedure for visually estimating forage biomass based on volumetric cover. The accuracy of this procedure was tested against actual dry biomass by clipping and weighing 41 plots of wax myrtle (*Myrica cerifera*). Visual estimates of forage biomass were significantly related ($P \leq 0.001$) to actual biomass determine by clipping ($r^2 = 0.925$; $y = 16.36 + 2.52\ X$, where y = dry biomass and X = volumetric cover). We developed this procedure to apply 3 white-tailed deer (*Odocoileus virginianus*) habitat suitability index (HSI) models to a suburban development. The 3 traditional HSI models evaluated did not include several variables unique to developed areas that could affect deer habitat quality. Therefore, the models may need to be modified before they can be applicable in developed areas.

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White-tailed deer have changed from a rare game species to an overabundant pest species in some areas during the past 50 years. Wildlife restoration programs and the adaptability of white-tailed deer have led to successful co-habitation of deer with humans (Warren 1997). High deer numbers and urban population centers often conflict as evidenced by a television special (60 Minutes) in November 1996 that featured suburban deer problems in the northeastern U.S., a recent conference devoted exclusively to urban deer (McAninch 1995), and the summer 1997 issue of the Wildlife Society Bulletin which focused on deer overabundance.

The need for innovative and non-traditional deer management methods is apparent. Traditional methods of wildlife management may not be applicable in urban environments. Developed areas often have different management goals than those of rural areas. In urban and suburban areas, the notion of a cultural carrying capacity (Minnis and Peyton 1995) may be far more important to the assessment of deer numbers and habitat quality than the classical notion of biological or *K* carrying capacity

(Macnab 1985). Thus, traditional wildlife management principles may not be suitable to urban and suburban environments.

Assessing wildlife habitat quality and type is a basic principle used when managing wildlife populations. Habitat suitability index (HSI) models have been used to evaluate the potential suitability of habitat for a species. This information then is used to determine the impact of environmental changes resulting from habitat modification. However, traditional HSI models may not be applicable in urban and suburban areas, nor may they adequately reflect the desired management objectives.

The objective of our study was to develop a non-destructive method of estimating forage biomass. This method was necessary to assess the applicability of 3 white-tailed deer HSI models in an urban environment. Two of the models we examined required measurement of forage biomass (i.e., standing crop of available vegetation and leaves of woody plants), which usually requires clipping plants. Clipping landscape vegetation is not acceptable in most urban-suburban areas. Therefore, a field method that is quick to administer and non-destructive is needed to sample suburban vegetation.

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Methods

Study Area

Sea Pines Plantation (SPP) is located at the southern tip of Hilton Head Island, South Carolina. For this study, we divided the 2,137-ha plantation into 3 areas: the southern region (~700 ha), the northern region (~1,192 ha), and the forest preserve (245 ha) (Fig. 1). Both the northern and southern regions are developed (i.e., residential, resort, retail, or commercial buildings), whereas the forest preserve is a park-like, natural area located inside the northern region. The southern region was first developed in the late 1950s and underwent a resurgence in development in the 1970s. Development of the northern region began in the 1970s. In 1996, deer density in the southern region was estimated using spotlight counts to be 0.4 deer/ha, compared to 0.9 deer/ha in the northern region (Henderson 1997). The forest preserve had an estimated deer density of 0.4 deer/ha.

Biomass Estimation (BME) Procedures

Biomass was determined by visually estimating the portion of a frame covered by vegetation. The frame measured $1 \times 1 \times 1.5$m (depth × width × height) and was constructed from 1.9-cm (0.75-inch) polyvinyl chloride (PVC) pipe (Fig. 2). Pipe connectors were used on the corners of the frame and were not glued so the sides could be disassembled to permit placement around vegetation.

A sheet of clear plastic demarcated with a grid was used to standardize the view

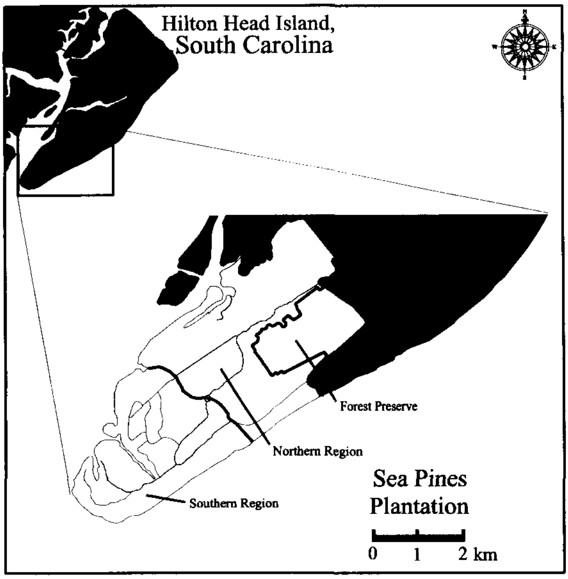

Figure 1. Sea Pines Plantation on the southern end of Hilton Head Island, South Carolina, showing the 3 regions evaluated using deer habitat suitability index models.

for estimation of biomass. The grid measured 7.5 × 10 cm and consisted of 1.5 × 1-cm blocks arranged in a pattern of 5 × 10 (Fig. 2). To visually estimate vegetation coverage, a person holds the clear sheet of plastic at arm's length and steps away from the plot until 1 vertical plane (i.e., side) of the sampling frame fully fills the grid. It is important to stoop down when using the BME so that the line of sight is horizontal to the ground and perpendicular to the vertical plane of the plot side. The distance away from the plot and the length of arm extension can be varied, because the alignment of the vertical and horizontal planes of the sampling frame with the grid standardizes the viewing area (Fig. 2). This procedure is repeated for the remaining 3 sides of the plot. If 1 side is completely obstructed, making it impossible to visually estimate forage biomass, then the estimate from the opposite side can be doubled and used for the missing side.

Cover data were tallied in a systematic manner. First, the number of 1.5- × 1-cm blocks completely obstructed by vegetation was counted. Then, each block that was about 50% obstructed by vegetation was counted and divided by half. Finally, the number of blocks obstructed <50% by vegetation was estimated by a modification of the "plant-cramming" technique (Hays et al. 1981). The number of obstructed squares was then doubled to represent percent cover.

Data from the 4 vertical plane estimates were averaged to represent horizontal cover on a 2-dimensional plane. Volumetric cover was considered to be a more valid estimate of biomass. Therefore, ground cover was determined and multiplied by the

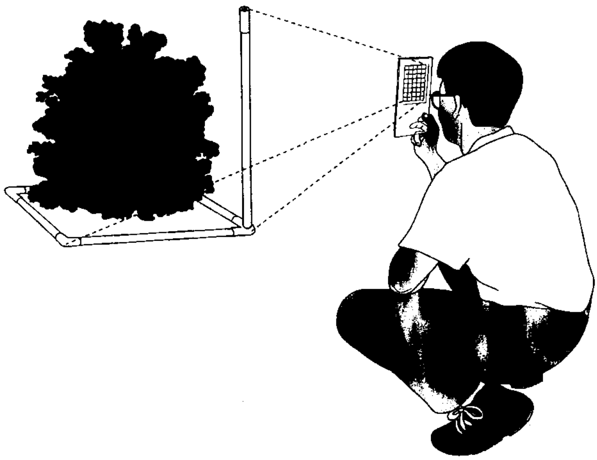

Figure 2. Depiction of sample frame placement and the use of the clear plastic grid to standardize the view for estimation of biomass.

mean from the 4 vertical plane estimates to derive volumetric cover. Ground cover was estimated by looking down from a height of 1.5 m toward the center of the plot and using the plant-cramming technique. The product of vertical cover multiplied by ground cover was multiplied by 100 to represent percent volumetric cover.

The BME was validated during October and November 1996 by comparing visual estimates of volumetric cover to actual dry biomass. A total of 41 plots containing wax myrtle at different levels of biomass was sampled. Wax myrtle was selected to test and calibrate the BME because it was readily available in the study area and was a common evergreen shrub used in suburban landscaping. Application of the BME to other plant species was not included in our study. After visual estimates were obtained from each plot, all leaves within the plot were stripped, ovendried at 60 C for 48 hours, and weighed to determine actual biomass in the plot. These data were analyzed by simple linear regression (Corel 1996) to determine the accuracy of the visual estimates, and thus enable the prediction of actual biomass (g) from volumetric cover (%).

Habitat Models

Field Survey.—Fifty sample points were chosen in each region to collect HSI data. Sample points in the northern and southern regions were located by using radiotelemetry stations placed for another study occurring at SPP (Henderson 1997). Points were representative of SPP habitats and were permanently marked. Telemetry stations were placed on streets using a painted marker. Points in the northern and southern regions were chosen to represent the availability of habitats on SPP. Sample points were marked in the forest preserve by driving 0.16 km along the road and placing a marker on the side of the road. Points also were marked on foot paths in the forest preserve every 91 m. From each of the 50 telemetry stations, 2 random compass bearings and distances were chosen to locate 2 plots. Thus, a total of 100 plots were sampled in each region for HSI data. Random distances were constrained between 2 and 37 m to ensure that plots would be located off roads but remain within the representative habitats being sampled. When a man-made structure was encountered, another random bearing was chosen. Data for all 3 models were collected simultaneously at each plot. Surveys were conducted from October to December 1996.

Short Model.—Short (1986) presents 4 different models. We chose model 3 because it was closest in format to the other HSI models and was the most applicable of the 4 models to an urban-suburban environment. The assumptions for application of this model include: (1) the area should be along the Gulf of Mexico or southern Atlantic Coastal Plain; (2) it should be applied during fall or winter; (3) it can be applied to forests, tree savannas, forested wetlands, shrublands, shrub savannas, scrub-shrub wetlands, grasslands, pastures, and haylands; (4) it should be applied to land units ≥40 ha; and (5) the HSI values from this model describe the potential of a habitat to supply food energy to white-tailed deer. This model provides only a general statement about the probable value of habitat for white-tailed deer during fall-winter. Model 3 incorporates only 2 variables—dry matter yield and stems/ha of mast-producing shrubs and trees—to calculate the HSI value. We estimated mast-producing plants by counting all species in 1-m^2 plots that provided hard and soft mast to white-tailed deer (Harlow and Hooper 1972). A suitability index value was then calculated based on the number of mast-producing plants. Biomass estimations were made using the BME. Biomass estimations were averaged and a suitability index value was determined.

Crawford/Marchinton Model—Crawford and Marchinton (1989) developed a simplified HSI for white-tailed deer in the Piedmont Region of the southeastern United States. The index is based entirely on quantity and quality of fall and winter foods. Free water was not taken into consideration because Crawford and Marchinton (1989) assumed that it was not a limiting factor. This model included 6 index variables: (1) standing crop of available herbaceous vegetation and leaves of woody plants (i.e., biomass) remaining green during late fall and winter; (2) basal area of oaks (*Quercus* sp.) ≥25-cm diameter at breast height (DBH); (3) the number of oak species in a stand equal to at least 5% of the total basal area; (4) site index of loblolly pine (*Pinus taeda*) or mixed oak; (5) percentage of agriculture land; and (6) distance from agriculture land to forest or shrub cover. We estimated biomass using the BME. Basal area (m^2/ha) was estimated using the Bitterlich method (Hays et al. 1981), and of those trees counted, the number of different species was recorded. The site index was obtained from Soil Conservation Service indices (U.S. Dep. Agric. 1980). Transect lines were drawn every 0.3 km on the map of site indices for loblolly pine. Site indices were determined every 0.2 km along the transect lines. These indices were averaged for all transect lines within each region to determine a region-specific site index. There was no agricultural land in the study area; therefore, the last 2 index variables (5 and 6) were assigned minimum values. Suitability index values were estimated from graphs provided in the HSI model and were inserted into the formula to derive the overall HSI value.

Armbruster/Porath Model.—The Armbruster and Porath (1980) model was developed for central Missouri with a different score sheet for different habitat types and times of the year. Upland forest score sheets were used for the northern and southern regions. Score sheets for upland and bottomland forests were used for the forest preserve. All 3 areas were scored using the fall-winter scores. Variables for the bottomland score sheet include: (1) tree size and canopy closure (2) number of important food plant species comprising >1% of total plants present; (3) plant food availability; (4) vegetative cover; (5) frequency, time, and duration of flooding; (6) habitat edge; (7) openings; (8) distance to cropland; (9) distance to other habitat types. The upland score sheet was the same except there was no variable for flood frequency. Canopy closure was estimated by using a 3.2-cm PVC connecting sleeve to restrict vision. Four estimates were made by looking directly upward through the PVC sleeve while standing and facing toward the cardinal points. The plant-cramming technique was used to condense the canopy foliage and derive an estimate. The size class of trees that obstructed vision were recorded. The number of important deer food plants (Armbruster and Porath 1980, Conover and Kania 1988) in a 1-m^2 plot was recorded. The total number of stems of important food plants in the plots was counted and recorded. Vegetation cover estimates were made by using the BME. Maps of the area were used to estimate edge width. Distances to permanent water were determined from the site index map. Measurements were made from each body of permanent water to determine the amount of area >1 km from permanent water. The same technique was used to determine the distance from other habitat types. There was no cropland; therefore, this variable was given a value of "NA."

Results

Biomass Estimation

The BME provided sufficient accuracy for use in estimating biomass of wax myrtle in this study. There was a positive correlation ($r = 0.96$) between dry weight of wax myrtle and volumetric cover (Fig. 3). The relationship between dry biomass (y) and volumetric cover (x) was $y = 16.36 + 2.52X$ ($r^2 = 0.925$, $P \leq 0.001$). Time required to collect BME data for validation ranged from 1 to 4 minutes per plot ($\bar{x} = 2$ minutes, $N = 41$ plots).

Habitat Suitability Models

Comparing HSI values among the 3 regions for each model, the forest preserve received the highest score in the Armbruster/Porath and the Crawford/Marchinton models (Table 1). However, the highest and lowest HSI values only differed by 0.03 (Table 1). All 3 areas received the same score from the Short model. Although HSI values were very similar among regions for each model, they varied greatly by model (Table 1).

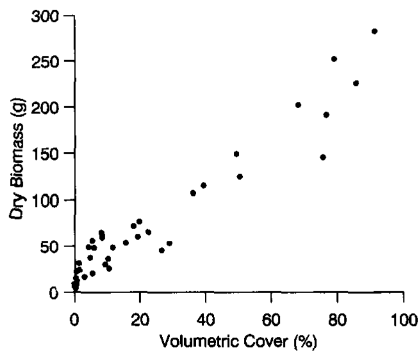

Figure 3. Relationship between clipped biomass of wax myrtle and estimates of volumetric cover using the biomass estimation method at Sea Pines Plantation, South Carolina.

Table 1. Weighted scores obtained from HSI models for 3 regions of Sea Pines Plantation, Hilton Head Island, South Carolina, October–December 1996 (maximum score = 1.00, minimum score = 0.00).

	Region		
HSI Model	Southern	Northern	Forest preserve
Short (1986)	1.00	1.00	1.00
Crawford/Marchinton (1989)	0.20	0.20	0.23
Armbruster/Porath (1980)	0.54	0.53	0.56

Discussion

The BME performed well in this suburban environment. It allowed accurate estimation of dry biomass of wax myrtle in a reproducible and objective manner. Short (1986) suggested visually estimating forage biomass, which is a subjective measurement with unknown error. An experienced, properly trained biologist can visually estimate biomass with double sampling (Ahmed and Bonham 1982). By double sampling, the observer would obtain an estimate of error and make adjustments in the calculations. However, double sampling would require clipping vegetation, which is unacceptable in a suburban, landscaped environment.

Another technique that could be used is the twig-count method (Shafer 1963). A minimal amount of clipping would be needed to define the relationship between the number of twigs and amount of biomass. This technique was attempted but abandoned due to the enormous amount of time needed to count twigs in a hedge. The BME was rapidly applied and produced results that could be analyzed quantitatively. In addition, we received no complaints from residents when using this technique, as compared to clipping.

The 3 models yielded widely varying estimates in the HSI value for each region. These differences can be attributed to the different variables used in each model. Mean forage biomass on our southern and northern regions was about 255 kg/ha, compared to about 340 kg/ha in the forest preserve. These values were much higher than the maximum level of 60 kg/ha in the Short model. The Crawford/Marchinton model, which was designed for use in the Piedmont, compensates for this deficiency by setting the highest forage biomass value at 1,120 kg/ha. Compared to the Piedmont, soils in most of the Coastal Plain are low in fertility, which causes low production of high-quality forage for deer (Newsom 1984). Crawford and Marchinton (1989) believed that forage biomass was the most important variable in their HSI because it provided the most reliable supply of nutrients and protein to produce healthy fawns. These differences in maximum forage biomass probably account for the different HSI values between the Crawford/Marchinton model and the Short model.

None of the models was adjusted for the modified habitat of an urban environment. Productivity is increased artificially by landscaping, fertilizing, and irrigating. Landscape vegetation destroyed by deer often is replaced by residents soon after it is eaten. The Crawford/Marchinton model compensates for productivity by utilizing site indices. However, the use of site indices in suburban habitats is probably ill-advised because of fertilization, soil compaction, or other influences caused by an urban population.

Another possible modification of deer carrying capacity on SPP is supplemental feeding. Supplemental feeding is provided by some residents of SPP (Henderson 1997). The exact number of residents feeding deer is unknown, but this factor can artificially raise deer carrying capacity and is not accounted for in the HSI models.

White-tailed deer are an edge species. Areas with well-interspersed edge have a greater deer carrying capacity (Kammermeyer and Thackston 1995). The amount of edge produced by the "green spaces" (corridors of natural vegetation) between subdivisions of the plantation yielded the maximum value in the Armbruster/Porath model. This variable is based on the width and amount of edge surrounding a site. Interspersed edge that transects a particular site is not accounted for in this model. Our entire study area was transected by a higher level of edge than allowed in this model variable. Thus, the maximum value for the model variable is too low to reflect the level of edge within our suburban area.

Wildlife agencies generally can estimate deer herd carrying capacity in undeveloped, rural areas based on available natural habitat features. However, these estimates may not be applicable in suburban, developed areas because of the removal of natural vegetation and replacement with fertilized landscaping. Traditional HSI models need to be modified before they can be applicable in developed areas. Urban and suburban residents may object to traditional methods of herd health determination via nutritional and reproductive indicators (Harder and Kirkpatrick 1994). Determining the quantity of available vegetation based on HSI models coupled with spotlight counts may provide an initial assessment of the relative population density of an urban deer herd.

White-tailed deer HSI's were originally developed for use in undeveloped areas. Their application in urban and suburban areas may be inappropriate, because development changes many of the habitat variables. Crawford and Marchinton (1989) stated their model should not be applied without substantial modifications where unusual situations exist (e.g., a large airport or in other areas of the country not similar to the Piedmont). These models have the advantage of being relatively quick to apply and non-destructive to planted vegetation, if the BME is used. Modifications to the models may improve their applicability in developed areas. An urban white-tailed deer HSI may have to include a survey to determine artificial habitat modifications, such as fertilization, frequency of re-landscaping and supplemental feeding. Soil quality may be tested or can be estimated by asking residents the frequency of fertilization. Other modifications could include the nutritional value of the plant species. Grasses are not normally grazed by deer, but in areas with well-fertilized lawns and golf courses, they may add substantial dietary nutrients.

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