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Bill Buffum

Scott R. McWilliams

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# Assessing the Density of Vegetation for Wildlife Cover in Regenerating Clearcuts via Analysis of Digital Imagery

**Bill Buffum**[*], **Scott R. McWilliams**

Department of Natural Resources Science, University of Rhode Island, 1 Greenhouse Road, Kingston, Rhode Island 02881, USA

[*]**Corresponding author:** Bill Buffum, Department of Natural Resources Science, University of Rhode Island, 1 Greenhouse Road, Kingston, Rhode Island 02881, USA. Tel: +14018747532; Fax: +14018744561; Email: buffum@uri.edu

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## Abstract

Increasing the availability of shrubland habitat is a major conservation priority in the Northeastern United States because many wildlife species require this habitat and its extent has been decreasing in recent decades. Conservation agencies often monitor the number of hectares of shrubland habitat created, but rarely monitor the density of the resulting vegetation because the process is tedious and time-consuming. The current study tested a new approach to assess vegetation density: Digital Imagery Vegetation Analysis (DIVA). We compared the density estimates of DIVA with four other methods (Cover Board, Robel Pole, Height of Obstruction, and Line Intercept), and assessed the advantages and disadvantages of using these five methods in shrubland studies. We concluded that DIVA offers two main advantages over the other methods: (a) it directly measures the vertical structure of the vegetation and thus better captures the complex wildlife habitat characteristics required by many wildlife, and (b) it does not rely on ocular estimates and thus avoids much of the bias associated with the other methods that estimate vertical structure. Furthermore, DIVA provides a rich documentation that permits quality control and other analyses to be conducted after the fieldwork is completed. However, DIVA is more time consuming than the other methods, thus we recommend either Robel Pole or Cover Board for routine monitoring.

## Introduction

Increasing the availability of shrubland habitat is a major conservation priority in the Northeastern United States because many wildlife species require this habitat [1-4] and its extent has been decreasing in recent decades in the region [3,5]. Conservation agencies recommend creating shrubland habitat on state and private land by clearcutting blocks of forest and allowing them to regenerate naturally [1,6]. Some of the proposed habitat creation programs are very ambitious: Williamson [7] recommended creating shrubland and young forest on 31% of forests (890,000 ha) in the Northeastern United States to restore populations of American woodcock (*Scolopax minor*) and other shrubland bird species. It is important to closely monitor these programs because the density of the resulting shrubland can be affected by various management decisions, such as selecting sites with appropriate slope, aspect and soil moisture [8], retaining coarse woody debris to reduce deer browsing [9,10], or retaining a small number of mature reserve trees in clearcuts to and provide a food source for wildlife [11].Conservation agencies can easily monitor the number of hectares of shrubland created by mapping the clearcuts with Global Positioning System (GPS) equipment, but few agencies directly monitor the density of the resulting vegetation because the process is tedious and time-consuming.

Four methods are often applied to studies of shrubland habitat: Cover Board [12,13], Robel Pole [14-17], Height of Obstruction [14, 18,19], and Line Intercept [18, 20-22]. Our study applied these four methods along with a potentially more rapid and convenient method of assessing the density of shrubland cover based on digital imagery vegetation analysis (DIVA). In recent years, DIVA has been used in a range of analyses, including calculating leaf area index [23], studying individual leaves of plants [24], assessing vegetative cover by analyzing aerial photos [25], assessing understory canopy cover by taking digital photos looking downward [26,27], assessing overstory canopy cover by taking digital photos looking upward [28], and assessing visual obstruction of prairie grasses by taking digital photos looking horizontally [29]. However, we know of no study to date that has used DIVA to assess the density of shrubland cover in regenerating clearcuts. The objective of our study was to compare the cover estimates of DIVA with the four traditional methods and assess the advantages and disadvantages of using these five methods in shrubland studies.

## Methods

In the summer of 2014, we conducted fieldwork at two sites in the state of Rhode Island where blocks of forest had recently been clearcut to create shrubland habitat for wildlife. The first site was in the Great Swamp Management Area of the Rhode Island Department of Environmental Management in South Kingstown, Rhode Island (lat 41.4564, long -71.5892) which was clearcut in 2012. This second site belonged to the Providence Water Supply Board in Scituate, Rhode Island (lat 41.7706, long -71.6490) and was clearcut in 2009.

In each site, we established 15 rectangular plots (24m x 8m) in locations without bare areas or trees taller than 3m. We did not select the plot locations randomly as our objective was to compare the five methods rather than to assess the entire sites. Each plot consisted of three adjacent 8 x 8m subplots, with a 24m transect running through the center of the subplots (Figure 1). We marked the centers of each subplot to use as locations for holding cover boards or poles (for all methods except Line Intercept), and the centers of the four sides of each subplot to use as viewing stations.

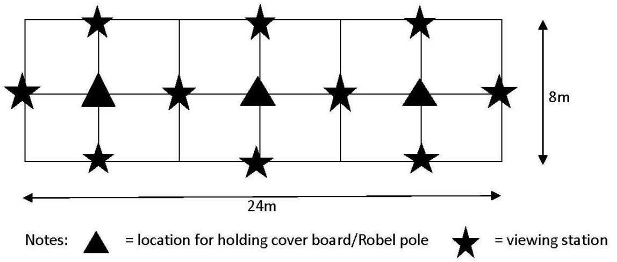


**Figure 1:** Layout of a plot with three adjacent subplots.

In each subplot, we applied five methods (DIVA, Cover Board, Robel Pole, Height of Obstruction, and Line Intercept) to assess the density of low shrub (0.5–1 m tall) and high shrub (1-2 m tall). The density of shrubs and saplings less than 2 m tall is a critical habitat attribute for many shrubland bird species [4,30]. For each height class, we used the mean density of the three subplots to produce our plot estimates.

We did not distinguish between species when estimating density. However, in order to describe the two study sites, we estimated the cover of each species detected in each site through ocular estimations using a modified Daubenmire scale with five cover classes [31]. We averaged the midpoint values of the cover classes for the 15 plots in each site to estimate the cover for each species detected (Table 1).

**DIVA:** We estimated vegetation density by taking digital photos of a vertical rectangular board constructed for this study (2 m tall and 0.5 m wide, with no markings) from a distance of 4 m and a standard height of 1 m. We selected this distance to maximize variation in foliage cover following the advice of Nudds [12]: if the distance is too great, the board will usually be fully obscured, whereas if the distance is too low the board will usually be fully visible.

We held the cover board in the center of each subplot, and took photos of it from each side of the subplot. We used a monopod to ensure that all photos were taken at the same camera height of 1 m. We recorded the plot number and photo direction on a small white board that we held next to the cover board in the original photos. We processed the photos using ImageJ, a public domain Java image processing program [32] which allows the user to (a) straighten the photos of the cover board when necessary, (b) crop the photos to the extent of the cover board, including the lower portion of the board that is obscured by vegetation, and (c) convert the photos to binary black and white which allows for an automated calculation of the percentage of the cover board obscured by vegetation. We ran separate analyses for the top half of the board, the bottom half, and the entire board. See Figure 2 for examples of original, cropped and binary photos of the entire board.

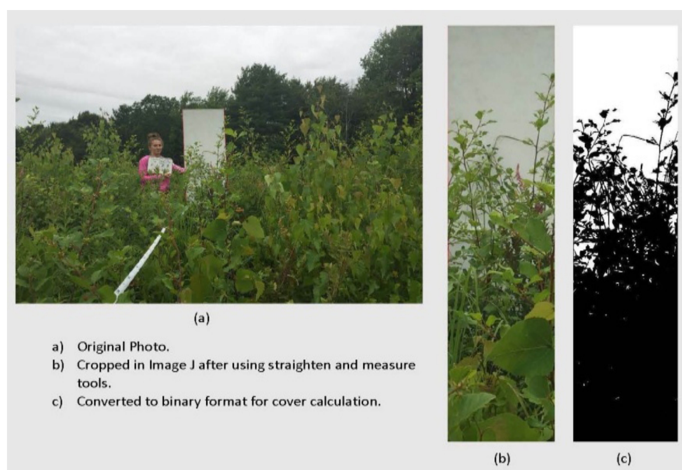


**Figure 2:** Example of original, cropped and binary photos used for an automated calculation of the percent of the cover board obscured by vegetation.

**Cover Board:** We estimated vegetation cover by making ocular estimates of the percentage of a rectangular cover board obscured by vegetation in four 0.5 m intervals [12,13]. We used a 2 m tall and 0.25 m wide cover board that our university has used in other field studies, which includes markings for each 0.5 m interval. We held the cover board in the center of the subplot, and took readings of each 0.5m interval from the four sides of the subplot.

**Robel Pole:** The approach was similar to Cover Board, but used a vertical pole (2 m tall, 3 cm diameter, with markings for each 10 cm) instead of a board for the ocular estimates [14-17]. We recorded the percentage of the pole that was obscured by vegetation in four 0.5m intervals.

**Height of Obstruction:** We used the same pole described above to estimate the lowest height of the vertical pole that was not obscured by vegetation [14,18,19]. This involved only one reading from each side of the subplot.

**Line Intercept:** We estimated vegetation cover in two height classes (0.5-1 m, 1-2 m) by recording the amount of vegetation that covered each meter of the transect [18,20-22]. Our transects were 24 m long, and passed though the center points of the three subplots.

We analyzed the results using IBM SPSS Version 24, and tested for differences between the cover estimates of DIVA and the four other methods, and for correlations. We ran separate tests for two height classes (0.5-1 m, 1-2 m) and for the combined height classes (0.5-2 m). A Kolmogorov-Smirnov test revealed that the data for some height classes did not have normal distributions (Table 2), so we used non-parametric tests to produce consistent results for all height classes. We tested for differences between medians with Wilcoxon Z (exact) and for correlations with Kendal's Tau.

## Results

### General

We detected 28 species in the two study areas: 18 species at Great Swamp dominated by *Acer rubrum* and *Smilax rotundifolia,* and 16 species at Providence Water dominated by *Betula populifolia* and *Frangula alnus*, with only five species common to both sites (Table 1). Neither of the sites included wetlands, but the Providence Water site was more xeric and included a very different species mix with lower and less dense vegetation.

| Scientific Name | Common Name | Average Cover (Percent) * | |
|---|---|---|---|
| | | Great Swamp | Providence Water |
| *Acer rubrum* | Red maple | 69 | 8 |
| *Achillea millefolium* | Common yarrow | | 5 |
| *Baptisia tinctoria* | Yellow wild indigo | | 14 |
| *Betula populifolia* | Grey birch | 29 | 66 |
| *Clethra alnifolia* | Sweet pepperbush | 30 | |
| *Comptonia peregrina* | Sweet fern | | 6 |
| *Dennstaedtia punctilobula* | Hay-scented fern | 6 | |
| *Rhamnus frangula* | Glossy buckthorn | | 47 |
| *Gaylussacia baccata* | Black huckleberry | 25 | |
| *Hamamelis virginiana* | American witch-hazel | 38 | |
| *Ilex opaca* | American holly | 15 | |
| *Osmunda cinnamomea* | Cinnamon fern | 26 | |
| *Parthenocissus quinquefolia* | Virginia creeper | | 12 |
| *Panicum clandestinum* | Deer tongue | | 1 |
| *Pinus strobus* | White pine | | 1 |
| *Populus tremuloides* | Quaking aspen | | 18 |
| *Quercus bicolor* | Swamp white oak | 23 | |
| *Quercus palustris* | Pin oak | 7 | 1 |
| *Rhododendron viscosum* | Swamp azalea | 7 | |
| *Rubus hispidus* | Dewberry | 7 | 12 |

| | | | |
|---|---|---|---|
| *Rubus occidentalis* | Black raspberry | | 7 |
| *Sassafras albidum* | Sassafras | 57 | |
| *Smilax glauca* | Catbrier | 12 | |
| *Smilax rotundifolia* | Common greenbrier | 71 | |
| *Toxicodendron radicans* | Poison ivy | 7 | 7 |
| *Vaccinium angustifolium* | Lowbush blueberry | 25 | 1 |
| *Vaccinium pallidum* | Early lowbush blueberry | 13 | |
| *Vitis labrusca* | Fox grape | | 25 |
| * We estimated the cover of each species by averaging the midpoint values of the cover class estimates for all plots in each site. | | | |

**Table 1:** Plant species detected in the two study areas and cover by species.

The median cover estimates of DIVA were significantly higher than the other methods in 18 of 22 site/height class combinations, and there were no cases of the DIVA estimates being significantly lower than any method in any height class in either site (Tables 2 & 3).

| Height Class | Site | Result | Percent Cover | | | | |
|---|---|---|---|---|---|---|---|
| | | | DIVA | Robel Pole | Cover Board | Height of Obstruction | Line Intercept |
| Combined height classes-0.5-2 m | Great Swamp | Mdn | 37 | 34 | 30 | 16 | NA |
| | | M | 37 | 35 | 31 | 17 | NA |
| | | SD | 15 | 13 | 13 | 13 | NA |
| | Providence Water | Mdn | 27 | 15 | 17 | 7 | NA |
| | | M | 26 | 20 | 22 | 12 | NA |
| | | SD | 19 | 18 | 19 | 15 | NA |
| 0.5 – 1 m | Great Swamp | Mdn | 55 | 56 | 46 | 45 | 27 |
| | | M | 56 | 55 | 47 | 43 | 29 |
| | | SD | 15 | 15 | 15 | 28 | 10 |
| | Providence Water | Mdn | 48 | 33 | 39 | 22 | 21 |
| | | M | 43 | 35 | 39 | 30 | 27 |
| | | SD | 25 | 27 | 28 | 31 | 17 |
| 1 – 2 m | Great Swamp | Mdn | 26 | 21 | 20 | 0 | 6 |
| | | M | 28 | 25 | 23 | | 7 |
| | | SD | 16 | 14 | 14 | | 7 |
| | Providence Water | Mdn | 14 | 8 | 8 | 0 | 4 |
| | | M | 18 | 13 | 13 | | 7 |
| | | SD | 17 | 16 | 15 | | 7 |
| **Notes:** Shaded attributes have normal distributions and include M and SD values. NA = not available because Line Intercept results for different height classes cannot be combined. | | | | | | | |

**Table 2:** Median (Mdn), mean (M) and standard deviation of Mean (SD) cover estimates by method and site (N=15 per site) and normality of the distributions.

| Height Class | Site | Z Scores for differences with DIVA | | | |
|---|---|---|---|---|---|
| | | Robel Pole | Cover Board | Height of Obstruction | Line Intercept |
| Combined height classes: 0.5 – 2 m | Great Swamp | *NS* | -3.764** | -5.807** | NA |
| | Providence Water | -2.929** | -2.150* | -5.119** | NA |
| 0.5 – 1 m | Great Swamp | NS | -3.595** | -2.602** | -5.582** |
| | Providence Water | -2.737** | *NS* | -2.613** | -3.493** |
| 1 – 2 m | Great Swamp | *NS* | -2.997** | -5.841** | -5.412** |
| | Providence Water | -2.557** | -2.139* | -5.514** | -5.514** |
| **Notes:** * significant at the 0.05 level (2-tailed). ** significant at the 0.01 level (2-tailed). NA = not available because Line Intercept results for height classes cannot be combined. Shaded attributes have normal distributions. NS = not significant. | | | | | |

**Table 3:** Wilcoxon Test (Z scores) for differences between median cover estimates of DIVA and other methods by site and height class (N = 15 per site).

The DIVA cover estimates exhibited significant correlations with the other methods in 19 of 22 site/height class combinations, with the strongest correlations with Robel Pole, slightly weaker correlations with Cover Board, and considerably weaker correlations with Height of Obstruction and Line Intercept (Table 4).

| Height Class | Sites | Kendal Tau correlations with DIVA | | | |
|---|---|---|---|---|---|
| | | Robel Pole | Cover Board | Hieght of Obstruction | Line Intercept |
| Combined height classes – 0.5 – 2 m | Great Swamp | .810** | .689** | .448* | NA |
| | Providence Water | .619** | .657** | .657** | NA |
| 0.5 – 1 m | Great Swamp | .543** | .619** | .440* | NS |
| | Providence Water | .619** | .676** | .638** | NS |
| 1 – 2 m | Great Swamp | .733** | .657** | NS | .371* |
| | Providence Water | .593** | .651** | .443* | .591** |
| **Notes:** * significant at the 0.05 level (1-tailed). ** significant at the 0.01 level. NA = not available because Line Intercept results cannot be combined for height classes. Shaded attributes have normal distributions | | | | | |

**Table 4:** Correlations (Kendal Tau) between DIVA Cover estimates with four other methods by site and height class (N = 15 per site).

In terms of time in the field, DIVA was comparable to the other field methods, as most of the time for all methods was involved in laying out transects and locating positions for taking readings or photos. DIVA did not require separate estimates for each height class as did the other methods, but a comparable amount of time was spent recording the plot number and photo direction on the small white board and ensuring that it was visible in the photo. Line Intercept required measuring the vegetative cover over the entire length of each transect, but it was not necessary to record any data to the left and right of the transects as in the other methods, and one person could record all of the data whereas two persons were required for the other methods.

However, processing the photos for DIVA was very time consuming: we found that an experienced technician required 1.2 hrs per plot in the office, as compared to approximately 10 minutes for each of the other methods. Thus, DIVA required much more total time than the other four methods.

## Discussion

We compared five methods for estimating shrubland cover in regenerating clearcuts. Each method offers advantages and disadvantages - unlike forest tree monitoring; there is a lack of precision and uniformity in the monitoring of shrubland vegetation [22]. Like DIVA, Cover Board, Robel Pole and Height of Obstruction assess vegetation density by taking horizontal readings of a vertically held board or pole. Other studies have found this general approach to be more effective than the vertical readings of Line Intercept in capturing the complex wildlife habitat characteristics influenced by mechanical, optical and thermal density properties of vegetation [12,16]. As we expected, our DIVA results were closely correlated with Cover Board and Robel Pole. However, DIVA produced significantly higher cover estimates in both of our study sites. After re-examining our binary photos, we became more confident in the DIVA cover estimates, and assume that our ocular estimates slightly under-estimated the density when using the Cover Board and Robel Pole methods. Other studies have also concluded that ocular estimates that increase the likelihood of observer bias [26,29].

The cover estimates from Height of Obstruction and Line Intercept were much lower and more weekly correlated with DIVA, which we attribute to the difference between the methodologies. Height of Obstruction measures horizontal density as does DIVA, but only considers the lower portion of the pole that is fully obscured. This method was designed for grasslands that generally would not obscure much of the vertical pole above the recorded height of obstruction. However, shrubby vegetation, in which Height of Obstruction has also been applied [19,33], is much more likely to obscure the higher sections of the pole even though the lower portions may be visible. This explains why our Height of Obstruction cover estimates were lower. Line Intercept is even more different from DIVA, as it measures vegetation density by looking down at a transect rather than looking horizontally at a board or pole. Furthermore, Line Intercept is considered to be most appropriate for sparsely vegetated shrubland [34], whereas shrubland in the Northeastern United States tends to be densely vegetated. These findings make us question the validity of using either Height of Obstruction or Line Intercept to estimate the density of shrubland cover in the Northeastern United States.

We hoped that DIVA would be less time-consuming than the other methods, but this was not the case due to the time required to prepare the photos for analysis. The ImageJ software converted the photos to a binary format before doing an automatic density calculation, but we had to carefully check each binary photo and adjust the sensitivity to eliminate false positive or false negative readings. We could have limited this problem by taking all of our photos on one overcast day [26], but this would not be practical for assessing a large number of plots. In theory our method could be streamlined by reducing the number of photos per subplot from four to two, which could be achieved by eliminating the two photos that were taken in our study from points perpendicular to the transect. In addition to reducing the number of photos, this approach would allow the study team to move across the study area in a straight line, which would be more efficient. The photo processing time could also be reduced by making one estimate of density for the combined height classes, rather than separate estimates for high and low vegetation as we did.

## Conclusions

We concluded that DIVA is a promising method for monitoring the density of vegetation in areas clearcut to produce shrubland habitat. Monitoring these areas is critical in the Northeastern United States because the extent of this habitat is decreasing, and the public often has a negative impression of clearcutting. DIVA offers two main advantages over the other methods used in the study: (a) it directly measures the vertical structure of the vegetation, and (b) it does not rely on ocular estimates and thus avoids much of the bias associated with other methods that estimate vertical structure. Furthermore, the photos provide a rich documentation that permits quality control and other analyses to be conducted after the fieldwork is completed. However, DIVA is more time consuming than the other methods, and is probably not appropriate for routine monitoring, for which we recommend either Robel Pole or Cover Board.

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