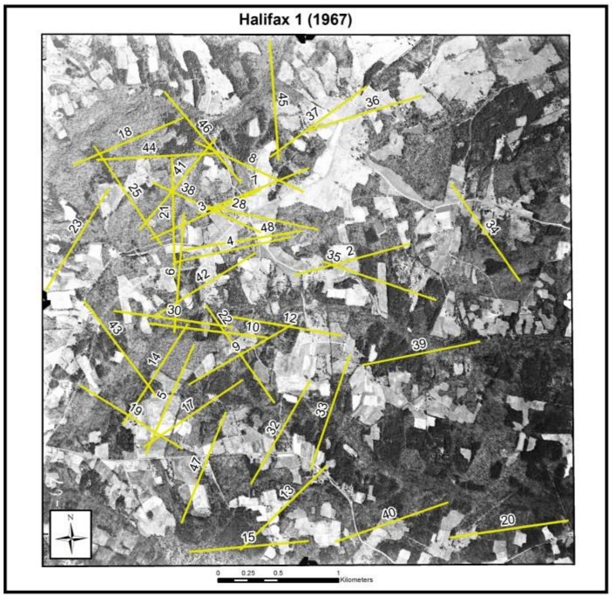
Evaluating Temporal Differences in Land Cover: Implications for Managing Bobwhite at the Landscape Scale in Virginia



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Introduction

The *Colinus virginianus* (northern bobwhite quail, Linneas 1758) has exhibited population declines across its range. This trend has been drastic in many locations including the Commonwealth of Virginia. Bobwhite populations have decreased by over 80% in many locations where it was once a common species and popular game bird.

A volume of research and management effort has been aimed at understanding and mitigating this decline. A number of factors may be contributing to bobwhite population decline including habitat quantity, habitat quality, predation, invasive species and health (Brennan 1991). Of these, habitat-related factors have emerged as the most significant contributor to bobwhite population declines.

Bobwhite quail prefer landscapes that contain a mix of grasslands and woody shrub areas that provide food and cover during all phases of their life cycle (Roseberry and Sudkamp 1998, Seckinger et al. 2010, Stoddard 1931, White et al. 2005). Croplands were also an important component of good bobwhite habitat. Not only were these types more prevalent in the past, but may have been arrayed in a way that further-improved their value to bobwhite quail. Smaller patches, greater edge lengths, and shorter distances between good habitat blocks likely resulted in increased habitat quality and greater nesting success (Guthery 1999, Riddle et al. 2010). Understanding both the composition and the juxtaposition of vegetation and land uses is critical for identifying quality bobwhite habitat over the landscape.

While these types once comprised a significant portion of the landscape in the Piedmont and Coastal Plain of Virginia where bobwhite populations were the highest, a trend of increasing forest (particularly pine plantations) and developed land on areas once used for agriculture has decreased the amount of types favorable to bobwhite quail (Felix et al. 1986). Further, changes to aspects of crop production including planting techniques, crop species (Barnes et al. 1995), and additives like herbicides and pesticides, have altered the value of remaining agricultural lands for bobwhite.

Current bobwhite management effort focuses on creating or improving bobwhite habitat on private lands. Best management practices for forestry, managing field borders, and planting native warm season grasses have been demonstrated to improve bobwhite quail habitat and use. Incentive programs have increased implementation of these conservation practices on private lands, but activities tend to be opportunistic and result in small, dispersed habitat across the landscape. Thus, the overall impact of these practices is relatively small at the landscape level.

Maximizing the habitat value of as much acreage as possible would yield the best outcome for the long-term sustainability bobwhite populations; however returning the landscape to the composition, patterns, and quality of the habitat that once resulted in large bobwhite populations is unrealistic. Alternatively, if management activities focused on specific habitat components that presented the largest obstacle to increasing quail numbers then the results would be improved. Providing a way for managers to examine a landscape, and understand how to target specific elements of habitat composition and arrangement could improve the overall success and maximize the effectiveness of limited resources.

Project Goal and Objectives

The goal of this project was to improve bobwhite habitat restoration efforts by identifying missing or degraded habitat elements on the landscape. Our approach involved examining landscapes in Southern Virginia from both the past and present to quantify changes and to determine which factors, if any, changed. Understanding how these landscapes have changed will assist habitat managers in their restoration and, presumably, improve bobwhite quail populations.

This was accomplished by comparing contemporary landscapes to the past to determine which elements have decreased and, presumably, resulted in a lower overall value including the amount of bobwhite quail habitat as well as the juxtaposition. This information may allow habitat managers to identify which elements in the contemporary landscape, if mitigated, would have the largest proportional impacts to bobwhite habitat value thus improving not only the local site but the landscape as well.

To accomplish this goal, we needed to identify a way to:

- evaluate both contemporary and historic landscapes effectively.
- quantify the differences observed to describe what changes, if any, occurred.

Once identified, those changes could serve as the focus of habitat restoration and habitat improvements would result in maximum benefit.

For example, if through comparison to more quail-beneficial landscapes of the past, we observe that the total amount of favorable bobwhite edge (e.g., hedgerows or weedy ditches) has decreased even though the overall composition of open areas has remained the same, then perhaps targeting available resources to install and maintain more of these edges would provide the best outcome. The new features would work in concert with existing favorable habitat patches to improve the landscape as a whole. It would also assist land managers in identifying key land owners, practices, or incentive programs to provide the best opportunities and results.

Methods

The primary analysis tool used for this project was photointerpretation. We examined available aerial photographs of seven study sites and measured bobwhite habitat metrics. All analysis was performed in the digital environment within a geographic information system (GIS).

Study sites were selected based on previous mapping efforts (Halifax County) and areas of interest submitted by the VDGIF (Sussex County). We selected 5 areas covering Halifax County and 2 areas in Sussex (Figure 1). It is important to note that the Sussex County sites were not chosen randomly and should not be interpreted as representative of the greater landscape.

Aerial Photographs

We identified available aerial photography for both the present and past time periods. Contemporary aerial photographs for the study sites were available for 2013 through the Virginia Base Mapping Program (VGIN 2013). These images were captured in true-color during a leaf-off period in the early spring season; therefore delineations of seasonal vegetation (e.g., types of row crops) could not be identified directly.

Historic aerial photography was obtained using the Earth Explorer tool provided by the United States Geological Survey (USGS). Images were reviewed by a photointerpreter to determine if the photographs contained sufficient detail and seasonality to effectively delineate the habitat features desired. Photographic sets from 1967-1969 were available at sufficient detail for all study sites but required additional image processing in order to georeference and allow spatial comparisons to contemporary images.

We used tools in ERDAS Imagine (Intergraph Corporation of Hexagon, Madison AL) to georeference the historical aerial photographs by selecting ground control points readily identifiable in the contemporary image (e.g., buildings, road intersections, etc.). While this approach could not assure absolute spatial agreement in images, the estimated accuracy was determined to be sufficient to proceed with the analysis.

Bobwhite Habitat Classes

We developed a land cover classification system specifically for this project. The system reflects land cover types in terms of structure rather than floristics. Bobwhite respond favorably to “early successional” vegetation types on the landscape including perennial native grasslands, row crop, hedgerows, and other woody non-forest types (Stoddard 1931).

We proposed a basic 12-class system (Table 1) that was reviewed and accepted by the VDGIF for use in this study. The types were selected based on their general use by bobwhite and our ability to accurately identify them in both past and present aerial photography.

Transects

Previous studies of bobwhite quail habitat comparing contemporary and historic landscapes focused on composition as depicted by habitat patches represented by polygons (CMI, previous unpublished work). While this method can be effective (particularly at very large scales) it is both difficult and expensive to replicate across landscapes at a sufficient scale to capture the detailed features bobwhite respond to on the landscape. We developed a technique that allowed photointerpreters to identify and delineate features at a large scale (i.e, greater than 1:6,000) over a relatively wide geographic area using transects, represented as line and point features, rather than polygons.

Transects were allocated in two ways. Transects for the Halifax study sites were allocated by randomly generating coordinate points within the photograph footprint. We then centered a 1-km transect on that point radiating in a random direction. Transects not entirely contained in the image were eliminated and we attempted to achieve between 35 and 40 full transects per image.

Transects in the Sussex county sites (i.e., the Focus Area and Reference Area) were allocated similarly except that 1km transect center points were systematically generated across the area starting from a randomly selected point and arrayed in a random direction (Appendix 2). This approach ensured that transects did not intersect each other and that the sampling effort was distributed evenly across the image area.

Identification and Delineation

Photointerpreters delineated the land cover composition by segmenting each transect according to the classification system. The minimum length for each segment was approximately 3-5 m according to type. Each segment was attributed with the corresponding habitat class and length and given a unique identifying number in the GIS (Figure 2).

In addition, we marked all habitat interfaces with a point feature aligned to the transect allowing us to identify additional large-scale features important to bobwhite quail, such as vegetated fence rows, that would otherwise be too small to represent. Each point was attributed with both the "from" type and the "to" type (Figure 3). If feature was too small to have representation as a segment (e.g., a row of newly planted pine seedlings) then it was attributed as both the "from" and "to" type (e.g., 55 designated a thin hedgerow). Points were also attributed with the identification number of the transect on which it was located.

We then assigned a value of either 0 or 1 to all the edge values (comprised of the "from" and "to" type codes) in an edge matrix. These assignments were made by VDGIF bobwhite experts by determining whether the edge between two types was beneficial to bobwhites or not. The resulting matrix was used to assign values to each unique edge value (Table 2).

Analysis

We compared observed differences between landscape composition, segment length, and the number of favorable quail edges at the site and transect level with Student's t-tests. All statistical analyses were performed using JMP Pro 11 (SAS Institute Inc. Cary, NC). We assumed results to be statistically significant at an alpha-level of 0.1 unless otherwise stated. Tabular analysis and graphing was completed in Microsoft Excel (Microsoft Corp. Redmond WA).

We compared the overall composition of each site between time periods to quantify changes in habitat classes. We calculated the overall proportion of each type by dividing each individual line segment length by the total length of all transects for the site, then summing for each class. We then quantified changes in type by comparing the proportion of the landscape from past to present. We further combined types into two general classes of bobwhite quail based on habitat requirements and labeled them as "favorable" or "not favorable" in order to account for our lack of information on the relative quality between types. This simplified our analyses to remove the potential impacts that varying degrees of "favorable" habitat might have in our analysis. Early successional classes (Field, Fallow, Shrub, Hedgerow, and Savannah) were grouped to favorable, and all other classes formed the not favorable class (forest classes, etc.). We determined the total number of segments per transect and compared between periods at each site.

We examined changes in the mean segment length for select classes within each study site. Road/Rail, Developed, and Water classes comprised few segments so they were omitted from further segment analysis. We calculated mean segment length per transect for each class and time period at each site and then compared those values using a Wilcoxon Signed Rank matched-pairs test. To examine the changes in fragmentation, we also examined the total number of edges detectable within the aerial photographs along the sampling transects. The interfaces between two habitat classes were further classified as favorable or not favorable for bobwhite using a classification matrix. Those that were classified as favorable received a value of one and not favorable was set at zero, then the total number of favorable bobwhite edges was calculated for each site for each time period.

We completed an analysis of habitat change by combining observed changes in composition, segment length, and amount of favorable edge. We summarized the results within each of these categories for each study site to facilitate interpretation of the observed changes on bobwhite habitat between the past and present.

Results

Land Cover Composition

All sites were dominated (> 50%) by forest types in both periods; although substantial changes in forest classes were observed in the Sussex County sites (Figure 4). Favorable types decreased within all of the Halifax County sites, and increased in both of the Sussex County sites (Figure 5) presumably due to recent forest harvest activities; however only differences observed at the Focus Area, Reference, and Halifax 5 sites were statistically significant ($P< 0.1$). The range of favorable habitat decline observed ranged from -2% to -49% at all the Halifax sites (Table 3).

We also calculated the changes in land cover by the proportional loss within each category where the change was greater than 5% (Table 4). The decrease in the Field classes ranged from -15.3% to -68.3% for the Halifax sites between the periods. Savannah and Shrub classes increased on the Focus Area site as a result of forest harvest and bobwhite habitat management, whereas Shrub (i.e., regenerating forest) and planted forest types increased on the Reference site.

Segment Number and Length

We determined the total number of segments per transect and compared between periods at each site. We observed significant changes in the mean total number of segments per transect at both Sussex County sites and at Halifax sites 1 and 4 (Figure 6., Table 5). We did a similar analysis with only the segments comprised of favorable bobwhite habitat (Figure 7) and observed significant differences at all sites except Halifax 2 (Table 6).

Significant changes in segment length were detected for each site and for each class in at least one site (Table 7 and Table 8). The Field class showed the most significant differences at five sites (all Halifax) with four of those decreasing in segment length. Other early successional types (Fallow and Shrub) did not exhibit significant differences in segment length, although mean length for Shrub did uniformly increase across 6 of 7 sites (only the Focus Area had a decrease).

Edge Characteristics

Favorable edges increased dramatically within both Sussex County sites particularly in the Focus Area (Table 9). Favorable edge decreased in four of five sites in Halifax County although these changes were statistically significant in only two sites; Halifax 3 and 5 (Figure 8; P-value < 0.1).

Habitat Summary

We summarized the results within each of these categories for each study site (Table 10) to facilitate interpretation of the observed changes on bobwhite habitat between the past and present. Overall, bobwhite habitat appears to have improved at both the Focus Area and Reference sites in Sussex County. Habitat significantly declined at Halifax sites 3 and 5, declined at sites 1 and 4, and remained the same at site 2; however the relative importance of the metrics used is unknown so these results may not reflect actual changes to quantifiable habitat measured on the ground.

Discussion

Our primary objective was to quantify differences in the landscape between time periods and across sites. Overall, we found that the composition, edge characteristics, and arrangements of the habitats delineated differed both through time and across the landscape. In general, the observed changes resulted in a decrease in overall bobwhite quail habitat; although there were several instances where values increased. In particular, bobwhite habitat improvement efforts in the Focus Area of Sussex County have greatly increased the available early successional habitat and landscape heterogeneity typical of good bobwhite habitat.

We observed a number of changes to landscape composition between the late 1960's and the present. The proportion of the landscape in the Field class decreased in all of Halifax County with the highest decrease in the western sites (sites 3, 4, and 5). These losses are particularly important when viewed in the context of the magnitude of change where 3 sites experienced greater than 30% decrease in the relative landscape composition of the Field class.

Much of this loss of agricultural area appears to have been to planted forests and related types (i.e., recently logged). Forested lands, in aggregate, increased within these landscapes even where the Forest class declined reflecting a shift in land management to timber production typically through short-rotation pine plantations (typically loblolly pine). Mature Planted Forest types increased across all sites with the exception of the Focus Area site where it was removed specifically for bobwhite habitat improvement.

The Fallow class remained constant through time comprising a relatively small proportion of the landscape. However areas identified as Fallow in the past time period resulted from different land use practices and were comprised of different plant species than areas identified as Fallow in the present. The latter often included areas with emerging herbaceous cover associated with recent disturbance from timber harvest. It is reasonable to assume that the proportion of areas comprised of forbs/grass mix typical of "old-field" succession is likely lower in the contemporary Fallow class than in the past. Differences in habitat quality between these types are not captured by our analysis.

Similarly, areas designated as Shrub in the 1960's were more likely to be dominated by true shrub species, whereas Shrub areas identified in the 2013 photographs had a higher probability of including regenerating hardwood stands after recent logging activity. Structurally, these may be similar (and were indistinguishable in aerial photographs) but may differ in quail habitat quality.

We also examined the change in the length of each habitat class segment at the transect level. Changes in mean length indicate expansion or contraction of types on the landscape. Coupled with the estimate of the mean number of segments per transect, this can provide insight into how patches of habitat are changing.

Field classes, in general, decreased in mean length per transect between the past and the present time periods equating to fewer, smaller patches on the landscape. The lone exception detected was for the Halifax 5 site where the mean length per transect increased while the number of segments per transect decreased. This may be the result of removing fine features such as woody hedgerows which also reduces available bobwhite habitat.

Our analysis of bobwhite edge frequency was both novel and informative. By categorizing the habitat class interfaces, we could assess the differences in frequency of favorable edges between time periods and landscapes. In Halifax County, all but one (Halifax 5) site exhibited a decrease in the proportion of favorable bobwhite edge (mean – 5.8%, range -19.9% - 4.0%) even though the total number of edges was nearly identical between periods. The largest decrease in bobwhite edge was observed at the Halifax 3 site (-19.9%) despite the total number of edges on the site increasing 18% between periods. We feel this decline in favorable bobwhite edge contributes to widespread bobwhite population decline in Virginia and has not been adequately assessed at the landscape scale.

Conversely, the sites in Sussex County that were predominantly forested in the past exhibited an increase in the number of edges in the present time period. These increases were substantial for both the focus area (281% all edges; 48% bobwhite edge) and the reference area (90% all edges; 23% bobwhite edge). This increase is largely due to the creation of savannah-like habitat within the Focus Area that generated a great deal of grass-shrub interface at the local scale. Recent timber harvest in the Reference Area suggested a similar pattern, although not as concentrated as in the Focus area.

The overall composition and arrangement of habitat classes was variable across the seven areas studied. Thus indicating that localized landscape composition, and the resulting habitat value to bobwhite, is also variable and likely results in differences in bobwhite numbers at these locations.

Our analysis did not assess the relative habitat quality of types between sites or time periods, and this could certainly further impact bobwhite populations and explain observed declines between these study periods. For example, while our methods could accurately classify fields in both the past and present aerial photographs, we cannot say which plant species comprise those fields. Fields of native warm season grasses likely comprised a larger proportion of this class in the past than they do at present, and these types would have been more favorable to bobwhite than the fescue-dominated fields of 2013. Similarly, land management practices such as tilling, herbicide/pesticide application, and harvest in the late 1960’s resulted in more favorable habitats for bobwhite than similar areas today.

Summary

This project employed a novel habitat assessment technique using both contemporary and historical aerial photography to quantify differences in landscape composition and arrangement for land cover classes important to bobwhite quail as habitat. The results suggest that the landscape in Halifax County has less favorable bobwhite habitat today than in the late 1960’s and that much of this loss was due to the conversion of agriculture to planted forests (overwhelmingly pine). In addition the present landscape contains as much, or more, fragmentation resulting in more edges; however fewer of these edges are considered to be beneficial for bobwhite quail. The combination of favorable habitat loss by area, by patch, and by edge likely magnifies the decrease in value to bobwhite and better-explains the major population decline observed.

Areas managed intensively as pine savannah in 2013 contained more favorable bobwhite quail edge than other areas studied during the present time period, and these areas had considerably more favorable bobwhite edge in 2013 than they did in the late 1960's. Whether these changes have resulted in an increased local bobwhite population is unknown.

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Table 1. Habitat classifications and descriptions used to attribute segments and edges.

Habitat Class Name	Code	Description
Field	1	All types dominated by managed herbaceous plant species including grassand/or row crop. Includes grazed pastures, hay, and row crop fields.
Fallow	2	Areas congaing long, seemingly unmanaged grass and shrub combinations. Includes areas succeeding after disturbance (e.g., 2-4 years post timber harvest) where grasses are the dominant vegetation cover.
Shrub/regeneration	3	Areas dominated by small, relatively short (< 5m), woody species. Includes areas with more shrub than grass as well as regenerating timber cuts dominated by hardwood regeneration and no apparent pine planting.
Forest	4	Areas dominated by large tree species forming a nearly continuous and closed canopy. Includes forests that are dominated by deciduous, or non-planted conifer, or mixed species.
Hedgerow	5	Areas of woody vegetation arrayed linearly on the landscape and comprised of edge forest that is less than 20m in width. Characterized by light penetration throughout the area and usually with a significant understory of shrubs, vines, and herbaceous plants.
Edge Forest	6	Portions of forest stands near non-forested edges where light penetration results in a higher density of young trees, shrubs, vines, and/or herbaceous plants. Nominally assessed for this analysis as 10m into the forest from any non-forest edge.
Planted Forest	7	Forests (typically conifer) obviously planted in rows with a closed canopy or nearly so. Understory components are not visible or are unlikely to be present based on over story density.
Road/Rail	8	Linear transportation features with non-natural surfaces. Often have "weedy" herbaceous strips associated with them particularly in historic images.
Developed	9	Areas including structures and surrounding "lawn" type grass management associated with homes, barns, and other buildings.
Water	10	Open water including ponds, lakes, or larger rivers.
Recently Logged	12	Areas where recent disturbance with predominantly non-vegetated surface (ie, dirt roads or duff) and often includes slash or other evidence of timber harvest. Presence of herbaceous plants or regeneration very limited or absent.
Savanna/Select Cut	13	Treed areas with sparse canopy where the understory (typically herbaceous) is evident in the photography. These areas are clearly not field/fallow because of the presence of mature trees.

Table 2. Matrix of edge values assigned to each possible combination of habitat classes. Values of 1 indicate favorable edge and 0 indicated non-favorable.

	Class	Field	Fallow	Shrub	Forest	Hedge -row	Edge Forest	Mature Planted Forest	Road /Rail	Developed	Water	Logged	Savanna/ Selective cut
Class	Code	1	2	3	4	5	6	7	8	9	10	12	13
Field	1	0	1	1	0	1	1	0	0	0	0	0	1
Fallow	2	1	1	1	1	1	1	1	0	0	0	1	1
Shrub	3	1	1	1	1	1	1	1	0	0	0	1	1
Forest	4	0	1	1	1	0	0	0	0	0	0	0	1
Hedgerow	5	1	1	1	0	1	0	0	0	0	0	0	1
Edge Forest	6	1	1	1	0	0	0	0	0	0	0	0	1
Mature Planted Forest	7	0	1	1	0	0	0	0	0	0	0	0	1
Road/Rail	8	0	0	0	0	0	0	0	0	0	0	0	0
Developed	9	0	0	0	0	0	0	0	0	0	0	0	0
Water	10	0	0	0	0	0	0	0	0	0	0	0	0
Logged	12	0	1	1	0	0	0	0	0	0	0	0	0
Savanna/ Selective cut	13	1	1	1	1	1	1	1	0	0	0	0	0

Table 3. Total proportion of habitat classes for each study area and time period.

	Halifax 1			Halifax 2			Halifax 3			Halifax 4		
Habitat Class	Past	Present	Change	Past	Present	Change	Past	Present	Change	Past	Present	Change
Field	29.5%	23.7%	-5.8%	41.2%	34.9%	-6.3%	42.0%	28.0%	-14.0%	25.0%	11.9%	-13.1%
Fallow	4.0%	4.8%	0.9%	2.1%	3.3%	1.2%	3.9%	2.8%	-1.1%	4.0%	7.6%	3.6%
Shrub	2.0%	5.2%	3.2%	1.4%	1.6%	0.2%	1.5%	5.4%	3.8%	6.0%	8.2%	2.2%
Forest	38.9%	34.8%	-4.1%	35.8%	34.9%	-1.0%	30.8%	29.8%	-1.1%	40.3%	35.3%	-5.0%
Hedgerow	0.4%	0.9%	0.5%	0.6%	1.2%	0.6%	1.2%	0.4%	-0.7%	0.6%	0.8%	0.2%
Edge Forest	6.1%	5.9%	-0.2%	6.0%	6.4%	0.4%	4.8%	4.5%	-0.3%	6.1%	4.9%	-1.3%
Mature Planted Forest	13.3%	16.3%	3.1%	9.4%	11.2%	1.8%	13.6%	19.2%	5.6%	15.5%	24.0%	8.6%
Road/Rail	1.0%	1.2%	0.1%	1.4%	1.1%	-0.4%	0.5%	1.3%	0.8%	0.9%	1.6%	0.7%
Developed	1.9%	3.0%	1.1%	1.1%	2.0%	0.9%	0.8%	1.2%	0.5%	1.1%	2.0%	0.9%
Water	0.4%	0.8%	0.4%	0.5%	0.6%	0.1%	0.8%	1.4%	0.6%	0.1%	0.4%	0.3%
Logged	2.6%	3.0%	0.4%	0.5%	2.9%	2.4%	0.1%	4.8%	4.7%	0.5%	2.5%	2.1%
Savanna/Selective cut	0.0%	0.4%	0.4%	0.0%	0.0%	0.0%	0.0%	1.3%	1.3%	0.0%	0.8%	0.8%

	Halifax 5			Focus Area			Reference Area		
Habitat Class	Past	Present	Change	Past	Present	Change	Past	Present	Change
Field	25.9%	8.2%	-17.7%	5.9%	5.3%	-0.6%	19.9%	20.6%	0.7%
Fallow	2.6%	2.1%	-0.5%	3.4%	12.0%	8.6%	3.8%	7.2%	3.4%
Shrub	2.7%	3.5%	0.9%	3.5%	2.3%	-1.2%	0.6%	11.8%	11.3%
Forest	32.2%	33.5%	1.3%	14.0%	5.8%	-8.2%	29.1%	7.5%	-21.5%
Hedgerow	0.7%	0.8%	0.2%	0.0%	0.2%	0.1%	0.4%	0.9%	0.5%
Edge Forest	6.0%	5.4%	-0.6%	0.4%	0.8%	0.5%	1.5%	2.4%	0.9%
Mature Planted Forest	14.2%	24.2%	10.0%	68.9%	41.1%	-27.8%	36.4%	41.4%	5.0%
Road/Rail	1.3%	0.8%	-0.4%	1.0%	1.3%	0.3%	1.7%	2.0%	0.3%
Developed	10.4%	14.7%	4.4%	0.0%	0.0%	0.0%	0.6%	0.8%	0.3%
Water	2.8%	3.2%	0.4%	0.0%	0.4%	0.4%	0.1%	0.3%	0.2%
Logged	1.3%	1.9%	0.6%	0.3%	2.3%	2.0%	0.0%	4.0%	4.0%
Savanna/Selective cut	0.0%	1.6%	1.6%	2.7%	28.6%	25.9%	6.0%	1.0%	-5.0%

Table 4. Relative change in proportion between the past and present time periods. Only instances where the class comprised more than 5% of the site during the period are included.

Habitat Class	Focus Area	Reference Area	Halifax 1	Halifax 2	Halifax 3	Halifax 4	Halifax 5
Field	-10.2%	3.3%	-19.8%	-15.3%	-33.4%	-52.4%	-68.3%
Fallow	253.5%	90.6%				90.3%	
Shrub		2013.8%	160.6%		254.2%	36.5%	
Forest	-58.4%	-74.1%	-10.5%	-2.7%	-3.4%	-12.5%	4.1%
Hedgerow							
Edge Forest			-3.9%	6.5%		-20.8%	-10.2%
Mature Planted Forest	-40.3%	13.7%	23.1%	19.6%	41.1%	55.4%	70.2%
Road/Rail							
Developed							42.0%
Water							
Logged							
Savanna/Selective cut	950.0%	-83.7%					

Table 5. Mean number of segments per transect for the past and present at each study site.

Site	N	Mean	Std Error	Mean	Std Error	P-value	Δ num	% Change
Focus	40	6.0	0.53	14.6	1.6	0.00	8.60	143%
Reference	37	9.4	0.7	16.9	1.7	0.00	7.50	80%
Halifax 1	40	16	0.94	13.8	0.7	0.07	-2.20	-14%
Halifax 2	35	12.4	0.95	13.9	0.84	0.24	1.50	12%
Halifax 3	39	13.9	0.97	14.1	1	0.91	0.20	1%
Halifax 4	36	16.7	0.73	14.2	0.81	0.02	-2.50	-15%
Halifax 5	35	13.3	0.62	12.3	0.61	0.26	-1.00	-8%

Table 6. Summary of the mean number of favorable bobwhite segments between the past and present time periods for all study sites.

Site	N	Mean	Std Error	Mean	Std Error	P-value	delta num	% Change
Focus	40	1.25	0.22	7.8	1.1	0.00	6.55	524%
Reference	37	3.0	0.45	7.0	0.9	0.00	4.00	133%
Halifax 1	40	5.82	0.48	4.6	0.4	0.05	-1.22	-21%
Halifax 2	35	4.7	0.51	5.0	0.55	0.67	0.30	6%
Halifax 3	39	6.0	0.58	4.6	0.49	0.06	-1.40	-23%
Halifax 4	36	6.1	0.48	4.2	0.51	0.01	-1.90	-31%
Halifax 5	35	4.3	0.42	3.0	0.49	0.04	-1.30	-30%

Table 7. Mean length (m) of favorable habitat per transect for each site and time period.

		Past		Present				
Site	N	Mean	Std Error	Mean	Std Error	P-value	Δ length	% Change
Focus	40	154.8	35.7	482.7	48.7	0.00	327.90	212%
Reference	37	307.1	37.8	415.1	47.7	0.08	108.00	35%
Halifax 1	40	358.5	31.7	350.4	34.2	0.86	-8.10	-2%
Halifax 2	35	453.0	42.1	409.3	46.5	0.49	-43.70	-10%
Halifax 3	39	486.2	45.1	378.6	48	0.11	-107.60	-22%
Halifax 4	36	355.7	34.0	293.0	40.2	0.24	-62.70	-18%
Halifax 5	35	318.8	33.1	163.1	31.4	0.001	-155.70	-49%

Table 8. Comparisons of mean segment length per transect between past and present time periods for select habitat classes (all values in meters). Entries in black indicate the difference is significant (P-value< 0.1). Full statistical analysis results are given in Appendix 1.

	Halifax 1			Halifax 2			Halifax 3			Halifax 4		
Habitat Class	Past	Present	Change	Past	Present	Change	Past	Present	Change	Past	Present	Change
Field	76.8	89.1	16%	143.3	121.9	-15%	154.1	91.8	-40%	73.8	48.6	-34%
Fallow	18.6	26.4	42%	12.9	16.8	30%	26.3	21.2	-19%	20.8	39.6	90%
Shrub	14.4	29	101%	8.8	13.2	50%	11.4	26.6	133%	34.1	44	29%
Forest	150.3	137.2	-9%	182.4	135.3	-26%	107.9	122.4	13%	130	136.2	5%
Hedgerow	3	8	167%	5.1	7.2	41%	7.8	2.6	-67%	4.7	7.8	66%
Edge Forest	16.8	19.8	18%	19	17	-11%	15.3	18.4	20%	14.8	14	-5%
Mature Planted Forest	67.1	75.2	12%	52.3	72.2	38%	56.6	64.8	14%	56.4	100.5	78%
Logged	20.5	23	12%	1.6	25.1	1469%	1.1	23.9	2073%	4	18.3	358%
Savanna/Selective cut	0	3.2	NA	0	0	NA	0	11.4	NA	0	6	NA

	Halifax 5			Reference Area			Focus Area		
Habitat Class	Past	Present	Change	Past	Present	Change	Past	Present	Change
Field	97.6	40.2	-59%	37.1	26.7	-28%	86.9	87.6	1%
Fallow	19.3	14.6	-24%	16	28.4	78%	25.7	15.6	-39%
Shrub	16.7	19.2	15%	23	12.1	-47%	5.2	53.9	937%
Forest	127.4	121.3	-5%	90	48.5	-46%	153.4	30.7	-80%
Hedgerow	5.7	6.1	7%	0.41	0.96	134%	2.6	7.6	192%
Edge Forest	18.9	19.4	3%	2.8	5.7	104%	8.7	8.8	1%
Mature Planted Forest	59	80.4	36%	368.6	143	-61%	153.8	121.1	-21%
Logged	13.2	12.9	-2%	3	14.8	393%	0	29.5	NA
Savanna/Selective cut	0	12.7	NA	24.5	91.8	275%	45.8	9.8	-79%

Table 9. Summary of the mean number of favorable bobwhite edge points per transect for the past and present.

		Past		Present			
Study Site	N	Mean	Std Error	Mean	Std Error	P-value	% Change
Focus	40	1.4	0.28	15	3.33	0.0002	971%
Reference	37	2.7	0.44	9.7	1.73	0.0002	259%
Halifax 1	40	6.2	0.55	5.3	0.76	0.35	-15%
Halifax 2	35	4.7	0.5	5.7	0.54	0.169	21%
Halifax 3	39	6.3	0.65	4.7	0.61	0.088	-25%
Halifax 4	36	7.2	0.64	6.6	0.98	0.6	-8%
Halifax 5	35	5	0.49	3.5	0.55	0.042	-30%

Table 10. Summary of observed landscape changes in favorable bobwhite habitat classes. "Significant" changes were determined statistically, increase/decrease are observations, and No Change is assigned when differences are less than 5%.

Site	Amount of Habitat	No. of Segments	No. of Edges
Focus	Sig. Increase	Sig. Increase	Sig. Increase
Reference	Sig. Increase	Sig. Increase	Sig. Increase
Halifax 1	No Change	Sig Decrease	Decrease
Halifax 2	Decrease	No Change	Increase
Halifax 3	Sig Decrease	Sig Decrease	Sig Decrease
Halifax 4	Sig Decrease	Sig Decrease	Decrease
Halifax 5	Sig Decrease	Sig Decrease	Sig Decrease

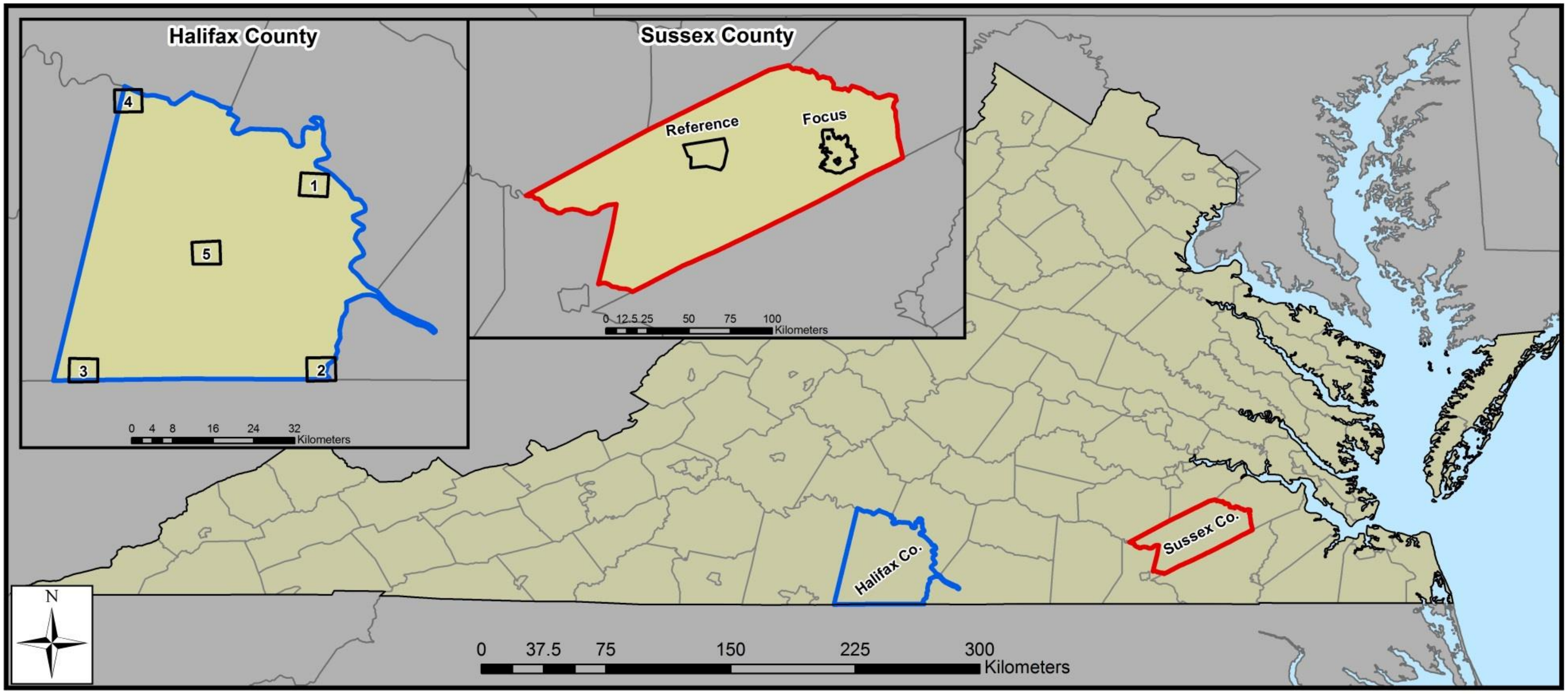


Figure 1. The study sites used for this project were located in Halifax and Sussex counties in Southern Virginia. Five sites were distributed in Halifax and labeled by number. The two Sussex County sites were labeled the "Focus Area" (where active bobwhite habitat management is ongoing) and the “Reference Area” (an area selected by VDGIF to represent the rest of the immediate region in 2013).

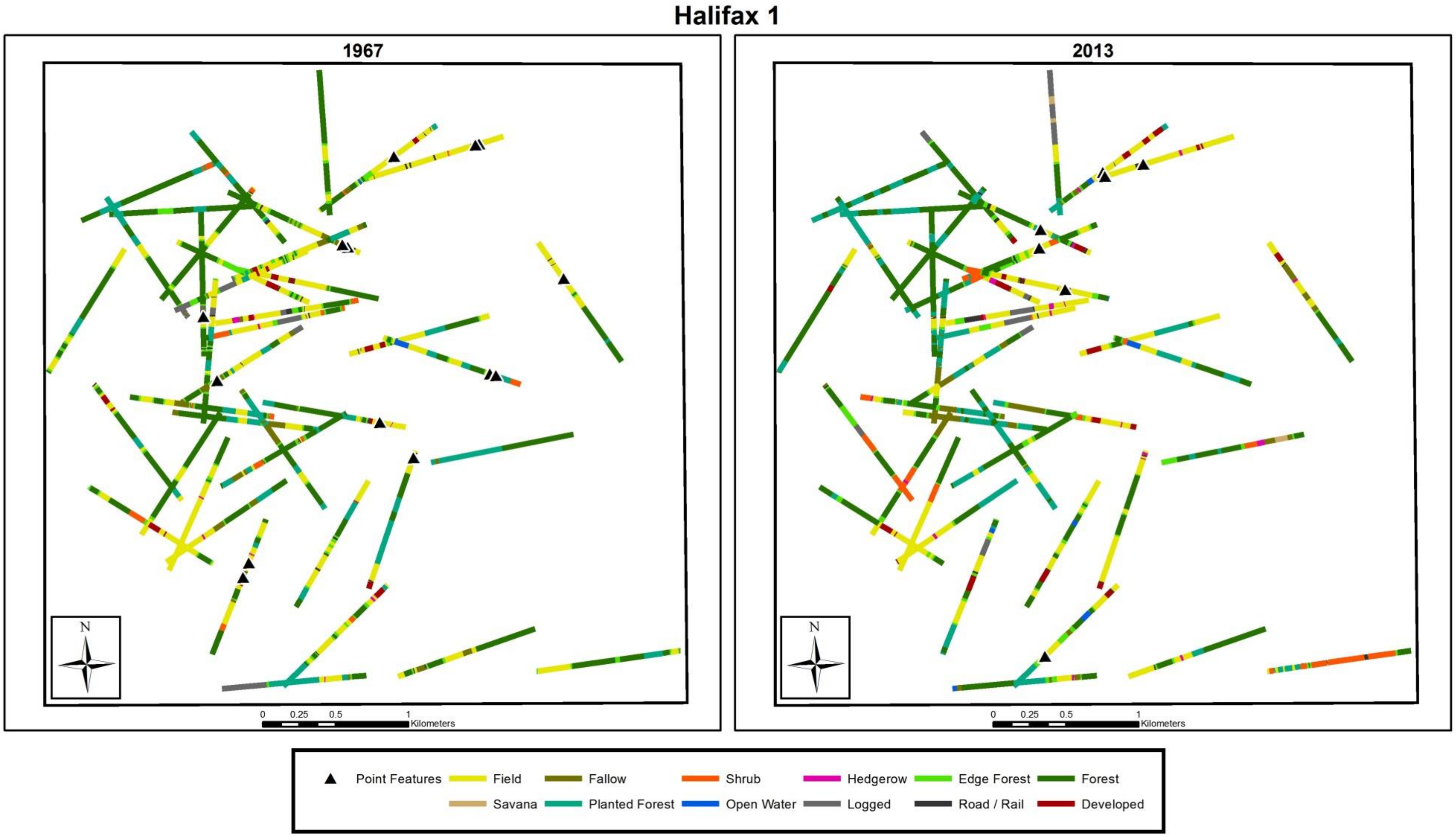


Figure 2. Example of delineated transects and edges (black triangles). Transects were classified for both the past and present time periods showing changes to segment types.

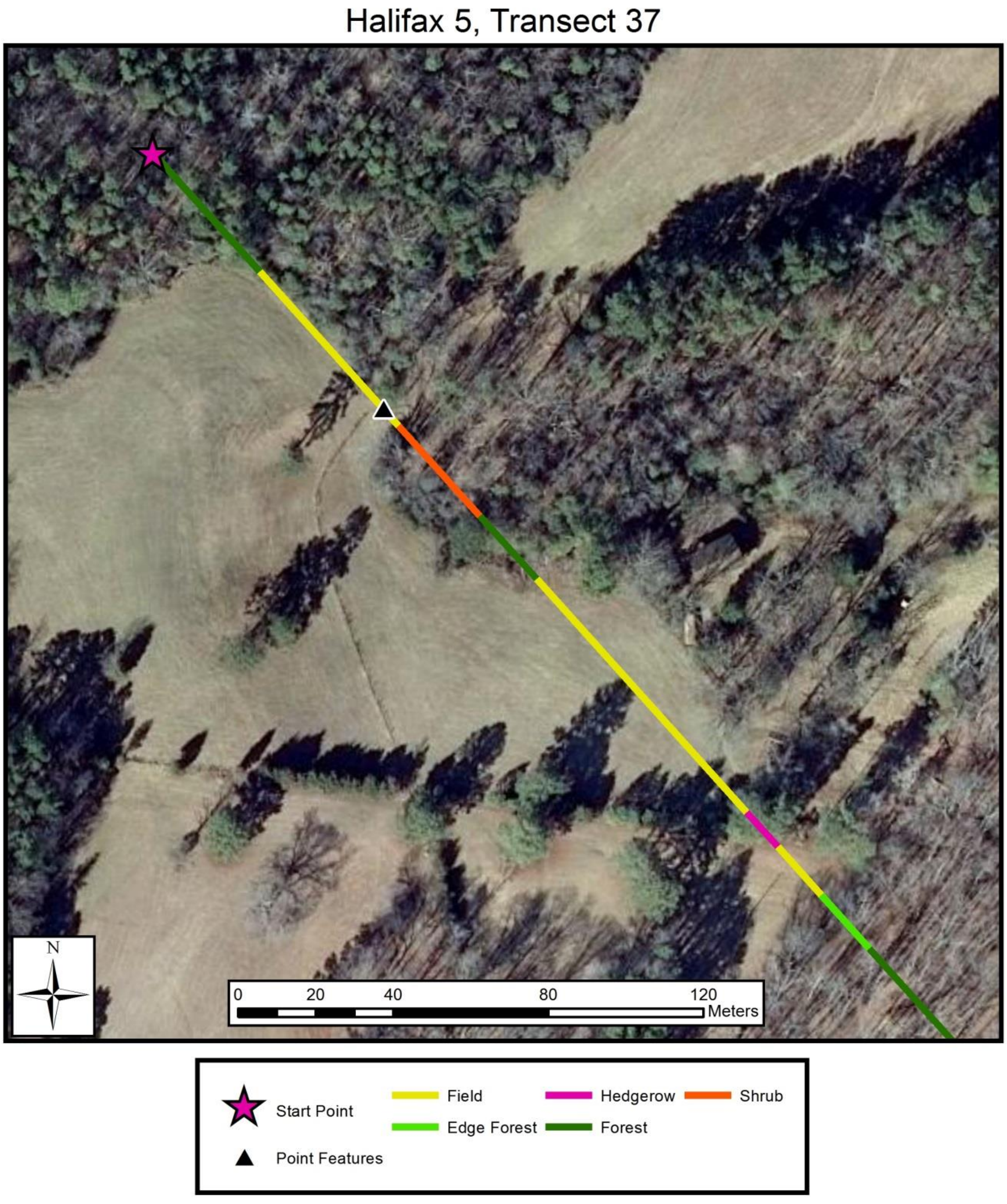
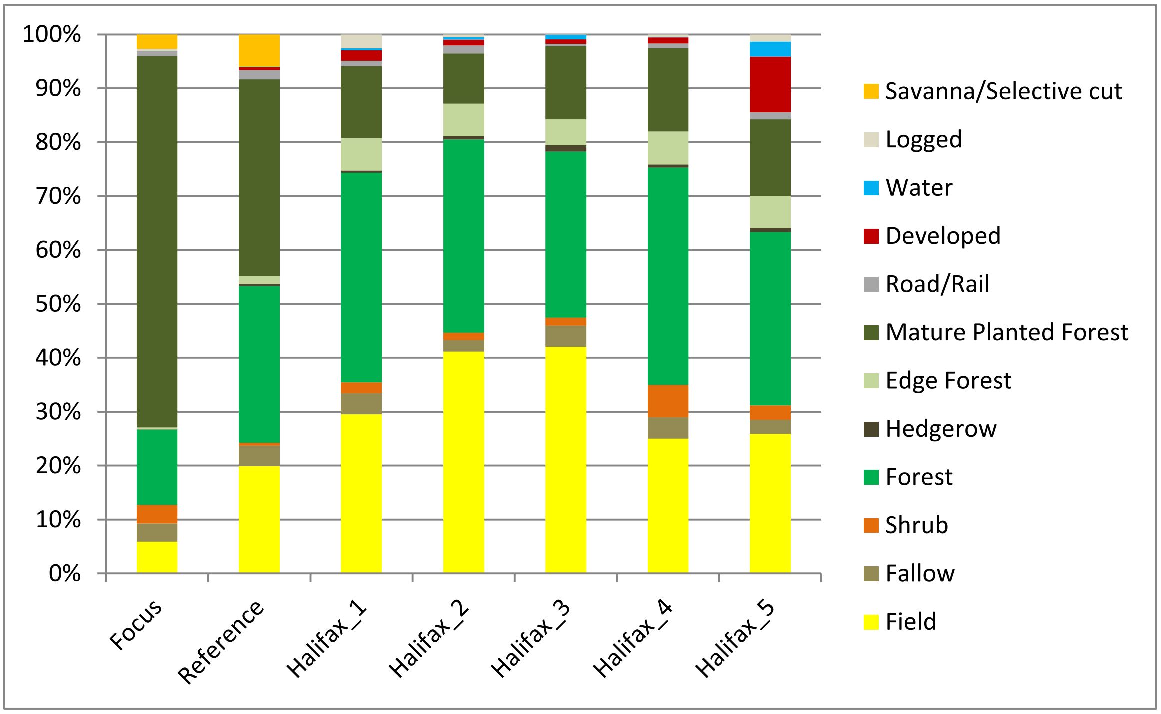


Figure 3. Close-up of a delineated transect. Each segment represents the habitat class identified in the photograph. Small features, such as a fence line (indicated by the black triangle) were recorded as point features.



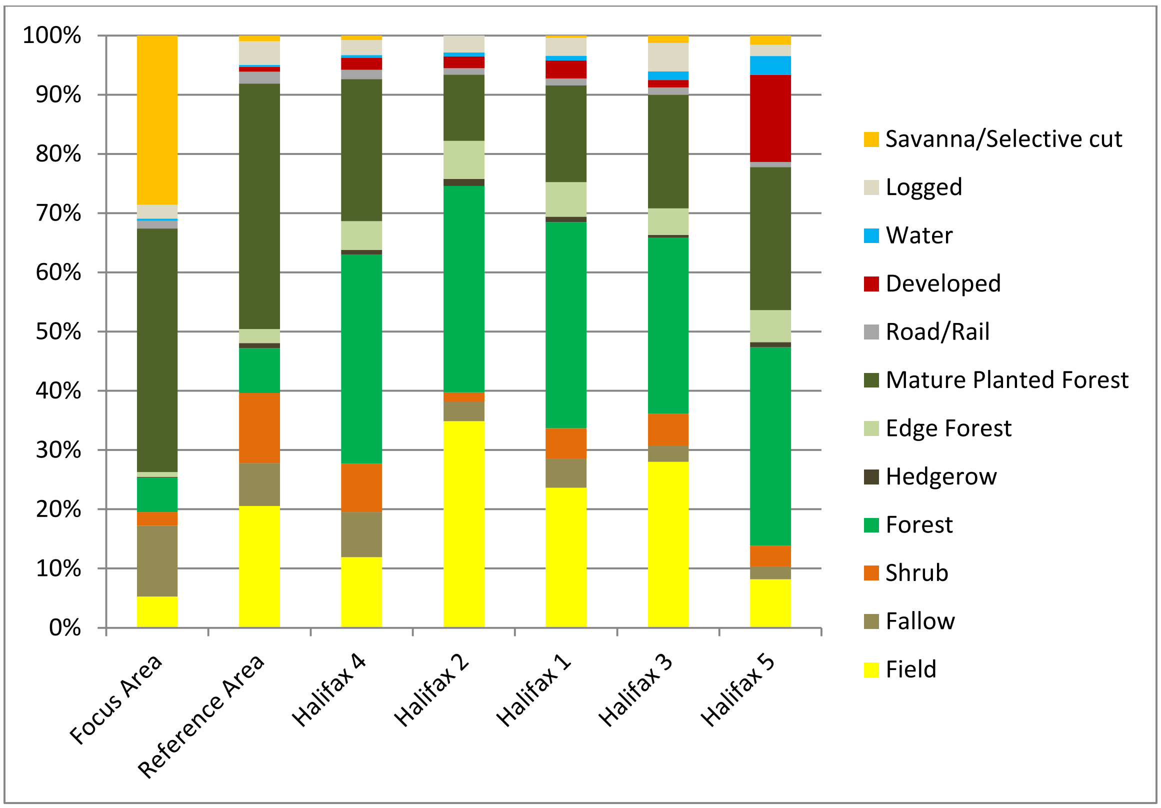


Figure 4. Comparison of the habitat class composition at each site in the past (top) and present (bottom).

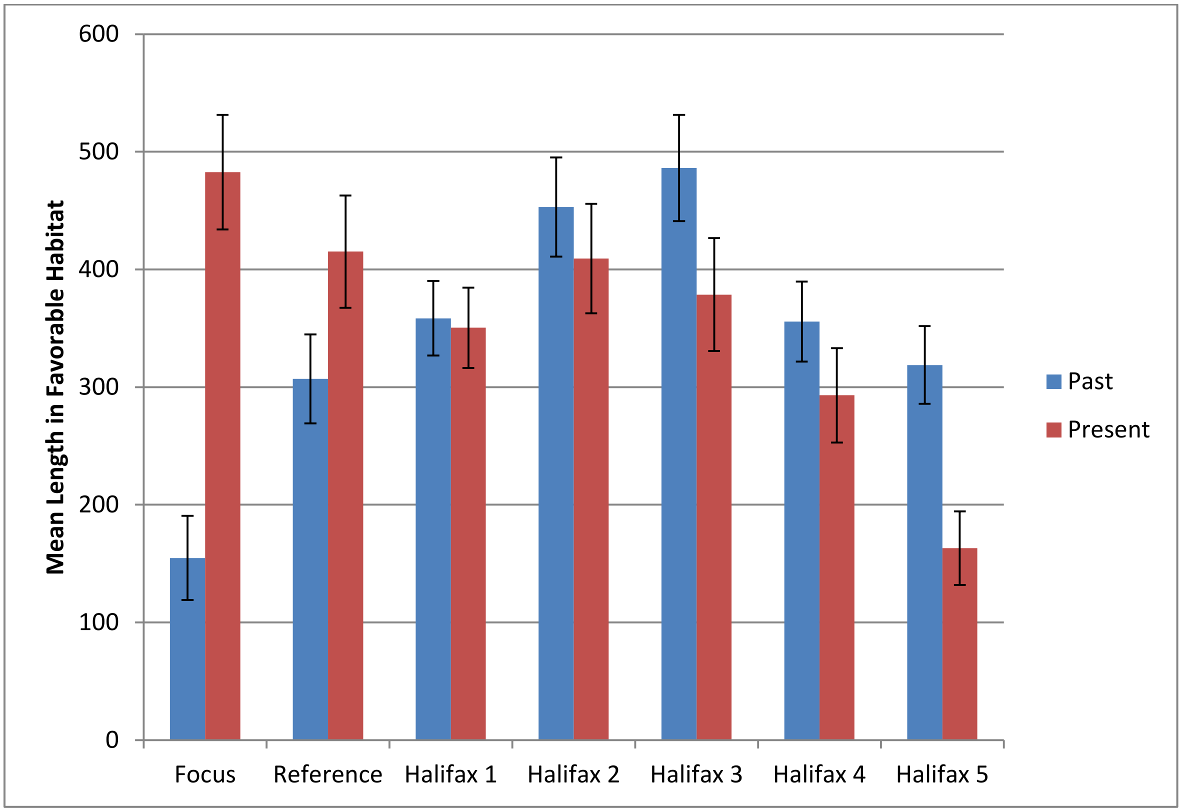
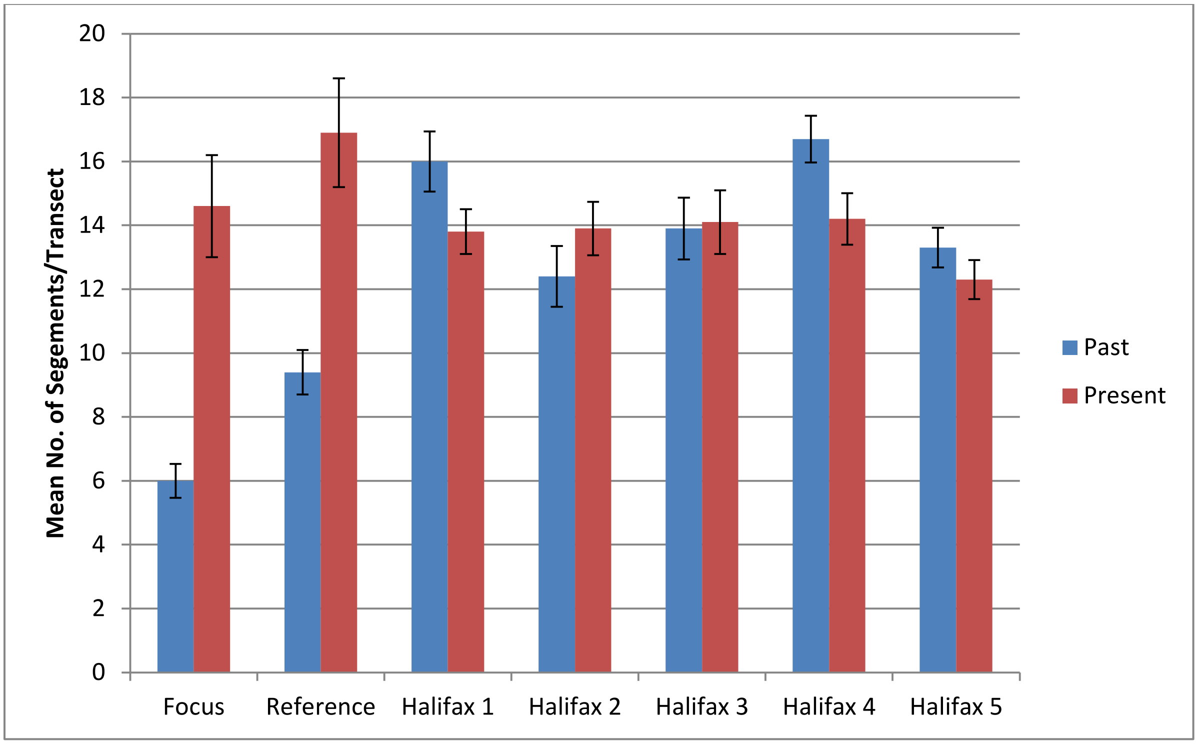


Figure 5. Comparison of the amount of favorable bobwhite habitat between the past and present time periods at each site.



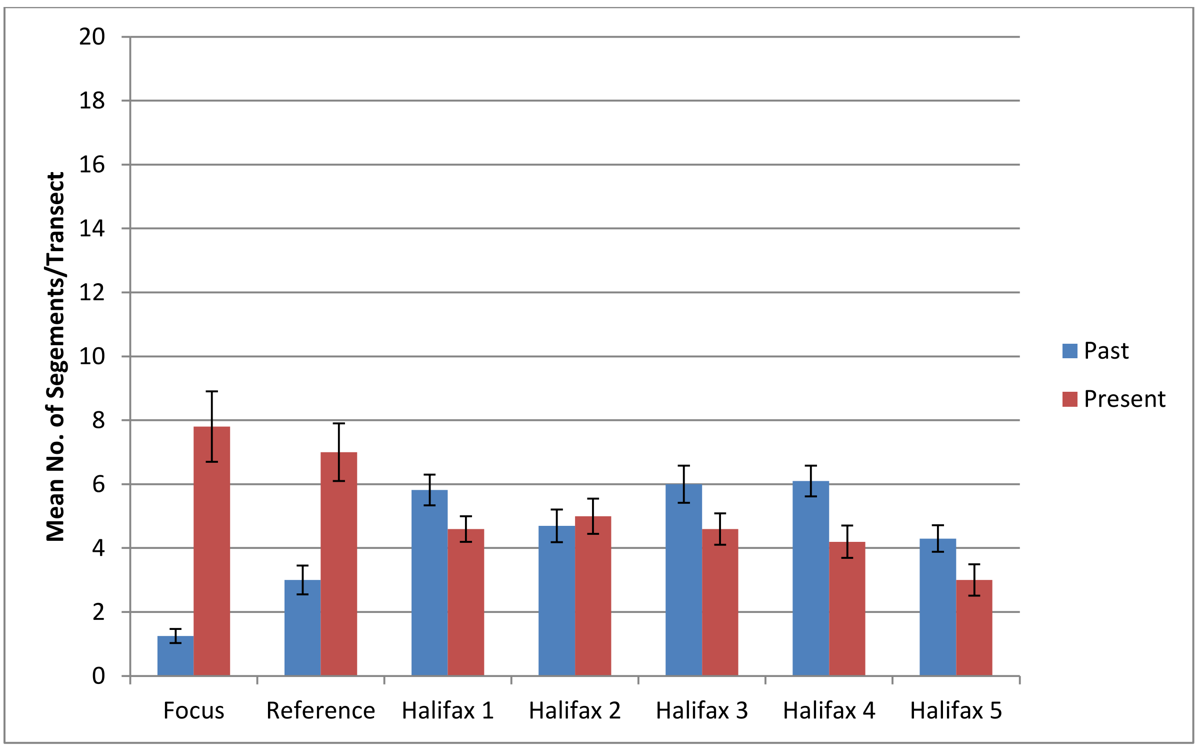


Figure 6. Comparison of the mean number of segments per transect for all types at each study site (top) and only segments classified as favorable (bottom).

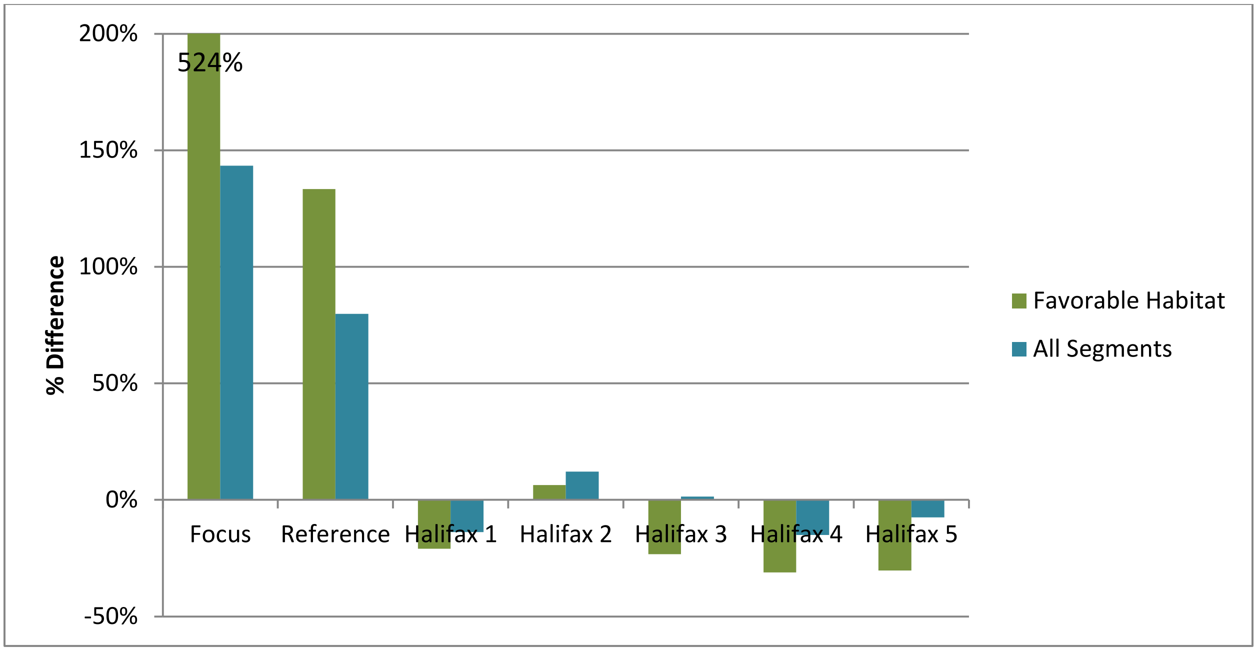
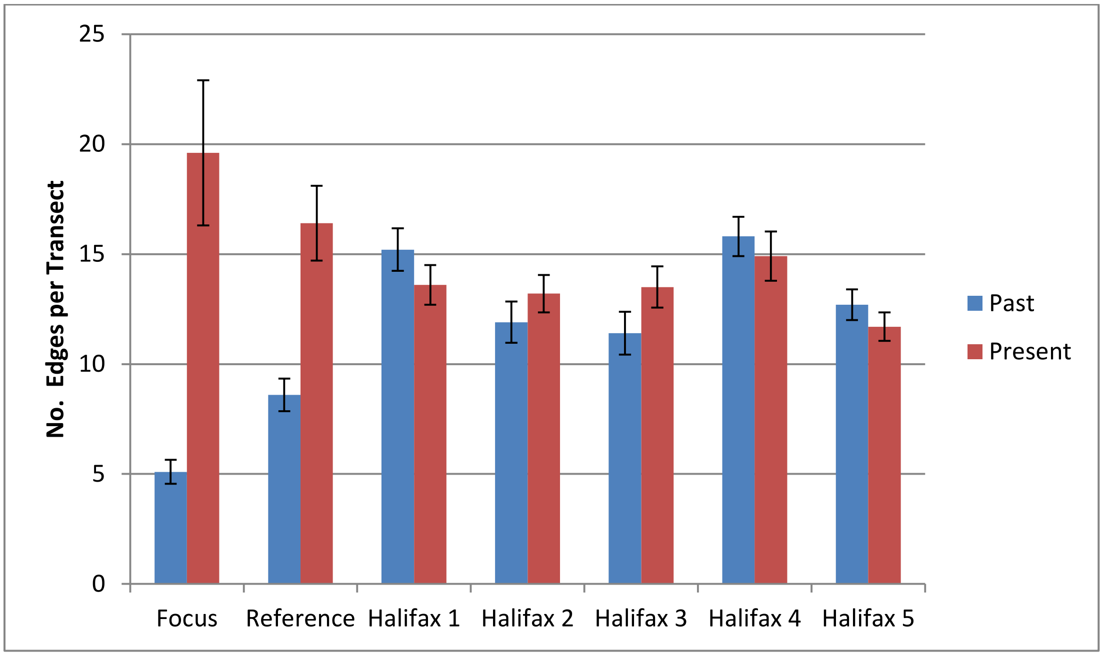


Figure 7. Comparison of the relative change of the number of segments between periods for all segments and favorable segments only.



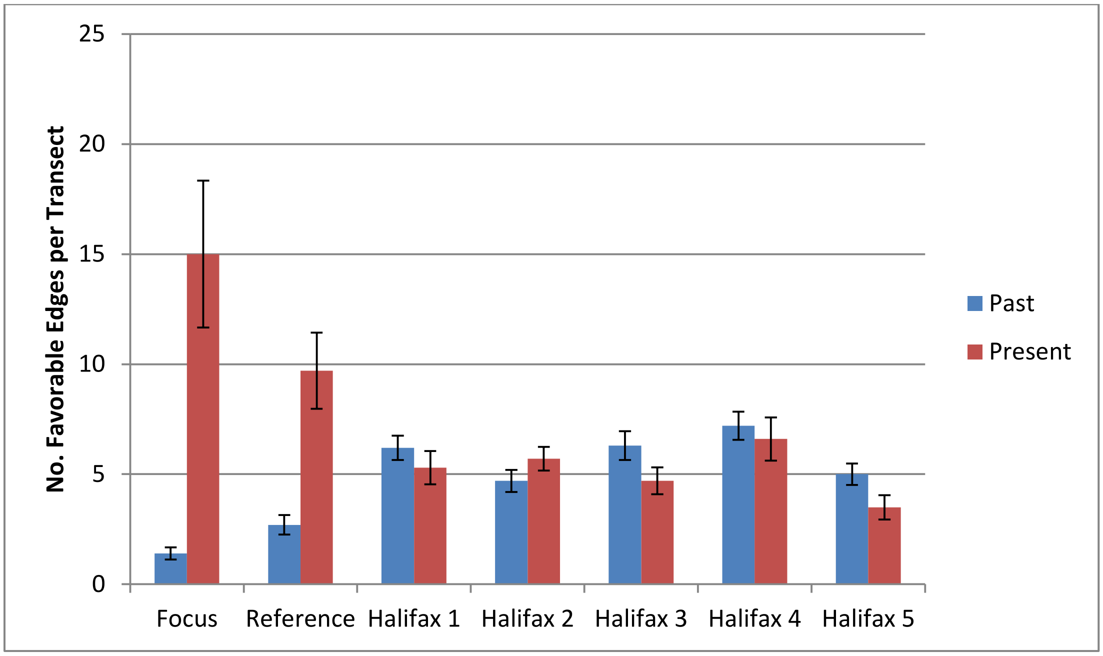


Figure 8. Graph showing the difference in the number of all edges (top) and favorable edges only (bottom) across sites for the past and present time periods.

Appendix 1 – Additional Tables

This appendix contains additional data tables corresponding to information presented in the report.

Summary tables for changes in segment length by site for each habitat class

Analyses were not completed for types Road/Rail, or Water due to low occurrence.

Field (1)	Past			Present				%
Site	N	Mean	Std Err	N	Mean	Std Err	P-value	Change
Focus	10	235.1	40.8	12	175.9	59.2	0.424	-25.2%
Reference	55	133.9	13.5	55	138.3	16.9	0.839	3.3%
Halifax 1	155	76.1	5.9	100	94.7	7.9	0.061	24.4%
Halifax 2	109	132.2	14.2	96	127.1	12.6	0.787	-3.9%
Halifax 3	153	107.1	11.1	91	120	13.5	0.464	12.0%
Halifax 4	117	76.9	5.1	58	73.9	7.5	0.734	-3.9%
Halifax 5	92	98.6	6.9	47	61.1	7.4	0.003	-38.0%

Fallow (2)	Past			Present				%
Site	N	Mean	Std Err	N	Mean	Std Err	P-value	Change
Focus	22	61.5	13.4	161	29.7	3.5	0.03	-51.7%
Reference	25	56.2	16	135	19.9	2.5	0.0339	-64.6%
Halifax 1	46	34.4	4.7	36	53.7	10.4	0.0492	56.1%
Halifax 2	24	30.5	7.2	43	26.6	5.4	0.659	-12.8%
Halifax 3	32	47.6	8.3	25	43.3	7	0.692	-9.0%
Halifax 4	51	28.3	2.8	51	53.8	9	0.009	90.1%
Halifax 5	24	38.1	6.7	17	44.1	9.3	0.301	15.7%

Shrub/Regen (3)	Past			Present				%
Site	N	Mean	Std Err	N	Mean	Std Err	P-value	Change
Focus	10	111.4	19.8	23	426.8	27.3	0.0001	283%
Reference	6	184.3	16.2	53	338.8	28.6	0.0001	83.8%
Halifax 1	20	758.1	42.9	24	725.7	30.6	0.73	-4.3%
Halifax 2	15	1911.1	28	10	1780.2	104.3	0.874	-6.8%
Halifax 3	23	2390.7	25.53	43	2280	29.6	0.007	-4.6%
Halifax 4	39	1368.2	26.5	27	1337.2	73.4	0.694	-2.3%
Halifax 5	28	174.3	15.3	22	565.1	190	0.026	224.2%

Forest (4) Site	Past N	Past Mean	Past Std Err	Present N	Present Mean	Present Std Err	P-value	% Change
Focus	45	105	53.3	31	374.2	130.6	0.0001	256.4%
Reference	68	163.9	109.3	57	290.6	20.6	0.0001	77.3%
Halifax 1	115	768.2	18.4	110	675.2	23.4	0.002	-12.1%
Halifax 2	81	1928.1	125.4	93	1663.2	145.7	0.0001	-13.7%
Halifax 3	105	2411	18.8	106	2273.3	21.8	0.0001	-5.7%
Halifax 4	121	1369.3	16.9	110	1289.7	37.8	0.057	-5.8%
Halifax 5	96	214.2	15.3	107	299.5	48.5	0.048	39.8%

Hedgerow (5) Site	Past N	Past Mean	Past Std Err	Present N	Present Mean	Present Std Err	P-value	% Change
Focus	1	16.33		3	22.7	13.1		
Reference	8	20.3	8.8	11	30.3	10.1	0.47	49%
Halifax 1	12	13.4	3.5	19	19.5	2.8	0.186	45.5%
Halifax 2	15	14.5	1.2	25	16.6	2.1	0.392	14.5%
Halifax 3	27	16.8	2.4	11	15.2	2.8	0.665	-9.5%
Halifax 4	14	14.8	3.9	15	19.5	5	0.456	31.8%
Halifax 5	8	29.4	10.7	13	22.1	7.2	0.527	-24.8%

Edge Forest (6) Site	Past N	Past Mean	Past Std Err	Present N	Present Mean	Present Std Err	P-value	% Change
Focus	13	10.9	0.4	16	20.2	6.6	0.178	85.3%
Reference	43	12.9	0.8	59	14.8	1.2	0.19	14.7%
Halifax 1	152	16	1.3	107	21.9	2.1	0.022	36.9%
Halifax 2	105	20.1	3.4	121	18.5	1.5	0.684	-8.0%
Halifax 3	111	16.8	1.1	91	19.1	1.6	0.221	13.7%
Halifax 4	139	15.9	1	96	18.2	1.6	0.208	14.5%
Halifax 5	98	21.6	2.1	67	28.3	3.1	0.036	31.0%

Planted Forest (7) Site	Past N	Past Mean	Past Std Err	Present N	Present Mean	Present Std Err	P-value	% Change
Focus	100	275.5	26.6	157	104.7	11.3	0.0001	-62.0%
Reference	87	154.9	17.6	184	83.3	8.8	0.0004	-46.2%
Halifax 1	61	86.9	10.5	81	80.6	7.8	0.629	-7.2%
Halifax 2	30	109.3	15.8	45	87.1	13.8	0.295	-20.3%
Halifax 3	58	91.4	9.4	89	84.1	6.5	0.521	-8.0%
Halifax 4	77	72.3	6.4	83	104.1	14.4	0.046	44.0%
Halifax 5	59	84.2	7.9	79	107	7.8	0.042	27.1%

Developed (9)	Past			Present				%
Site	N	Mean	Std Err	N	Mean	Std Err	P-value	Change
Focus								
Reference	1	205.8		3	103.1	50.7		
Halifax 1	19	40.5	5.3	23	53	32	0.151	0.308642
Halifax 2	6	64.1	7	11	64	11.8	0.996	-0.2%
Halifax 3	6	50.7	12.3	7	69.1	10.6	0.28	36.3%
Halifax 4	13	31.2	4.4	14	52.2	11.1	0.048	67.3%
Halifax 5	26	139.4	24.8	41	125.5	18.7	0.657	-10.0%

Recently cut (12)	Past			Present				%
Site	N	Mean	Std Err	N	Mean	Std Err	P-value	Change
Focus	2	30.6	3.4	12	78.3	29.8	0.567	155.9%
Reference	0			5	297	46.3		
Halifax 1	13	79.8	23.2	10	120.9	15.3	0.156	51.5%
Halifax 2	3	56.8	10.2	4	252.4	74.3	0.038	344.4%
Halifax 3	1	43.2		15	124.3	17.8		187.7%
Halifax 4	3	57.6	30	8	114.4	34.3	0.252	98.6%
Halifax 5	2	230.4	119.5	6	110.1	28.2	0.493	-52.2%

Savannah (13)	Past			Present				%
Site	N	Mean	Std Err	N	Mean	Std Err	P-value	Change
Focus	7	155.6	49.8	112	102.1	11.4	0.33	-34.4%
Reference	18	123.6	30	6	60.3	19.5	0.091	-51.2%
Halifax 1				3	56.8	20		
Halifax 2								
Halifax 3				9	56.1	15.5		
Halifax 4				5	57.7	16.1		
Halifax 5				6	93.8	30.6		

Segment Analysis

The total number of segments for each site by habitat class.

Class	Reference		Focus		Halifax_1		Halifax_2		Halifax_3		Halifax_4		Halifax_5	
	Past	Present	Past	Present	Past	Present	Past	Present	Past	Present	Past	Present	Past	Present
Field	55	55	10	12	155	100	109	96	153	91	117	58	92	47
Fallow	25	135	22	161	46	36	24	43	32	25	51	51	24	17
Shrub	6	53	10	23	20	24	15	10	23	43	39	27	28	22
Forest	68	57	45	31	115	110	81	93	105	106	121	110	96	107
Hedgerow	8	11	1	3	12	19	15	25	27	11	14	15	8	13
Edge Forest	43	59	13	16	152	107	105	121	111	91	139	96	98	67
Mature Planted Forest	87	184	100	157	61	81	30	45	58	89	77	83	59	79
Road/Rail	36	52	31	54	42	30	41	32	20	49	26	37	27	18
Developed	1	3	0	0	19	23	6	11	6	7	13	14	26	41
Water	1	5	0	3	3	7	4	6	6	12	1	6	6	8
Logged	0	5	2	12	13	10	3	4	1	15	3	8	2	6
Savanna/Selective cut	18	6	7	112	0	3	0	0	0	9	0	5	0	6
Total Segments	348	625	241	584	638	550	433	486	542	548	601	510	466	431

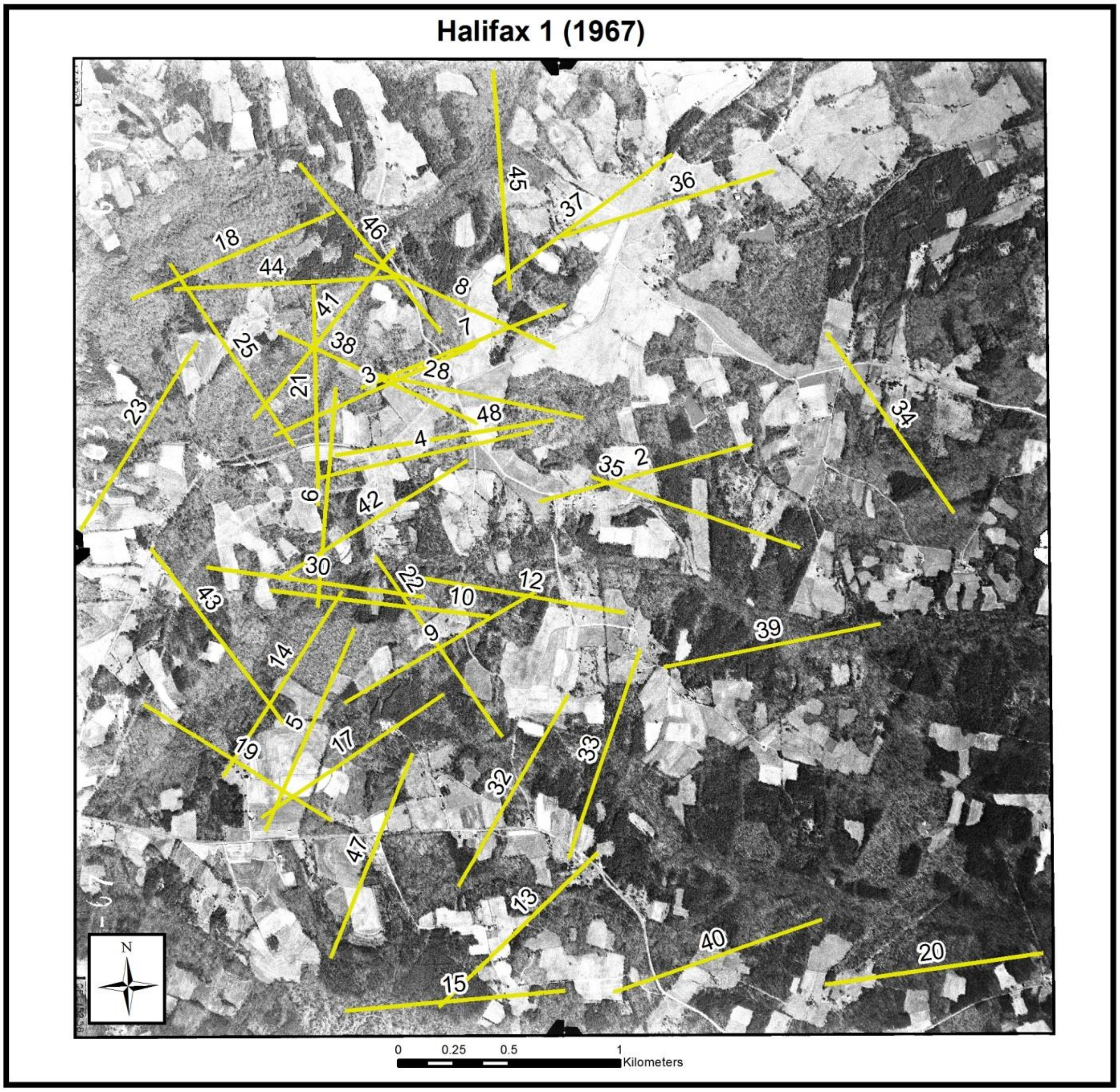
Edge Analysis

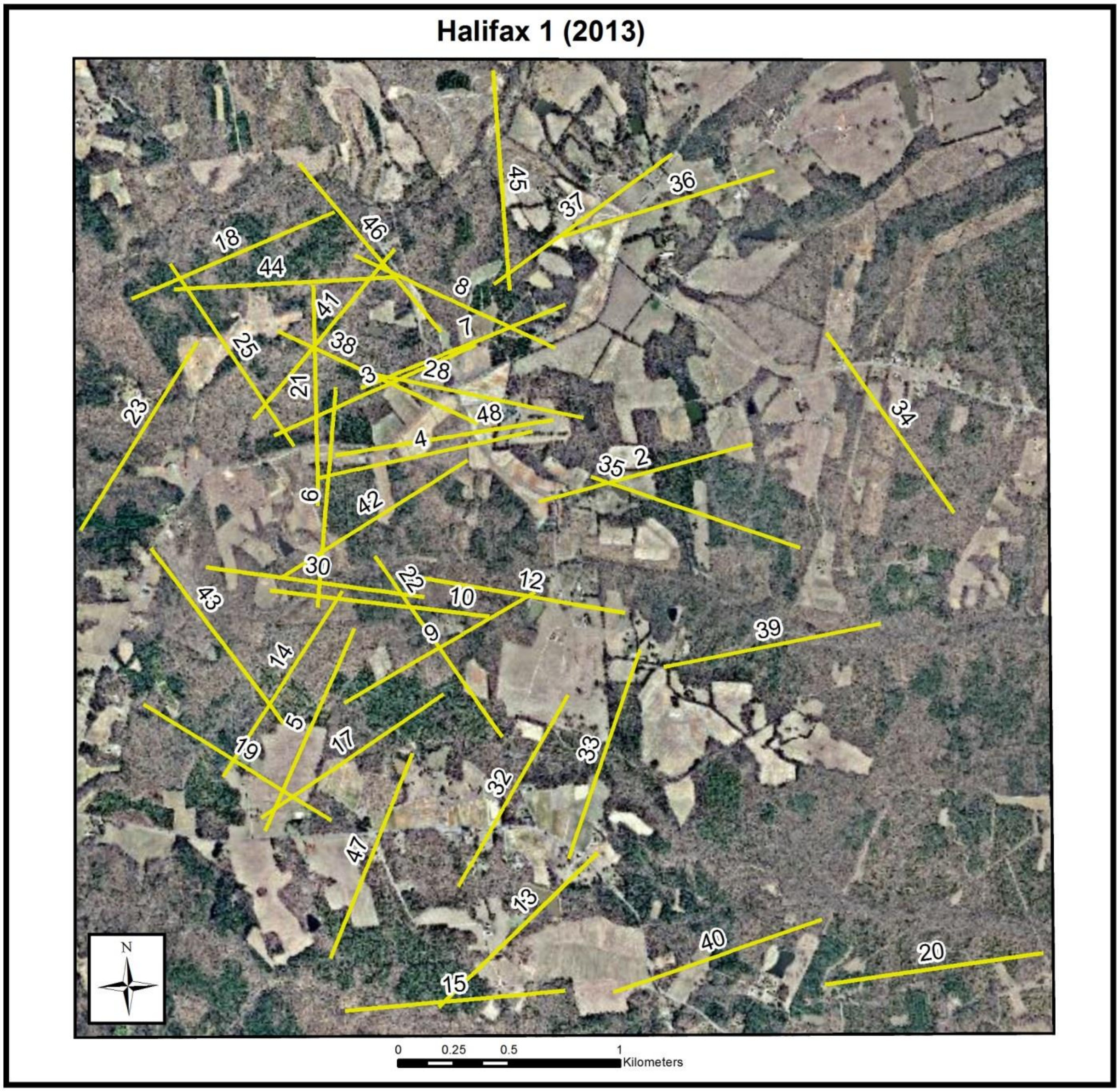
This table provides the total number of edges for each site and time period. Favorable edges were assigned a value of 1 and non-favorable a value of 0.

	Past			Present		
Site	0	1	Total	0	1	Total
Focus	149	55	204	186	598	784
Halifax_1	362	248	610	332	213	545
Halifax_2	254	163	417	263	199	462
Halifax_3	201	245	446	343	185	528
Halifax_4	308	260	568	299	238	537
Halifax_5	268	175	443	286	122	408
Reference	220	100	320	249	358	607
Grand Total	**1762**	**1246**	**3008**	**1958**	**1913**	**3871**

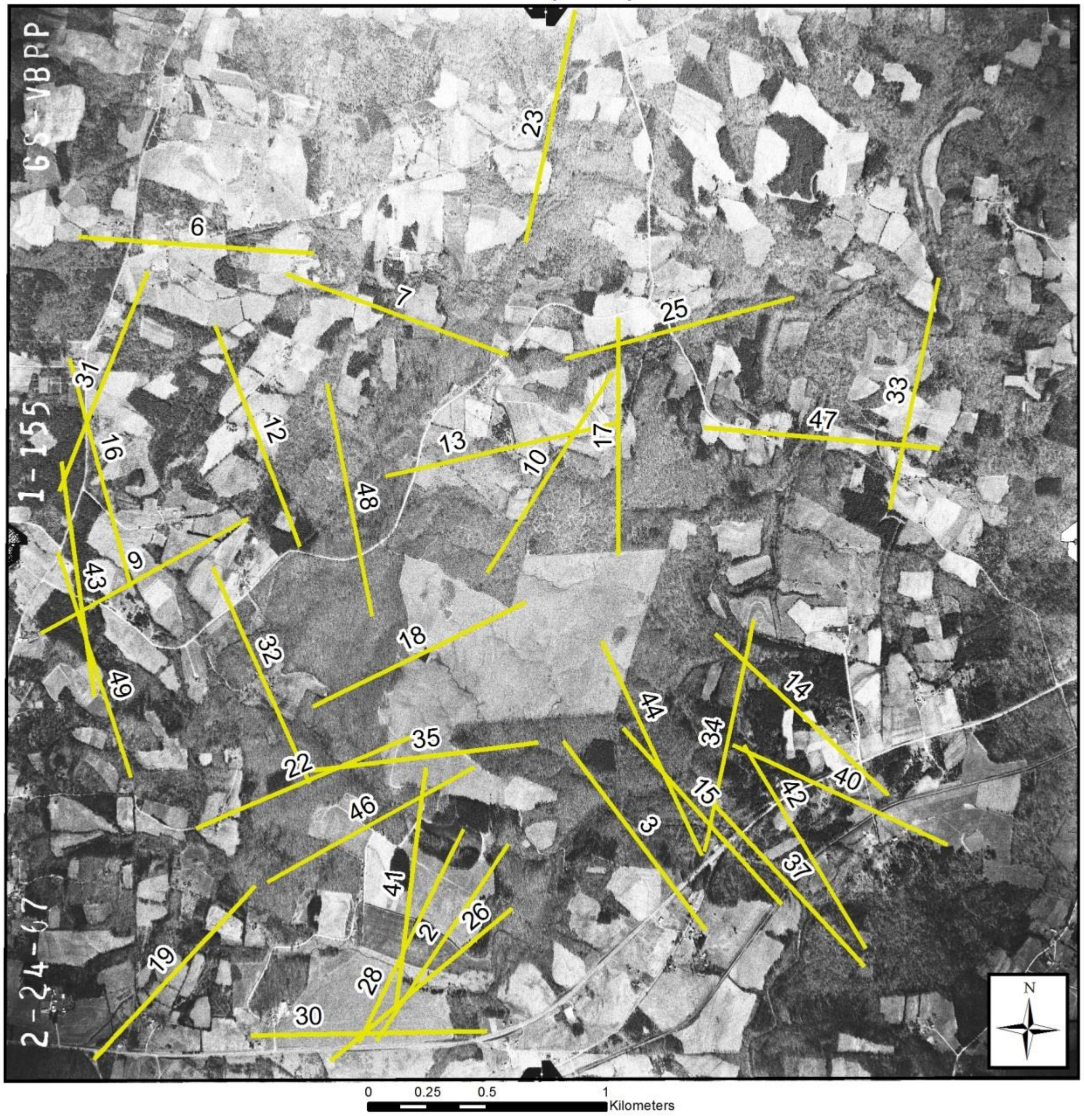
Appendix 2 – Figures

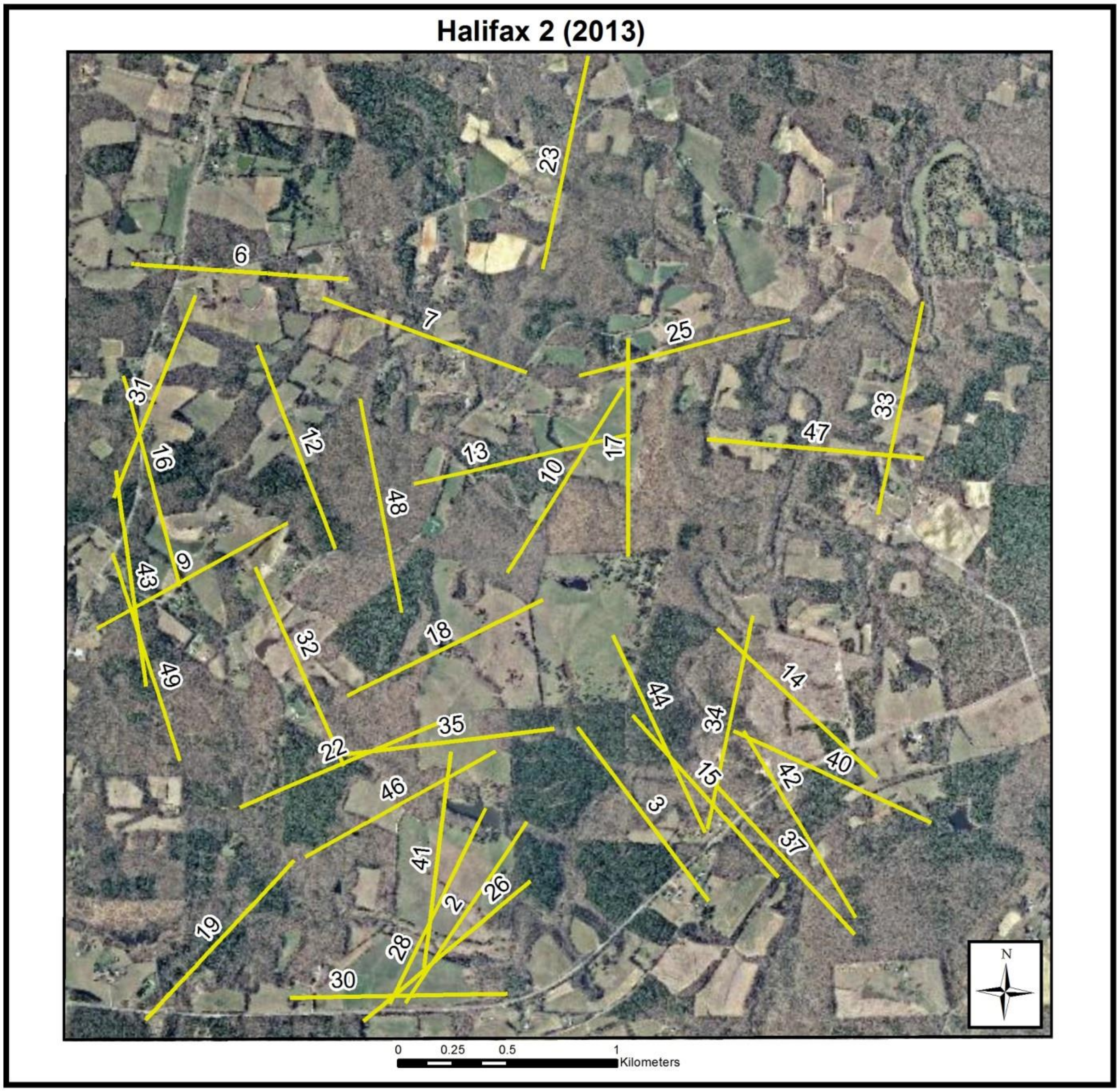
This appendix contains images of each study site along with the transect locations.




Halifax 1 (2013)
45
36
37
18
46
44
8
41
7
38
25
3
28
21
48
23
4
34
35
2
6
42
30
22
12
10
43
9
39
14
5
17
19
33
32
47
13
40
20
15
N
0
0.25
0.5
1
Kilometers

Halifax 2 (1967)





Halifax 2 (2013)
23
6
7
25
31
33
12
47
16
13
17
10
48
9
43
18
32
14
49
44
34
35
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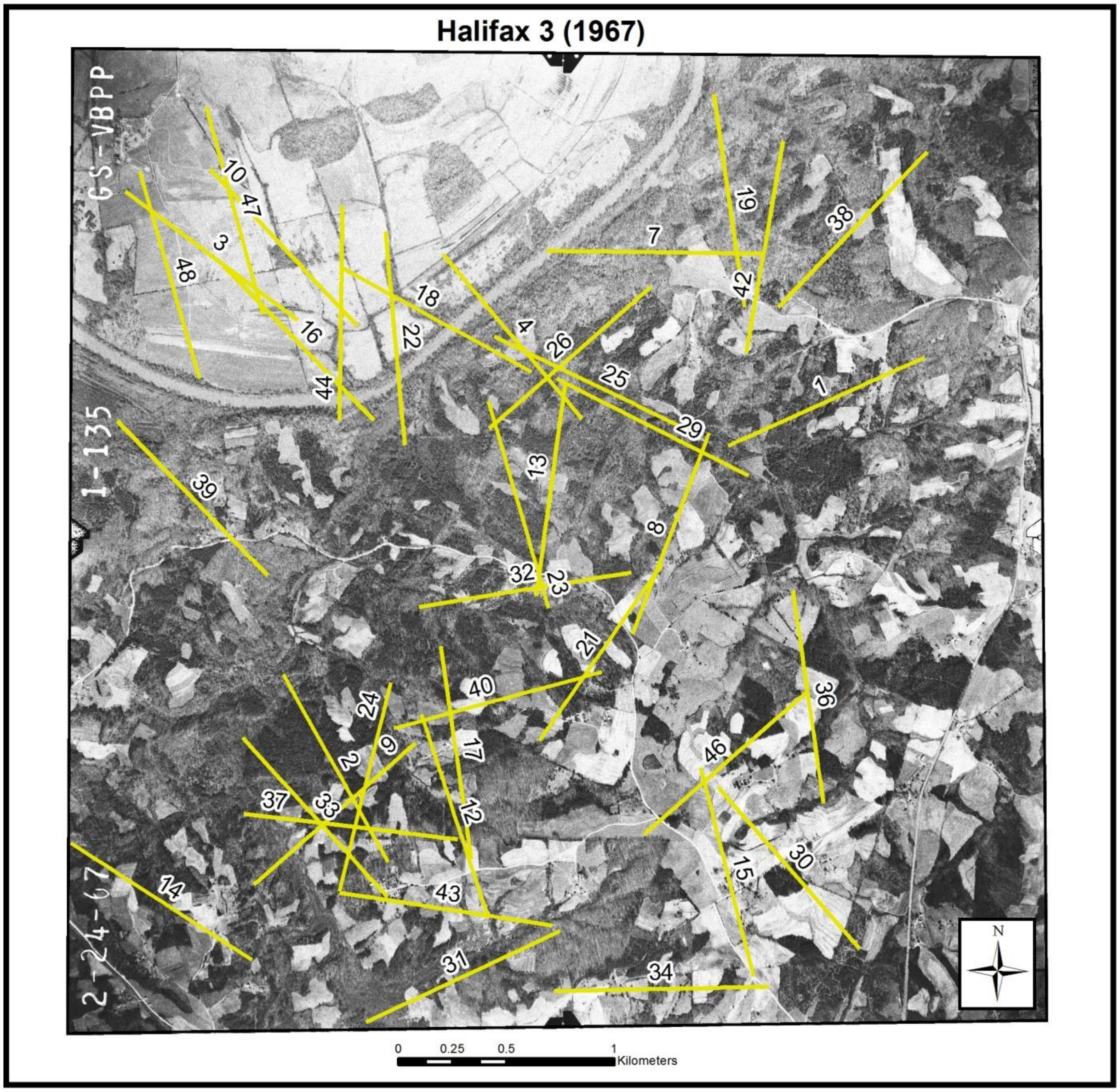
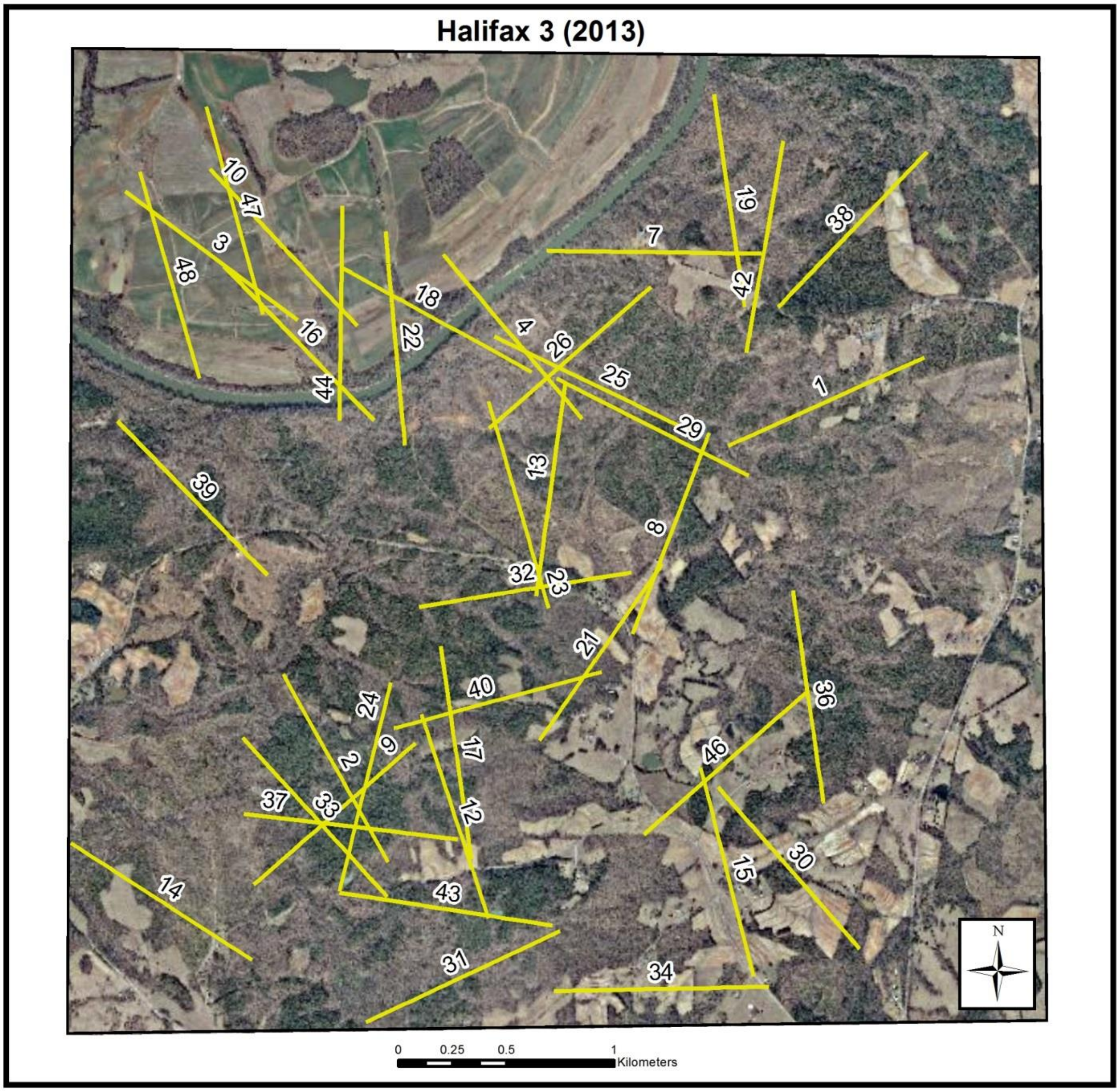
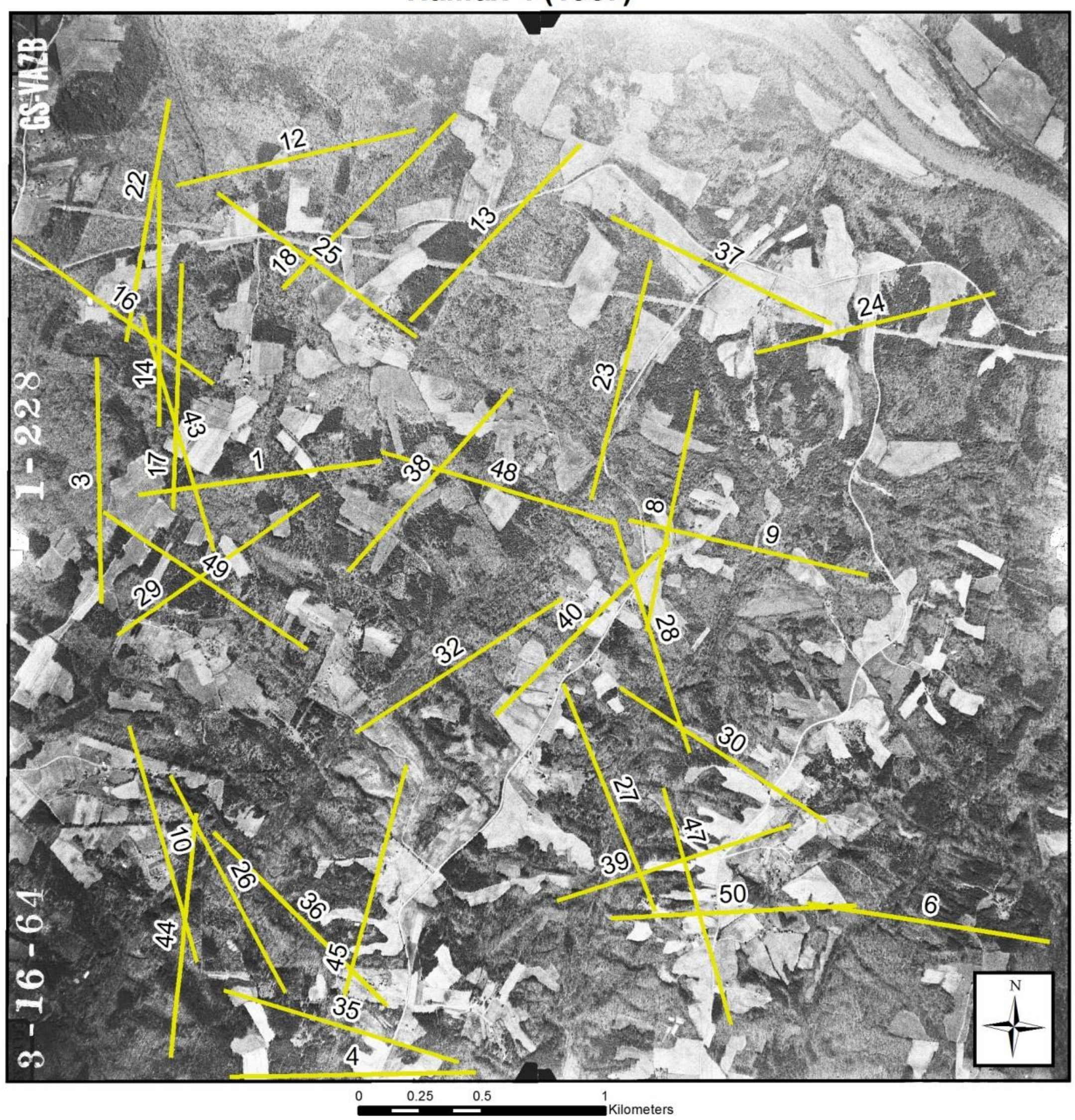
0.5
1
Kilometers



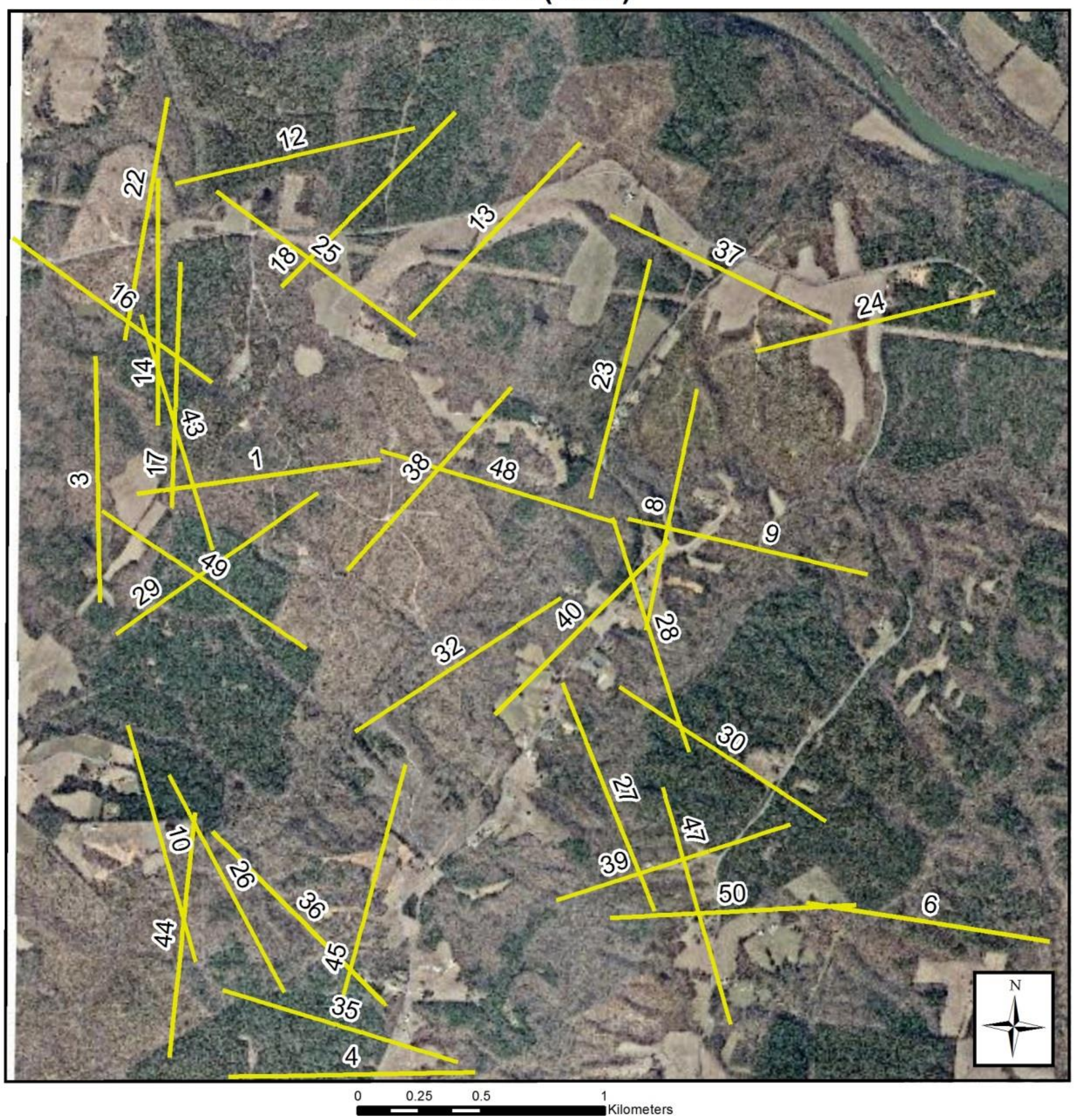
Halifax 3 (1967)
GS-VBPP
1-135
2-24-67
0 0.25 0.5 1 Kilometers
N


Halifax 3 (2013)
0
0.25
0.5
1
Kilometers
N

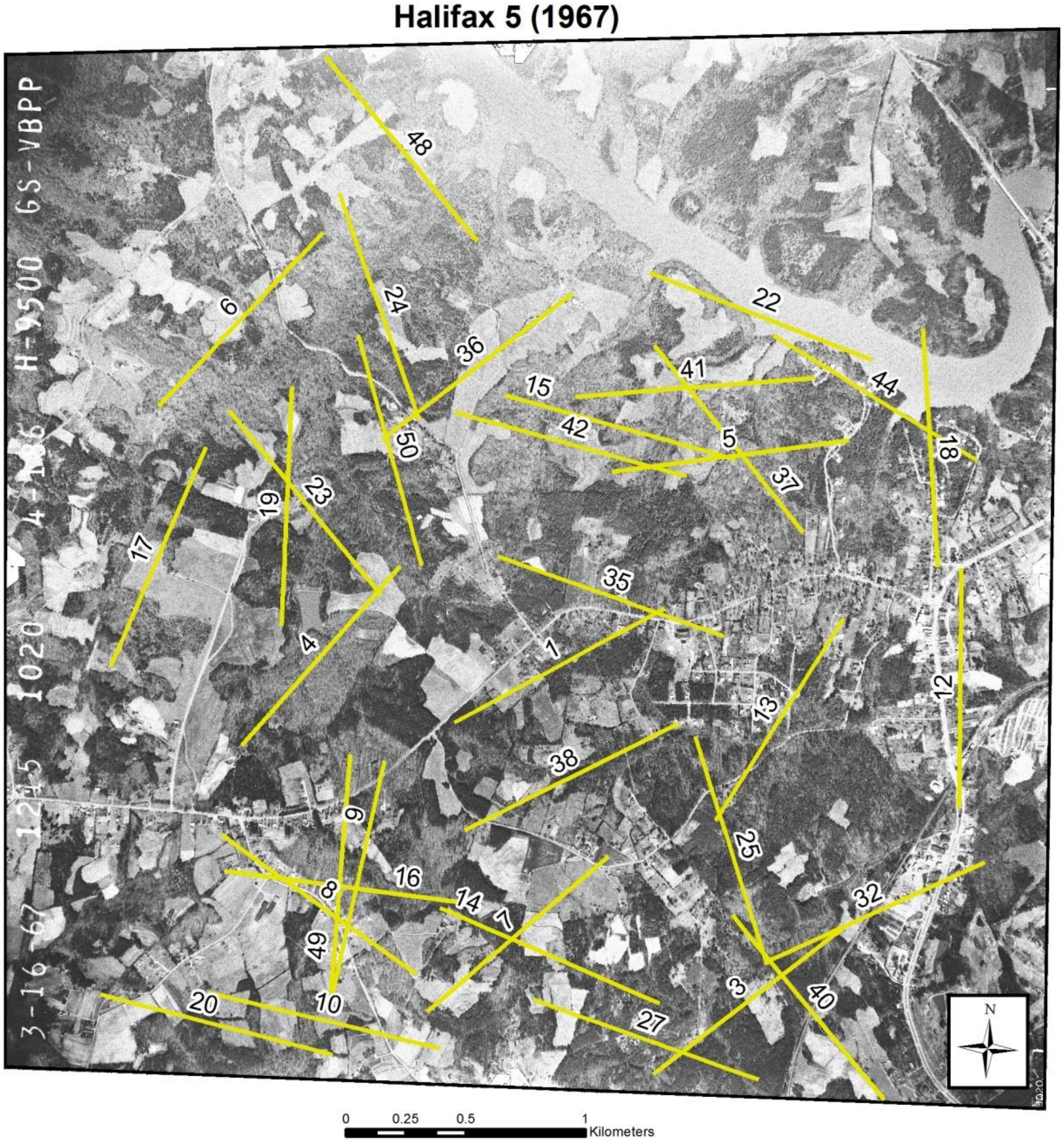
Halifax 4 (1967)



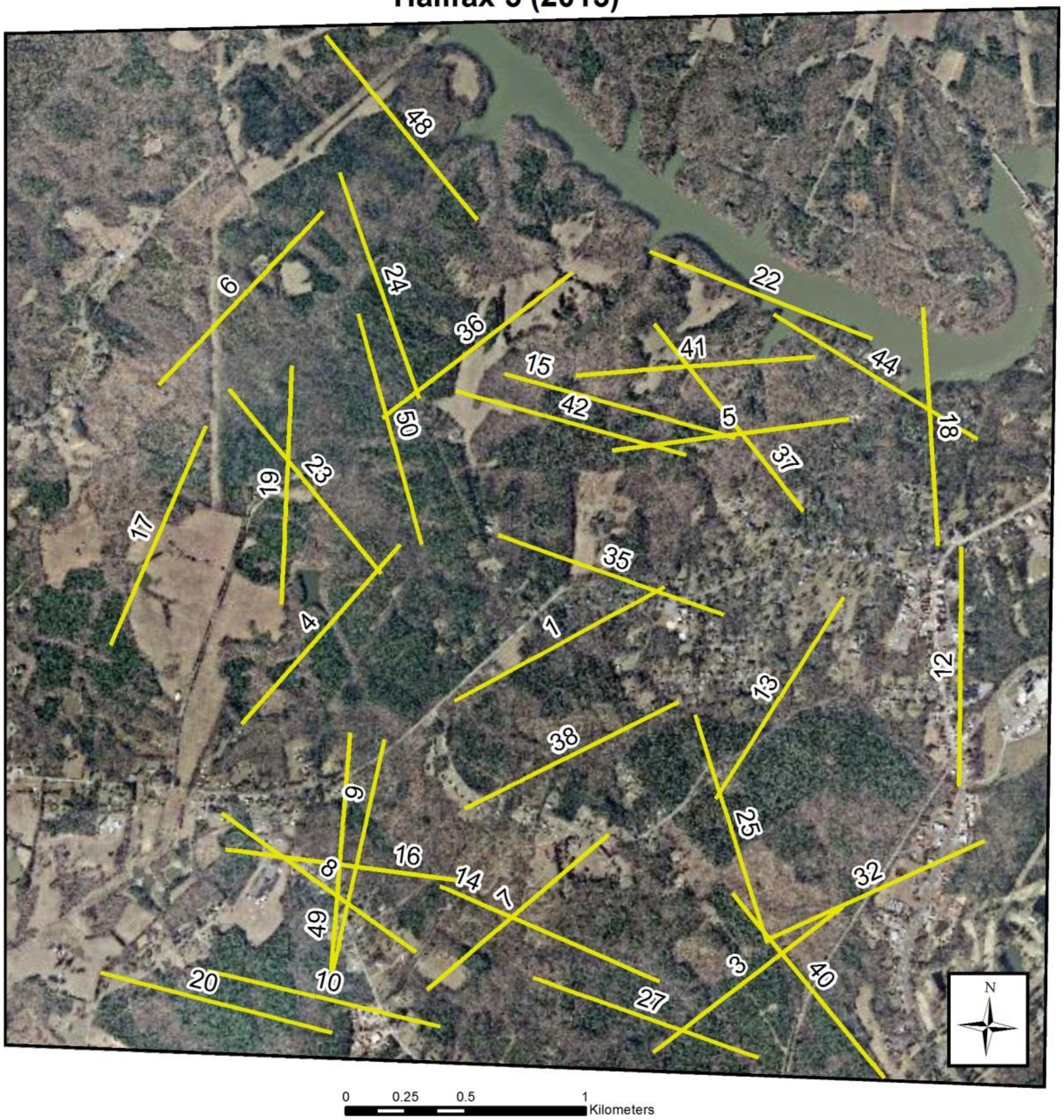
Halifax 4 (2013)



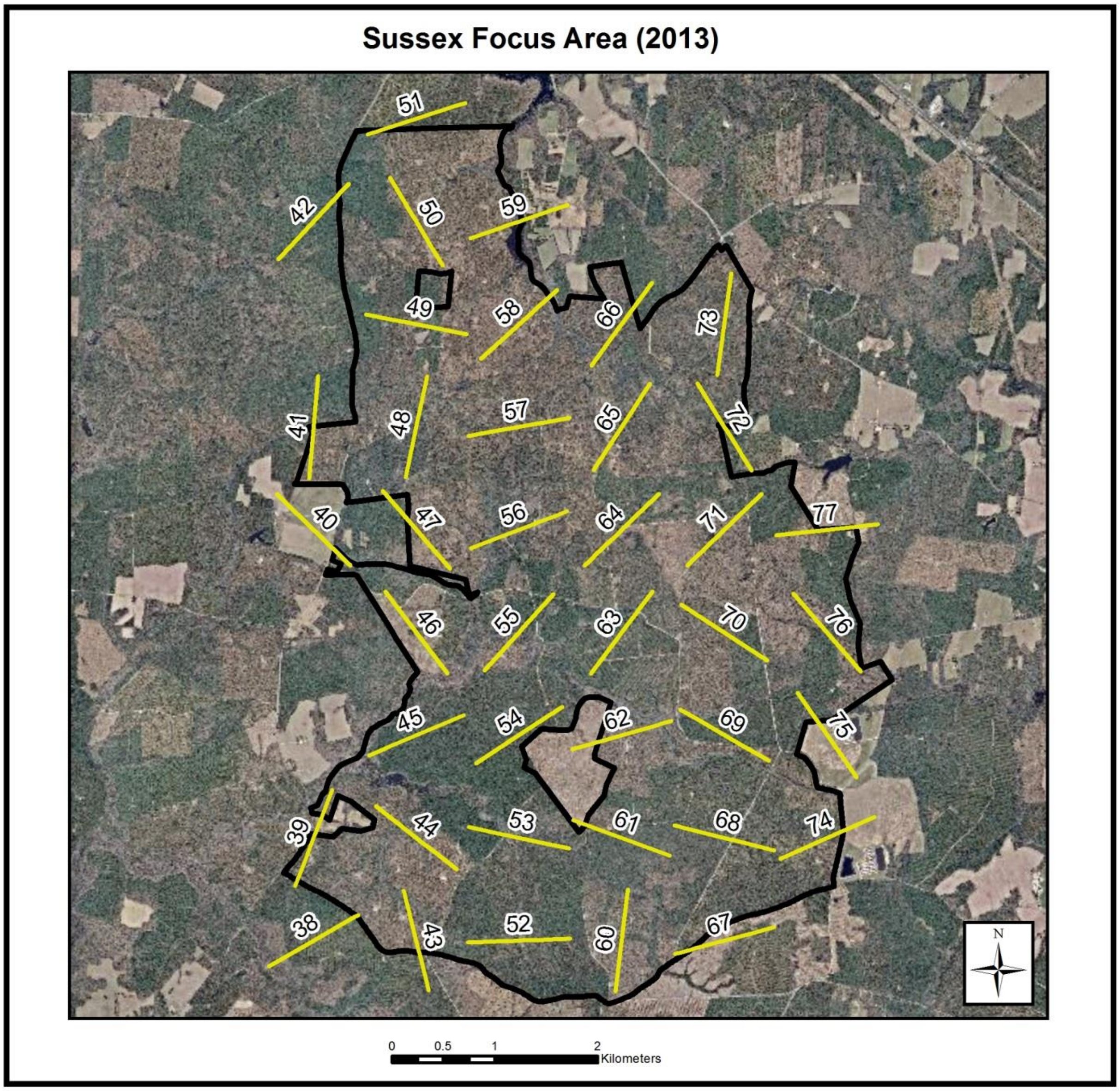
Halifax 5 (1967)



Halifax 5 (2013)

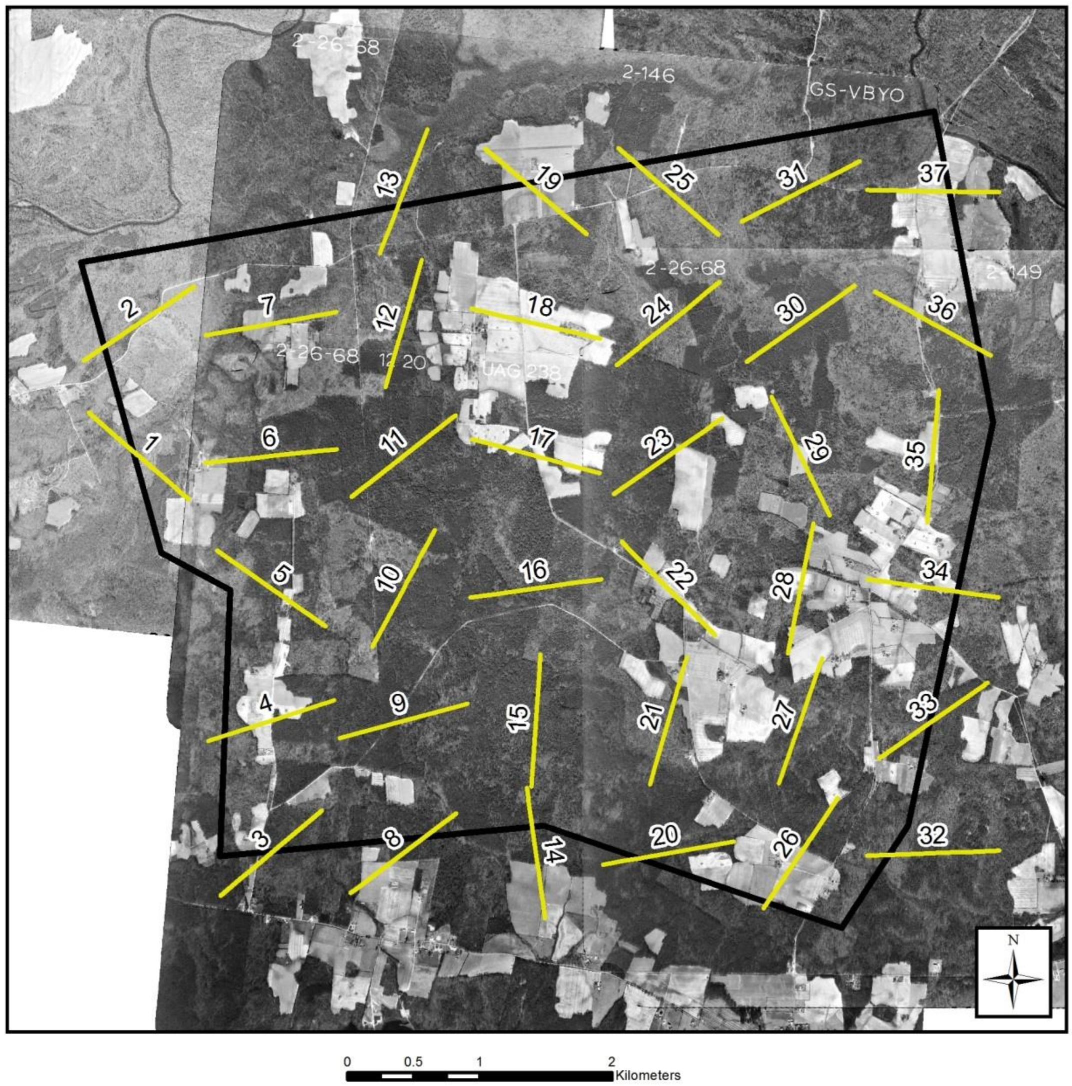


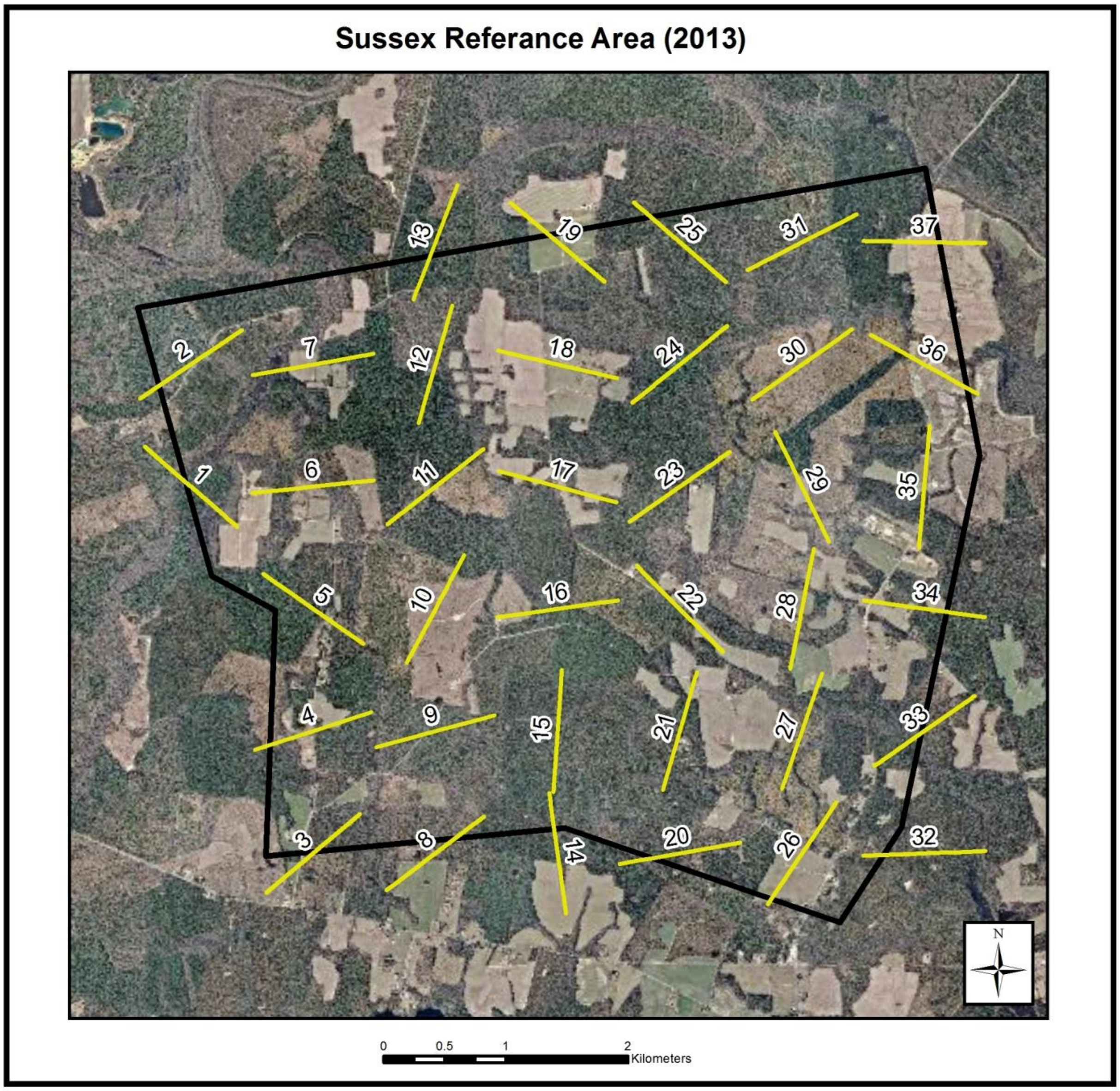
Sussex Focus Area (1966)



Sussex Focus Area (2013)
51
42
50
59
49
58
66
73
41
48
57
65
72
40
47
56
64
71
77
46
55
63
70
76
45
54
62
69
75
39
44
53
61
68
74
38
43
52
60
67
N
0
0.5
1
2
Kilometers

Sussex Referance Area (1968)




Sussex Referance Area (2013)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
N
0 0.5 1 2
Kilometers