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Relationships Between Landscape-Level Changes and Seasonal Bird Communities at Fort Benning, Georgia

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PURPOSE: The Strategic Environmental Research and Development program (SERDP), Ecosystem Management Project (SEMP), Ecosystem Characterization and Monitoring Initiative (ECMI) is a long-term, multiagency effort in operation at Fort Benning, Georgia. The purpose of this program is to characterize the environment in and around Fort Benning and to document, in databases, information about environmental conditions in the ecosystem over a long period of time. The land cover characterization portion of this program provides the foundation needed to derive vegetation classification, density and land cover patterns (Kress 2001). Another program, Land Condition Trend Analysis (LCTA), was established at Fort Benning to monitor flora and fauna present on the installation during 1991 - 1996 (Tazik et al. 1992, Bern et al. 1999). In this technical note, data from both programs are used to describe a procedure to monitor both landscape-level changes in vegetation characteristics and seasonal bird communities. This approach will provide managers with better information about the impacts of land-use changes on important bird species — particularly endangered, threatened, or regionally indentified sensitive species.

BACKGROUND: Habitat loss through the process of fragmentation is characterized by the apportioning of extensive habitat tracts into numerous smaller, more isolated patches (Wiens 1995, Boutin and Hebert 2002), and is a frequently cited factor contributing to the decline of both forest-dwelling and early-successional North American breeding bird species (Askins et al. 1990, Martin and Finch 1995, Cunningham 2000, Winter et al. 2000, Belisle et al. 2001, Donovan et al. 2002). This process negatively impacts bird communities by direct loss of habitat and by exposing individuals to harmful edge effects, including increased nest predation and brood parasitism (Robbins et al. 1989, Saunders et al 1991, Belisle et al 2001, Wiegand et al. 2005). Moreover, the increased isolation of habitat patches in fragmented landscapes may reduce movement among patches, thereby impeding the processes of patch colonization and juvenile dispersal; this, in turn, may lead to irrevocably altering regional population demographics (Forman and Godron 1986, Belisle et al. 2001, Wiegand et al. 2005).

Military activities, including military training operations, habitat-clearing for range expansion, forest management activities, expansion of cantonment areas, and construction of support facilities, all potentially fragment and degrade available habitat for seasonal bird communities. However, human disturbance on military installations is generally much lower than in intensively managed agricultural or highly urbanized landscapes, and concerns of landscape-level habitat fragmentation are rarely addressed (e.g., Stein et al. 2008, McKee and Berrens 2001). Military installations are mandated to monitor and conserve migratory bird populations within their boundaries (Department of Defense Instructions (DODI), no. 4715.3 (DODI 1996), Army Regulations

(AR 200-3, Department of the Army 1995), and Executive Order 13186 (Presidential Documents 2001)), and the new Migratory Bird Rule (U.S. Fish and Wildlife Service (USFWS) 2007). Furthermore, in response to the documented long-term population declines of many migratory bird species, the Department of Defense (DoD), in 1991, became a signatory member of the Partners in Flight (PIF) initiative that enlists the cooperation of over 300 federal and state agencies and nongovernmental organizations in the management and conservation of North American bird populations (DoD 2006).

Military installations employ numerous methods to monitor the impacts of their operations on natural resources in order to meet compliance requirements and conservation goals. This technical note outlines how two disparate efforts may be better coordinated to monitor long-term impacts of military operations on breeding and wintering bird communities utilizing habitats at Fort Benning, Georgia. Under the ECMI effort, long-term monitoring of landscape patterns on Fort Benning, Georgia was officially begun in 1999 (Graves and Bourne 2002), although installation personnel had been monitoring landscape changes on the installation since 1974 (Olsen et al. 2001). Bird communities were monitored on the installation from 1991-1996, using the LCTA program (Tazik et al. 1992, Bern et al. 1999).

Bird species are considered excellent indicators of environmental change, especially the kind of change brought on by human use and alteration of the landscape (Morrison 1986, Croonquist and Brooks 1991, Canterbury et al. 2000, O'Connell et al. 2000, Bryce et al. 2002). Birds are conspicuous and relatively easy to detect and observe; in addition, they are of considerable public interest, making them ideal subjects to use for monitoring the impacts of military activities on ecosystems (Nott 2000). Changes in landscape structure and configuration have been used to predict changes in bird populations (Canterbury et al. 2000, Nott 2000, Villard et al. 1999); however, most studies focus largely on forest-dwelling breeding birds while ignoring early-successional and winter bird communities. Furthermore, most fragmentation studies focus on heavily impacted urban or agricultural landscapes. Few studies have examined the relationship between landscape-level change and seasonal bird communities on military installations. The main objectives for this technical note were to: 1) document changes in landscape metrics, including core habitat area, patch, edge, and shape metrics for various broad habitats types at Fort Benning, Georgia; 2) document any changes in the breeding and wintering bird communities in the various habitat types during the monitoring period; and 3) correlate landscape metrics to seasonal bird communities on the installation to illustrate how changes in the landscape may impact seasonal bird communities. This approach utilizes ECMI landscape-level data collected between 1986 and 2003 in addition to bird community data from LCTA plots collected during breeding and wintering seasons in 1991 - 1996. These data reflect broad habitat types available, and therefore represent an ecosystem management approach to the monitoring of bird communities throughout the installation.

STUDY AREA: Fort Benning is a large military installation, positioned in West Central Georgia, just south of Columbus, Georgia, and east of Phoenix City, Alabama (Figure 1) (Bourne and Graves 2001). Encompassing over 74,000 ha, Fort Benning is one of the nation's largest training facilities for infantry and tank training exercises (Krzysik et al. 2000). Historically, Central Georgia within the vicinity of Fort Benning was dominated by large expansions of longleaf pine (*Pinus palustris* Mill.) savannahs (Olsen et al. 2001). A relatively large watershed, formed by the confluence of Upatoi Creek into the Chattahoachee River, supports large areas of bottomland hardwoods and other riparian habitats. This riparian zone acts as a potential biological corridor in the landscape and may be important for the migration and dispersal of many native wildlife species, by providing cover that permits movement through an area dominated by managed pine forests of longleaf pine and loblolly pine (*P. taeda*), and by providing nesting and foraging habitat for a variety of species. Elsewhere on the installation, extensive military training has created many patches of open grasslands and early successional areas. Frequent disturbance, habitat alterations and past fire suppression have resulted in a hardwood invasion throughout much of the installation's native pine forests. Additionally, during the past decade, installation managers have focused on restoring native longleaf pine savannahs and populations of the Red-cockaded Woodpecker (*Picoides borealis* Vieillot) (Barren 2001).

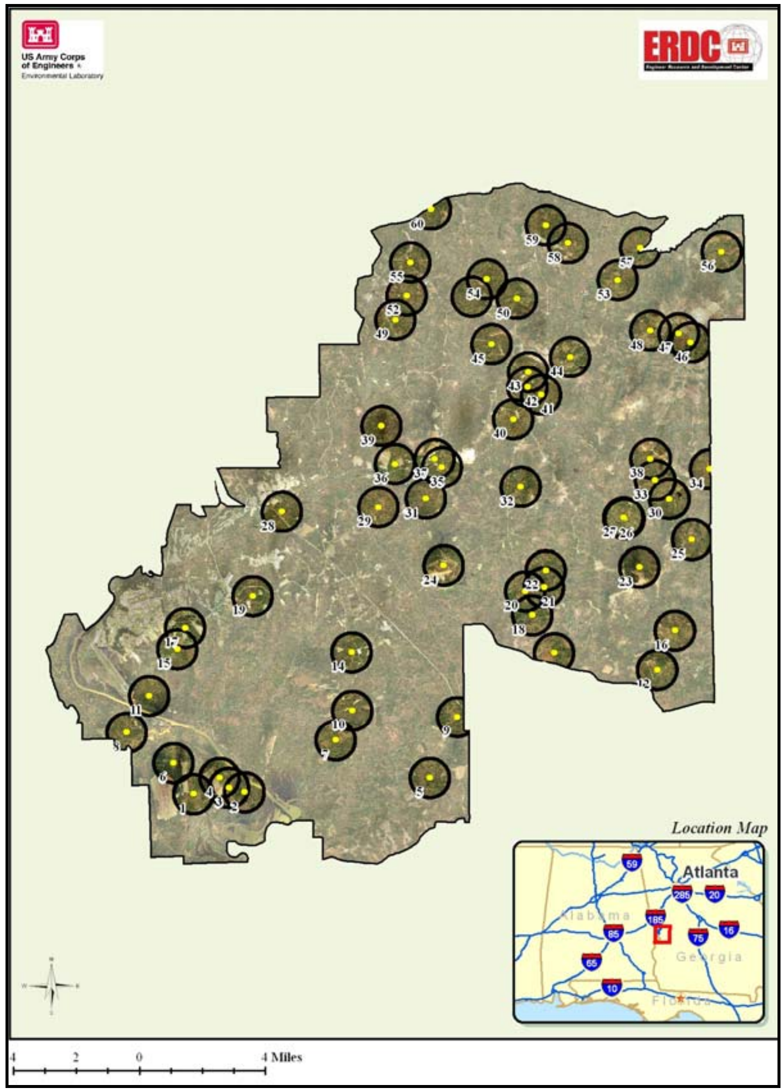

Figure 1. Location of Fort Benning in West Central Georgia, and the location and distribution of the 60 LCTA monitoring plots surveyed for seasonal bird community data during the 1991-1996 breeding seasons, and the 1992, and 1994-1996 winter seasons.

METHODS

Collection of Seasonal Bird Community Data: Bird communities on Fort Benning were surveyed by conducting line transects during the breeding season from 1991 through 1996, and during the wintering season of 1992, and of 1994-1996. These transects were conducted on LCTA plots established throughout the installation. Each LCTA plot consists of one 100 m transect. Over 200 LCTA plot locations are distributed throughout the installation; however, avian community surveys were conducted at only 60 of these plots during the breeding season, and at 58 plots during the winter (Figure 1). While conducting surveys, observers recorded all birds detected visually or aurally for 6 minutes within 100 m of either side of the transect. At the end of each transect, the observer conducted an eight minute point-count survey. Then the observer returned along the transect for an additional six minutes, so that twenty minutes were spent surveying at each plot. During the return along the transect, the observer focused on identification of species or individuals not detected earlier in the survey, and efforts were made to avoid the double-counting of birds. Species detected outside of 100 m and flyovers were recorded, but not included in the analyses. One morning and evening sampling event was conducted for each plot during the breeding and wintering seasons, and the average count data was used in the analysis. Morning surveys were conducted within four hours of sunrise, and all breeding season surveys were conducted during a two-week period, generally from May 6 through June 6 during all years. Winter surveys were conducted during a one-week period, generally between December 13 and January 10 during all years. Specific methodologies for collecting plant and animal community data for LCTA plots are detailed in Tazik et al. (1992) and Bern et al. (1999).

Landscape Metrics: Land cover classifications were used for 1986 and 1991 (60 m resolution) as described in Olsen et al. (2001. For the years 2001 and 2003, we used land cover classifications (30 m resolution) as described in Bourne and Graves (2001) and Graves and Bourne (2002). Land cover classification datasets were developed from Landsat 5 ETM images for years 1986 through 1991, and Landsat 7 ETM images for years 2001 and 2003. Land cover data were incorporated into an ArcGIS database, and the Fragstats software program (McGarigal and Marks 1995) was then used to measure seven landscape metrics within a 0.6 mile (1 km) circumference around the center of each LCTA bird survey plot for each year of coverage (Table 1, Figure 1). These landscape metrics were selected through a search of existing literature that suggests they may be important predictors of habitat quality for birds and other vertebrate communities at the landscape scale (Forman and Godron 1986, Peyman-Dove 2001, Lichstein et al. 2002, Watson 2003). We combined the landscape cover types identified from the Landsat imagery into five broad habitat types likely to be important to numerous bird species, including hardwood forest, pine forest, mixed forest, open shrub and grassland (includes herbaceous areas) and urban (buildings, roads, and bare ground) (Bourne and Graves 2001, Peyman-Dove 2001, Graves and Bourne 2002). For each year data were calculated, we determined a mean value for each landscape metric over the 60 LCTA survey plots; all calculations of edge measures for each habitat type were based on natural edge delineations existing in the landscape (e.g., artificial edges formed by the boundary of the installation or the edge of the 1-km circle around each plot were excluded).

Statistical Analysis: Bird species were categorized into habitat guilds based on Whitcomb et al. (1981). Habitat guilds include hardwood forest birds, mixed forest birds, edge birds, open grass/shrub birds, and habitat generalists. An additional category was created for bird species identified as Priority Bird Species by Partners in Flight (PIF). These species are prioritized according to the procedure described by Hunter et al. (2001) for the South Atlantic Coastal Plain Physiographic Region. All bird species included in the analyses, along with scientific names and guild classifications, are listed in Table 2. Individual detectabilities for each species could not be calculated from the available data; however, organizing birds into ecologically relevant response guilds ameliorates these differences and increases the value of bird community data as indicators of environmental change (Croonquist and Brooks 1991, Pendleton 1995, Canterbury et al. 2000, Nichols et al. 2000, Hutto and Young 2002). While birds in each guild are linked by their preference to a particular habitat type, PIF priority birds are generally linked in their sensitivity to anthropomorphic disturbances among habitat types (Hunter et al. 2001).

The amount of change in mean values among years for both landscape and bird community metrics were estimated using simple linear regression (e.g., Yong and Finch 1997). A Pearson's Correlation analysis was conducted to test the interdependence between the annual mean abundance of bird species groups calculated from 60 LCTA plots and the estimated annual changes in landscape metrics surrounding each of the 60 LCTA plots surveyed on the installation. Landscape metrics and bird metrics were log-transformed to meet assumptions of parametric correlation analyses (Sokal and Rohlf 1995). All analyses were conducted using Statistical Analysis Software (SAS) (SAS Institute, Inc. 2004).

Table 1. Landscape metrics calculated for each broad habitat category within a 1.6-km radius of each of the 60 LCTA survey plots; measured from Landsat satellite coverages of Fort Benning, GA, during 1986, 1991, 2001, and 2003.

Landscape Metric	Short Code	Description
Habitat Core Area	Core	Indices based on internal core area of patches (area 100 m from edge).
Percentage of Habitat Core Area	Percent	Percentage of total habitat core area in landscape.
Number of Habitat Patches	PatchNo	Number of habitat patches in landscape.
Habitat Patch Density	PatchD	Density of habitat patches (#patches/ha) in landscape.
Habitat Patch Shape Index	PatchSI	Measures the average perimeter-to-area ratio for habitat patch and is indexed by comparing to a standard circular shape; index increases as patch shapes become noncircular (Peyman-Dove 2001).
Total Habitat Edge	TEdge	Total length (m) of habitat edge in landscape.
Habitat Edge Density Index	EdgeD	Sum of the lengths of habitat edge divided by total habitat area in landscape.
Habitat Shape Index	Shape	Sum of patch perimeter divided by the square root of patch area for each habitat type; adjusted by a constant for a circular standard and divided by the number of habitat patches in landscape (Forman and Godron 1986, Peyman-Dove 2001).

Table 2. Common name, scientific name, full authority, season observed, and habitat guild classification of breeding birds detected during the spring 1991-1996 monitoring period; wintering birds detected during the winter 1992, and during the 1994-1996 monitoring period, on Fort Benning, GA.

Common Name	Scientific Name	Season Observed	Habitat Guild[1]
Acadian Flycatcher[2]	*Empidonax virescens* (Vieillot)	Spring	Hardwood Forest
American Crow	*Corvus brachyrhynchos* (Brehm)	Spring/Winter	Habitat Generalist
American Goldfinch	*Carduelis tristis* (Linnaeus)	Spring/Winter	Edge Habitat
American Kestrel[2]	*Falco sparverius* (Linnaeus)	Spring/Winter	Open Country Habitat
American Redstart	*Setophaga ruticilla* (Linnaeus)	Spring	Hardwood Forest
American Robin	*Turdus migratorius* (Linnaeus)	Spring/Winter	Habitat Generalist
Barred Owl	*Strix varia* (Barton)	Spring/Winter	Hardwood Forest
Barn Swallow	*Hirundo rustica* (Linnaeus)	Spring	Open Country Habitat
Bachman's Sparrow[2]	*Aimophila aestivalis* (Lichtenstein)	Spring/Winter	Mixed Forest
Black-and-white Warbler	*Mniotilta varia* (Linnaeus)	Spring	Mixed Forest
Belted Kingfisher	*Ceryle alcyon* (Linnaeus)	Winter	Edge Habitat
Blue-gray Gnatcatcher	*Polioptila caerulea* (Linnaeus)	Spring	Hardwood Forest
Brown-headed Cowbird	*Molothrus ater* (Boddaert)	Spring	Edge Habitat
Brown-headed Nuthatch[2]	*Sitta pusilla* (Latham)	Spring/Winter	Mixed Forest
Blue-headed Vireo	*Vireo solitarius* (Wilson)	Spring/Winter	Hardwood Forest
Blue Grosbeak	*Guiraca caerulea* (Linnaeus)	Spring	Edge Habitat
Blue Jay	*Cyanocitta cristata* (Linnaeus)	Spring/Winter	Habitat Generalist
Black Vulture	*Coragyps atratus* (Bechstein)	Spring/Winter	Habitat Generalist
Brown Creeper	*Certhia americana* (Bonaparte)	Winter	Mixed Forest
Brown Thrasher	*Toxostoma rufum* (Linnaeus)	Spring/Winter	Edge Habitat
Broad-winged Hawk	*Buteo platypterus* (Vieillot)	Spring	Edge Habitat
Carolina Chickadee[2]	*Poecile carolinensis* (Audubon)	Spring/Winter	Hardwood Forest
Cattle Egret	*Bubulcus ibis* (Linnaeus)	Spring	Open Country Habitat
Canada Goose	*Branta canadensis* (Linnaeus)	Spring	Open Country Habitat
Carolina Wren	*Thryothorus ludovicianus* (Latham)	Spring/Winter	Habitat Generalist
Cedar Waxwing	*Bombycilla cedrorum* (Vieillot)	Winter	Mixed Forest
Common Ground-Dove[2]	*Columbina passerina* (Linnaeus)	Spring	Open Country Habitat
Chipping Sparrow	*Spizella passerina* (Bechstein)	Spring/Winter	Edge Habitat
Chimney Swift	*Chaetura pelagica* (Linnaeus)	Spring	Open Country Habitat
Common Grackle	*Quiscalus quiscalus* (Linnaeus)	Spring/Winter	Edge Habitat
Common Nighthawk	*Chordeiles minor* (Forster)	Spring	Habitat Generalist
Common Yellowthroat	*Geothlypis trichas* (Linnaeus)	Spring/Winter	Edge Habitat
Chuck-Will's-Widow[2]	*Caprimulgus carolinensis* (Gmelin)	Spring	Edge Habitat
Dark-eyed Junco	*Junco hyemalis* (Linnaeus)	Winter	Mixed Forest
Downy Woodpecker	*Picoides pubescens* (Linnaeus)	Spring/Winter	Mixed Forest
Eastern Bluebird	*Sialia sialis* (Linnaeus)	Spring/Winter	Edge Habitat
Eastern Kingbird[2]	*Tyrannus tyrannus* (Linnaeus)	Spring	Open Country Habitat
Eastern Meadowlark	*Sturnella magna* (Linnaeus)	Spring/Winter	Open Country Habitat
Eastern Towhee[2]	*Pipilo erythrophthalmus* (Linnaeus)	Spring/Winter	Edge Habitat
Eastern Wood-pewee[2]	*Contopus virens* (Linnaeus)	Spring	Hardwood Forest
Eastern Tufted Titmouse	*Baeolophus bicolor* (Linnaeus)	Spring/Winter	Hardwood Forest
European Starling	*Sturnus vulgaris* (Linnaeus)	Spring	Habitat Generalist
Evening Grosbeak	*Coccothraustes vespertinus* (Cooper)	Winter	Mixed Forest

(Continued)

Table 2. Continued

Common Name	Scientific Name	Season Observed	Habitat Guild[1]
Fish Crow	*Corvus ossifragus* (Wilson)	Spring	Habitat Generalist
Field Sparrow[2]	*Spizella pusilla* (Wilson)	Spring/Winter	Open Country Habitat
Fox Sparrow	*Passerella iliaca* (Merrem)	Winter	Mixed Forest
Great-crested Flycatcher	*Myiarchus craniums* (Linnaeus)	Spring	Hardwood Forest
Golden-crowned Kinglet	*Regulus satrapa* (Lichtenstein)	Winter	Mixed Forest
Gray Catbird	*Dumetella carolinensis* (Linnaeus)	Spring/Winter	Edge Habitat
Green Heron	*Butorides virescens* (Linnaeus)	Spring	Edge Habitat
Great Blue Heron	*Ardea herodias* (Linnaeus)	Spring	Edge Habitat
Hairy Woodpecker	*Picoides villosus* (Linnaeus)	Spring/Winter	Hardwood Forest
Hermit Thrush	*Catharus guttatus* (Pallas)	Winter	Mixed Habitat
House Finch	*Carpodacus mexicanus* (Muller)	Spring/Winter	Habitat Generalist
Hooded Warbler[2]	*Wilsonia citrina* (Boddaert)	Spring	Hardwood Forest
House Wren	*Troglodytes aedon* (Vieillot)	Winter	Habitat Generalist
Indigo Bunting	*Passerina cyanea* (Linnaeus)	Spring	Edge Habitat
Kentucky Warbler[2]	*Oporornis formosus* (Wilson)	Spring	Hardwood Forest
Killdeer	*Charadrius vociferus* (Linnaeus)	Spring	Open Country Habitat
Loggerhead Shrike[2]	*Lanius ludovicianus* (Linnaeus)	Spring/Winter	Open Country Habitat
Louisiana Waterthrush[2]	*Seiurus motacilla* (Vieillot)	Spring	Hardwood Forest
Mourning Dove	*Zenaida macroura* (Linnaeus)	Spring/Winter	Edge Habitat
“Myrtle” Warbler (Yellow-rumped)	*Dendroica coronata* (Linnaeus)	Winter	Mixed Forest
Northern Bobwhite[2]	*Colinus virginianus* (Linnaeus)	Spring	Edge Habitat
Northern Cardinal	*Cardinalis cardinalis* (Linnaeus)	Spring/Winter	Edge Habitat
Northern Harrier	*Circus cyaneus* (Linnaeus)	Winter	Open Country Habitat
Northern Mockingbird	*Mimus polyglottos* (Linnaeus)	Spring/Winter	Habitat Generalist
Northern Parula[2]	*Parula americana* (Linnaeus)	Spring	Hardwood Forest
Northern Rough-winged Swallow	*Stelgidopteryx serripennis* (Audubon)	Spring	Open Country Habitat
Orchard Oriole[2]	*Icterus spurius* (Linnaeus)	Spring	Edge Habitat
Palm Warbler	*Dendroica palmarum* (Gmelin)	Winter	Edge Habitat
Pine Warbler[2]	*Dendroica pinus* (Wilson)	Spring/Winter	Mixed Forest
Pileated Woodpecker	*Dryocopus pileatus* (Linnaeus)	Spring/Winter	Hardwood Forest
Prairie Warbler[2]	*Dendroica discolor* (Vieillot)	Spring	Open Country Habitat
Prothonotary Warbler[2]	*Protonotaria citrea* (Boddaert)	Spring	Hardwood Forest
Purple Finch	*Carpodacus purpureus* (Gmelin)	Winter	Habitat Generalist
Purple Martin	*Progne subis* (Linnaeus)	Spring	Open Country Habitat
Red-breasted Nuthatch	*Sitta canadensis* (Linnaeus)	Winter	Mixed Forest
Red-bellied Woodpecker	*Melanerpus carolinus* (Linnaeus)	Spring/Winter	Hardwood Forest
Red-cockaded Woodpecker[2]	*Picoides borealis* (Vieillot)	Spring/Winter	Mixed Forest
Red-eyed Vireo	*Vireo olivaceus* (Linnaeus)	Spring	Hardwood Forest
Red-headed Woodpecker[2]	*Melanerpes erythrocephalus* (Linnaeus)	Spring/Winter	Hardwood Forest
Rock Dove	*Columba livia* (Gmelin)	Spring	Habitat Generalist
Red-shouldered Hawk	*Buteo lineatus* (Gmelin)	Spring/Winter	Edge Habitat
Red-tailed Hawk	*Buteo jamaicensis* (Gmelin)	Spring/Winter	Edge Habitat
Ruby-crowned Kinglet	*Regulus calendula* (Linnaeus)	Winter	Mixed Forest
Ruby-throated Hummingbird	*Archilochus colubris* (Linnaeus)	Spring	Hardwood Forest
Rusty Blackbird	*Euphagus carolinus* (Muller)	Winter	Hardwood Forest
Red-winged Blackbird	*Agelaius phoeniceus* (Linnaeus)	Spring/Winter	Open Country Habitat

(Continued)

Table 2. Concluded			
Common Name	**Scientific Name**	**Season Observed**	**Habitat Guild[1]**
Savannah Sparrow	*Passerculus sandwichensis* (Gmelin)	Winter	Open Country Habitat
Swainson's Warbler[2]	*Limnothlypis swainsonii* (Audubon)	Spring	Mixed Forest
Summer Tanager[2]	*Piranga rubra* (Linnaeus)	Spring	Hardwood Forest
Turkey Vulture	*Cathartes aura* (Linnaeus)	Spring/Winter	Habitat Generalist
White-breasted Nuthatch	*Sitta carolinensis* (Latham)	Spring/Winter	Hardwood Forest
White-eyed Vireo[2]	*Vireo griseus* (Boddaert)	Spring/Winter	Edge Habitat
Wild Turkey	*Meleagris gallopavo* (Linnaeus)	Spring/Winter	Mixed Forest
Wood Duck[2]	*Aix sponsa* (Linnaeus)	Spring/Winter	Hardwood Forest
Wood Thrush[2]	*Hylocichla mustelina* (Gmelin)	Spring	Hardwood Forest
Western Palm Warbler	*Dendroica palmarum* (Gmelin)	Winter	Edge Habitat
White-throated Sparrow	*Zonotrichia albicollis* (Gmelin)	Winter	Mixed Forest
Yellow-breasted Chat	*Icteria virens* (Linnaeus)	Spring	Open Country Habitat
Yellow-billed Cuckoo[2]	*Coccyzus americanus* (Linnaeus)	Spring	Hardwood Habitat
Yellow-bellied Sapsucker	*Sphyrapicus varius* (Linnaeus)	Winter	Mixed Forest
Yellow-shafted Flicker	*Colaptes auratus* (Linnaeus)	Spring/Winter	Mixed Forest
Yellow-throated Vireo[2]	*Vireo flavifrons* (Vieillot)	Spring	Hardwood Forest
Yellow-throated Warbler[2]	*Dendroica dominica* (Linnaeus)	Spring	Hardwood Forest

[1] Adapted from the classifications by Whitcomb et al. (1981).
[2] Identified by Partners in Flight as a Priority Species (PIF Concern Score $\geq$17) for the South Atlantic Coastal Plain (Physiographic Region #3) (Hunter et al. 2001) where Fort Benning, GA, is located.

RESULTS: During the years for which landscape coverage data were available, the PatchNo and PatchD of hardwood forest and open shrub/grassland habitats increased; Core and Percent also increased for open areas (Table 3). With the increase in hardwood patches, there was also a trend for increasing TEdge, EdgeD and the Shape index for hardwood patches, yet these trends were non-significant for open shrub/grasslands. The Core and Percent of mixed forest habitat increased, yet PatchNo, PatchD, TEdge, EdgeD, and Shape of mixed forest stands decreased during the monitoring period (Table 3). As the PatchNo and PatchD decreased for pine forest habitat, TEdge, EdgeD, and Shape decreased as well (Table 3). However, for urban areas, PatchNo and PatchD decreased, while the TEdge, EdgeD, and Shape had an increasing trend during the monitoring period (Table 3).

During the breeding season from 1991 - 1996, a significant increase ($P < 0.05$) in mean abundance was detected for hardwood forest birds, mixed forest birds, and PIF birds; no significant changes were detected for the other bird guilds. Mean abundance of generalist birds increased significantly ($P < 0.05$) during the winter season; however, there was considerable variation among years and the overall explanatory power of the regression model was low. A review of the raw data indicated that large annual variations in the number of American Robins (from a high of 343 in 1996 to a low of six in 1994) caused this result. When the American Robin data are removed, mean values of the generalist bird group no longer show such fluctuations, and the annual winter regression trends are no longer significant.

During the breeding season, only one significant correlation, a negative relationship to Shape of mixed forest habitat, was observed for hardwood forest birds (Table 4). Mixed forest bird species were also negatively correlated with Shape of mixed forest, and were also negatively correlated with the PatchNo, PatchD, and EdgeD of urban areas on the installation (Table 4). Edge birds were positively correlated with Core, Percent, and TEdge of hardwood forest habitat, and negatively correlated with PatchNo of pine forest and Percent and EdgeD of open shrub/grassland habitats (Table 4). Open shrub/grassland birds were positively correlated to Core of hardwood forests and Shape of open shrub/grassland habitats, and negatively correlated to the Percent, TEdge, and EdgeD of urban habitats. Generalist birds were positively correlated with the Core and Percent cover in landscape of hardwood, pine, and mixed forest habitats, and urban areas; on the other hand, they were negatively correlated to PatchI of open shrub/grass areas, and PatchNo and PatchD of urban areas (Table 4). Mean abundance of PIF birds were positively correlated with Percent and PatchI of hardwood forest habitat, and negatively correlated with PatchD of pine forest, Shape of mixed forest, the PatchNo and PatchD of urban areas (Table 4). During the winter season, few significant correlations were observed. Edge birds were negatively correlated with the Percent of open shrub/grasslands, while open shrub/grassland birds were positively correlated to hardwood forest habitat (Table 4). PIF birds had more significant correlations than other bird groups, and were negatively correlated with the Core of pine, mixed forest habitats, and urban areas (Table 4).

Table 3. Linear regression results (intercept+slope[±stderr]) of landscape metrics[1] showing significant changes in landscape configuration for the broad habitat categories available at Fort Benning, GA, during 1986, 1991, 2001, and 2003 (n=240; 60 values of each variable per plot for four years of monitoring).

Landscape Variable	Hardwood Forest	Mixed Forest	Open Country	Pine Forest	Urban Area
Core	N.S.	0.22+0.10(±0.06)*	0.58+0.19(±0.09)*	N.S.	N.S.
Percent	N.S.	0.11+0.05(±0.05)*	0.31+0.13(±0.09)*	N.S.	N.S.
PatchNo	2.59+0.11(±0.12)***	3.54-0.06(±0.12)**	2.14+0.15(±0.19)***	3.30-0.13(±0.07)***	1.52-0.09(±0.23)*
PatchD	1.64+0.09(±0.12)***	2.49-0.05(±0.12)**	1.27+0.13(±0.19)***	2.27-0.12(±0.06)***	0.86-0.07(±0.25)*
PatchSI	N.S.	2.27-0.09(±0.33)*	N.S.	N.S.	0.63+0.12(±0.87)*
TEdge	9.35+0.12(±0.09)*	10.51-0.16(±0.08)***	N.S.	10.13-0.14(±0.10)***	5.82+0.37(±0.20)*
EdgeD	3.76+0.10(±0.09)**	4.81-0.16(±0.08)***	N.S.	4.23-0.13(±0.10)***	1.450.23(±0.20)**
Shape	1.74+0.06(±0.05)***	2.39-0.08(±0.07)***	N.S.	2.18-0.09(±0.08)***	0.80+0.15(±0.14)***

[1] Landscape metrics are log-transformed; *P<0.05, **P<0.01, ***P<0.001

Table 4. Pearson correlation analyses between bird community and landscape metrics[1] (n=60) for all LCTA plots surveyed for birds and landscape metrics.

Bird Assemblage	Hardwood Forest	Pine Forest	Mixed Forest	Open Shrub/Grass	Urban Area
Spring Breeding Season:					
Hardwood Birds			Shape(-)*		
Mixed Forest Birds			Shape(-)*		PatchNo(-)* PatchD(-)** EdgeD(-)*
Edge Birds	Core(+)* Percent(+)*** TEdge(+)**	PatchNo(-)*		Percent(-)** EdgeD(-)*	
Open Shrub/Grass Birds	Core(+)*			Shape(+)*	Percent(-)* TEdge(-)* EdgeD(-)*
Generalist Birds	Core(+)**	Core(+)* Percent(+)* PatchSI(+)**	Core(+)* PatchSI(+)*	PatchSI(-)*	Core(+)* Percent(+)* PatchNo(-)** PatchD(-)*
PIF Birds	Percent(+)*	PatchD(-)*	Shape(-)*		PatchNo(-)** PatchD(-)***
Wintering Season:					
Hardwood Birds					
Mixed Forest Birds					
Edge Birds				Percent(-)*	
Open Shrub/Grass Birds	Core(+)*				
Generalist Birds					
PIF Birds		Core(-)*	Core(-)*		Core(-)*

[1] Bird and landscape metrics are log-transformed; $^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$

DISCUSSION: Habitat fragmentation has been shown to influence bird community composition and distribution (Robbins et al. 1989, Rosenzwig 1995, McGarigal and McComb 1995, Villard et al. 1999, Belisle et al. 2001, Peyman-Dove 2001, Lichstein et al. 2002, Watson 2003). Investigating the relationships of landscape-level metrics to bird community abundance and distribution permits researchers and managers to identify, locate, and manage high quality habitat for the purpose of avian conservation (Herkert 1996, Haire et al. 1997, O'Connor et al. 1999, Peyman-Dove 2001, Saveraid et al 2001). Moreover, the use of landscape structure and patterns to monitor ecological conditions (Rosenzwig 1995, Debinski and Holt 2000, Olsen et al. 2001, Bourne and Graves 2001, Kress 2001, McGarigal and Cushman 2002, Bissonette and Storch 2003) and to study avian community patterns (McGarigal and McComb 1995, Haire et al. 1997, Belisle et al. 2001, Peyman-Dove 2001, Saveraid et al. 2001, Watson 2003) is increasing in scientific literature. For example, aspects of urban development detrimental to bird habitat have been identified and then altered to increase avian habitat quality in urban settings (Miller et al. 2001). Incorporating and standardizing bird monitoring protocols into landscape monitoring efforts remains elusive nonetheless. Currently, no standardized avian monitoring methodology incorporates landscape monitoring (e.g., Ralph et al. 1993, Hamel et al. 1996) as well.

Many military installations are actively monitoring ecological trends (including landscape-level changes and vertebrate population trends) to minimize negative impacts within their boundaries for conservation purposes and for meeting compliance requirements (Bern et al. 1999, Bourne and Graves 2001, Kress 2001). However, since the process of habitat fragmentation on military installations is generally much slower than in other human-dominated landscapes (Stein et al. 2008), few military installations consider the impacts of habitat fragmentation in their efforts to manage and conserve seasonal bird communities. In this study, we used data from two separate monitoring efforts as a proof-of-concept to demonstrate that we can increase our knowledge and understanding of factors influencing bird community distributions at the landscape level at Fort Benning, Georgia.

Over the course of the monitoring period, the installation was in the process of implementing restoration of longleaf pine savannahs (Barren 2001, Olsen et al. 2001). Consequently, efforts were made to harvest existing mature and marketable loblolly (*Pinus taeda* L.) stands and replant with longleaf pine. Concurrently, trends of fire suppression and hardwood invasion likely continued unabated. The cumulative impacts of these actions appears to have been an increase in the number of patches and patch density of hardwood forests, and an increase in the size, number of patches, and overall percentage of cover of open shrub/grassland habitats throughout the installation. Meanwhile, pine forest habitats decreased in overall percentage of land cover, number of patches and patch density in the landscape. Mixed forest habitats increased in overall size and percentage of land cover, while the number of patches and patch density decreased during the monitoring period, indicating that while some patches of mixed forest were lost, other patches increased in size on some areas of the installation. Similarly, while urban areas decreased in overall percentage of land cover and number of patches during the monitoring period, the total edge and edge density increased, suggesting that some urban patches increased in size or complexity (i.e., there was an increase in urban edges).

During the breeding season, the abundance of several bird guilds increased during the monitoring period, including PIF priority species and birds that utilized mature forest habitats. These results may be explained in part by the increase in the number and density of hardwood forest patches that were observed during landscape monitoring efforts. Although mean abundance of edge birds remained unchanged during the monitoring period, these birds were correlated with hardwood forest habitats, particularly with the total hardwood forest edge and percent of hardwood forest in the landscape. The dependence of these species on forest edge habitats was apparent with the negative correlation of edge birds with the percent of open country in the landscape. The harvesting of pine forests throughout the installation may have created more edges along hardwood forest patches, and may have occurred around survey stations surrounded by hardwood forests along the Upatoi Creek and Chattahoachee River. The creation of open, cut-over habitats adjacent to areas of hardwood forest within 1 km around some of the survey stations may have resulted in the positive relationships of open shrub/grassland birds to core of hardwood forest, although this possibility requires further investigation. Most bird species groups, including mixed forest birds, open shrub/grassland birds and PIF birds were negatively correlated with several landscape features of urban areas, particularly the percent of urban areas in the landscape, number of urban patches, and urban patch density. Only generalist birds were positively correlated with aspects of urban areas in the landscape. Negative impacts of urban areas on bird communities, especially forest interior and open country specialists, is commonly reported in scientific literature (e.g., Whitcomb et al. 1981, Robbins et al. 1989, Saunders et al 1991, Marzluff et al. 2001, Peyman-Dove 2001).

Few studies have investigated landscape-level relationships of bird communities during the winter months. However, the winter season is often a period of resource limitation (Fretwell 1972) and most adult mortality likely occurs during this period of the annual cycle (Wiens 1989). Moreover, destruction and degradation of wintering habitat has been implicated in the decline of many Neotropical migratory species (Askins et al. 1990, Martin and Finch 1995) and grassland birds (O'Connor et al. 1999). Many North American grassland birds winter in the southeastern United States, including at Fort Benning. Several open shrub/grassland birds that winter on Fort Benning are PIF priority species on their northern breeding grounds (e.g., Loggerhead Shrike) (Casey 2000). Therefore, monitoring winter bird communities and associated landscape level relationships should be an essential element for conservation of bird populations (Gutzwiller 1991). Although no significant changes in mean bird abundance were observed during the winter monitoring period, several bird habitat guilds were significantly correlated with landscape-level features. Curiously, as during the breeding season, open country birds were positively correlated to core and percent area of hardwood forests. During the winter, this result may reflect a propensity of some grassland birds (e.g., sparrows) to utilize more forest edge habitat during the winter and to avoid large open areas, perhaps because of beneficial shelter and wind protection along wooded edges during the winter months (Byers et al. 1995). The PIF bird guild consisted of fewer forest bird species during the winter, yet results evidenced a negative correlation with core pine, mixed forest, and urban habitat; this suggests that even during the winter season, fragmentation of forest habitat by pine management practices and urban sprawl may negatively impact this group of species.

SUMMARY: This study represents a cursory look at seasonal relationships of bird communities to landscape-level patterns on Fort Benning, Georgia, and is meant to illustrate how data from different monitoring efforts can be used to provide information on bird communities utilizing habitats on the installation. Although landscape-level relationships to bird communities can often be ambiguous (McGarigal and McComb 1995, Lichstein et al. 2002, Bissonette and Storch 2003), many of the results observed in this study are consistent with similar research in the region (e.g., Peyman-Dove 2001). However, the sampling periods for both the landscape and bird community monitoring were relatively short, and were not coordinated. Landscape-level data were collected for a year (during 1986) before, during (1991), and several years after (2001 and 2003) the bird-monitoring efforts took place. Landscape data were also collected at a higher resolution during 2001 and 2003. The lack of temporal coordination means that only a small portion of the bird community data can be related directly to existing landscape conditions. Furthermore, the bird community data were collected at a relatively small subset of possible locations and may not represent all features available on the landscape. In addition, the small number of plots and short duration of the monitoring period, do not permit a rigorous analysis of bird populations trends (e.g., Nur et al. 1999). For this reason, presented trends are best treated as potential trends that require further data for verification. These analyses are only exploratory and much more work must be done to test and verify these relationships; certainly, these data open the possibility of developing a priori hypotheses for future research efforts at Fort Benning that would increase our understanding of bird community dynamics on the installation.

In future monitoring efforts, landscape-level data must be collected consistently at a specific resolution. Bird community data will need to be collected during the same period that satellite imagery is available. This data must also be collected from a larger proportion of the installation, and over a longer period of time (e.g., $\geq$5-10 years) (Nur et al. 1999). Furthermore, the impacts of habitat fragmentation may vary temporally; for example, territorial behavior in birds may result in time lags when the habitat quality is reduced by fragmentation (e.g., birds may remain on territory even when formally good habitat becomes poor habitat) (Wiens 1989). Consequently, monitoring the impacts of landscape changes on regional bird populations may require several years of data before discernable patterns are detectable (Debinski and Holt 2000, Bissonette and Storch 2003). The recorded LCTA data in this study did not include any means of calculating detection indices for the bird species recorded. Variability in the detection probabilities for many birds may alter observed bird/habitat relationships (Nichols et al. 2001); thus, future monitoring efforts should include protocols that permit estimation of detectability functions for each recorded species. Linking monitoring efforts on military installations with local and regional initiatives, such as Coordinated Bird Monitoring (CBM) (Bart et al. 2004), would provide a starting point for establishing clear objectives and scientifically defensible survey methods. This approach has been advocated for DoD lands managed by the U.S. Army Corps of Engineers (Guilfoyle and Fischer 2007).

A well-coordinated monitoring effort that ties both landscape-level and seasonal bird community data together may provide insights into the impacts of land-use changes on the installation-wide bird communities. These insights may lead to a better understanding of the impact of military training operations, forestry practices and urban encroachment on bird populations, particularly on PIF priority species. Current efforts on the installation to increase longleaf pine savannahs to benefit red-cockaded woodpecker and Bachman's sparrow populations (Barren 2001) may have negative impacts on species that utilize mature hardwood or open country habitats (Wilson et al. 1995). Establishing a well-coordinated monitoring program may help to predict and ameliorate these impacts, permit identification of important landscape features to sustaining bird populations, and aid in the long-term planning for, and the protection and restoration of high quality breeding and wintering bird habitat on the installation.

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