MANAGEMENT STRATEGIES FOR REVERSING DECLINES IN LANDBIRDS OF CONSERVATION CONCERN ON MILITARY INSTALLATIONS:

A LANDSCAPE-SCALE ANALYSIS OF MAPS DATA

A REPORT TO THE

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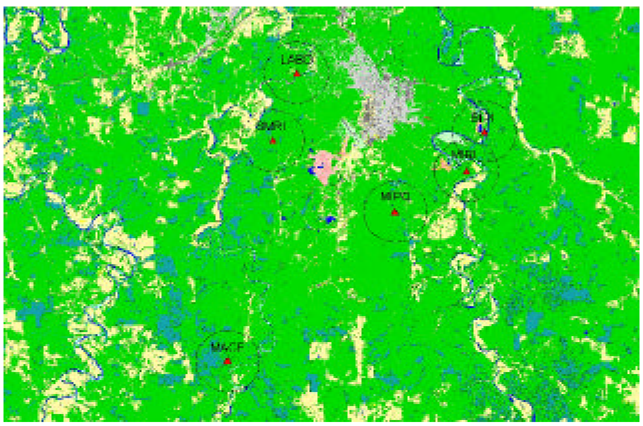
Executive Summary

The U.S. Department of Defense manages over 420 military installations throughout the United States that cover approximately 10 million hectares. These installations provide important habitats for many songbird species because they often contain portions of important ecosystems, hotspots of biodiversity, critical breeding habitat, or stopover habitat used during migration.



Locations of six MAPS stations on Fort Leonard Wood, MO, superimposed on National Land Cover Dataset. Circles represent 2-km radii around each station.

Natural resource managers of installations face considerable challenges in balancing the application of federal laws that protect bird populations with the requirements of military mission. This is especially relevant where management activities such as those associated with readiness and sustainment of military ranges may impact Neotropical migrant birds that breed on DoD installations throughout the United States.

Other activities, such as logging and cattle grazing on installations may also impact breeding bird populations. Ecological models that quantify the effects of landscape pattern and structure on avian population dynamics can help managers meet these challenges. Managers require decision-making tools that will enable them to predict the effects of proposed land use change and habitat management on avian demographics, including population densities, reproductive success, and the direction of population trajectories.

The Institute for Bird Populations, through its Monitoring Avian Productivity and Survivorship (MAPS) program (1994-2001), effectively monitored 31 landbird species on 13 DoD installations (or groups of nearby installations) across the eastern and central United States. Of these 31 species, we identified ten that are nationally or regionally listed (as of December, 2002) by the US Fish and Wildlife Service as "***Birds of Conservation Concern***."

We combined banding data for these species with data from the National Land Cover Dataset (NLCD; 1992) and constructed landscape-scale (1000's of hectares) management models for reversing the declines in Neotropical migratory birds and other resident and migratory landbirds.

MAPS intern recording wood thrush data at Crane Naval Surface Warfare Center, Indiana.

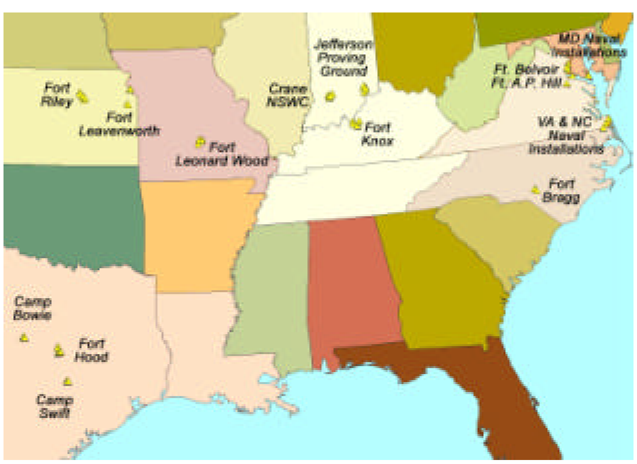
Using a state-of-the-art statistical approach, we combined multiple regression analyses with model selection by an information complexity criterion (ICOMP). From these analyses we constructed 44 demographic-landscape models relating to numbers of adults and young, population trend, and reproductive success.

We intend to test these models, in collaboration with natural resource managers of installations, by monitoring the effects of new or ongoing spatially extensive management actions and comparing them with model predictions.

Table 1. Population trends from MAPS data for ten species of management concern that were effectively monitored between 1994 and 2001 on 13 DoD installations. Increasing adult populations are denoted by (+) symbols and declining populations are denoted by (-) symbols. Shaded cells indicate statistical significance (0.001
of management concern and the total number of species effectively monitored are provided for each installation.

Installation / ***Species Common Name***	Fort Belvoir/ Fort A.P. Hill	Pax. River/ Indian Head/Dahlgren	Tidewater, VA Naval Complex	Fort Bragg	Jefferson Proving (Big Oaks NWR)	Fort Knox	Crane Naval Warfare Center	Fort Leonard Wood	Fort Leavenworth/ Sunflower	Fort Riley	Camp Swift	Fort Hood	Camp Bowie
Forest													
Acadian flycatcher	-	+	+		+	+	+	-					
Wood thrush	-	-	+	-	-	+	+	+	+	+			
Worm-eating warbler		-			-	-	+	-					
Louisiana waterthrush	-	+				-	+	-	+	+			
Kentucky warbler		-			-	-	+	-	-				
Scrub/successional													
Bewick's wren												-	-
Blue-winged warbler					-	-	-	+					
Prairie warbler				-	-	+	-	+					
Field sparrow					-		-	-	-	+		-	-
Painted bunting											-	+	+
Species of concern	**3**	**5**	**2**	**2**	**7**	**7**	**8**	**8**	**4**	**3**	**1**	**3**	**3**
Total species monitored	**15**	**17**	**14**	**14**	**24**	**16**	**22**	**21**	**16**	**17**	**6**	**12**	**8**

Species of management concern were identified at 13 DoD installations or groups of nearby installations (above). Four locations east of the Appalachians (Belvoir to Bragg) most effectively monitor forest species of management concern, except Fort Bragg where prairie warblers are also common breeders.



Map of the southeastern portion of the United States featuring the locations of DoD installations where MAPS stations were operated through 2002.

Three locations in Indiana and Kentucky, Fort Jefferson (now Big Oaks NWR), Fort Knox, and Crane Naval Surface Warfare Center, support eight species of management concern including three scrub/successional species.

Three locations in Kansas and Missouri, Fort Leonard Wood, Fort Leavenworth and Fort Riley, also support breeding populations of five forest and three scrub/successional species.

In Texas, the more scrubby habitats typical of Camp Swift, Fort Hood, and Camp Bowie allow effective monitoring of three scrub/successional species of management concern.

Overall, seven locations, Fort Jefferson, Fort Knox, Crane Naval Surface Warfare Center, Fort Leonard Wood, Fort Leavenworth, Fort Riley, and the Pax. River , Indian Head, and Dahlgren (MD) Navy installations can effectively monitor between 16 and 22 landbird species each.

Species-landscape models revealed important predictors of avian demographics among the ten species of management concern. Overall, selected models for those species that prefer to nest in forests and woodlands suggest that land managers should conserve large areas of contiguous forest (upwards of 700 ha) in a 1256 hectare, 2-kilometer radius area. Clearly, within those forested areas, canopy cover, as well as the density of undergrowth and ground cover, should be managed in a manner consistent with published microhabitat management procedures for the target species.

Acadian flycatcher. Management for this species should be directed at maintaining high reproductive success by conserving large tracts of contiguous forest – this will increase the numbers of adults (because core area is a positive function of total forest cover), but will increase the numbers of young at an even higher rate, and tend to produce source habitat. We conclude that maintaining contiguous forest tracts of between 500 and 900ha would benefit Acadian flycatchers. Water sources, agricultural land (possibly misclassified clearcut) and even shrubland should be maintained in small patches that total only 5-10% of the landscape.

Wood thrush. Because wood thrush populations decrease with increasing levels of forest management, we suggest that maintaining contiguous forest tracts of between 600 and 900ha will benefit wood thrushes in both the eastern and central regions of the United States. Small areas of agricultural land (eastern) and both forest and shrubland edge (central) also appear to be beneficial to both adult and young wood thrushes, presumably because those habitats fulfill post-breeding and post-fledging needs of the species.

Worm-eating warbler. Overall, on military installations in eastern and central United States, worm-eating warbler demographic parameters were found to be negatively related to forest fragmentation, although small areas of shrubland appeared to be beneficial, presumably, as in wood thrush, for post-breeding and post-fledging dispersal of both adults and young. We recommend that, for worm-eating warblers, land managers should maintain contiguous forest tracts of at least 1,000 hectares (within a 2-kilometer radius area) with small patches of adjacent shrubland.

Louisiana waterthrush. We suggest that a successful management strategy for Louisiana waterthrush is to maintain the upland forested streams, that provide primary breeding habitat, in near pristine condition, and to manage forested areas in such a way as to maintain or increase the amount of dense, shrubby forest-edge habitat for post-fledging utilization, while decreasing the overall amount of shrubland cover in the landscape.

Kentucky warbler. Kentucky warblers appear tolerant of some degree of forest fragmentation, especially in the western portion of their range, where they appear to breed in forest remnants and isolated woodlots. Our models suggest that, while the total amount of forest cover should be kept high and the total amount of forest edge (and thus the amount of forest fragmentation) should be kept low, small amounts of shrubland edge should be maintained, again probably as a target location for post-breeding and post-fledging dispersal. We recommend that large patches of contiguous forest should be maintained covering 50-80% of the area (600-1000ha in a 2-kilometer-radius area), and that small patches of shrubland habitat that cover 5-15% of the area (60-180ha in the 2-kilometer-radius area) should be scattered through the landscape. Moderate levels of fragmentation such as these can also provide some amount of habitat suitable for scrub/successional species.

Scrub/successional species-landscape models typically suggested that maintenance of a heterogeneous mosaic of different habitat types is desirable. In general these species were captured at those stations surrounded by landscapes that contained various levels of forest fragmentation. This fragmentation resulted either from active management of the forested landscape or from habitat types that naturally form heterogeneous mosaics, such as the shrublands of central Texas.

Bewick's wren. We suggest that Bewick's wrens benefit from maintaining a mosaic of shrubland and forest (open, low-canopy oak-juniper woodland) with small patches of grassland. The shrubland component is the most important and should be maintained as large patches with complex shapes covering 40% or more of the area. The forest component provides trees for song perches and snags with cavities for nesting. This suggests that there likely are relationships that could be explored between the adjacency of forest and shrubland and various demographic parameters. Developed areas and large core areas of agriculture should be kept to a minimum in the landscape. While their edges may be attractive to adult Bewick's wrens, they have a negative effect on numbers of young and productivity, tend to reduce population trends, and appear to act as population sinks.

Blue-winged warbler. We recommend maintaining landscapes with 60-90% total forest cover (750-1100ha in a 2-kilometer-radius area) in a fragmented landscape interspersed with small patches of shrubland. We also suggest maximizing the spatial complexity of the forest/shrubland edge. These strategies are designed primarily to increase reproductive success; we suggest, however, that they may increase adult population sizes as well.

Prairie warbler. We suggest that the optimal management strategy for prairie warblers is to maintain relatively small brushy openings in extensive forested habitat. This could be accomplished by appropriate forestry practices, including creation of small clearcuts, group selection, or even mechanical thinning, or by carefully controlled fire practices.

Field sparrow. For field sparrows, we recommend that managers maintain a fragmented landscape of forest (about 50% of the landscape) with many patches of grassland covering 25-40% of the total landscape, each of a size less than about 150ha (about 100ha of core area). Ideally, these grassland areas should be proximal to areas of shrubland or abandoned agriculture (covering 10-25% of the landscape) along the edges of forest. In this way, management can maintain the open patchy landscape that provides good habitat for field sparrows. Rotation of "disclimax" management among the different patches may provide the key for optimal field sparrow management, and will likely benefit other species of successional and scrubland habitats.

Painted bunting. We suggest that the ideal landscape pattern for painted bunting (shown below courtesy of Steven Kazianis) populations may be similar to that for field sparrow populations, whereby a mosaic of relatively large sized patches of forest (with a total landscape coverage of 40-70%), shrubland (10-20%), grassland (10-20%), and agriculture (10-20%) are actively maintained (or rotated through time) in the landscape.

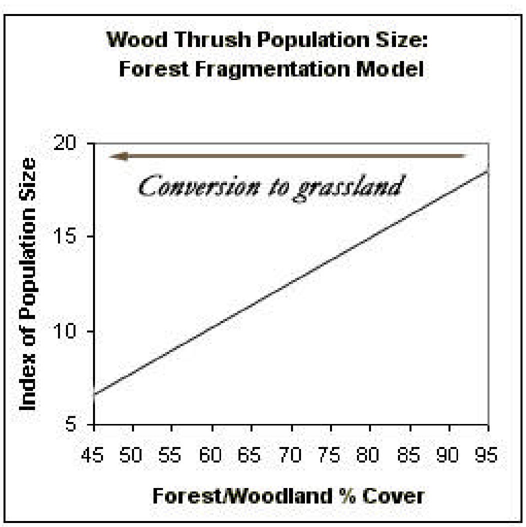
Importantly, for painted buntings (and likely other species) many small, scattered sources of water, including riparian areas and other wetlands, should be conserved or restored because the shrubby vegetation at the water's edge is likely to be an important resource for foraging. In areas where cattle grazing is allowed, lush waterside vegetation is often lacking, because it is either trampled or eaten by cattle. Cattle grazing also undoubtedly increases the probability of cowbird parasitism which can drastically reduce annual reproductive success. Thus, cattle should be excluded from all or part of these natural water sources.

In summary, a critical consideration for managing scrub-successional species at the landscape scale is to maintain an appropriately scaled mosaic of successional-stage habitats. It may be possible to integrate such a management strategy into efforts to increase military readiness and range sustainment, as well as into large-scale fire-control efforts and forestry plans.

Applying species-landscape models to landbird conservation efforts on U.S. Department of Defense installations can be a relatively simple process. The hypothetical but realistic example (below) applies to management of the landscape surrounding the Sulphur Creek MAPS station on Crane Naval Surface Warfare Center in Indiana. The installation is heavily forested but is actively managed through small-scale logging and the creation of regeneration gaps.

We explored a multivariate model designed to predict the effect of clearcutting forest, to create grassland, on an index of wood thrush population size (numbers of adults captured). We entered the real values of relevant landscape parameters from this station into the wood thrush model. The 2-kilometer radius area surrounding this station is currently 95% forested. In this case, three landscape model parameters were included – forest cover, forest edge, and agricultural cover. The model estimated the current adult population size index to be approximately 18 individuals.

However, if logging (to create grassland) were to reduce this coverage to 45% the model predicts the population size index to decrease by 65% to six individuals. This is a very simple example. In reality, a manager may want to assess the effects of several alternative management scenarios on species of management concern.

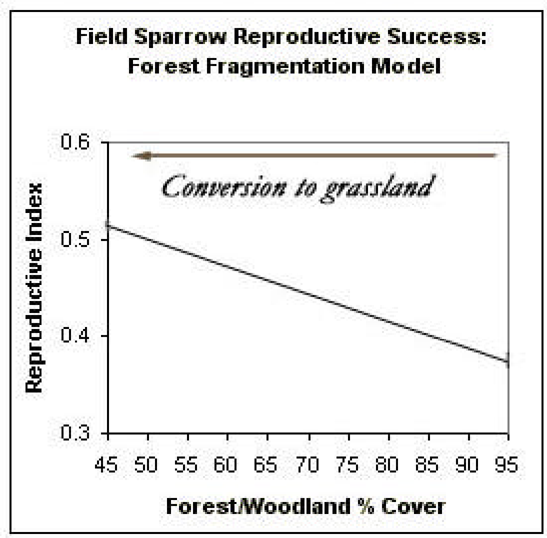


Species-landscape model showing the effect of forest fragmentation on wood thrush adult population size.

A land manager would apply these models in the following manner:

- identify a target species of management concern in an area of the installation.
- using GIS, spatially analyze the existing 2 kilometer radius to obtain estimates of spatial parameters relevant to the target species.
- estimate the expected reproductive success, numbers of adults, and numbers of young.
- using GIS, simulate the proposed management actions (e.g. deforestation) within the existing 2-kilometer radius landscape.
- repeat steps two and three to obtain "new" estimates of demographic parameters.
- Evaluate the demographic predictions relative to management goals.

This process allows managers to assess the likely effects of alternative proposed management actions on the species of management concern.



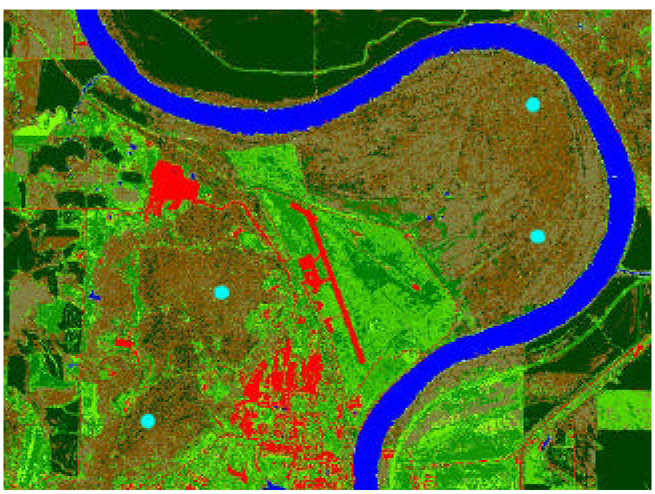
Species-landscape model showing the effect of forest fragmentation on field sparrow reproductive success

Multiple species effects, however, are inevitable. Management actions that benefit one species may adversely affect another species. Although clear-cutting reduces wood thrush populations, it may benefit other species. The predicted effect on field sparrows of converting forest to grassland is a 37% increase in the fledglings produced per adult, from 0.38 to 0.52. Thus, the effects of proposed actions should be assessed on a suite of species of management concern that breed in the same area.

Range sustainment and readiness is crucial to the military mission and necessitates many types of management activities that can impact breeding habitat for many North American songbirds, including Neotropical migrants.

The models constructed in this research can act as guidelines to the potential effects of spatially extensive land management on songbird populations. These include "area" effects on forest birds such as Acadian flycatchers, for which a reduction of the size of forested patches can cause a disproportionate reduction in the population size. For other species, such as field sparrows, these models emphasize the importance of habitat edges as predictors of population size and trajectory.

We conclude that the NLCD (1992) dataset provides an effective but coarsely scaled tool for constructing species-landscape models. It is likely, however, that improved spatial analyses of alternative high-resolution land cover datasets will increase the usefulness of these models.



Supervised classification of multispectral IKONOS imagery for Fort Leavenworth, Kansas showing forested tracts (brown), grassland (green), developed land (red) and locations of four MAPS stations (blue dots). Image courtesy of Andrew Schmidt.

High-resolution land cover datasets, such as the IKONOS multispectral satellite data (Space Imaging Inc.), provide the opportunity to explore species-landscape relationships at a spatial resolution of four meters. Such high-resolution data allow the estimation of important ecological parameters, such as forested canopy cover, because the spatial resolution is less than the crown diameter of many trees. Likewise, high-resolution land cover imagery enables the identification of potentially ecologically important water sources, such as small ponds and creeks, as well as some fire roads and wider trails that may cause habitat fragmentation.

Also, topographical parameters, such as slope, aspect and topographical diversity or complexity, may be calculated from digital elevation models and included in the species-landscape models.

Future landbird monitoring efforts on DoD installations should focus on the effects of land management on *Birds of Conservation Concern* as listed by USFWS. This will require additional clusters of MAPS stations to be established on installations that support abundant or declining populations of those species. We intend improve our models through the development of more sophisticated analysis and modeling techniques.

IBP is already committed to monitoring the effects of recent (or imminent) management actions in the vicinity of existing MAPS stations at Fort Bragg, Fort Leonard Wood, Camp Bowie and Camp Swift. For instance, at Fort Leonard Wood, two MAPS stations have been relocated to act as control sites for studying the effects of "disclimax" management of scrub/successional habitats that provide breeding habitat for prairie warblers. Effectiveness monitoring of this kind is also possible at several other installations such as Crane NSWC, Jefferson Proving Ground, Fort Knox, Fort Riley, and Fort Leavenworth.

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We also wish to acknowledge the interns, biologists and Department of Defense personnel whose hard work and commitment to avian monitoring and conservation made this research possible.

INTRODUCTION

The purpose of the research documented in this report was to use eight years (1994-2001) of Monitoring Avian Productivity and Survivorship (MAPS) data collected by The Institute for Bird Populations (IBP) from 78 MAPS stations on 13 DoD installations (or groups of nearby installations) across the eastern and central United States to identify and formulate management actions on these (and other) DoD installations to reverse the declines in Neotropical migratory birds and other resident and migratory landbirds.

Protecting avian diversity on military installations

The U.S. Department of Defense manages over 420 military installations throughout the United States that cover approximately 10 million hectares. These lands provide important habitats for many bird species because they often contain portions of important ecosystems, hotspots of biodiversity, and critical breeding or stopover habitat. Because these lands are federally protected, they are mostly unavailable to agriculture, property development and other anthropogenic disturbances that have degraded habitats elsewhere. DoD lands support a high diversity of animals, plants, and birds including over 300 federally listed species that inhabit rapidly disappearing communities such as old-growth forests, tall-grass prairies, pine barrens, riparian forests, and vernal pool wetlands.

In 2001, by executive order 13186 of the president of the United States and in furtherance of the purposes of five conservation Acts of Congress, including the Migratory Bird Treaty Act, all federal agencies are mandated to protect migratory birds. More specifically, this order emphasizes the importance of protecting "species of concern" as those priority species identified in the Endangered Species Act and in physiographic regional lists provided by the North American Bird Conservation Initiative (NABCI) or the Neotropical Migratory Bird Conservation Initiative, "Partners in Flight" (PIF). More recently in 2002, the U.S. Fish and Wildlife Service (FWS) published a list of 131 "Birds of Conservation Concern" (BCC) as a guide to recognizing candidate species for research, monitoring, and management initiatives. Priority is assigned to species at spatial scales of NABCI Bird Conservation Regions, FWS regions, and nationally.

In recent decades the DoD's environmental stewardship has scored major successes in facilitating ecological research on military installations and in successfully protecting important refugia for rare, threatened, or endangered species, such as the red-cockaded woodpecker, golden-cheeked warbler, black-capped vireo, and California gnatcatcher. Department of Defense lands also represent a critical network of habitats for Neotropical migrants, offering these birds migratory stopover areas for resting and feeding, and many suitable sites for nesting and rearing their young. Natural resource managers of DoD installations face considerable challenges in balancing the application of federal laws that protect these bird populations with the requirements of military mission. In fact, the forests of military installations constitute some of the largest undeveloped tracts of natural or semi-natural forests in the nation, and consequently provide primary breeding habitat for many neotropical migratory landbirds such as wood thrushes and worm-eating warblers.

A number of land management practices on DoD installations can impact landbird populations. These include the leasing of logging or grazing rights which may raise issues of forest fragmentation and the loss of forest interior, or the destruction of shrub and understory vegetation that provides important nesting habitat for many landbird species. The primary mission of many DoD installations is to operate airfields, drop zones, bombing ranges, and other types of training areas that require frequent management to maintain these open areas and protect the surrounding landscape from the risk of wildfire. Although management of this kind can be detrimental to some forest interior species, it can also be potentially very beneficial to some species that prefer to breed in the scrub or successional habitats that result. It is important, therefore, to quantify the effects of such management on populations of breeding landbirds of all habitat types.

The Department of Defense, as the key member in the Partners in Flight program, of which IBP is also a signatory, has developed a strategic plan for the conservation and management of Neotropical migratory birds and their habitats on Department of Defense lands. DoD has contributed significant resources through the Legacy Resources Management Program and other funding sources to support the PIF initiative and the work described here. This report provides species-specific landscape models of avian demographics that apply to ten BCC species of management concern that breed in early (five species) and late (five species) successional habitats on military installations of the southeast and south-central United States. These models and the management recommendations formulated from them should better inform the decision-making process of natural resource managers on DoD installations towards effective avian conservation and management.

Constructing avian population management models

The Institute for Bird Populations began operating 78 constant-effort mist netting stations during 1992 (six stations), 1993 (12 stations), 1994 (42 stations), and 1995 (18 stations) on 13 DoD installations (or groups of nearby installations). DoD Legacy funding supported the operation of these MAPS stations and this research through the breeding season of 2002. The banding data collected at these stations included data on numerous landbird species, including many Neotropical migrants, that breed in forest and scrub/successional communities. The ultimate goal of the research documented here was to identify and formulate management strategies on these (and other) DoD installations to reverse declining populations and maintain stable or increasing populations of target Neotropical migratory landbirds and other species. We achieved this goal by constructing species-landscape models for a suite of species that prefer forested or successional habitats. This involved several steps. First, we described the demographics (by species and DoD installation) of those species that the MAPS program effectively monitored on DoD installations. We then compared this list with the list of FWS birds of conservation concern and, for the purposes of this report, classified those species in common as “species of management concern” and categorized them by habitat preference (i.e. forest species or scrub/successional species).

For each installation, we identified which of the species of management concern were declining and identified the stations at which they were declining. We provide installation-specific recommendations concerning which species and which existing MAPS stations should become the focus of future monitoring efforts. We also suggest which stations should be discontinued in favor of relocating them to areas where they can more effectively monitor species of management concern. Finally, we discussed many of these recommendations and suggestions with natural resource managers of installations of particular conservation value.

For four installations, we document specific management and monitoring plans that managers have, in principle, already agreed to. At the time of this report, at least one installation (Fort Leonard Wood) has taken management actions to reverse recent population declines in two scrub/successional species, the effects of which we will continue to monitor.

We then constructed species-landscape models by combining the demographic data for species of conservation concern with “landscape metrics” derived from spatial analyses of land coverages surrounding those MAPS station at which the species was captured in sufficient numbers. Critical to this process was the development of software routines to a) correct for bias introduced by missed effort in the banding data, b) calculate values for various demographics that can be derived from MAPS data, c) automate the process of spatially analyzing 78 landscapes at differing spatial scales and vertical resolutions, and d) perform multiple regression analyses and select statistically defensible models that incorporate maximum-likelihood estimation and measures of information complexity.

For each species of management concern we reviewed existing literature pertaining to management issues and summarize that literature in this report along with descriptions of the species-landscape models we constructed. Finally, we discuss these models within the framework of DoD installation natural resource management and particularly with reference to habitat management associated with military range sustainment and readiness. These population management principles and models can also apply to those DoD installations that do not provide range-training opportunities. Military weapons storage facilities, for instance, generally discourage the use of controlled fire as a management tool but, on forested installations, may create firebreaks and permit limited logging operations.

METHODS

In this investigation we constructed species-landscape models to act as management guidelines designed to reverse declining population trends among birds that breed on Department of Defense installations. We analyzed multiple years of bird banding data (MAPS data) from 78 monitoring stations to provide a list of 31 species for which we recorded an average of at least 2.5 aged individuals per year (including at least one hatching-year individual in at least one year). Furthermore, we identified 10 target species by comparing this list with those species identified by U.S. Fish and Wildlife (2002) as "Birds of Conservation Concern" (BCC). Station-specific analyses of the banding data allowed us to quantify 10 demographic parameters for each of 10 BCC species. From extensive literature searches we provide a synopsis of the management issues relating to each of these species. We then collated multiple spatial statistics associated with a 2-km area centered on each MAPS station by analyzing reclassified portions of the publicly available National Land Cover Dataset (NLCD 1992). Combining these spatial data and the avian demographic data we constructed species-landscape models by applying information theory and maximum likelihood principles to numerous multivariate regression analyses.

MAPS DATA

The Institute for Bird Populations (IBP), through its Monitoring Avian Productivity and Survivorship (MAPS) program (DeSante et al. 1998; DeSante and O'Grady 2000), collected breeding season mist netting and banding data from 78 constant-effort monitoring stations on United States Department of Defense installations in the Mid-Atlantic States and in the Southeastern and South-central US. These 78 stations are divided evenly among 13 installations, or groups of nearby installations and other federal land, in Maryland, Virginia, North Carolina, Indiana, Kentucky, Missouri, Kansas, and Texas. Six stations are located on each of the installations (or groups of installations and other federal land), as shown in Table 1. Of these, 5 stations have operated since 1992, 13 since 1993, 40 since 1994, 19 since 1995, and 1 since 1996. Table 1 also includes three discontinued stations that operated for only one or two years, and are not included in this analysis. We collected and analyzed banding data from each station to obtain study-wide, installation-specific, and station-specific demographic parameters for 31 species.

Table 1. Names, locations, station numbers, and geographic coordinates of 81 Monitoring Avian Productivity and Survivorship (MAPS) bird-banding stations located in the Southeast or South-central MAPS regions at eleven US Department of Defense installations (or groups of installations), including eight Department of the Army installations or groups of installations (U.S. Army Fort Belvoir, U.S. Army Fort A.P. Hill, and Mason Neck National Wildlife Refuge (BELV); U.S. Army Fort Bragg (BRAG); U.S. Army Jefferson Proving Ground (JEFF*) now operated by USFWS as Big Oaks NWR; U.S. Army Fort Knox (KNOX); U.S. Army Fort Leavenworth and Sunflower Army Ammunition Plant (LEAV); U.S. Army Fort Leonard Wood (LEON); U.S. Army Fort Riley (RILE) and U.S. Army Fort Hood (HOOD)), and three Department of the Navy installations or groups of installations (Patuxent River Naval Air Station, Dahlgren Naval Surface Warfare Center, and Indian Head Naval Weapons Support Center (NAVY); Naval Amphibious Base Little Creek Annex Camp Pendleton, Naval Air Station Oceana, Naval Air Station Oceana Auxiliary Landing Field Fentress, and Naval Security Group Activity Northwest (TIDE),and Crane Naval Surface Warfare Center (CRAN)). This list also includes two Texas National Guard installations, Camps Bowie (BOWI) and Swift (SWIF).

Location	Station Abbr.	Station Name	Station Number	State	Lat	Long	Elev (m)	Years Operated
BELV	BUPL	Belvoir Upland	16644	VA	38.736	-77.150	38	1995 - 2001
BELV	BLOW	Belvoir Lowland	16645	VA	38.739	-77.133	9	1995 - 2001
BELV	MAS1	Mason Neck 1	16646	VA	38.626	-77.173	6	1995 - 2001
BELV	MAS2	Mason Neck 2	16647	VA	38.626	-77.201	6	1995 - 2001
BELV	APH1	A.P. Hill 1	16648	VA	38.139	-77.339	55	1995 - 2001
BELV	APH2	A.P. Hill 2	16649	VA	38.150	-77.339	61	1995 - 2001
NAVY	PLOW	Patuxent Lowland	16610	MD	38.269	-76.436	30	1992 - 2001
NAVY	PUP1	Patuxent Upland 1	16611	MD	38.253	-76.422	21	1992 - 2001
NAVY	PUP2	Patuxent Upland 2	16612	MD	38.253	-76.422	30	1992 - 2001
NAVY	DAHL	Dahlgren	16613	VA	38.344	-77.050	7	1992 - 2001
NAVY	INHE	Indian Head	16614	MD	38.575	-77.197	6	1992 - 2001
NAVY	STNE	Stump Neck	16619	MD	38.553	-77.197	9	1993 - 2001
TIDE	FENT	Fentress	16650	VA	36.683	-76.150	4	1995 - 2001
TIDE	PEND	Pendleton	16651	VA	36.806	-75.981	3	1995 - 2001
TIDE	OWLS	Owls Creek	16652	VA	36.822	-75.992	3	1995 - 2001
TIDE	BOAR	Boardwalk	16653	NC	36.533	-76.269	5	1995 - 2001
TIDE	POND	Oceana Pond	16654	VA	36.811	-76.003	6	1995 - 2001
TIDE	ROTH	Rothr Antenna	16655	VA	36.558	-76.281	6	1995 - 2001
BRAG	I102	I102	16656	NC	35.139	-79.328	94	1995 - 2001
BRAG	I104	I104	16657	NC	35.128	-79.317	100	1995 - 2001
BRAG	I113	I113	16658	NC	35.092	-79.325	95	1995 - 2001
BRAG	S110	S110	16659	NC	35.119	-79.336	94	1995 - 2001
BRAG	S112	S112	16660	NC	35.111	-79.367	114	1995 - 2001
BRAG	S114	S114	16661	NC	35.047	-79.269	70	1995 - 2001
JEFF	AR54	Area 54	16620	IN	38.897	-85.375	268	1994 - 2001
JEFF	AR27	Area 27	16621	IN	38.997	-85.375	277	1994 - 2001
JEFF	AR66	Area 66 *	16622	IN	38.831	-85.447	258	1994 - 1995
JEFF	AR16	Area 16	16623	IN	39.014	-85.394	274	1994 - 2001
JEFF	AR31	Area 31	16624	IN	38.967	-85.456	259	1994 - 2001
JEFF	AR07	Area 07	16625	IN	39.036	-85.436	259	1994 - 2001
JEFF	AR64	Area 64	16669	IN	38.933	-85.378	270	1996 - 2001
KNOX	OHRI	Ohio River	16632	KY	37.975	-86.031	131	1994 - 2001
KNOX	MCSP	McCracken Springs	16633	KY	37.892	-86.031	171	1994 - 2001
KNOX	CEDA	Cedar Creek	16634	KY	37.811	-85.828	151	1994 - 2001
KNOX	SARI	Salt River	16635	KY	37.942	-85.769	140	1994 - 2001
KNOX	DULA	Duck Lake	16636	KY	37.967	-85.781	131	1994 - 2001
KNOX	LDLA	Lower Douglas Lake	16637	KY	37.825	-85.878	221	1994 - 2001

Location	Station Abbr.	Station Name	Station Number	State	Lat	Long	Elev (m)	Years Operated
CRAN	FIRS	First Creek	16626	IN	38.872	-86.903	162	1994 - 2001
CRAN	WICE	Williams Cemetery	16627	IN	38.808	-86.883	219	1994 - 2001
CRAN	SEED	Seedtick Creek	16628	IN	38.758	-86.886	149	1994 - 2001
CRAN	SULP	Sulphur Creek	16629	IN	38.886	-86.736	177	1994 - 2001
CRAN	EABO	East Boggs	16630	IN	38.794	-86.836	152	1994 - 2001
CRAN	AR14	Area 14	16631	IN	38.839	-86.794	198	1994 - 2001
LEON	BIPI	Big Piney	14422	MO	37.739	-92.044	235	1993 - 2001
LEON	LABO	Laughlin Bottoms	14423	MO	37.778	-92.178	300	1993 - 2001
LEON	MIPO	Miller Pond	14424	MO	37.694	-92.111	326	1993 - 2001
LEON	MACE	Macedonia	14425	MO	37.611	-92.236	360	1993 - 2001
LEON	SMRI	Smith Ridge	14426	MO	37.739	-92.197	320	1993 - 2001
LEON	MIRI	Miller Ridge	14427	MO	37.717	-92.058	270	1993 - 2001
LEAV	FOSU	Fort Sully	13326	KS	39.344	-94.936	274	1993 - 2001
LEAV	NOWE	North Weston	13327	KS	39.386	-94.892	235	1993 - 2001
LEAV	CAMI	Camp Miles	13328	KS	39.369	-94.928	259	1993 - 2001
LEAV	SOWE	South Weston	13329	KS	39.369	-94.892	233	1993 - 2001
LEAV	RADE	Rabbit's Demise	14448	KS	38.925	-95.033	256	1994 - 2001
LEAV	SPHA	Sparrow's Haven	14449	KS	38.889	-94.997	274	1994 - 2001
RILE	TICR	Timber Creek	14428	KS	39.292	-96.953	369	1993 - 2001
RILE	KARI	Kansas River	14429	KS	39.056	-96.786	323	1993 - 2001
RILE	MYPR	Myersdale Prairie	14450	KS	39.231	-96.950	381	1994 - 2001
RILE	ESDR	Estes Draw	14451	KS	39.111	-96.828	381	1994 - 2001
RILE	RIPO	Richardson's Posts	14452	KS	39.164	-96.811	396	1994 - 2001
RILE	RCPR	Rush Creek Prairie *	14453	KS	39.158	-96.856	381	1994
RILE	TMCR	Three Mile Creek	14462	KS	39.094	-97.567	323	1995 - 2001
SWIF	PIPE	Pipeline	14436	TX	30.283	-97.328	143	1994 - 2001
SWIF	EALW	East Loop West	14437	TX	30.262	-97.272	152	1994 - 2001
SWIF	EALE	East Loop East	14438	TX	30.262	-97.263	152	1994 - 2001
SWIF	WCLO	Wine Cellar Loop	14439	TX	30.274	-97.320	137	1994 - 2001
SWIF	SAJU	Sandy Junction	14440	TX	30.286	-97.290	155	1994 - 2001
SWIF	MCCR	McLaughlin Creek	14441	TX	30.271	-97.282	137	1994 - 2001
HOOD	SHOR	Shorthorn	14430	TX	31.360	-97.664	220	1994 - 2001
HOOD	TAYL	Taylor Field	14431	TX	31.179	-97.559	240	1994 - 2001
HOOD	DEER	Deer Camp **	14432	TX	31.306	-97.678	280	1994
HOOD	ENGI	Engineer Lake	14433	TX	31.153	-97.665	280	1994 - 2001
HOOD	VIRE	Vireo	14434	TX	31.164	-97.636	280	1994 - 2001
HOOD	BROO	Brookhaven Mountain	14435	TX	31.182	-97.622	275	1994 - 2001
HOOD	TABR	Taylor Branch	14454	TX	31.191	-97.567	210	1994 - 2001
BOWI	STON	Stonehouse	14442	TX	31.595	-98.907	442	1994 - 2001
BOWI	NIGH	Nighthawk	14443	TX	31.625	-98.950	485	1994 - 2001
BOWI	MOCK	Mockingbird Lane	14444	TX	31.604	-98.924	479	1994 - 2001
BOWI	BEDR	Bedrock	14445	TX	31.642	-98.936	442	1994 - 2001
BOWI	MESQ	Mesquite	14446	TX	31.650	-98.910	396	1994 - 2001
BOWI	DEVI	Devil's Hill	14447	TX	31.618	-98.894	424	1994 - 2001

* discontinued for logistic reasons

** discontinued due to extreme disturbance

Correcting for missed banding effort

We have developed a reliable methodology and corresponding software algorithms for adjusting productivity indices to account for missing effort in constant-effort mist-netting data (Nott & DeSante 2000; Appendix 1). Minor adjustments were applied to the numbers of individual adult and young birds captured each year to reflect the small amounts of effort that were missed at each station each year due to inclement weather and unforeseen problems with logistics. To do this, we used a modification to the approach suggested by Peach et al. (1998). Our approach involved pooling effort and age-specific capture data for each year for each species from all stations in the region (Appendix 1), in this case, the Southeast and South-central MAPS Regions. The annual temporal pattern of the proportion of effort completed (effort expended/effort expected) in the region is expressed as a two-dimensional matrix of 10-day-period by 10-minute-capture-time-block for that year. The temporal patterns of age-specific captures for each species for the region are also expressed in analogous two-dimensional matrices of 10-day-period by 10-minute-capture-time-block and are converted to annual species- and age-specific matrices expressing the proportion of the total regional captures of that species in each 10-day-period by 10-minute-capture-time-block. The annual station-specific numbers of captures of each age of each species are then adjusted by comparing the annual station-specific effort profile to the annual regional effort profile and regional age- and species-specific capture profiles and inflating the captures of that age class of that species at that station in that year.

In a preliminary study we applied the methodology to an analysis of banding data collected at 40 Alaskan MAPS stations over a ten-year period (1992-2001). The results supported our expectations. For stations and years in which effort was missed early in the season (when most captures are adults) the expected productivity was lower than that calculated from the raw data. For stations and years in which effort was missed late in the season (when many captures are juveniles) the expected productivity was greater than that calculated from the raw data. The model conveys greater precision to models that relate MAPS data to population trends, landscape structure and climate/weather data because it obviates the need to include numerous effort parameters in those models.

Because the annual number of visits to each station varies across the study, and in some cases the number of nets varies, we corrected parameters to reflect 600 net hours of annual effort (i.e. 10 nets x 10 visits x 6 hours per visit) at each station. We applied this methodology to acquire less effort-biased estimates of adult captures, young captures, and indices of reproductive success.

Demographic parameter descriptions

From the corrected MAPS data we calculated a suite of demographic parameters that represent useful metrics for identifying the meso-scale effects of landscape pattern on avian populations. Many studies correlate landscape indices with numbers of birds detected during point count surveys. However, as Villard et al. (1999) suggested such studies should also consider the reproductive output of populations. Basing conservation efforts on numbers of adults alone may be counter-productive because high densities of adults are not necessarily correlated with high reproductive output unless the population conforms to the concept of an ideal free distribution (Sutherland 1983) in which the numbers of individuals in a given area are proportional to the resources available. Many bird species conform to a despotic distribution in which primary breeding habitat is competed for and subsequently inhabited by the fittest individuals that hold large territories. Reproductive output per individual is normally higher in such areas than it is in areas of secondary habitat in which the rest of the population is found in high densities occupying small territories. Also, information on vital rates provides a clear index of habitat quality. Because of confounding effects of population sources and sinks, information on presence/absence or even relative abundance or population size can provide misleading indicators of habitat quality (Van Horne 1983, Pulliam 1988). Thus, consideration of the following parameters in the landscape models may offer more insight into the ecological processes operating on avian populations.

AHY – the mean number of after-hatch-year (adult) individuals (unique band numbers) captured during a single year of operation.
AHYyr – a magnitude independent adult population trend. The annual rate of change in the adult population is expressed as a percentage of the mean number of adult individuals captured annually.
YNG – the mean number of hatch-year individuals (young) captured in a year.
RImean – the mean annual reproductive index (RI). Annual reproductive indices are calculated as the ratio of young to adults captured (YNG_t / AHY_t).

Identifying species of management concern

We selected, for potential inclusion in landscape analyses, a set of 31 species for which effective monitoring could be conducted on at least six MAPS stations (Table 2). For each species, we recorded the overall trends and the number of stations and MAPS installations with increasing or decreasing trends. The stations in this study lie in six Bird Conservation Regions (BCR) and one FWS management region for which the Fish and Wildlife Service assigned priority status (FWS 2002) to certain species that breed in those regions. Those BCRs are a) 20 – Edwards Plateau, b) 21 – Oaks and Prairies, c) 22 – Eastern Tallgrass Prairie, d) 24 - Central Hardwoods, e) 27- Southeastern Coastal Plain, f) 30 – New England/Mid-Atlantic Coast, and g) FWS Region 4 (southeastern US). For each of the 31 species, we summarized the national FWS priority status and the status for each BCR (Table 2). A subset of 10 species of management concern (SMC) emerged as the focus of management recommendations to reverse adult population declines on DoD installations. These are the species common to the FWS listed BCC species (USFWS 2002) and those species captured in acceptable numbers at MAPS stations and are shown in bold and shaded in Tables 2 and 3, respectively.

From extensive literature reviews for each of these species, we summarized and briefly discussed existing management issues and recommendations. Also, for various reasons, such as a lack of understory under dense canopy forest, some stations at some installations effectively monitor few species of interest. We identified these “slow” stations and discussed how they could be relocated to help monitor SMC species in control or managed areas.

For each installation we classified the species that met the basic selection criteria for the number of annual individual captures as breeding in forest/woodland or breeding in scrub/successional habitats (Table 3). In addition, for each species and installation, we reported the direction of the population trend and the statistical significance associated with that trend, highlighting those species and installations where MAPS populations of BCC species had declined during the station’s period of operation.

Table 2. Summary table for 14 forest species and 17 scrub-successional species given by four-letter codes given in Table 3. The direction of the overall adult population trends calculated from MAPS data is signified as declining (dec) or increasing (inc), bold type denotes statistical significance (P<0.10) of the annual percent change in the adult population. The number of stations from which the overall adult population trends are estimated are split into those with increasing (positive) and decreasing (negative) trends. Similarly, the number of MAPS locations from which the overall trends are estimated are split into those with increasing (positive) and decreasing (negative) trends, the number of those trends that show statistical significance (P<0.10) is given in parentheses. Delta score indicates the balance of negative and positive trends by location whereby negative numbers indicate that more locations have negative trends than have positive trends. FWS priority status is denoted by "X" and species of management concern are identified by bold species codes.

	Overall	Annual	Station-specific		Installation-specific			FWS Priority by BCR						FWS
	MAPS	Percent	Positive	Negative	Positive	Negative	Delta							
Species	Trend	Change	Trend	Trend	Trend	Trend	Score	20	21	22	24	27	30	Region 4
Forest														
DOWO	dec	-3.77	10	18	2 (1)	7 (2)	-5							
ACFL	Inc	0.52	13	13	5 (0)	2 (1)	3			X				
REVI	Inc	-2.93	14	14	5 (1)	5 (3)	0							
BLJA	dec	-4.80	2	6	2 (0)	2 (0)	0							
CACH	dec	-3.66	15	24	5 (0)	6 (1)	-1							
TUTI	inc	0.90	29	32	7 (1)	6 (0)	1							
BGGN	**inc**	8.49	8	4	4 (1)	1 (1)	3							
WOTH	inc	0.12	20	16	6 (3)	4 (1)	2			X	X	X	X	X
BAWW	**inc**	11.76	8	3	5 (3)	1 (0)	4							
WEWA	inc	1.31	5	4	1 (1)	4 (1)	-3		X	X	X		X	X
OVEN	inc	3.91	17	11	4 (1)	3 (1)	1							
LOWA	inc	3.72	8	4	4 (1)	3 (0)	1			X	X			X
KEWA	dec	-1.84	14	14	3 (2)	5 (2)	-3	X	X	X			X	
HOWA	inc	2.02	6	5	3 (1)	3 (1)	0							
Scrub/ Successional														
WEVI	inc	2.22	20	9	5 (2)	4 (1)	1							
CARW	inc	6.06	33	19	7 (3)	5 (0)	2							
BEWR	dec	-6.83	4	8	0 (0)	2 (0)	-2			X	X	X		X
HOWR	**inc**	16.49	5	1	2 (2)	1 (0)	1							
AMRO	**dec**	-14.65	4	6	2 (0)	4 (3)	-2							
GRCA	dec	-0.45	5	10	2 (1)	3 (1)	-1							
NOMO	**dec**	-31.29	0	6	0 (0)	2 (2)	-2							
BRTH	inc	3.35	4	3	2 (1)	3 (0)	-1							
BWWA	dec	-2.78	5	6	1 (0)	3 (2)	-2			X	X		X	
PRAW	inc	3.81	7	4	2 (1)	3 (0)	-1				X	X		X
COYE	**dec**	-7.25	8	16	2 (0)	6 (3)	-4							
YBCH	dec	-1.57	3	4	2 (0)	1 (1)	1							
FISP	**dec**	-3.31	4	11	1 (0)	6 (4)	-5	X	X	X				
NOCA	**dec**	-5.63	24	45	3 (0)	10 (2)	-7							
INBU	inc	5.34	10	10	4 (0)	2 (1)	2							
PABU	dec	-0.87	6	9	2 (0)	1 (0)	1	X	X					X
COGR	inc	2.56	5	3	4 (0)	1 (1)	3							

Table 3. Table of direction and significance in adult population trends for 14 forest species and 17 scrub/successional species on 13 military installations. The direction of the trend is indicated as decreasing (-) or increasing (+), and significance is indicated by multiple plus or minus characters (e.g. + non-significant, ++ 0.05 P<0.10, +++ 0.01 P<0.05, and ++++ P<0.01). Gray shading indicates species listed by U.S. Fish and Wildlife Service (FWS) as species of conservation concern (December, 2002) and candidate species of management concern at individual installation where populations are declining (see Section).

Installation/ Common Name	CODE	BELV	NAVY	TIDE	BRAG	JEFF	KNOX	CRAN	LEON	LEAV	RILE	SWIF	HOOD	BOWI
Forest														
Downy woodpecker	*DOWO*	+	--	---		-	-	++++	-	-	-			
Acadian flycatcher	*ACFL*	-	+	+		+	+	+	--					
Red-eyed vireo	*REVI*	---	-		+	-	--	+	+	+	+		--	
Blue jay	*BLJA*		+	+						-	-			
Carolina chickadee	*CACH*	-	+	-	+	+	+	+++	-			-	-	---
Tufted titmouse	*TUTI*	+	-	-	+	+	+	+	-	-	+++	+	-	-
Blue-gray gnatcatcher	*BGGN*				---	+			+		+		+++	
Wood thrush	*WOTH*	-	---	++++	-	-	+	+	++	+++	+			
Black-&-white warbler	*BAWW*	+		+		+		++	-				+++	
Worm-eating warbler	*WEWA*		-			---	-	+++	-					
Ovenbird	*OVEN*	+	-	+	+	---		+++	-					
Louisiana waterthrush	*LOWA*	-	+				-	+	-	++	+			
Kentucky warbler	*KEWA*		-			--	-	+	-	-				
Hooded warbler	*HOWA*	-	+	+	-	--		++++						
Scrub/successional														
White-eyed vireo	*WEVI*	+++	+		-	---	-	-	+			+	+++	
Bell's vireo[1]	*BEVI*										-			
Carolina wren	*CARW*	+++	++	+	+	+	++	-	-	-	-	+	-	
Bewick's wren	*BEWR*												-	-
House wren	*HOWR*					-				++	++			
American robin	*AMRO*	-	---	+		--				---	+			
Gray catbird	*GRCA*				-	-		---		++++	+			
Northern mockingbird	*NOMO*												---	----
Brown thrasher	*BRTH*			-	-	+				-	+++			
Blue-winged warbler	*BWWA*					-	---	---	+					
Prairie warbler	*PRAW*				-	-	+	-	++					
Common yellowthroat	COYE	+			-	----	---	-	-	+	----			
Yellow-breasted chat	YBCH					+		----	+					
Field sparrow	FISP					--		----	-	---	+		---	-
Northern cardinal	NOCA	-	-	+	-	-	-	+	+	-	-	--	--	-
Indigo bunting	INBU					-	----	+	+	+	+			
Painted bunting	PABU											-	+	+
Common grackle	COGR	+	+++	-							+			+
No. of forest species		10	12	9	7	11	9	12	12	7	7	2	5	2
No. of succ. species		5	5	5	7	13	7	10	9	9	10	4	7	6

[1] Although Bell's vireo is only caught in acceptable numbers at 3 stations (on Fort Riley) it is included because IBP recognizes a need to increase MAPS monitoring of this species.

Landscape Data

One problem in designing land management models for birds that breed on DoD installations is that the focus and spatial resolution of local GIS-based land cover layers differ from installation to installation. To establish species-landscape relationships using MAPS data from multiple MAPS stations located on up to 13 installations requires a common land cover database. Also, landscape effects on birds operate at spatial scales of 2km or more, but most DoD installation's GIS layers are restricted to the boundaries of the installation and do not measure the landscape pattern and structure of surrounding lands that might influence the ecology of habitats within the installation. For these reasons, we utilized the publicly available National Land Cover Dataset (Vogelmann et al. 1991).

Landscape data and scale

We extracted a set of 18 landscape coverages each incorporating up to six of the 78 MAPS stations from the 21 class, 30-m resolution National Land Cover Dataset available from the U.S. Geological Survey (NLCD, http://landcover.usgs.gov/natllandcover.html, 2002; Table 4). In previous studies, we looked at the relationships between station-specific productivity indices and landscape metrics of 2 or 4 km radius "local landscapes" around each MAPS station. This study will focus on the results obtained from analyses of 2-km radius landscapes because many stations are so closely clustered that 4-km radius landscapes would include considerable overlap and introduce aspects of spatial autocorrelation. In addition, 2-km landscapes restrict the spatial extent to areas within the boundaries of the installation where management actions can be realized without involving private lands.

Reclassification of NLCD 1992 dataset

To identify landscape determinants of avian demography and community structure, we superimposed MAPS data on the 21 class, 30m-resolution National Land Cover Dataset (NLCD 1992) provided by USGS (provide reference/website). False color images of the landscapes surrounding clusters of nearby MAPS stations are depicted in Appendix 2. Preliminary investigations suggested that for many species the cover class vertical resolution of the NLCD data was too fine. For instance, three of the 21 NLCD classes identify different kinds of forest cover. For more generalist forest-inhabiting species, this delineation is redundant. Wood thrushes, for example, breed successfully in mixed forest (classified as mixed), bottomland hardwoods (classed as deciduous) and cypress swamps (classified as evergreen), and therefore, these cover classes must be pooled into a single class to enable important landscape parameters to be measured and related to wood thrush demographic data. In this case, measurements of the core area of individual forest types cannot be related to the core area of all forest types pooled which wood thrushes respond to. In accordance, we defined a 7-class system (see below) of aggregated classes to better represent the overall landscape fragmentation pattern and the pattern of general habitat types (e.g. Forest-woodland, shrub-successional, grasslands, wetlands). We developed ArcView/Avenue scripts to handle this time consuming reclassification by batch processing NLCD themes prior to spatial analysis. These also allow for future reclassifications based on alternate systems of aggregating the base NLCD classes.

Table 4.National Land Cover Dataset (NLCD) System Key – (Rev. July 20, 1999) describing 21 cover classes (Code). These classes are aggregated into 7 classes (CL7) for spatial analysis of MAPS data : water sources (1), development (2), barren (3), shrub/scrub (4), forested (5), grassland (6), agricultural (7).

Code	**Classification**	*CL7*	**Code**	**Classification**	*CL7*
Water			***Shrubland***		
11	Open Water	***1***	51	Shrubland	***4***
12	Perennial Ice/Snow	***1***	***Non-natural Woody***		
Developed			61	Orchards/Vineyards/Other	***4***
21	Low Intensity Residential	***2***	***Herbaceous Upland***		
22	High Intensity Residential	***2***	71	Grasslands/Herbaceous	***6***
23	Commerce/Industry/Transport	***2***	***Herbaceous Planted/Cultivated***		
Barren			81	Pasture/Hay	***7***
31	Bare Rock/Sand/Clay	***3***	82	Row Crops	***7***
32	Quarries/ Mines/Gravel Pits	***3***	83	Small Grains	***7***
33	Transitional	***4***	84	Fallow	***7***
Forested Upland			85	Urban/Rec. Grasses	***6***
41	Deciduous Forest	***5***	***Wetlands***		
42	Evergreen Forest	***5***	91	Woody Wetlands	***5***
43	Mixed Forest	***5***	92	Emergent Herbaceous Wetlands	***1***

Specifically, we aggregated NLCD cover types to produce seven new combined cover types of possible biological significance as follows. Combining the *Open Water* and *Perennial Ice/Snow* types (Classes 11 and 12; see Appendix XX) with *Emergent Herbaceous Wetlands* (Class 92) provided a **Water** sources type (1). We combined the coverage of the three *Developed* types (Classes 21-23) to create a single habitat type, **Development** (2). *Bare Rock/Sand/Clay* and *Quarries/Mines/ Gravel Pits* (Classes 31 and 32) were combined to provide a **Barren** habitat type (3). The *Transitional, Shrubland,* and *Non-natural Woody* classes (33, 51, and 61) were combined to create a **Shrubland** type (4). We combined deciduous, evergreen, and mixed *Forested Upland* types with *Woody Wetlands* to represent total **Forest** cover (5). *Herbaceous Upland* grassland (class 71) was combined with *Urban/Rec. Grasses* (class 85) to produce a **Grassland** habitat type (6). Finally, we combined the coverage of the remaining four *Herbaceous Planted/Cultivated* classes (81-84) into a single **Agricultural** habitat type (7). We then calculated the spatial statistics (using Patch Analyst) of each new type within a 2-km radius of each MAPS station. High resolution maps (1 pixel = 30m x 30m) depicting the landscapes surrounding clusters of MAPS stations (and 2-km radii) at each installation are shown in Appendix 3.

In addition, we described up to five habitats covering more than 1ha at each station as part of the MAPS Habitat Structure Assessment (Nott et al. 2002), which assesses the pattern and composition of the habitats within the 20 ha area of each banding station. We provided descriptions of the primary and secondary habitats (dominant and sub-dominant, respectively, in terms of area), percent of the station covered by the primary and secondary habitats, and percent of the station covered by water, taken from the 2000 Habitat Structure Assessments (Appendix 2). The most common species in each habitat are listed in order of dominance, with common names capitalized (e.g., White Oak, Virginia Pine) and congenic group names (e.g., oak, pine) in lower case. The term “mixed” refers to a habitat that contains both deciduous and coniferous species if used at the beginning of the habitat description (e.g., “Mixed oak, Virginia Pine forest”), but refers to a combination of several hardwood species, often within the same congenic group, if used after the species or group name(s) (e.g., “Oak, Sweetgum, Tulip Poplar mixed forest”).

Landscape analyses

We mapped the geographic locations of 78 of the 81 MAPS stations (Table 1; Figure 1; the three stations that operated for only one or two years were ignored) onto portions of the NLCD coverage in which the stations are located (Appendix 2). Around each station we spatially analyzed a circular area of the reclassified NLCD data using Arcview 3.2 (ESRI 1996) in conjunction with the Patch Analyst 2.2 extension (McGarigal and Marks 1994, Elkie et al. 1999).

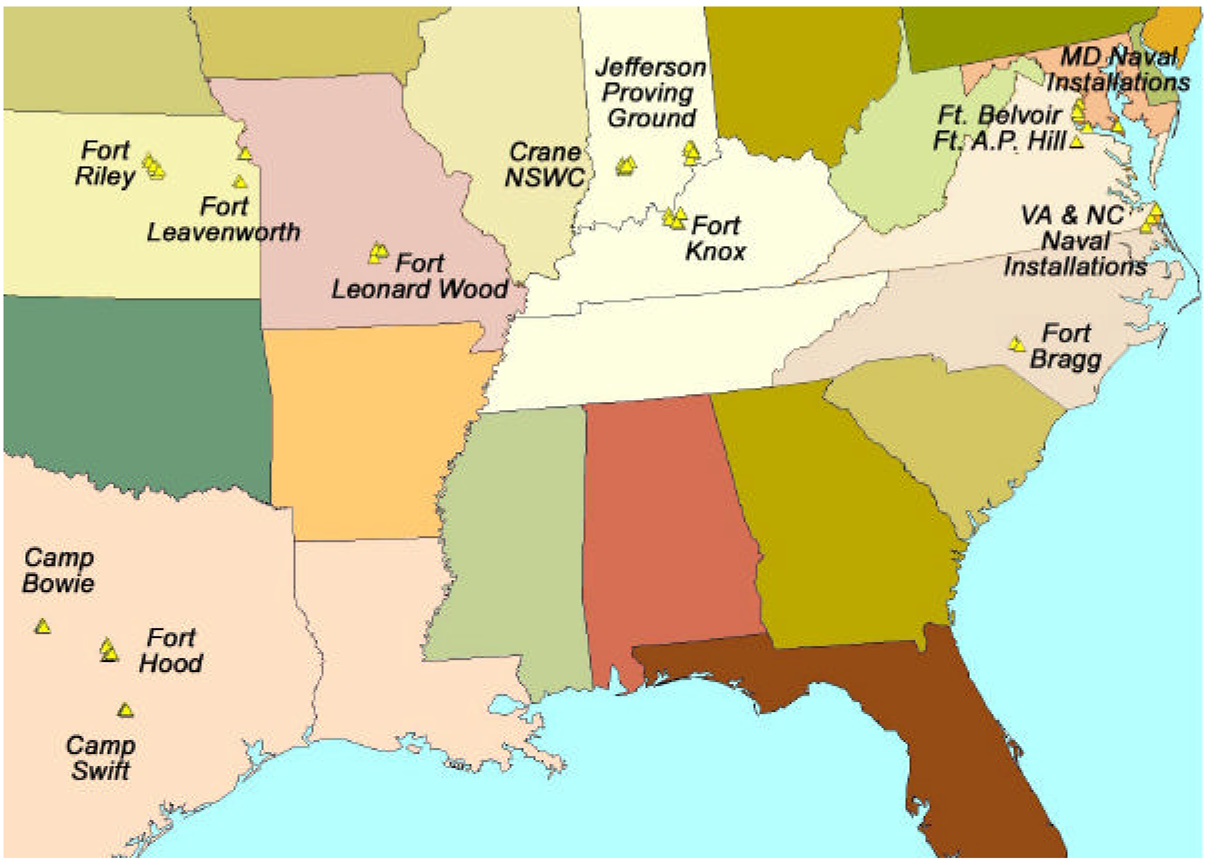

Figure 1. Map of 13 DoD installations (or group of nearby installations) where MAPS stations (yellow triangles) are operated in Maryland, Virginia, North Carolina, Indiana, Kentucky, Missouri, Kansas, and Texas.

It is important to note that we analyzed the landscapes at two different levels: the "landscape" level and the "class" level. At the landscape level, statistics from Patch Analyst reflect the number, size and spatial distribution of all patches (regardless of cover classes) that provide measures of the landscape fragmentation including the total amount of edge, and landscape heterogeneity (alpha diversity and evenness of patch size and class). These parameters were not used in later multivariate models but they are mentioned in the text when appropriate. At the class level, statistics from Patch Analyst reflect the size, shape and distribution (within the rest of the landscape) of each cover class (e.g., deciduous forest) in the context of the rest of the landscape.

Availability of data and GIS software

The landscape management models are designed to be easily accessible to DoD installation natural resource managers, wildlife biologists, and GIS specialists. As previously mentioned, the land cover database is publicly available from USGS (on CD or downloadable from the internet). The spatial analysis techniques are relatively simple and can be conducted using combinations of either ArcInfo (ESRI Inc.) and FragStats (McGarigal and Marks 1994), or ArcView (ESRI Inc.) and Patch Analyst (Elkie et al. 1999). We can provide the following materials to help installation managers and other persons who would like to apply these models:

a) the ArcView/Avenue scripts needed for batch processing spatial analyses of NLCD data within 2km radii (or larger radii) around a set (or sets) of geographic centers of interest (e.g. approximate geographic center of a forest stand).
b) Instructions on conducting the spatial analysis using these scripts.

Avian Demographic-Landscape Models

We constructed species-landscape models for a) numbers of adults, b) adult population trends (the annual percentage rate of change in the numbers of adults), c) numbers of young, and d) reproductive success as measured by the ratio of young to adults. In these we relaxed the capture rate criterion to an average of 1.5 birds per year for the less widespread species (associated with less than 16 stations under the original criteria).

Model selection

We constructed the models using multivariate regression techniques, information theory and maximum likelihood principles. Initially, we selected a suite of landscape parameters for inclusion in each model based on known or proposed ecological relationships from the literature. In addition, we inspected the correlation matrix of dependent and independent variables for evidence of other significant correlations. We used custom software (Luh 1994 - modified by Nott in 2003) to regress all unique combinations of N parameters plus the intercept term, which for 10 parameters results in 1,023 regression models each with their associated regression statistics. For each model, the software calculates values of Akaike Information Criteria (AIC) (Akaike 1973) and the closely related Bozdogan's index of informational complexity (ICOMP) (Bozdogan 1990, 1994). The "best" model minimizes these criteria based on the maximum likelihood and the number of parameters. Thus, a model with a high "goodness-of-fit" may be penalized by AIC for having too many parameters.

Typically, regression analyses of spatial statistics are confounded with high levels of collinearity and dependence among the parameter estimates (Riitters et al. 1997). To account for this problem we selected models using ICOMP that, unlike AIC, penalizes models for which it detects high levels of both overparameterization and covariance. In each case, we reported the top 10 models, that is, the 10 models with the lowest values of ICOMP, and calculated the contribution (proportional representation) of each parameter. We also reported the regression statistics and estimates of each coefficient for the top selected model.

From the model selection process we report 44 species-landscape models for the 10 species (plus Bewick's wren) highlighted in Table 3. Wood thrush analyses were split into eastern and central regions, because existing literature suggests that the ecology of this species differs among those regions. Of these 44 models, 25 showed high statistical significance at the $P<0.05$ (or higher) level, and another eight models were marginally significant at the $P<0.10$ level. We then used these models to formulate management strategies for the 10 BCC species.

RESULTS

Overview

The demographic analysis of MAPS data for the 36 species in this investigation provides a large volume of summary data, which includes species-specific data whereby demographic estimates are reported a) by the entire study area (all stations pooled), b) by individual DoD installation, and c) by individual MAPS station. For this reason we present the results both as summary information here in the main report, and as more detailed tables and interpretations in Appendices 4 and 5.

Appendix 4 contains brief descriptions of the conservation status of each species according to analyses conducted by the Breeding Bird Survey, Partners in Flight, and MAPS data. It also contains tables of species-specific demographic estimates presented by MAPS station and brief reports of species-specific demographic patterns given by DoD installation. These reports are derived from data presented in Appendix 5 in which species-specific demographic patterns are tabulated by DoD installation.

Part I of the Results section further summarizes the station- and installation-specific demographic patterns (Appendices 4 and 5, respectively) and outlines avian conservation concerns at each of the 13 military locations or installations for those species effectively monitored by the MAPS program. The goal of this section is to identify species of management concern at each installation, the stations at which they are effectively monitored, and the stations at which monitoring might be discontinued. Reference is also made to the kinds of management that might help reverse the observed population declines, the existing management strategies that are practiced on the installation, and possible future management strategies that have already been discussed with land managers of particular installations. Part II of the Results then provides detailed descriptions and discussion of species-specific management recommendations derived from the species-landscape models constructed in this study (see Appendix 6) as well as a discussion of existing recommendations extracted from the literature.

Part I: Summary of demographic analyses

For each installation (or group of nearby installations), a table is provided that includes those species that are effectively monitored, i.e., for which acceptable numbers of individuals were captured each year (see Methods; Appendix 5). Species listed in these tables are categorized depending on a) increasing or decreasing adult population trends at the installation, b) migratory status – Neotropical or temperate overwintering range, and c) preference for forested/wooded habitat or scrub/successional habitat (as categorized by the Breeding Bird Survey). We also reported the statistical significance of the population trends (1994-2001) and highlighted those species that are "*Birds of Conservation Concern*" (BCC), as defined by the U.S. Fish and Wildlife Service (e.g. Wood thrush). We focused on BCC species as priority species of management concern at each installation/station if both acceptable numbers of individual birds were captured, and if the adult population trend (as derived from MAPS data) was declining. We identified a total of 10 priority species across the entire study – five forest/woodland species (Acadian flycatcher, wood thrush, worm-eating warbler, Louisiana waterthrush, and Kentucky warbler) and five successional/scrub species (Bewick's wren, blue-winged warbler, prairie warbler, field sparrow, and painted bunting).

The major goal of this project is, at each installation, to identify declining priority species and provide management recommendations to reverse those declines. Towards this goal, we are collaborating with natural resource managers, foresters, and GIS specialists at selected installations to identify appropriate management actions that may be applied in the vicinity of those MAPS stations for which population declines of a particular species are reported. In future years, funding permitting, MAPS stations will monitor the effects of those actions on both the target species and other species that are captured at those stations.

To assess the effectiveness of management actions in reversing declines, it is necessary to monitor areas that have been managed and compare the resulting demographic estimates with those obtained from a similar "control" area that was not subjected to management. Consequently, for each installation, we highlight those stations at which the population trends of priority species are declining, thereby identifying the stations and species at which management actions may be directed. We also identify "control" stations that would monitor the target species in the absence of management action. Finally, we identify MAPS stations that are currently in operation but capture few species, especially those stations associated with closed canopy forest and sparse understory or vegetative ground cover. We suggest that these stations should be re-established in locations where they can better monitor the effects of management actions intended to benefit species of management concern (i.e., capture more individuals of the priority species) or, alternatively, act as control stations.

Our goals are to a) collaborate with land managers of particular installations in devising management plans to reverse local population declines of at least one bird species of conservation concern, b) devise those plans to cover all 10 species highlighted in this report, and c) give due consideration to the fact that actions intended to benefit one species of management concern will impact other species or guilds.

Virginia Army Installations and Mason Neck National Wildlife Refuge (BELV)

This location comprises two stations at each of three sites to the west of the Potomac River in Virginia: Fort Belvoir, Mason Neck National Wildlife Refuge, and Fort A.P. Hill. Of 17 species captured in acceptable numbers (Table 5a), nine species show increases in adult populations and eight species show declines. Three significant trends include a negative trend for red-eyed vireo (P<0.05) and positive trends for white-eyed vireo (P<0.05) and Carolina wren (P<0.05).

Table 5a. Lists of species captured in acceptable numbers at six MAPS stations operated on the Virginia Army Installations and Mason Neck National Wildlife Refuge (BELV). Species are categorized by the direction of the adult population trend (statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01), migratory status, and preferred habitat type - either forest (normal typeface) or scrub/successional habitat (italics). Birds of conservation concern (USFWS 2002) are highlighted.

Neotropical wintering species		Temperate wintering species	
Increasing	Decreasing	Increasing	Decreasing
White-eyed Vireo **	Acadian Flycatcher	Downy Woodpecker	Carolina Chickadee
Black & White Warbler	Red-eyed Vireo **	Tufted Titmouse	*American Robin*
Prothonotary Warbler	Wood Thrush	*Carolina Wren* **	*Northern Cardinal*
Ovenbird	Louisiana Waterthrush	*Common Grackle*	
Common Yellowthroat	Hooded Warbler		

Candidate Species of Management Concern

Three species of conservation concern to the Fish and Wildlife Service (FWS 2002) are declining at the BELV location and emerge as candidate species for management concern there, Acadian flycatcher, wood thrush, and Louisiana waterthrush (Table 5b). Acadian flycatchers are captured at all six stations, and although they show a non-significant decline at the location level, they are declining at four stations, significantly (P<0.05) so at the Belvoir Upland (BUPL) station. Similarly, wood thrushes are captured at four of the six stations and are declining at three. Although they also show a non-significant decline at the location level, wood thrushes are significantly declining (P<0.01) at the Fort A.P. Hill #2 (APH2) station. In 1999, adult captures dropped to zero at APH2, and declined sharply at A.P. Hill #1 (APH1). In fact, the majority of species show declines at the four stations on Fort Belvoir and Fort A.P. Hill, whereas the majority of species are increasing at the two Mason Neck stations. Louisiana waterthrushes are only captured in acceptable numbers at the two A.P. Hill stations and are declining non-significantly at A.P.Hill #1. Notable among the remainder of species are red-eyed vireo, Carolina chickadee and northern cardinal. Red-eyed vireos shows significant declines at both A.P. Hill stations, whereas chickadees show non-significant declines at three of four stations, and northern cardinals shows declines at all five of the stations at which they are captured.

Table 5b. Table of adult population trends (annual percentage change derived from MAPS data) for landbirds that can be effectively monitored by MAPS stations at the BELV location. Statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01. Birds of conservation concern (USFWS 2002) and associated negative trends are highlighted in gray.

Species	BUPL	BLOW	MAS1	MAS2	APH1	APH2
DOWO	-30.6	-1.7	15.6	*18.2		
ACFL	**-16.1	-3.2	5.8	5.7	-3.1	-10.6
REVI		1.6		-8.6	**-19.7	*-17.0
CACH	-15.7	-15.1	2.7	-9.1		
TUTI	-8.9	-15.9	5.0	**17.2	-3.1	7.1
WOTH		-19.3	**54.4		-9.4	***-39.0
BAWW					1.6	
OVEN	3.9		***25.9	3.1	5.7	-3.0
LOWA					-27.7	12.1
HOWA					-1.0	-14.0
WEVI				**16.2		
CARW	13.9	14.9	18.4	**30.6	10.9	
AMRO		-34.3				
COYE		0.1				
NOCA	-10.1	-7.8	-1.2	-4.9	-18.0	
COGR			6.3	7.3		
N(#neg.)	7 (5)	10 (7)	9 (1)	10 (3)	9 (6)	6 (4)

In summary, appropriate management actions could be applied at the two Belvoir stations (BUPL and BLOW) to reverse the declines in Acadian flycatcher and wood thrush populations. Such actions will likely also benefit the other forest bird populations including downy woodpeckers, Carolina chickadees, tufted titmice, and ovenbirds. Such management, however, may negatively affect non-forest species such as the Carolina wren and northern cardinal. Management actions could also be applied to both the A.P. Hill stations to conserve populations of Acadian flycatcher, wood thrush (especially at A.P Hill #2), and Louisiana waterthrush at A.P. Hill #1. It is likely that such actions may also benefit red-eyed vireo, tufted titmouse, ovenbird, and hooded warbler populations at one or both of the stations.

Maryland and Virginia Naval Installations (NAVY)

This location consists of three stations at the Patuxent River Naval Air Station, MD, a single Virginia station at Dahlgren Naval Surface Warfare Center (NSWC), south of the Potomac River, and two stations on the east bank of the Potomac at Indian Head Naval Weapons Support Center, MD. Of18 species captured in acceptable numbers (Table 6a), eight species show increases in adult populations and ten species show declines. Four significant trends include negative trends for wood thrush ($P<0.05$), downy woodpecker ($P<0.10$), and American robin ($P<0.05$) and a positive trend for Carolina wren ($P<0.10$).

Table 6a. Lists of species captured in acceptable numbers at six MAPS stations operated on Maryland and Virginia Naval Installations (NAVY). Species are categorized by the direction of the adult population trend (statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01), migratory status, and preferred habitat type - either forest (normal typeface) or scrub/successional habitat (italics). Birds of conservation concern (USFWS 2002) are highlighted.

Neotropical wintering species		Temperate wintering species	
Increasing	Decreasing	Increasing	Decreasing
Acadian Flycatcher	Red-eyed Vireo	Carolina Chickadee	Downy Woodpecker *
White-eyed Vireo	Wood Thrush **	Blue Jay	Tufted Titmouse
Louisiana Waterthrush	Northern Parula	*Carolina Wren* *	*American Robin* **
Hooded Warbler	Worm-eating Warbler	*Common Grackle*	*Northern Cardinal*
	Ovenbird		
	Kentucky Warbler		

Candidate Species of Management Concern

Four species of conservation concern to the Fish and Wildlife Service (FWS 2002) emerge as candidate species for management concern at the NAVY stations - Acadian flycatcher, wood thrush, worm-eating warbler, and Kentucky warbler (Table 6b). Acadian flycatchers are captured at all six stations, and although they show a non-significant increase at the location level, they are declining at three of the six stations. Wood thrushes are declining at five of the six stations at which they are captured and show a significant ($P<0.05$) decline at the location level. At the station level they are highly significantly declining ($P<0.01$) at the Patuxent Upland #1 (PUP1) and Dahlgren (DAHL) stations. Worm-eating warblers are captured in acceptable numbers only at Stump Neck (STNE) and show a non-significant decline. Kentucky warblers are captured at four of the six stations and, although they also show a non-significant decline at the location level, they are significantly declining at PUP1

(P<0.05) and PUP2 (P<0.10). Of the Patuxent stations, PUP1 shows a majority of increasing trends, PUP2 shows a majority of decreasing trends, and the other stations show fairly equal proportions of increasing and decreasing trends.

Notable among the remainder of species are downy woodpeckers that are declining at both Indian Head (INHE) and Stump Neck, and American robins that are declining at Dahlgren (P<0.05). The other species captured at these stations, especially scrub/successional species, show relatively stable or increasing populations at the stations at which they are captured.

Table 6b. Table of adult population trends (annual percentage change derived from MAPS data) for landbirds that can be effectively monitored by MAPS stations at the NAVY location. Statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01. Birds of conservation concern (USFWS 2002) and associated negative trends are highlighted in gray.

Species	PLOW	PUP1	PUP2	DAHL	INHE	STNE
DOWO					-8.3	-26.7
ACFL	-4.0	0.4	-5.8	-5.3	**13.0	4.2
REVI	-4.3	4.9	-8.6	-6.2		-4.2
BLJA				**35.4		-7.4
CACH	26	10				0.3
TUTI	-12.2	9.5	11.9	4.4	*-14.7	*-12.8
WOTH	-12.4	-7.9	***-24.4	***-27.9	-6.8	7.6
WEWA						-6.4
OVEN	11.3	*-11.3	2.1	-5.4		
LOWA						2.4
KEWA	8.0	**-38.8	*-16.6			-5.0
HOWA		2.0				
WEVI		*17.2	-2.1			
CARW	**27.8	*50.8		19.1	31.3	5.5
AMRO				**-26.6		
NOCA	-5.9	9.0	-8.5	6.0	2.8	4.4
COGR					**39.0	
N(#neg.)	9 (5)	11 (3)	8 (6)	9 (5)	7 (3)	12 (6)

In summary, management actions could be applied in the vicinity of the adjacent PUP1 and PUP2 stations to reverse declines in Acadian flycatcher, wood thrush, and Kentucky warbler populations. Such actions may also positively impact other forest species such as red-eyed vireo, tufted titmouse, ovenbird, and hooded warbler. These actions may, however, negatively impact non-forest species such as white-eyed vireo, Carolina wren and northern cardinal. Alternatively, management could also be applied at Dahlgren to conserve Acadian flycatcher and wood thrush populations, which may also impact declining red-eyed vireo and ovenbird populations, as well as blue jay, tufted titmouse, Carolina wren, northern cardinal, and significantly declining ($P<0.05$) American robin populations.

Finally, these results suggest that the worm-eating warbler populations in the vicinity of Stump Neck are declining. Restorative management actions intended to reverse this decline will likely positively impact four other BCC species. Kentucky warbler populations are slightly decreasing and populations of Acadian flycatcher, wood thrush, and Louisiana waterthrush are relatively stable or slightly increasing. Management actions at Indian Head could be directed towards declining populations of wood thrush.

Virginia and North Carolina Naval Installations (TIDE)

This location consists of three tightly clustered coastal stations (OWLS, POND and PEND) at the Naval Air Station Oceana, MD, and adjacent Naval Amphibious Base Little Creek Annex Camp Pendleton, and one inland station (FENT) at the Naval Air Station Oceana Auxillary Landing Field, Fentress. The two remaining stations (BAOR and ROTH) are 50-km away at the Naval Security Group Activity Northwest installation located on the border of Virginia and North Carolina. Of 15 species captured in acceptable numbers (Table 7a), nine species show increases in adult populations and six species show declines. Four significant trends include negative trends ($P<0.05$) for downy woodpecker and common grackle, and positive trends for wood thrush ($P<0.01$) and black-and-white warbler ($P<0.10$).

Table 7a. Lists of species captured in acceptable numbers at MAPS stations operated on Virginia and North Carolina Naval Installations (TIDE). Species are categorized by the direction of the adult population trend (statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01), migratory status, and preferred habitat type - either forest (normal typeface) or scrub/successional habitat (italics). Birds of conservation concern (USFWS 2002) are highlighted.

Neotropical wintering species		Temperate wintering species	
Increasing	Decreasing	Increasing	Decreasing
Acadian Flycatcher	Prothonotary Warbler	Blue Jay	Downy Woodpecker **
Wood Thrush ***		*Carolina Wren*	Carolina Chickadee
Black & white Warbler *		*American Robin*	Tufted Titmouse
Ovenbird		*Northern Cardinal*	*Brown Thrasher*
Hooded Warbler			*Common Grackle* **

Candidate Species of Management Concern

Two species of conservation concern to the Fish and Wildlife Service (FWS 2002) are captured at the TIDE location, but neither emerges as a candidate species for management concern there. Acadian flycatchers are increasing at the location level but decreasing slightly at the Boardwalk (BOAR) station. Wood thrush populations are increasing at the installation level, and at all five stations at which they are captured; highly significantly ($P<0.01$) at Fentress (FENT), and significantly ($P<0.05$) at ROTH. The Pendleton (PEND) station is suffering declines in seven of 10 species and should be subjected to appropriate management to reverse these declines; however, none of the declining species is a BCC species.

Of the remaining species, downy woodpecker and common grackle populations are declining at all the stations at which they are captured, and consequently are also declining at the installation level. The significant ($P<0.05$) declining trend in downy woodpeckers is based on very low capture rates (<1 adult/yr) and is therefore not a good candidate species.

Table 7b. Table of adult population trends (annual percentage change derived from MAPS data) for landbirds that can be effectively monitored by MAPS stations at the TIDE location. Statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01. Birds of conservation concern (USFWS 2002) and associated negative trends are highlighted in gray.

Species	FENT	PEND	OWLS	POND	BOAR	ROTH
DOWO		*-69.6				*-26.7
ACFL					-1.3	6.3
BLJA		-0.7	7.7	-3.5		
CACH		-33.3		-4.1		
TUTI		-20.5	-19.2	*-36.8	2.9	5.1
WOTH	***39.1	28.3		8.6	4.4	**13.8
BAWW					*30.8	
OVEN	-5.7	7.7	-2.8	**-9.2	3.8	**13.0
HOWA					19	
CARW	14.2	9.8	14.8	3.3	4.5	-0.6
BRTH		-11.2				
NOCA	**21.9	-2.0	*33.6	14.0	-6.6	16.1
COGR		-39.0	-46.6		-24.8	
N(#neg.)	4 (1)	10 (7)	6 (2)	7 (4)	9 (3)	7 (2)

In summary, although it appears that no urgent management actions need to be taken at TIDE, management might be directed to affect the PEND and/or POND stations where the forest species captured at those stations are declining (excluding wood thrush at both stations and ovenbird at PEND). Furthermore, low numbers of target species (and low numbers of individuals of those species) were captured at the Fentress and Owl's Creek (OWLS) stations. We therefore recommend that they be discontinued in favor of establishing two new stations close to Pendleton/Oceana, or on the Naval Security Group Activity Northwest installation, to capture more individuals of BCC species.

Fort Bragg (BRAG)

This location consists of a group of six stations tightly clustered along a small watershed on Fort Bragg in North Carolina. Of 15 species captured in acceptable numbers (Table 8a), five species show increases in adult populations and 10 species, including seven Neotropical wintering species, show declines. Blue-gray gnatcatchers represent the only significant (P<0.05) negative trend.

Table 8a. Lists of species captured in acceptable numbers at six MAPS stations operated on Fort Bragg (BRAG). Species are categorized by the direction of the adult population trend (statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01), migratory status, and preferred habitat type-either forest (normal typeface) or scrub/successional habitat (italics). Birds of conservation concern (USFWS 2002) are highlighted.

Neotropical wintering species		Temperate wintering species	
Increasing	Decreasing	Increasing	Decreasing
Red-eyed Vireo	*White-eyed Vireo*	Carolina Chickadee	*Brown Thrasher*
Ovenbird	Blue-gray Gnatcatcher**	Tufted Titmouse	*Eastern Towhee*
	Wood Thrush	*Carolina Wren*	*Northern Cardinal*
	Gray Catbird		
	Prairie Warbler		
	Common Yellowthroat		
	Hooded Warbler		

Candidate Species of Management Concern

Two species of conservation concern to the Fish and Wildlife Service (FWS 2002) are declining and emerge as candidate species for management concern at the BRAG location - wood thrush and prairie warbler. Wood thrush is caught in acceptable numbers at only one station (S112) (Table 8b) and therefore is not a good candidate species for restorative management because no station can act as a “control” station. Prairie warblers were captured in acceptable numbers at four of the six stations. They are declining at two of those stations but show no significant trends at the installation or individual station level.

Notable among the remainder of species is the blue-gray gnatcatcher that shows declines at two stations (significantly (P<0.05) at I104) resulting in a location level decline of 20% annually. Hooded warblers also show declines at two of three stations and significantly (P<0.10) at S112. White-eyed vireos and gray catbirds show significant (P<0.05) declines at

I104 and I102, respectively. Northern cardinals show no significant trends at the station level but are declining (by 7-16%) at four of the six stations.

Table 8b. Table of adult population trends (annual percentage change derived from MAPS data) for landbirds that can be effectively monitored by MAPS stations at the BRAG location. Statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01. Birds of conservation concern (USFWS 2002) and associated negative trends are highlighted in gray.

Species	I102	I104	I113	S110	S112	S114
REVI					2.9	
CACH	-5.8	-6.2	17.5	18.7	-6.5	32.8
TUTI		10.7	13.7	16.5	25.9	-1.2
BGGN		**-25.0		-15.4		
WOTH					-8.9	
OVEN					11.1	
HOWA		-16.2			*-30.7	16.0
WEVI		**-53.0	22.7	-6.5		30.4
CARW	-7.3	-5.3	15.8	-8.7	27.3	4.5
GRCA	**-44.3	10.0	-4.8			
BRTH	1.1			-22.5		
PRAW	-22.3	-8.5	2.5	15.0		
COYE	-5.9	-10.6	2.1	7.9		
NOCA	-7.4	-11.5	0.1	4.1	-10.6	-15.8
N(#neg.)	7 (6)	10 (8)	8 (1)	9 (4)	8 (4)	6 (2)

In summary, management actions should be taken in the vicinity of the I102 and I104 stations to reverse the declines in prairie warblers. Such actions will likely affect other declining species such as white-eyed vireo, gray catbird, common yellowthroat and northern cardinal. In the interests of conservation, however, I102 was discontinued in 2003 to reduce the probability of incidental captures of federally endangered red-cockaded woodpeckers (RCWO) that breed within the boundaries of that station. In collaboration with RCWO researchers and MAPS interns, IBP established a new MAPS station in the Sandhill area of Fort Bragg to replace I102. This new station is located in the southwest corner of the installation and successfully captures prairie warblers and field sparrows that breed among the mosaic of upland patchy forest, shrubland and grassland areas of the station (2003 preliminary data - pers. comm. Kendra Noyes). These areas are frequently maintained by the installation's natural resource management in order to reduce fire risks.

Big Oaks National Wildlife Refuge (JEFF) - *formerly Jefferson Proving Ground.*

This location consists of six stations distributed throughout a large deciduous forest remnant comprising Jefferson Proving Ground in Indiana. Since July 2000, the Fish and Wildlife Service has managed this installation as Big Oaks National Wildlife Refuge. The property is mostly surrounded by agricultural land and isolated woodlots, but the southeast corner is proximal to a heavily forested watershed. Of 25 species captured in acceptable numbers (Table 9a), eight species show increases in adult populations and 17 species show declines, including eight significant declines; white-eyed vireo, worm-eating warbler, ovenbird, Kentucky warbler, common yellowthroat, hooded warbler, American robin, and field sparrow. Of the 17 declining species, 13 are Neotropical wintering species.

Table 9a. Lists of species captured in acceptable numbers at six MAPS stations operated on Jefferson Proving Ground / Big Oaks National Wildlife Refuge (JEFF). Species are categorized by the direction of the adult population trend (statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01), migratory status, and preferred habitat type - either forest (normal typeface) or scrub/successional habitat (italics). Birds of conservation concern (USFWS 2002) are highlighted.

Neotropical wintering species		Temperate wintering species	
Increasing	Decreasing	Increasing	Decreasing
Acadian Flycatcher	*White-eyed Vireo* **	Carolina Chickadee	Downy Woodpecker
Blue-gray Gnatcatcher	Red-eyed Vireo	Tufted Titmouse	*American Robin* *
Black & white Warbler	*House Wren*	*Carolina Wren*	*Field Sparrow* *
Yellow-breasted Chat	Wood Thrush	*Brown Thrasher*	*Northern Cardinal*
	Gray Catbird		
	Blue-winged Warbler		
	Prairie Warbler		
	Worm-eating Warbler **		
	Ovenbird **		
	Kentucky Warbler *		
	*Comm. Yellowthroat****		
	Hooded Warbler *		
	Indigo Bunting		

Although declines are reported for five species listed by the USFWS as species of conservation concern, it must be noted that Big Oaks NWR is being actively managed to conserve breeding populations of Henslow's sparrow within large grassland patches that also exist on the property. As an obligate grassland species, Henslow's sparrow is a poor candidate for monitoring using the MAPS protocol.

Candidate Species of Management Concern

Of the 25 species that are effectively monitored at Big Oaks NWR (Table 9b), seven are species of conservation concern to the Fish and Wildlife Service (FWS 2002). Of these seven species, five are declining at the installation level and emerge as candidate species for management concern. The majority of forest species are declining at the Area 16 (AR16) and Area 07 (AR07) stations (five of six species and six of eight species, respectively). Of BCC species monitored at these stations, Acadian flycatcher, wood thrush, and Kentucky warbler, are declining non-significantly at AR16. Although the vicinity of AR07 is heavily forested, the data show dramatic declines in six of eight forest species, including three BCC species, wood thrush, worm-eating warbler, and Kentucky warbler. Two explanations may account for these declines. The forest canopy is closing (Joe Robb pers. comm.), which generally reduces both the understory biomass and the invertebrate biomass, and there has also been some logging activity in the vicinity, which may have reduced the core area of the surrounding forest. Kentucky warbler is also significantly declining at Area 31 (AR31).

Data from Area 54 (AR54) suggest that the local avian community is shifting towards forest species. Eight of the 10 forest species populations are increasing, significantly so for Kentucky warbler ($P<0.10$) and hooded warbler ($P<0.05$). In contrast, eight of the ten scrub/successional species are declining, four of them significantly, white-eyed vireo ($P<0.01$), American robin ($P<0.10$), prairie warbler ($P<0.10$), and common yellowthroat ($P<0.05$). Previous management practices in this area included herbicide treatment to keep the habitat open. Although in recent years the area has been left to succeed naturally, which may partly explain the community shift towards forest birds, it will remain subject to prescribed burns in the future (Joe Robb pers. comm.). Such burns would be expected to reverse the recent population declines in scrub/successional species.

Of the remaining species, white eyed vireo is significantly declining ($P<0.01$) at two of three stations, gray catbird is declining at four of five stations, significantly so ($P<0.05$) at two stations. Common yellowthroat is declining at all three stations, but highly significantly (P<0.01) at AR54 and AR64. Northern cardinal is declining at four of six stations and significantly so at two of those stations, AR16 (P<0.05) and AR31 (P<0.10).

Table 9b. Table of adult population trends (annual percentage change derived from MAPS data) for landbirds that can be effectively monitored by MAPS stations at the BRAG location. Statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01. Birds of conservation concern (USFWS 2002) and associated negative trends are highlighted in gray.

Species	AR54	AR27	AR16	AR31	AR07	AR64
DOWO	-3.5			-3.1	3.6	
ACFL	22.0		-1.6			
REVI	13.7	5.9	-5.7		0.18	8.8
CACH	6.3			16.1		12.7
TUTI	14.1	2.1	-2.5	3.4		
BGGN						23.6
WOTH	13.4	8.1	-1.4		**-13.9	1.5
BAWW	23.5				-11.6	
WEWA					**-19.9	
OVEN	-13.6	**-2.0	***1.1	26.3	-7.8	
KEWA	*24.0	1.9	-8.3	*-15.9	***-15.2	14.7
HOWA	**54.7				***-36.8	
WEVI	***-27.5			***-24.4		11.0
CARW						39.0
HOWR	-1.1					
AMRO	*-19.8					
GRCA	-14.5	-16.2		**-20.9	**-60.5	17.6
BRTH	19.3					
BWWA	-10.1			0.0		20.7
PRAW	*-27.2			5.3		
COYE	***-35.5			-0.6		***-18.8
YBCH				4.0		5.3
FISP	-9.5			*-1.7		
NOCA	5.5	3.5	**-22.7	*-19.0	-15.7	-12.2
INBU						-0.3
N(#neg.)	20 (10)	7 (2)	7 (6)	13 (7)	10 (8)	13 (3)

Although stations in Area 27 (AR27) and Area 16 (AR16) effectively monitor Kentucky warbler and wood thrush populations, they catch relatively few species and could be discontinued in favor of establishing two new stations designed to monitor prairie warbler and/or field sparrow. Currently, these two species are only captured in acceptable numbers at Area 54 and Area 31 stations.

In summary, two stations (AR27 and AR16) should be discontinued and re-established elsewhere on the installation in order to more effectively monitor species of management concern. Management might be directed at declining forest species of at AR07, which might include thinning of those forested tracts with sparse undergrowth, and allowing previously logged areas to regenerate. Also, AR54 will monitor the effects of proposed future fire management in the vicinity that may reverse the declines in scrub/successional species. A combination of small-scale logging and burning of late-successional shrubland can create patches of early-successional habitat that are suitable for breeding populations of prairie warblers and field sparrows.

Fort Knox (KNOX)

This location comprises six stations distributed throughout a large deciduous forest remnant delineated by the perimeter of the 44,000-hectare Fort Knox installation in Kentucky. Of 17 species effectively monitored at Fort Knox (Table 10a), seven species show increases in adult populations and 10 species show declines, including four significant declines: red-eyed vireo, blue-winged warbler, common yellowthroat and indigo bunting.

Table 10a. Lists of species captured in acceptable numbers at six MAPS stations operated on Fort Knox (KNOX). Species are categorized by the direction of the adult population trend (statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01), migratory status, and preferred habitat type - either forest (normal typeface) or scrub/successional habitat (italics). Birds of conservation concern (USFWS 2002) are highlighted.

Neotropical wintering species		Temperate wintering species	
Increasing	Decreasing	Increasing	Decreasing
Acadian Flycatcher	*White-eyed Vireo*	Carolina Chickadee	Downy Woodpecker
Wood Thrush	Red-eyed Vireo *	Tufted Titmouse	*Northern Cardinal*
Prairie Warbler	*Blue-winged Warbler* **	*Carolina Wren* *	
Prothonotary Warbler	Worm-eating Warbler		
	Louisiana Waterthrush		
	Kentucky Warbler		
	Common Yellowthroat **		
	Indigo Bunting ***		

Candidate Species of Management Concern

The 17 species that are effectively monitored on Fort Knox (Table 10b) include seven species of conservation concern to the Fish and Wildlife Service (FWS 2002), all of which are Neotropical wintering species. Four of these species are declining at the installation level and emerge as candidate species for management concern - blue-winged warbler (P<0.05), worm-eating warbler, Louisiana waterthrush, and Kentucky warbler. Worm-eating warblers are captured at only two stations and show a non-significant decline at the Cedar Creek (CEDA) station, and Louisiana waterthrush is only captured at one station, making them poor candidates for management concern. Kentucky warblers, on the other hand, are captured at five of the six stations and show declines (significant at SARI; P<0.05) at three stations.

Blue-winged warblers show annual declines of ~17% annually at two distant stations - Cedar Creek (CEDA) and Salt River (SARI). Closer inspection of the data reveals that SARI is a poor candidate station for this species because so few individuals are captured. At CEDA, no adult blue-winged warblers were captured in 2001 and no young were captured in the four-year period 1998-2001. However, both adult and young captures appear in the 2002 data. Although wood thrushes show an installation-wide increase, they are non-significantly declining at two of the four stations at which they are captured. The two remaining BCC species are increasing at those stations that effectively monitor them - Acadian flycatcher (2 stations) and prairie warbler (1 station).

Of particular interest among the remaining species, red-eyed vireo is declining at three stations, but significantly so at OHRI ($P<0.01$). Three scrub/successional species are declining at all of the stations at which they are effectively monitored - common yellowthroat (3), Northern cardinal (5), and indigo bunting (4).

Table 10b. Table of adult population trends (annual percentage change derived from MAPS data) for landbirds that can be effectively monitored by MAPS stations at the KNOX location. Statistical significance is denoted by: * 0.05 $P<0.10$, ** 0.01 $P<0.05$, and *** $P<0.01$. Birds of conservation concern (USFWS 2002) and associated negative trends are highlighted in gray.

Species	OHRI	MCSP	CEDA	SARI	DULA	LDLA
DOWO				-13.6	0.75	
ACFL	3.6	0.1				
REVI	***-24.9			-6.1	-10.0	
CACH					12.2	
TUTI	-8.5			**25.9	1.7	
WOTH	-30.8	-6.7	8.0	**20.7		
WEWA			-20.1	2.4		
LOWA		-2.5				
KEWA	11.6	*13.6	-4.0	**-12.3	-9.4	
WEVI	**33.1		**-29.4			
CARW	22.7	16.5	0.7	15.9		
BWWA			**-17.5	-16.5		
PRAW					7	
COYE	-1.9		**-17.3		-17.2	
NOCA	-7.1	-8.4	-13.4	-0.6	-7.7	
INBU	-4.9		-7.7	*-25.3	-13.7	
N(#neg.)	10 (6)	6 (3)	9 (7)	10 (6)	9 (5)	0 (0)

In summary, management could be directed at Cedar Creek to reverse declines in blue-winged warblers, which might include maintaining nearby habitat patches in an early successional state using fire or tree/sapling removal. Such actions will likely affect all the other five scrub/successional species that are captured there, four of which are declining, two of those significantly - white-eyed vireo ($P<0.05$) and common yellowthroat ($P<0.05$). No species are effectively monitored at the LDLA station and only six species are effectively monitored at the MCSP station. We therefore recommend that these two stations should be re-established elsewhere on the installation to better monitor blue-winged warblers.

Crane Naval Surface Warfare Center (CRAN)

This location comprises six stations distributed throughout a 19,800-hectare forest remnant within the 25,300-hectare Crane Naval Surface Warfare Center in Indiana. Of 23 species effectively monitored there (Table 11a), 14 species show increases in adult populations and nine species show declines, including four significant declines; gray catbird, blue-winged warbler, yellow-breasted chat and field sparrow. The Crane NSWC installation is adjacent to extensive agricultural lands and isolated woodlots to the west and forested lands abutting Hoosier National Forest to the east. At the installation-level, the data suggest that a community shift towards Neotropical wintering, forest inhabiting species has occurred. Ten of the 14 species that show increasing population trends are Neotropical wintering species, and twelve of the 14 species are forest species. Conversely, all nine declining species are successional/scrub species. This community shift is consistent with an active logging operation across the installation that only harvests 30-40% of the annual timber growth and leaves large patches of late-successional forest.

Table 11a. Lists of species captured in acceptable numbers at six MAPS stations operated on Crane Naval Surface Warfare Center (CRAN). Species are categorized by the direction of the adult population trend (statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01), migratory status, and preferred habitat type - either forest (normal typeface) or scrub/successional habitat (italics). Birds of conservation concern (USFWS 2002) are highlighted.

Neotropical wintering species		Temperate wintering species	
Increasing	Decreasing	Increasing	Decreasing
Acadian Flycatcher	*White-eyed Vireo*	Downy Woodpecker ***	*Carolina Wren*
Red-eyed Vireo	*Gray Catbird* **	Carolina Chickadee **	*Eastern Towhee*
Wood Thrush	*Blue-winged Warbler* **	Tufted Titmouse	*Field Sparrow* **
Black & white Warbler *	*Prairie Warbler*	*Northern Cardinal*	
Worm-eating Warbler **	*Common Yellowthroat*		
Ovenbird **	*Yellow-breasted Chat* ***		
Louisiana Waterthrush			
Kentucky Warbler			
Hooded Warbler ***			
Indigo Bunting			

Candidate Species of Management Concern

Three species of conservation concern to the Fish and Wildlife Service (FWS 2002) emerge as candidate species for management concern at Crane Naval Surface Warfare Center: blue-winged warbler, prairie warbler, and field sparrow. At the Sulphur Creek (SULP) station two successional species are declining – blue-winged warbler (P<0.05) and field sparrow (P<0.01) of which no adults were captured in 2001. Clearly, a community shift has occurred at this station from scrub/successional species to forest species with seven of the nine scrub/successional species declining (3 significantly) and eight of the 10 forest species increasing (2 significantly). Gray catbirds and yellow-breasted chats are declining at all stations.

Table 11b. Table of adult population trends (annual percentage change derived from MAPS data) for landbirds that can be effectively monitored by MAPS stations at the CRAN location. Statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01. Birds of conservation concern (USFWS 2002) and associated negative trends are highlighted in gray.

Species	FIRS	WICE	SEED	SULP	EABO	AR14
DOWO		***19.2	**46.3	9.5		
ACFL	7.9	12.3	-0.6		7.1	-6.0
REVI		-0.4		2.3		
CACH		11.8		**21.7	-8.3	
TUTI	-2.8	32.2	15.5	-15.9	-21.1	
WOTH	-1.3	30.9	-15.6	14.3	6.2	-0.4
BAWW				**29.7		
WEWA		23.1		24.3	**32.5	**9.1
OVEN		13.3	***47.7	30.8	14.8	12.4
LOWA	8.3		12.3	-19.6	4.9	
KEWA	-4.5	*-5.7	-4.6	4.2	2.1	*17.8
HOWA				**42.5	**30.1	
WEVI		1.1		-8.3	-3.1	
CARW	-25.0	-0.2			5.6	
GRCA		*-14.4		*-18.2	-5.7	
BWWA		-3.2		**-12.0	4.8	
PRAW		6.6		-3.8		
COYE	10.2	-4.7	4.9	-9.8	-3.4	
YBCH	***-39.0			-11.5	-1.5	
FISP				***-22.6		
NOCA	-0.8		17.1	3.7	14.9	
INBU		0.1	**32.0	3.4	-4.7	
N(#neg.)	9 (6)	16 (6)	10 (3)	20 (9)	17 (7)	5 (2)

In contrast, five forest BCC species are increasing at the installation-level: Acadian flycatcher, wood thrush, worm-eating warbler, Louisiana waterthrush, and Kentucky warbler. Kentucky warbler is declining at three of six stations, significantly so (P<0.10) at the Williams Cemetery (WICE) station, whereas flycatchers and wood thrushes are declining at 2 of 5 and 3 of 5 stations, respectively.

In summary, Crane NSWC has an active forestry program that harvests only 30-40% of the annual growth allowing many stands to mature. It is, therefore, not surprising that populations of forest species are generally increasing at both the installation and station level. For instance, both the Williams Cemetery and Sulphur Creek are clearly experiencing a community shift towards forest species. Management actions, including creating forest regeneration openings up to two hectares in area, could be taken in the vicinity of Sulphur Creek to reverse the observed declines in the field sparrow population. Unfortunately, although post-breeding fire management is the conventional management technique to maintain field sparrow shrub/grassland habitat in an early successional stage, it is not applicable at Crane NSWC because of the danger fire poses to the installation's weapon storage mission. Although management actions designed to benefit field sparrows may negatively affect forest species breeding in the vicinity of SULP, they will likely benefit populations of blue-winged warblers, prairie warblers, and gray catbirds.

The Area 14 (AR 14) station captures only five species in acceptable numbers and, therefore, could be discontinued in favor of establishing another station elsewhere on Crane to monitor the effects of silvicultural practices (typically regeneration openings) on avian communities. IBP is currently discussing with Steve Andrews, the Crane Division natural resources manager, a) the proposed plans for creating regeneration openings in the vicinity of Sulphur Creek, and b) establishing a new MAPS station close to an existing mosaic of regeneration openings. We also obtained (from GIS specialist Trent Osman) GIS coverages of proposed forest stand management plans. These coverages, and other coverages depicting open areas (e.g. parking lots and mown grassland areas), have been reclassified so that they can be superimposed upon the reclassified (21-class aggregated to 7-class; see Methods) NLCD data. Several methods are available to create an altered NLCD coverage that represents the post-management pattern of forest and openings. From a spatial analysis of the altered coverage we can make predictions of the effect of the management on a target species by using the appropriate species-landscape model for the demographic of interest. From these data we can also identify suitable locations for establishing a new MAPS station to replace the AR14 station.

Fort Leonard Wood (LEON)

This location comprises six stations distributed throughout a large deciduous forest tract delineated by the perimeter of the 25,500-hectare Fort Leonard Wood installation in Missouri. An oak-prairie habitat type dominated this region prior to European settlement of the area, which was maintained by grazing of large herds of ungulates (e.g. antelope and bison) and by seasonal burning practices of the native American tribes people of the area. Of 21 species captured in acceptable numbers (Table 12a), nine species show increases in adult populations and 12 species show declines, including a significant (P<0.10) decline for Acadian flycatcher.

Table 12a. Lists of species captured in acceptable numbers at six MAPS stations operated on Fort Leonard Wood (LEON). Species are categorized by the direction of the adult population trend (statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01), migratory status, and preferred habitat type - either forest (normal typeface) or scrub/successional habitat (italics). Birds of conservation concern (USFWS 2002) are highlighted.

Neotropical wintering species		Temperate wintering species	
Increasing	Decreasing	Increasing	Decreasing
White-eyed Vireo	Acadian Flycatcher *	*Northern Cardinal*	Downy Woodpecker
Red-eyed Vireo	Black & white Warbler		Carolina Chickadee
Blue-gray Gnatcatcher	Worm-eating Warbler		Tufted Titmouse
Wood Thrush *	Ovenbird		*Carolina Wren*
Blue-winged Warbler	Louisiana Waterthrush		*Field Sparrow*
Prairie Warbler *	Kentucky Warbler		
Yellow-breasted Chat	*Common Yellowthroat*		
Indigo Bunting			

Candidate Species of Management Concern

Five species of conservation concern to the Fish and Wildlife Service (FWS 2002) emerge as candidate species for management concern at Fort Leonard Wood. Acadian flycatcher is declining at the only two stations it is captured in acceptable numbers (Table 12b), but is significantly declining at Laughlin Bottom (LABO), where four of seven forest species are declining and five of nine successional/scrub species are also declining, including field sparrow. LABO is a brushy bottomland with a riparian forest that attracts relatively high (and increasing) numbers of prairie warblers and field sparrows, and for that reason should not be subject to new management at this time. In fact, this station could be used as a control for management actions applied to the vicinity of the Macedonia (MACE) station to increase field sparrow populations. Few field sparrow adults or young have been captured there in recent years, probably because of the succession of the old-field portion of the station. Fire management intended to restore warm grassland habitat at FLW is normally applied in the springtime prior to the breeding season. Such actions are scheduled to affect the Miller Pond and Macedonia stations in the spring of 2003.

Wood thrushes, worm-eating warblers, and Louisiana waterthrushes are poor candidates for management because they are only caught in acceptable numbers at the Big Piney (BIPI) station. Kentucky warblers are captured at four of the six stations but are only declining at the Miller Ridge station.

Table 12b. Table of adult population trends (annual percentage change derived from MAPS data) for landbirds that can be effectively monitored by MAPS stations at the LEON location. Statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01. Birds of conservation concern (USFWS 2002) and associated negative trends are highlighted in gray.

Species	BIPI	LABO	MIPO	MACE	SMRI	MIRI
DOWO	-16.5	-10.8	-6.4			
ACFL	-2.25	**-11.8				
REVI	-4.3	7.1	*40.0		2.1	
CACH		5.0	-11.4	-8.4		
TUTI		-11.8	11.4	-18.3	16.5	-21.4
BGGN		18.7	*-20.4			
WOTH	*15.8					
BAWW		-10.5		9.4		
WEWA	-2.4					
OVEN				-7.5		1.27
LOWA	-3.7					
KEWA	1.0	4.0	5.8			-22.6
WEVI	*7.0	*6.9	24.3			
CARW	*-23.6	-12.1	-8.4			
BWWA	-5.0	3.1	5.1			
PRAW		14.3	*14.7			
YBCH		-6.3	8.5			
FISP		-3.9	5.8	**-32.5		
NOCA	*17.4	-4.3	3.5			
INBU	5.6	-3.4	5.3	-5.7		
N(#neg.)	12 (7)	16 (9)	14 (4)	6 (5)	2 (0)	3 (2)

In summary, there are three species of particular conservation concern at Fort Leonard Wood, Acadian flycatcher, blue-winged warbler, and field sparrow. Fire management of open scrubby habitats surrounding Miller Pond and Macedonia stations, applied in the spring of 2003, may help increase field sparrow populations there. Also, the two heavily forested upland stations, Smith Ridge (SMRI) and Miller Ridge (MIRI), capture only a few individuals of few species each year. In 2003, these stations were discontinued in favor of establishing two new stations to monitor populations of USFWS scrub/successional species of conservation concern in other areas of the installation.

Discussions with FLW natural resources manager, Joe Proffitt, revealed several candidate areas for establishing the two new MAPS stations on Fort Leonard Wood. These included, for forest species, a heavily forested area (accessible via the Hayfield site) of silver maple, sycamore, and mixed hardwood that would act as a replicate of the Big Piney (BIPI) station. Alternatively, two candidate areas would allow monitoring of warm grassland areas. The Ichord House vicinity is burned in springtime on a 3-5 year cycle and could be used to monitor prairie warblers and field sparrows. Lastly, the Bradford Cemetery vicinity was previously managed for warm grassland species but can now be left to succeed. This area is proximal to a pine forested area and will likely succeed towards pine forest, during which time, monitoring should be conducted to detect population changes of blue-winged warblers, prairie warblers, and field sparrows. We eventually decided to establish the new stations on the Hayfield and the Bradford Cemetery sites.

Neotropical wintering species		Temperate wintering species	
Increasing	Decreasing	Increasing	Decreasing
Red-eyed Vireo	Kentucky Warbler		Downy Woodpecker
House Wren *			Blue Jay
Wood Thrush **			Tufted Titmouse
Gray Catbird ***			*Carolina Wren*
Louisiana Waterthrush *			*American Robin* **
Common Yellowthroat			*Brown Thrasher*
Indigo Bunting			*Field Sparrow* **
			Northern Cardinal

field sparrows are significantly (P<0.05) declining, probably due to succession of the oldfield habitat at the station. Again, post-breeding fire management of this area should be effective, but uncertainty regarding future commercial development of these areas precludes investing time and effort into formulating and implementing any management plans.

Table 13b. Table of adult population trends (annual percentage change derived from MAPS data) for landbirds that can be effectively monitored by MAPS stations at the LEAV location. Statistical significance is denoted by: * 0.05 $P<0.10$, ** 0.01 $P<0.05$, and *** $P<0.01$. Birds of conservation concern (USFWS 2002) and associated negative trends are highlighted in gray.

Species	FOSU	NOWE	CAMI	SOWE	RADE	SPHA
DOWO	**-26.3	-8.7	-7.8	1.0	3.2	2.5
REVI			12.7	2.2		
BLJA	*-42.4			-11.3		
TUTI	-3.1	-0.03	-3.5	16.4	-14.2	6.3
WOTH		8.9	12.9	17.3		
LOWA			**30.0		16.4	
KEWA	5.8		3.4		***-13.2	
CARW	-6.5	1.4	-7.8	-5.0	-8.6	4.4
HOWR		*14.9		**27.2		
AMRO	***-26.9		**-50.9	21.1		
GRCA		***39.4		3.8		
BRTH						-3.5
COYE		16.4		4.6		
FISP						**-12.8
NOCA	-4.0	***22.6	-6.6	-12.2	-9.1	-5.7
INBU	6.6	16.9	4.8	-2.6		5.3
N(#neg.)	8 (6)	9 (2)	10 (5)	12 (4)	6 (4)	7 (3)

Finally, although three temperate-wintering species, Carolina wren, American Robin, and northern cardinal show declines at the majority of stations at which they occur on Fort Leavenworth, none of these are species of conservation concern.

Fort Riley (RILE)

This location comprises six stations on the 40,700-hectare Fort Riley installation in Kansas. Of 21 species captured in acceptable numbers (Table 14a), 13 species show increases in adult populations, including three BCC species, wood thrush, Louisiana waterthrush, and field sparrow. Conversely, eight species show declines including two highly significantly (P<0.01) declining species; yellow warbler and common yellowthroat. Bell's vireos, another BCC species, is captured at three of the stations and is declining at two. Unfortunately, although Bell's vireo is high on the Fish and Wildlife list of species of conservation concern, it is not included in the species-landscape analyses that follow in Part II of the Results section because, across the entire study, it is only caught in acceptable numbers at those three stations.

Table 14a. Lists of species captured in acceptable numbers at six MAPS stations operated on Fort Riley (RILE). Species are categorized by the direction of the adult population trend (statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01), migratory status, and preferred habitat type - either forest (normal typeface) or scrub/successional habitat (italics). Birds of conservation concern (USFWS 2002) are highlighted.

Neotropical wintering species		Temperate wintering species	
Increasing	Decreasing	Increasing	Decreasing
Red-eyed Vireo	*Bell's Vireo*	Tufted Titmouse **	Downy Woodpecker
House Wren *	*Yellow Warbler* ***	*American Robin*	Blue Jay
Blue-gray Gnatcatcher	*Comm. Yellowthroat* ***	*Brown Thrasher* **	*Carolina Wren*
Wood Thrush		*Field Sparrow*	*Northern Cardinal*
Gray Catbird		*Grasshopper Sparrow*	*Brown-headed Cowbird*
Louisiana Waterthrush		*Common Grackle*	
Indigo Bunting			

Candidate Species of Management Concern

Only one bird of conservation concern to the Fish and Wildlife Service (FWS 2002), Bell's vireo, emerges as a candidate species for management concern at Fort Riley (Table 14b). Bell's vireos are captured at three stations but are significantly declining at the Estes Draw station (ESDR). Closer inspection of the MAPS data reveals that the numbers of vireo young captured each year significantly (P<0.01) declined to zero between 1994 and 1997; since then no young have been captured. This species is declining across the entire mid-western states as its preferred riparian forest breeding habitat is disturbed by agriculture and development. Bell's vireo populations in the Fort Riley area might benefit from a program of cowbird eradication, which is known to lower the frequency of brood parasitism (Robinson et al. 1995). Several species at Fort Hood appear to have benefited from such a program.

Of the remaining species, yellow warblers are declining at both the MYPR and ESDR (P<0.10) stations, and common yellowthroats are also significantly declining at those stations (P<0.10 and P<0.05, respectively). Although these species are common cowbird hosts, there is no evidence of declines in the numbers of young captured, or the reproductive success of these two species. Despite this we suggest that a cowbird eradication program be established and that levels of cowbird parasitism should be monitored. However, because the area around this station is constantly being disturbed by tank activity, loss of breeding habitat cannot be discounted as a major factor causing these declines.

Table 14b. Table of adult population trends (annual percentage change derived from MAPS data) for landbirds that can be effectively monitored by MAPS stations at the RILE location. Statistical significance is denoted by: * 0.05   P<0.10, ** 0.01   P<0.05, and *** P<0.01. Birds of conservation concern (USFWS 2002) and associated negative trends are highlighted in gray.

Species	TICR	KARI	MYPR	ESDR	RIPO	TMCR
DOWO	-14.7		30.9	-1.2		-7.5
REVI		11.0				
BLJA						-4.6
TUTI	7.2	19.6				20.6
BGGN	1.8					
WOTH						6.0
LOWA	15.9					
BEVI			-10.6	**-12.3	*39.6	
CARW		-2.9				-5.4
HOWR	23.9		*30.6	10.1		
AMRO						40.1
GRCA			-1.8	4.3		
BRTH			8.1	***16.5		
YWAR			-15.1	***-13.0		
COYE	-6.4		*-20.8	**-17.6		
FISP	10.3		5.0	**17.5		
NOCA	1.7	4.5	-8.1	-8.9		
INBU	3.9			-4.8		
N(#neg.)	9 (2)	4 (1)	9 (5)	10 (6)	1 (1)	6 (3)

In summary, the current locations of MAPS stations on Fort Riley, excepting Estes Draw, effectively monitor very few species of conservation concern. Future MAPS monitoring would be best focused on relocating stations into Bell's vireo habitats to better monitor demographic changes in this highly threatened species. Unfortunately, the MAPS program catches too few Bell's vireos at too few stations to facilitate a landscape study. Any attempts to construct a species-landscape model for this species will require data from at least eight stations at which they are captured in acceptable numbers.

Camp Swift (SWIF)

This location comprises six tightly clustered stations on 22,700-hectares of Camp Swift in the hilly uplands and flat lowlands in south-central Texas. Of six species captured in acceptable numbers (Table 15a), three species show increases in adult populations, and three species show declines including northern cardinal (P<0.10). Painted bunting is the only declining species on the Fish and Wildlife Service's list of species of conservation concern that is effectively monitored here.

Table 15a. Lists of species captured in acceptable numbers at six MAPS stations operated on Camp Swift (SWIF). Species are categorized by the direction of the adult population trend (statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01), migratory status, and preferred habitat type - either forest (normal typeface) or scrub/successional habitat (italics). Birds of conservation concern (USFWS 2002) are highlighted.

Neotropical wintering species		Temperate wintering species	
Increasing	Decreasing	Increasing	Decreasing
White-eyed Vireo	*Painted Bunting*	Tufted Titmouse	Carolina Chickadee
		Carolina Wren	*Northern Cardinal* *

Candidate Species of Management Concern

Painted bunting emerges as the only candidate species for management concern at Camp Swift. Captures of painted bunting adults are declining at five of the six stations and significantly at three stations. Of these, East Loop East (EALE), East Loop West (EALW), and Wine Cellar Loop (WCLO) capture the highest numbers of adults but they are declining significantly at EALE (P<0.05), WCLO (P<0.10), and SAJU (P<0.10).

Painted buntings are in decline across their geographic range. Loss or alteration of breeding habitat is thought to be the major threat to painted bunting populations but other factors include the pet trade on their Central American overwintering grounds, and cowbird parasitism on their breeding grounds. Conventional management for this species includes keeping a mix of open, shrubby and wooded areas and managing them through fire, mowing, herbicide application, and thinning to maintain these habitats in early- and mixed-successional stages. Current fire management practices conducted in the spring or fall upon the installation tend to promote monocultural swathes of little bluestem grass. It is known, however, that warm season (summer) burns, result in a more natural and diverse cool-season grassland and a richer springtime/early summer forb community, given adequate winter precipitation. This kind of fire regime may benefit those bird species that utilize the grassland for foraging or breeding by attracting a rich community of arthropods, early in the year, and suitable cover for grassland breeding birds to nest in. Summer burning, applied over a number of years, changes the landscape in different ways compared to cool season burns. Without fire, the habitats in this region tend to become dominated by juniper. Summer fires are generally hotter than cool-season burns and tend to more effectively remove juniper bushes and trees, whereas oaks, although more tolerant of fire, tend to form large low shrubs rather than trees. The net result is a landscape that is patchy with fewer trees but a higher component of oaks compared to the less patchy, more forested, juniper-dominated landscape that results from cool-season burn regimes.

Table 15b. Table of adult population trends (annual percentage change derived from MAPS data) for landbirds that can be effectively monitored by MAPS stations at the SWIF location. Statistical significance is denoted by: * 0.05   P<0.10, ** 0.01   P<0.05, and *** P<0.01. Birds of conservation concern (USFWS 2002) and associated negative trends are highlighted in gray.

Species	PIPE	EALW	EALE	WCLO	SAJU	MCCR
CACH	*11.7			-18.5	***-2.3	
TUTI	-15.5			-8.4	**14.1	
WEVI	5.6	9.0	01.0	0.3		2.1
CARW	-5.8	16.5	3.5	1.0	0.1	0.3
NOCA	-5.5	-6.5	-3.0	-6.8	**-14.9	-6.3
PABU	4.2	**-21.1	-1.4	*-10.6	*-24.4	-0.6
N(#neg.)	6 (3)	4 (2)	4 (2)	6 (4)	5 (3)	4 (2)

In summary, management actions could be directed towards restoring painted bunting populations in the vicinity of Wine Cellar Loop and/or East Loop West. The McLaughlin Creek station (MCCR) could be discontinued in favor of establishing a new station to monitor painted buntings elsewhere on Camp Swift. It is proposed to introduce warm-season fire regimes on the installation, which will help restore the natural grassland components of the forest-shrubland-grassland habitat mosaic, and subsequently monitor the effects of this management on the avian community, especially painted buntings.

Fort Hood (HOOD)

This location comprises six tightly clustered stations on 88,000-hectares of karst scenery featuring limestone escarpments that define the woodlands, prairies, and streams of Fort Hood Military Reservation in central Texas. Of 13 species captured in acceptable numbers (Table 16a), four Neotropical species show increases (3 significant trends; P<0.05) in adult populations, and nine species show declines including significant declines associated with red-eyed vireo (P<0.10), northern mockingbird (P<0.05), rufous-crowned sparrow (P<0.05), field sparrow (P<0.05), and northern cardinal (P<0.10). Bewick's wren is high on the Fish and Wildlife list of species of conservation concern and is also declining.

Two federally endangered species, golden-cheeked warbler and black-capped vireo, breed at Fort Hood. This report makes no mention of these species because they are not well represented in the MAPS data, and also because intensive ecological study and management of these species is already a goal of the natural resources program at Fort Hood (JettJ et al. 1998).

Table 16a. Lists of species captured in acceptable numbers at six MAPS stations operated on Fort Hood (HOOD). Species are categorized by the direction of the adult population trend (statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01), migratory status, and preferred habitat type - either forest (normal typeface) or scrub/successional habitat (italics). Birds of conservation concern (USFWS 2002) are highlighted.

Neotropical wintering species		Temperate wintering species	
Increasing	Decreasing	Increasing	Decreasing
White-eyed Vireo **	Red-eyed Vireo *		Carolina Chickadee
Blue-gray Gnatcatcher**			Tufted Titmouse
Black & White Warbler **			*Carolina Wren*
Painted Bunting			*Bewick's Wren*
			N. Mockingbird **
			*Rufous-crnd. Sparrow***
			Field Sparrow **
			Northern Cardinal *

Candidate Species of Management Concern

Two species of conservation concern to the Fish and Wildlife Service (FWS 2002) emerge as candidate species for management concern at Fort Hood. Bewick's wren is significantly declining ($P<0.10$) at Shorthorn (SHOR) station and Taylor Branch (TABR), and declining at Taylor Field (TAYL). Captures of field sparrow also significantly ($P<0.05$) declined at TAYL, perhaps due to succession of the oldfield habitat around the station. Again, "disclimax" post-breeding fire maintenance of oldfield and open woodland-scrub areas near these stations should reverse succession and lead to local recoveries in populations of field sparrows.

It is worth noting that, at the installation level, the majority of declining species are temperate wintering species of successional/scrub habitats. This might suggest that winter weather is increasingly less favorable to these species, that the successional/scrub habitats are changing, or that other conditions during the non-breeding season are unfavorable.

Table 16b. Table of adult population trends (annual percentage change derived from MAPS data) for landbirds that can be effectively monitored by MAPS stations at the HOOD location. Statistical significance is denoted by: * 0.05   P<0.10, ** 0.01   P<0.05, and *** P<0.01. Birds of conservation concern (USFWS 2002) and associated negative trends are highlighted in gray.

Species	SHOR	TAYL	ENGI	VIRE	BROO	TABR
REVI						*-24.3
CACH	6.9	-11.8	-14.0	-18.7	-1.7	**-21.1
TUTI		-19.8	*28.6	-9.9	-10.1	
BGGN	-6.9	-.8	*53.6	16.7	21.4	12.1
BAWW			*49.1	26.3	-8.1	2.8
WEVI	-23.1	**10.7	**12.4	*12.4	4.9	9.1
CARW	23.2	11.8		-8.6	12.3	2.5
BEWR	*-25.3	-3.8	9.6	6.7	5.0	*-23.7
NOMO		**-40.7				
FISP		**-23.9				-13.2
NOCA	***-17.2	-1.7	-0.3	1.1	1.7	**-12.8
N(#neg.)	6 (4)	9 (6)	7 (2)	8 (3)	8 (3)	9 (5)

Camp Bowie (BOWI)

This location comprises six tightly clustered stations on the 3,500-hectares of Camp Bowie in central Texas. This installation is part of the Cross Timbers and Prairies physiographic region and features patchy plateau live oak and midgrass savanna with water sources that are restricted to seasonal (or intermittent) streams, pothole ponds, and stock ponds. Of nine species captured in acceptable numbers (Table 17a), three species show increases in adult populations, and six species show declines, including significant declines in populations of Carolina chickadee ($P<0.05$), and northern mockingbird ($P<0.01$). Also declining are populations of two BCC species, Bewick's wrens and field sparrows, whereas painted buntings are increasing.

Table 17a. Lists of species captured in acceptable numbers at six MAPS stations operated on Camp Bowie (BOWI). Species are categorized by the direction of the adult population trend (statistical significance is denoted by: * 0.05 $P<0.10$, ** 0.01 $P<0.05$, and *** $P<0.01$), migratory status, and preferred habitat type - either forest (normal typeface) or scrub/successional habitat (italics). Birds of conservation concern (USFWS 2002) are highlighted.

Neotropical wintering species		Temperate wintering species	
Increasing	Decreasing	Increasing	Decreasing
Painted Bunting		*Rufous-crnd. Sparrow*	Carolina Chickadee **
		Common Grackle	Tufted Titmouse
			Bewick's Wren
			N. Mockingbird ***
			Field Sparrow
			Northern Cardinal

Candidate Species of Management Concern

Although avian diversity is generally low at Camp Bowie, three species of conservation concern to the Fish and Wildlife Service (FWS 2002) emerge as candidate species for management concern. Bewick's wren is declining at five of the six stations (Table 17b) but is highly significantly declining ($P<0.01$) at Mockingbird Lane (MOCK) and significantly declining ($P<0.10$) at Devil's Hill (DEVI). Closer inspection of the data reveal that although the adult population is declining non-significantly at Bedrock (BEDR) the numbers of young captured are also declining significantly ($P<0.05$) both there and at MOCK. Field sparrows are captured at three stations and are declining at MOCK, whereas painted buntings are non-significantly declining at three of four stations including MOCK and Devil's Hill (DEVI). Post-breeding fire maintenance of oldfield and open scrub/woodland areas near these stations should reset succession and effect local recoveries in populations of all three BCC species. Cattle grazing on the installation also poses a threat to these species because they destroy the critical understory and shrub-nesting habitats. Therefore, exclusion of grazing from key habitats may also be an effective management strategy. Proximity of grazing to nesting areas may seriously affect songbird population dynamics, not only through habitat disturbance but also through cowbird parasitism. A previous study of Texas stations (Nott 2002) concluded that exclusion or reduction of grazing pressure might benefit the avian communities at Camp Bowie.

These data suggest that there is an installation-wide problem facing songbird populations that breed at Camp Bowie. Excepting Stonehaven (STON), nearly all the species captured at each station are declining. Similar to the situation at Fort Hood, all the declining species are temperate wintering species, which suggests that perhaps winter conditions that affect the southern-central United States may be, at least partially, responsible.

Notable among other species are the installation-wide declines in Carolina chickadee and tufted titmouse as well as the near extirpation of northern mockingbirds from five stations. The reason for the dramatic decline in mockingbird populations is unknown. One hypothesis is that they have emigrated to breed in suitable habitats among the rapidly expanding suburban developments. Reasons for these declines should be explored.

Table 17b. Table of adult population trends (annual percentage change derived from MAPS data) for landbirds that can be effectively monitored by MAPS stations at the BOWI location. Statistical significance is denoted by: * 0.05 P<0.10, ** 0.01 P<0.05, and *** P<0.01. Birds of conservation concern (USFWS 2002) and associated negative trends are highlighted in gray.

Species	STON	NIGH	MOCK	BEDR	MESQ	DEVI
CACH	-17.0		**-37.6	-15.6-	-14.1	-13.0
TUTI	4.8	-3.3	-3.0	-3.7	-7.3	-6.0
BEWR	-8.1	-3.6	***-23.0	-9.3	4.3	*-9.1
NOMO	**-50.6	***-30.3	-52.8		-6.5	***-22.1
FISP	8.4		-8.8			0.7
NOCA	1.3	0.8	-0.5	-21.5	-17.4	-2.5
PABU	12.3		-1.9		-6.6	-0.9
COGR					21.9	
N(#neg.)	7 (3)	4 (3)	7 (7)	4 (4)	7 (5)	7 (6)

In summary, management actions should be directed at conserving populations of Bewick's wrens, field sparrows, and painted buntings. These actions might include maintaining a mosaic of habitats in early- to late-successional stages, especially in the vicinity of the Mockingbird Lane, Mesquite, and Devil's Hill MAPS stations where nearly all species are declining. In areas where cattle are allowed to graze, understory vegetation and lush waterside vegetation is often lacking because it is either trampled or eaten by cattle. Also, the presence of livestock undoubtedly increases the probability of cowbird parasitism. Thus, cattle should be excluded to allow potential painted bunting nesting habitat to recover and to protect ground-nesting birds such as field sparrows. Many species might benefit from a program of cowbird eradication, as have several species at Fort Hood, which is known to lower the frequency of brood parasitism (Robinson et al. 1995).

A published goal of the Integrated Management Plan for Camp Bowie is "to return lands to their original sustainable condition by use of prescribed burns and restoration of native plant species". Towards this goal, the existing management plans for Camp Bowie include fire management and, most importantly, the restoration of wet-season riparian corridors that will require the removal of stock ponds, and re-establishment of the natural watercourses and native vegetation.

Part II: Summary of management models

Scope and Approach

Species-landscape models previously constructed from MAPS avian demographic data and NLCD landscape data, and described in previous reports, differ considerably from current models reported here in both their approach and spatial extent. Those previous models were univariate, and covered spatial extents that varied from the local landscapes surrounding the six stations on a single military installation (e.g., Jefferson Proving Ground), through the 18 stations on a group of three installations in southeast Texas, to the 42 stations on national forests in the forested region of Washington, Oregon, and Idaho.

The management models presented here, however, result from multivariate regression analysis and the use of information theory and maximum likelihood principles applied to sets of four demographic parameters (dependent variables) for each of 10 species listed as *Birds of Conservation Concern* by USFWS (2002). The independent variables are comprised of numerous landscape metrics derived from 2-km-radius areas of the National Land Cover Dataset surrounding those MAPS stations (out of a set of 78 stations located on 13 military installations or groups of nearby installations) where each species could be effectively monitored. The spatial extent of this set of 78 MAPS stations was large; it extended across south-central and southeastern United States from Kansas and Texas to Maryland and North Carolina. For each of the 10 species, we summarize the results of a literature review we conducted to identify known or proposed ecological relationships between various landscape metrics and population responses. We then selected suites of landscape parameters to be included in our models based on the results of this literature review.

We chose to model four demographic parameters that help us interpret the effects of proposed changes in the landscape on the demographics of each of the ten species. The number of individual adults (AHY - after hatching-year) captured provides an index of the adult population density. Over time, the number of adults may increase or decrease because of changes in the amount or quality of suitable habitat, and because of changes in productivity and/or survival. Because adult population densities vary across the region, we expressed the change in adult population density as the percentage change per year relative to the mean annual number of adult individuals captured (AHYyr).

One might argue that as the quality or amount of habitat decreases, the density of adults breeding there should also decrease. Researchers have found, however, that adult densities are sometimes higher in sink habitats (where productivity does not balance mortality and populations are maintained by immigration from source habitats) than in source habitats (where productivity more than balances mortality and excess young are produced that emigrate to other habitats). Thus, it is important to include measures of productivity in the demographic parameters modeled as well as adult population densities and trends. We use the number of juveniles captured (YNG) to provide an index of the size of the juvenile population. We also calculate annual ratios of the number of young individuals captured to the number of adult individuals captured and derive an index of reproductive success (RImean) as the mean of these annual ratios. This number indexes reproductive success in terms of young per adult.

Importantly, a management action might change the landscape in such a manner as to cause an increase in the number of adults but a decrease in the index of reproductive success. This can happen if the numbers of young produced do not increase at the same rate as adults, or perhaps decrease as adults increase. Such a situation may not be an acceptable conservation goal; in effect, it results in the creation of sink habitat. Similarly, a management action might change a landscape in such a way that reproductive success remains constant because both the numbers of adults and young decrease at the same rate; again, this may not be a desirable conservation goal. Ideally, management actions for a particular species should effect increases in both the numbers of adults and the numbers of young such that the reproductive success remains fairly constant or increases.

For each species, our regression analysis created individual species-landscape models for every combination of the four dependent and many independent variables. We selected the top ten models as those with the ten lowest values of ICOMP, an index of information complexity that, like AIC, penalizes models for overparameterization but, unlike AIC, also penalizes models with high levels of co-linearity and covariance among landscape parameters. For each of the top ten models, we calculate the contribution (or proportional representation) of each landscape parameter included in the model to give an overall impression of which elements of the landscape appear to drive the particular demographic. We present the detailed results of these analyses in Appendix 6. Then, for the top selected model for each of the four demographic parameters, we perform a multivariate regression using data from all of the stations (N) at which it was sampled effectively, and report the mean (Mean), standard deviation (S.D.), and regression coefficients of each landscape metric included in the models for each demographic parameter. Finally, we present the overall R-squared value, F-statistic, and P-value for the top-selected model for each demographic parameter.

In the following pages, we present the results of our demographic parameter-landscape models for each of the ten Species of Conservation Concern. The results for the top-selected model are presented in a table within the species accounts that follow. In all of the following results, the landscape class “agriculture” should be viewed with caution as it likely includes recent clearcuts or burned areas and other cleared land, rather than agricultural land *per se*.

Acadian flycatcher

Background

The Acadian flycatcher is considered a forest-interior, area sensitive species that prefers to breed in deciduous forests near streams, bottomland hardwoods, or cypress swamps with developed canopies. Although the species shows a non-significant surveywide decline in BBS data of 0.3% annually for the period 1980-2001, it has declined significantly ($P<0.05$) in FWS Region 5 by 0.8% annually. Estimates of area sensitivity vary across the geographic range from <5ha in Maryland (Whitcomb et al. 1981) to 24ha in Illinois (Blake and Karr 1984). Robbins (1979, 1980) estimated 30-50ha as the minimum contiguous forest area required for a viable population. Acadian flycatchers also seem to avoid nesting close to the forest edge; Chasko and Gates (1982) reported that maximum nest densities occur beyond 60m interior from the edge. Although low rates of cowbird parasitism are reported for forest interior nests (0-11%), Whitehead (1992) found rates of 18% in sites adjacent to clearcut areas. Forest management practices that maintain large tracts of mature mesic forest are favorable to Acadian flycatchers. Although disturbing the canopy is thought to be harmful to populations of this species, they may de able tolerate some selective thinning practices.

Landscape model

Acadian flycatcher demographics responded to elements of water, shrubland, forest, and agriculture in the landscape (Appendix 6). The top-selected models for each of the four demographic parameters were significant or nearly significant, with the strongest models being for adult population trend and numbers of young (Table 18). Numbers of adult captures increased most strongly with increasing amounts of forest cover, but also increased with increasing amounts of water and forest edge and decreasing amounts of agricultural edge. This model suggests that forest cover should be maintained at levels of no less than 40% and preferably 70% or more. The model also suggests that water sources should be maintained and that “feathering” the edges of forest tracts (to increase the amount of edge) may also lead to larger population sizes.

Although the population trend, like population size, was an increasing function of the amount of water, it also responded positively to the amount of shrubland and agricultural areas (at least as long as they are minor elements of the landscape -- about 5 and 10%, respectively). In contrast to adult population size, population trend responded negatively to the amount of forest edge; this is consistent with the forest-interior, area sensitive status of Acadian flycatchers. Moreover, the number of young and productivity responded positively to the total forested core area; this was, in fact, the only factor that affected the number of young produced. Productivity also increased, however, as amount of agricultural edge increased.

Table 18. List of landscape cover class and spatial parameters selected using information complexity measures in multiple regression analyses to identify landscape determinants of Acadian flycatcher demographics. Regression statistics (mean, S.D.) for each spatial parameter and regression coefficients for the selected parameters and four demographic variables – numbers of adults (AHY), adult population trend (AHY/yr), numbers of young (YNG), and the mean annual reproductive index (RImean) -- are given.

Landscape class	Spatial parameter	Mean	S.D.	AHY	AHYyr	YNG	RImean
WATER	%Cover	9.94	19.20	0.0509	0.1758		
SHRUBLAND	%Cover	4.94	6.98		0.4292		
FOREST	%Cover	68.24	19.66	0.1246			
FOREST	Core Area	683	77.65			0.0015	0.0013
FOREST	Edge(m/ha)	69.58	31.29	0.0412	-0.1213		
AGRI	%Cover	8.88	8.09		0.6154		
AGRI	Edge(m/ha)	33.11	25.95	-0.0675			0.0011
	N = 26						
	R-squared			0.290	0.416	0.245	0.127
	F			2.96	5.244	8.13	3.42
	P			0.055	0.007	0.009	0.077

After inspection of all of the interdependencies among these parameters, we suggest that management for this species should be directed at maintaining high reproductive success by conserving large tracts of contiguous forest – this will increase the numbers of adults (because core area is a positive function of total forest cover), but will increase the numbers of young at an even higher rate, and tend to produce source habitat. We conclude that maintaining contiguous forest tracts of between 500 and 900ha would benefit Acadian flycatchers. Water sources should be maintained and agricultural land (possibly misclassified clearcut) and even shrubland should be maintained in small patches that total only 5-10% of the landscape.

Wood Thrush

Background

Various factors are attributed to the range-wide declines in wood thrush populations reported by the Breeding Bird Survey and other researchers (e.g. Holmes and Sherry 1988, Hussell et al. 1992, Witham and Hunter 1992). The predominant reasons purported for these declines are breeding habitat degradation and fragmentation and the associated threats of brood parasitism and predation. Adult wood thrush population levels are clearly a function of available habitat. Whitcomb et al. (1981) reported that although wood thrushes were present in small forest fragments (1-14 ha), densities were nearly twice as high in woodlots larger than 70 ha. Robbins (1979) estimated 100 ha as the minimum area required to support a viable breeding population. Unfortunately, the relationships between wood thrush population dynamics and patterns of forested landscapes show considerable spatial variation across their geographic range. Therefore, great caution must be taken when applying published management recommendations intended to restore or improve wood thrush breeding habitat.

Although stressors may impact any portion of the wood thrush life cycle, many researchers report on the source/sink dynamics of local populations as a function of reproductive success and landscape patterns. Robinson (1992) reported that wood thrushes declined between 1985 and 1989 in small forest fragments in Illinois (14, 25, and 65 ha). Hoover (1992) showed that nest survival (1990-1991) was positively correlated with forest area, forest core area, and percent forest within a 2-km radius of each study site. Weinberg and Roth (1998) tested the "area" hypothesis more thoroughly and found that the values of demographic parameters were more consistent with population viability in a 15ha forest patch compared to 17.5ha of smaller patches. More recently Burke and Nol (2000) reported that reproductive success was predominantly determined by woodlot size in south-central Ontario, and that wood thrushes required more than 23 ha of forest core area (equated to 25 ha woodlot size) for reproductive effort to replace mortality (i.e. support a source population).

Threshold values for species-landscape relationships vary greatly across the geographic range of the wood thrush. A study by Trine (1998) in Shawnee National Forest in southern Illinois suggested that large >2500 ha tracts may be necessary to support source populations compared to 20 ha in eastern North America. However, not all small woodlots in midwestern states represent sink populations. Fauth (2001) showed that in some agricultural regions of northern Indiana, small woodlots may act as source populations for wood thrushes, despite high levels of cowbird parasitism, because they produce multiple clutches and can fledge both cowbirds and their own chicks. Interestingly, he revealed a negative relationship between the numbers of adults detected from point count surveys, the number of nests, and forest fragment size. He concluded that forest area was not a good predictor of reproductive success in the midwestern states. The reasons for these regional differences have not been adequately explained, although many researchers suggest that the midwestern states act as population sinks and are therefore exhibit highly variable demographics. Breeding habitat, however, is not the only management consideration; Vega-Rivera et al. (1998) suggest that conservation of post-fledging habitat, to which both young and adults disperse prior to fall migration, may also be critical.

Natural succession plays a major role in wood thrush population dynamics. Although wood thrushes are considered to be an interior-edge species, maximal densities are found in mid- to late-successional stage forest (Bond 1957). Holmes and Sherry (2001), however, reported that wood thrush populations in the relatively undisturbed forest habitats of Hubbard Brook Experimental Forest declined significantly as the forests matured over 30 years, being replaced by species that prefer more fully mature forests.

The effects of forest management vary widely. Powell et al. (2000) applied a winter burning and thinning treatment designed to improve red-cockaded woodpecker habitat in Piedmont NWR, GA. This resulted in increased wood thrush population growth to near or above replacement levels suggesting that canopy closure may depress wood thrush populations. The treatment apparently did not affect reproductive success or survival. Conversely, single-tree and group selection cuts of 0.02-0.4 ha within a 2,000 ha deciduous forest in extreme southern Illinois did not result in significantly different abundances of wood thrushes compared to uncut areas (Robinson and Robinson 1999). Similarly, Lang et al. (2002) reported no effects on wood thrushes of burning and thinning in mature loblolly pine habitats (~50 ha blocks in 400 ha compartments) of the Piedmont NWR.

It is possible that regional patterns of succession may account for some of the range-wide declines observed in wood thrush populations. By the early part of the 20th century, across much of southern North America, clear-cut forestry practices had leveled a large percentage of the mature forests. By 1900, in most counties, 50-100% of land was farmed. By 1950, these percentages had dropped to 50% or less. Much of the abandoned farmland, that had not been developed for housing/commercial use or returned to an agricultural cycle, has experienced forest regeneration, in some cases to the extent of forest canopy closure. Perhaps this extensive maturation of these forests, coupled with increased conversion of less mature forests to housing/commercial use, has contributed to the decline in this species.

Another critical portion of the wood thrush life cycle is that of overwintering survival. Survival may depend upon conditions affecting migration, or on the quality of wintering habitats in Mexico and Central America. Brown and Roth (2002) concluded that life history strategies among wood thrushes vary as a function of late season nesting and overwintering survival. Donovan and Flather (2002) found from BBS data that the proportion of the population occupying fragmented landscapes decreased with time (1970-1980), thereby supporting the fragmentation hypothesis, but suggested that other factors including overwintering survival may be responsible. Overall, MAPS data showed low annual apparent adult survival rates for wood thrushes between 1992 and 1998 (e.g., 0.406 (0.032SE) for the Northeast MAPS Region; 0.464 (0.026 SE) for the Southeast MAPS Region; DeSante and O'Grady 2000); these values are especially low considering the wood thrush's relatively large body mass. These same MAPS data, however, also showed generally low annual reproductive indices for wood thrush that averaged 0.328 and 0.307 young/adult over the seven years, 1992-1998, in the Northeast and Southeast MAPS Regions, respectively (DeSante et al. 1998, 2000, DeSante and O'Grady 2000). Taken together, these results suggest that both low productivity on the breeding grounds and low survivorship (presumably on the wintering grounds and during migration) may be driving the widespread population declines in this species.

Landscape model (eastern dataset)

Because of differences reported in the literature between the East and Midwest in responses of wood thrushes to the landscape, we present separate landscape models for wood thrush for our eastern and central datasets. In the eastern dataset, wood thrush demographics responded to several forest elements and to agriculture cover in the landscape (Appendix 6). Top-selected models for numbers of both adults and young as well as adult population trends were significant, but all models for reproductive success were weak and non-significant (Table 19). Not surprisingly, numbers of both adult and young wood thrushes and their population trends increased with increased amounts of forest cover and decreased amounts of forest edge; thus, numbers of adults and young and population trends increased with decreased levels of forest fragmentation. Interestingly, numbers of adults and young and adult population trends also increased with small (about 15%), but increasing, amount of agricultural cover. Radio-telemetry data on post breeding adult and post-fledging young dispersal of wood thrushes indicate that individuals generally leave forest interior breeding territories and often move to food-rich (often with much fruit) and cover-rich edge habitats for molting and staging prior to migration. The positive response to small but increasing amounts of agricultural land in the eastern dataset may reflect the availability of such edge habitat on eastern military installations.

Table 19. List of landscape cover class and spatial parameters selected using information complexity measures in multiple regression analyses to identify landscape determinants of wood thrush demographics (eastern region). Regression statistics (mean, S.D.) for each spatial parameter and regression coefficients for the selected parameters and four demographic variables – numbers of adults (AHY), adult population trend (AHY/yr), numbers of young (YNG), and the mean annual reproductive index (RImean) -- are given.

Landscape class	Spatial parameter	Mean	S.D.	AHY	AHYyr	YNG	RImean
FOREST	%Cover	56.67	21.49	0.2379	0.1555	0.0722	
FOREST	Edge(m/ha)	69.20	29.24	-0.0918	-0.3020	-0.0355	
AGRI	%Cover	15.45	19.26	0.1146	0.6069	0.0256	
	N = 16						
	R-squared			0.607	0.39	0.501	
	F			8.36	4.16	5.68	
	P			0.005	0.040	0.017	

At the landscape level (results not tabulated), all four demographic parameters decrease with total amount of edge calculated from all habitat types in the landscape(r=-0.478, P<0.10) and the distribution of patches as indicated by Shannon's indices of a) diversity (r=-0.511, P<0.05) and, b) evenness (r=-0.518, P<0.05). Numerous significant relationships exist with those landscape variables associated with forested areas, especially forest cover and core area. However, the effects of landscape change on the ratio of young to adults can be assessed by comparing the relative effects on adults and young.

Landscape model (central dataset)

In the central dataset, wood thrush demographics responded to elements of forest and shrubland and, to a lesser extent, agriculture and water (Appendix 6). Top-selected models for numbers of both adults and young were significant, but models of adult population trend and reproductive success were very weak and non-significant (Table 20). Numbers of both adult and young wood thrushes responded positively to total forest cover, while mean reproductive success also responded positively, although weakly, to forest cover. However, numbers of adults also responded positively to increased forest edge while numbers of young responded positively to amount of shrubland edge. Thus, it would appear that the response of wood thrushes to forest fragmentation in the central region differs from that in the eastern region, although total forest cover was an important determinant of the numbers of adults and young in both areas. Interestingly, contrary to general pattern of forests over the eastern two-thirds of the continent, landscapes surrounding MAPS stations on installations in the central region had higher total forest cover (72%) than analogous landscapes on installations in the eastern region (57%). It also seems likely that the positive responses of adults to forest edge and of young to shrubland edge reflect the same post-breeding and post-fledging needs on installations in the central region that agricultural cover provided on installations in the eastern region.

Table 20. List of landscape cover class and spatial parameters selected using information complexity measures in multiple regression analyses to identify landscape determinants of wood thrush demographics (central region). Regression statistics (mean, S.D.) for each spatial parameter and regression coefficients for the selected parameters and four demographic variables – numbers of adults (AHY), adult population trend (AHY/yr), numbers of young (YNG), and the mean annual reproductive index (RImean) -- are given.

Landscape class	Spatial parameter	Mean	S.D.	AHY	AHYyr	YNG	RImean
SHRUBLAND	Edge(m/ha)	24.14	22.47			0.0444	
FOREST	%Cover	71.68	21.53	0.0447		0.0270	0.0048
FOREST	Edge(m/ha)	63.07	24.59	0.1125			
	N = 20						
	R-squared			0.210		0.255	
	F			5.46		6.055	
	P			0.031		0.024	

Because wood thrush populations decrease with increasing levels of forest management, we suggest that maintaining contiguous forest tracts of between 600 and 900ha will benefit wood thrushes in both the eastern and central regions of the United States. Small areas of agricultural land (eastern) and both forest and shrubland edge (central) also appear to be beneficial to both adult and young wood thrushes, presumably because those habitats fulfill post-breeding and post-fledging needs of the species.

Worm-eating warbler

Background

Although worm-eating warbler populations are stable according to the BBS data, because of their relatively small population sizes, limited range, and apparent habitat specialization, they are considered a species of conservation concern. They are considered seasonal foliage foraging specialists, utilizing clumps of dead leaves in trees in the winter and live leaves and sprouting buds in the summer. A major cause of conservation concern is that they overwinter with mixed flocks of resident species in the primary tropical forests of the Caribbean basin (Greenberg 1987), a rapidly declining habitat. During the breeding season in North America they are found on slopes of wooded ravines of late-successional and mature forests with well-developed understories. Although they may nest in forest patches as small as 20-70ha (Robinson 1992, Gale et al. 1997, Bushman and Therres 1998), other studies suggest that they require at least 300ha of contiguous forest to support viable populations (Robbins et al. 1989, Robinson et al. 1995) and even then may require proximity to larger tracts (Wenny et al. 1993).

Although there is little published evidence, it is believed that worm-eating warblers can tolerate some forest management techniques that involve selective thinning of the oldest trees and creation of regeneration gaps. Overall, relatively little is known about the species because it occurs in low densities, is relatively secretive, forages in areas with dense understories, often on relatively steep slopes, vocalizes less than some other warbler species, and builds cryptic nests. Constant-effort mist netting is a relatively effective method of monitoring this species because they nest on the ground and generally forage relatively close to the ground.

Landscape model

Worm-eating warbler demographics responded primarily to elements of forest and shrubland and, to a lesser extent, water and agriculture (Appendix 6). Models of the number of adults captured were weak but included positive relationships with forest cover, core area, and mean patch size, all of which held high values across the 11 stations included in this analysis (e.g., mean forest cover of 84%). The selected model, which was not significant, showed a weak positive relationship with core area (Table 21). In contrast, the top-selected model for adult population trend, which was nearly significant, showed a decrease with total forest cover and an increase with the amounts of forest and shrubland edge.

Top-selected models for numbers of young and mean reproductive index (Table 21) were significant (highly so for numbers of young). Numbers of young decreased with the amounts of forest and shrubland edge implying that they, like adults, tended to increase with decreased forest fragmentation. Numbers of young also increased with small amounts of shrubland cover. Reproductive index also increased with increased forest cover and decreased forest edge, but increased with increased shrubland edge and decreased mean forest patch size. The fact that worm-eating warbler reproductive index and adult population trends showed opposite relationships to total forest area and total forest edge suggests that reproductive index was increased by a decrease in numbers of adults, rather than by an increase in numbers of young. This suggests that low adult survival rates (high adult mortality), perhaps during the winter months or on migration, may be important in driving the population declines of this species.

Table 21. List of landscape cover class and spatial parameters selected using information complexity measures in multiple regression analyses to identify landscape determinants of worm-eating warbler demographics. Regression statistics (mean, S.D.) for each spatial parameter and regression coefficients for the selected parameters and four demographic variables – numbers of adults (AHY), adult population trend (AHY/yr), numbers of young (YNG), and the mean annual reproductive index (RImean) -- are given.

Landscape class	Spatial parameter	Mean	S.D.	AHY	AHYyr	YNG	RImean
SHRUBLAND	%Cover	3.69	5.42			0.4745	
SHRUBLAND	Edge(m/ha)	20.77	28.16		0.1890	-0.0619	0.0039
FOREST	%Cover	84.12	13.00		-0.1747		0.0157
FOREST	Core Area	889	207	0.004			
FOREST	Edge(m/ha)	63.41	26.77		0.3113	-0.0408	-0.0118
FOREST	MPSize	238	373				-0.0010
	N = 11						
	R-squared				0.459	0.931	0.756
	F				3.59	31.54	5.925
	P				0.077	<0.001	0.025

Overall, on military installations in eastern and central United Sates, worm-eating warbler demographic parameters were found to be negatively related to forest fragmentation, although small areas of shrubland appeared to be beneficial, presumably, as in wood thrush, for post-breeding and post-fledging dispersal, during which time both adults and young are known to forage more frequently in patches of dense shrub (Greenberg 1987). In conclusion, we recommend that, for worm-eating warblers, land managers maintain contiguous forest tracts of at least 1,000 hectares (within a 2-km-radius area) with small patches of adjacent shrubland.

Louisiana waterthrush

Background

Louisiana waterthrush is considered a forest-interior species that prefer clear upland streams and their associated wetlands occurring in deciduous or mixed forest (Prosser and Brooks 1998). Conservation concern for this species focuses on its critical habitat that is threatened by multiple factors. These include logging and various types of runoff from the agricultural, mining, and development activities that are common in upland areas. Acid ion deposition from precipitation is another problem that this and other ground foraging species, such as wood thrush, face (Hames et al. 2002). This is especially critical in habitats, such as the southern Appalachians, where acid ion deposition affects soil fauna (Rusek and Marshall 2000) upon which ground foraging species rely.

This species is usually included in management plans for other neotropical migrant forest-interior species, but specific guidelines for this species include maintaining continuous upland riparian forest, with 50 meter buffers on each bank, totaling over 100ha. In addition, Mulvihill (1997) suggested that thick cover be maintained for post-fledgling utilization.

Landscape model

Louisiana waterthrush demographics were influenced primarily by elements of forest, water, and shrubland in the landscape, although agriculture was also important for population trends (Appendix 6). The top-selected models were significant for each of the four demographic parameters (Table 22). Not surprisingly, these analyses show that Louisiana waterthrushes were associated with forested landscapes of 50-90% forest cover (600-1100ha in a 2-km-radius area) that include 50-100ha of water. Numbers of both adults and young and reproductive index showed positive relationships with the total amount of water and the amount of forest edge, suggesting the species was not dependent upon continuous forest but preferred some fragmentation. The positive influence of forested edges, which typically contain a dense shrub component, is consistent with the Mulvihill’s suggestion that dense shrub cover should be maintained adjacent to the breeding habitat. In contrast, however, numbers of both adults and young decreased with small but increasing amounts of shrubland cover, while the number of young and productivity decreased with increasing amounts of water edge; the ecological significance of these latter two relationships is not clear. Also of interest is that adult population trend decreased with increasing total forest cover and increased with the total amount of agriculture edge.

Table 22. List of landscape cover class and spatial parameters selected using information complexity measures in multiple regression analyses to identify landscape determinants of Louisiana waterthrush demographics. Regression statistics (mean, S.D.) for each spatial parameter and regression coefficients for the selected parameters and four demographic variables – numbers of adults (AHY), adult population trend (AHY/yr), numbers of young (YNG), and the mean annual reproductive index (RImean) -- are given.

Landscape class	Spatial parameter	Mean	S.D.	AHY	AHYyr	YNG	RImean
WATER	%Cover	4.20	7.91	0.1455		0.2997	0.0283
WATER	Edge(m/ha)	7.99	7.42			-0.1615	-0.0216
SHRUBLAND	%Cover	5.05	7.54	-0.1246		-0.0766	
FOREST	%Cover	60.87	29.53		-0.0757		
FOREST	Edge(m/ha)	62.76	25.54	0.0557		0.0502	0.0092
AGRI	Edge(m/ha)	44.22	39.25		0.2092		
	N = 16						
	R-squared			0.443	0.464	0.488	0.434
	F			4.50	12.05	4.22	5.38
	P			0.033	0.004	0.030	0.020

We conclude that a successful management strategy for Louisiana waterthrush is to maintain the upland forested streams, that provide primary breeding habitat, in near pristine condition, but to manage forested areas in such a way as to maintain or increase the amount of dense, shrubby forest-edge habitat for post-fledging utilization, while decreasing the overall amount of shrubland cover in the landscape.

Kentucky warbler

Background

Significant declines of between 1.5 and 3.0% per year are apparent for Kentucky warbler in BBS data from FWS Regions 4, 5, and 6, as well as survey wide for the period 1980-2001. Like other forest-interior, Neotropical migrant species, Kentucky warbler populations are threatened by forest fragmentation, high levels of cowbird parasitism, and nest predation by mammals, snakes, and other birds. Its tolerance to patch size appears, like wood thrush, to be geographical variable. Although several studies report edge effects (e.g., Kroodsma 1982, Chasko and Gates 1982, Dunn and Garrett 1997, McDonald 1998) in which nesting densities are higher in the forest interior, other studies (e.g., Gibbs and Faaborg 1990) failed to detect this effect. Overall, the minimum size of forest fragment thought to support a viable population is between about 100ha (Robbins 1979, 1980) and 300ha (Hayden et al. 1985), although the species will breed in patches as small as 8-19ha (Anderson and Robbins 1981).

One problem with monitoring this species is that unmated males tend to sing up to five times more frequently than paired males (Gibbs 1998); thus, point count data may be biased in suggesting that less suitable habitats for breeding (that contain a preponderance of unmated males) hold higher densities of birds. Constant-effort mist netting and bird banding allows relative numbers of young to be counted and reproductive success to be indexed as the ratio of young to adults, thus conferring less bias on species-habitat relationships.

Existing management guidelines suggest that forest tracts of a minimum 500ha area should be maintained with a dense understory and a well-developed ground cover. There are conflicting evidence as to the type and magnitude of logging operation that Kentucky warbler populations can withstand. The species is thought to tolerate canopy openings and therefore be able to withstand low levels of selective cutting (Whitcomb et al. 1977, Crawford et al. 1981). Although Adams and Barrett (1976) reported declines after such practices, Kentucky warblers have been known to repopulate small clearcuts after only seven years (Conner and Adkinson 1975). However, there is no information as to how these practices affect reproductive success.

Landscape model

Kentucky warbler demographics were influenced primarily by elements of forest and shrubland in the landscape, although grassland cover, agriculture cover, and water edge also had minor effects (Appendix 6). The top-selected models for each of the four demographic parameters were significant, with those for numbers of young and reproductive index being highly significant (Table 23). Numbers of adults and young and mean reproductive index for Kentucky warbler increased with increasing amounts of forest cover and shrubland edge, but (except for reproductive index) decreasing amounts of forest edge, in the landscape. These two landscape parameters, forest cover and shrubland edge, account for, depending upon the demographic parameter being modeled, between 50 and 70% of the selected parameters (Appendix 6). Numbers of adults also appeared to increase with very low but increasing levels of grassland cover, although this may have been a spurious result.

Adult population trend became more positive with increasing amounts of shrubland edge, but became less positive with increasing forest cover in the landscape. As noted in previous species accounts, this latter result was also found for worm-eating warbler and Louisiana waterthrush, as well as for Kentucky warbler. This pattern may be a result of forest succession within the 2-km-radius areas surrounding the MAPS stations. All three of these species prefer relatively mature forested areas. If, during the 10 years since 1992, forested habitat surrounding the stations tended to be filling in and maturing, then populations of these three species in landscapes that were less forested in 1992 would tend to be increasing relative to populations in landscapes that were already more forested in 1992, regardless of the actual population trend in the area. This is because more habitat will be reaching the critical maturity level to support these species each year in the originally less-forested landscapes than in the originally more-forested landscapes.

Kentucky warblers appear tolerant of some degree of forest fragmentation, especially in the western portion of its range, where they appear to breed in forest remnants and isolated woodlots.

Table 23. List of landscape cover class and spatial parameters selected using information complexity measures in multiple regression analyses to identify landscape determinants of Kentucky warbler demographics. Regression statistics (mean, S.D.) for each spatial parameter and regression coefficients for the selected parameters and four demographic variables – numbers of adults (AHY), adult population trend (AHY/yr), numbers of young (YNG), and the mean annual reproductive index (RImean) -- are given.

Landscape class	Spatial parameter	Mean	S.D.	AHY	AHYyr	YNG	RImean
SHRUBLAND	Edge(m/ha)	19.02	21.80	0.1285	0.2400	0.0846	0.0033
FOREST	%Cover	72.39	22.04	0.1506	-0.0903	0.0593	0.0047
FOREST	Edge(m/ha)	65.26	25.21	-0.0633		-0.0294	
GRASSLAND	Cover	3.28	8.02	0.3560			
	N = 28						
	R-squared			0.326	0.166	0.453	0.362
	F			3.79	5.16	9.84	13.21
	P			0.023	0.032	0.001	0.001

Our models suggest that, while the total amount of forest cover should be kept high and the total amount of forest edge (and thus the amount of forest fragmentation) should be kept low, relatively small amounts of shrubland edge should be maintained, again probably as a target location for post-breeding and post-fledging dispersal. We recommend that large patches of contiguous forest should be maintained covering 50-80% of the area (600-1000ha in a 2-km-radius area), and that small patches of shrubland habitat that cover 5-15% of the area (60-180ha in the 2-km-radius area) should be scattered through the landscape. Moderate levels of fragmentation such as these can also provide some amount of habitat suitable for scrub-successional species.

Bewick's wren

Background

Bewick's wren appears to be threatened by geographic range contraction. BBS data (Sauer et al. 2002) show population declines on the periphery of its range in North America including British Columbia, northern California, Nevada, Texas, Missouri, Tennessee and Kentucky. The species is nearly extirpated from most of eastern United States and is considered very rare in few places where it still occurs. Although the cause of these declines is not clearly understood, it is believed that a number of factors may be responsible, including competition from other cavity nesting species such as European starlings, house sparrows, and house wrens (Hamel 1992), habitat succession towards forest, severe winter weather or summer droughts, and predators (Byrd and Johnston 1991, Ehrlich et al. 1992, LeGrand 1990, Simpson 1978, Mengel 1965, Robbins et al 1986).

Management guidelines that have been suggested in various Bird Conservation Plans include fire maintenance of scrub/woodland successional habitat, removal of non-native competitors, and establishment of nest boxes in areas where nesting sites may be limited (e.g. agricultural areas and pastureland).

Landscape model

Our analyses of Bewick's wren demographics were derived solely from the heterogeneous landscapes associated with the shrublands at 12 stations on Camp Bowie and Fort Hood in Texas. Bewick's wrens responded demographically primarily to a number of landscape elements that define the shape and coverage of the dominant cover types of shrubland (Appendix 6). The species also showed important demographic responses, some of which were strongly negative, to forest, grassland, agriculture, and development. The top-selected models for numbers of adults and young and reproductive index were each nearly significant, while the top-selected model for adult population trends was highly significant (Table 24).

Numbers of adults and reproductive index increased with increasing shrubland cover and increasing forest cover of up to 70% (900ha). Numbers of adults also increased with increasing agriculture core area, but reproductive index decreased with agriculture core area, suggesting that nesting areas adjacent to large blocks of agriculture land are population sinks. This negative influence of agricultural lands on productivity may have been due to elevated rates of nest predation (because nests would likely be on the shrubby edges of agricultural areas), or the influences of herbicide and pesticide applications. Increased cowbird parasitism was unlikely to be a strong factor because cavity nesters, like Bewick's wrens, are generally relatively immune to cowbird parasitism. Development, although a very minor proportion of the landscape surrounding most stations, also provided a negative influence on demographics, especially on adult population trends and the numbers of young. It is possible that predation by domestic and feral cats may have been responsible for this effect.

The negative response of adult population trend to shrubland core area may have been an effect of the successional maturation of shrubland during the period of study, similar to the hypothesized effect of maturation of forested lands discussed above for Kentucky warbler. Finally, numbers of young responded positively to increased patch shape complexity (area weighted mean patch fractal dimension or AWMFPD) of shrubland while adult population trend responded positively to increased grassland AWMFPD.

Table 24. List of landscape cover class and spatial parameters selected using information complexity measures in multiple regression analyses to identify landscape determinants of Bewick's wren demographics. Regression statistics (mean, S.D.) for each spatial parameter and regression coefficients for the selected parameters and four demographic variables – numbers of adults (AHY), adult population trend (AHY/yr), numbers of young (YNG), and the mean annual reproductive index (RImean) -- are given.

Landscape class	Spatial parameter	Mean	S.D.	AHY	AHYyr	YNG	RImean
SHRUBLAND	%Cover	32.14	24.72	0.0700			0.0209
SHRUBLAND	AWMFPD	1.26	0.11			4.1517	
SHRUBLAND	Core Area	138.9	145.3		-0.0798		
FOREST	%Cover	34.99	23.19	0.0330			0.0175
GRASSLAND	AWMFPD	1.18	0.04		11.2537		
AGRI	Core area	44.3	71.31	0.0172			-0.0014
DEVEL	%Cover	0.87	1.30		-10.207	-0.8202	
	N = 12						
	R-squared			0.450	0.794	0.279	0.522
	F			3.49	16.90	3.75	3.66
	P			0.075	0.001	0.082	0.069

These results suggest that Bewick's wrens benefit from maintaining a mosaic of shrubland and forest (open, low-canopy oak-juniper woodland) with small patches of grassland. The shrubland component is the most important and should be maintained as large patches with complex shapes covering 40% or more of the area. The forest component provides trees and snags with cavities for nesting, as well as song perches. This suggests that there likely are relationships that could be explored between the adjacency of forest and shrubland and various demographic parameters. Developed areas and large core areas of agriculture should be kept to a minimum in the landscape. While their edges may be attractive to adult Bewick's wrens, they have a negative effect on numbers of young and productivity, tend to reduce population trends, and appear to act as population sinks.

Blue-winged warbler

Background

Blue-winged warblers are declining across much of their range. BBS data (Sauer et al. 2002) show significant declines in all the FWS Regions in which they are recorded as well as survey-wide. The species is opportunistic in its use of early successional habitats including oldfield, scrubland, forest gaps (<5 ha) and artificial corridors (Gill et al. *in press*). Suburban development of successional habitats, conversion of shrubland to grassland or agriculture, and succession of scrubland to woodland/forest are possible threats to local populations. As a ground nesting species it also risks nest predation by feral and domestic cats. It is known to nest in recent clearcuts with low shrub canopy heights, and close to openings such as those provided by powerlines or roads. To provide optimal breeding habitat, these open areas require a thick grass and herb layer with sparse shrubs. During the winter, blue-winged warblers are confined to the rapidly disappearing tropical forests of Mexico and Central America, although even there they prefer second growth. As with some other species, point count data on blue-winged warblers may provide an unreliable indicator of habitat quality, because high densities of reproductively unsuccessful pairs have been recorded in marginal habitats (Van Horne 1983). Suggested management guidelines include maintaining oldfield/scrubland habitats, small clearcuts, powerline rights-of-way, and feral cat control.

Table 25. List of landscape cover class and spatial parameters selected using information complexity measures in multiple regression analyses to identify landscape determinants of blue-winged warbler demographics. Regression statistics (mean, S.D.) for each spatial parameter and regression coefficients for the selected parameters and four demographic variables – numbers of adults (AHY), adult population trend (AHY/yr), numbers of young (YNG), and the mean annual reproductive index (RImean) -- are given.

Landscape class	Spatial parameter	Mean	S.D.	AHY	AHYyr	YNG	RImean
WATER	%Cover	0.99	1.98		-2.645	-0.4414	
WATER	Edge(m/ha)	4.91	8.74	-0.3172			
SHRUBLAND	%Cover	4.91	5.42	-0.3069			
SHRUBLAND	Edge(m/ha)	23.62	23.92				0.0015
FOREST	%Cover	84.13	12.51	0.0977			0.0024
AGRI	%Cover	8.96	9.97	-0.5527			
AGRI	Edge(m/ha)	25.20	17.64	0.3608			
	N = 11						
	R-squared			0.599		0.194	0.373
	F			2.29		2.17	4.82
	P			0.175		0.175	0.056

Landscape model

Models of blue-winged warbler demographics based on analyses of the landscapes surrounding 11 MAPS stations were mainly inconclusive. The top-selected models for numbers of adults and young and for adult population size were not significant ($0.174 \leq P \leq 0.183$), but the top-selected model for reproductive index was nearly significant ($P = 0.056$) (Table 25). In that model, reproductive index was found to be a positive function of total forest cover and shrubland edge.

We recommend maintaining landscapes with 60-90% total forest cover (750-1100ha in a 2-km-radius area) in a fragmented landscape interspersed with small patches of shrubland. We also suggest maximizing the spatial complexity of the forest/shrubland edge. These strategies are designed primarily to increase reproductive success; we suggest, however, that they may increase adult population sizes as well.

Prairie warbler

Background

According to BBS data (Sauer et al. 2002), prairie warbler populations have experienced significant declines during the period 1980-2001, both survey-wide and in FWS Regions 3, 4, and 5. Although, because of its wide distribution and ability to quickly inhabit a variety of newly created early successional habitats, it is not considered globally threatened, breeding habitat for the prairie warbler is diminishing due to continued succession of old farmland and development of oldfield and shrubland habitats. Moreover, because of its dependence on relatively short-lived successional habitats, the temporal populations dynamics of prairie warblers are thought to be naturally highly variable. Nevertheless, large-scale development of critical breeding and overwintering habitats can lead to long-term declines. For instance, permanent alteration and destruction of the dry lowland forest and wetland habitats of the Caribbean basin (Wunderle and Waide 1993) in which prairie warblers overwinter in relatively large numbers and with moderate to high site fidelity (Latta and Faaborg 2001), may decrease overwintering survival and limit population size.

Stochastic climate effects may also impact population size either positively or negatively. Serious droughts and increased fire frequency in early to mid-successional breeding habitats may tend to make these habitats more suitable, whereas increased hurricane activity or drought during the non-breeding season may be responsible for high mortality and habitat destruction or degradation. Interestingly, relatively recent population levels of this and other successional-stage species are thought to have been much higher than they were before European settlement of North America (Nolan 1978). This is because the creation and subsequent abandonment of agricultural land created large areas of early successional habitat. More recently, however, much of that abandoned agricultural land has now either been developed or is succeeding back into forest.

Suggested management guidelines for this and other early successional specialists include maintenance of a shifting mosaic of successional seres that ensures local persistence of suitable breeding habitat patches within the dispersal distances of source populations that produce large numbers of fledglings as well as populations that are forced to abandon habitat that is becoming less suitable. Patches of optimal habitat, such as oldfield and scrubland proximal to forest, can be maintained using fire or herbicide treatment, or perhaps even mechanical means to deter the growth of tree saplings and tall shrubs. Although natural habitats include the shrubby edges of forest-grassland ecotones, maintenance of powerline rights-of-way in forested landscapes can successfully mimic such habitats. Perhaps even more importantly, the conservation of a variety of coastal and lowland wintering habitats, including mangroves and more xeric woodlands throughout the Caribbean, may be critical for the species conservation.

Landscape model

Prairie warblers responded to landscape elements that define the shape and coverage of water sources, agricultural land, shrubland, and forest. Although agricultural land cover represented 20% of the chosen parameters in the top 10 models it is likely that much of this may have been misclassified clearcut or oldfield habitat, both of which are utilized by prairie warblers (Appendix 6). Interestingly, the percentage of forest cover was relatively high (mean 85%) in the landscapes surrounding each of the 11 stations used in the prairie warbler models, while both shrubland and agricultural land cover was low (Table 26). Of the top-selected models for each of the four demographic parameters, only the models for numbers of adults and young were statistically significant, with the model for numbers of young being highly significant.

These models indicate that numbers of both adults and young prairie warblers increased with increasing amounts of forest cover and with small but increasing amounts of agricultural cover, but decreased with increasing amounts of forest edge and small but increasing amounts of water edge. Although not significant, the top-selected model for reproductive index also showed weak increases with increasing forest and agriculture cover and decreasing water edge. Thus, landscape factors that increased adult population sizes also tended to increase productivity.

Interestingly, numbers of adults also increased with decreasing amounts of shrubland cover, as did adult population trends, although the model for population trend was not significant.

This seems anomalous at first glance since prairie warblers are thought to prefer early successional stage habitats. The preferred habitats, as defined by Ehrlich et al. (1988), however, are dry brushy clearings, forest margins, and pine barrens. This suggests that a critical habitat component for prairie warblers might be that the required open brushy habitat be so well integrated with the forest that the habitat will appear as forest, rather than shrubland, in GIS coverage. This also suggests that large tracts of open shrubland will not necessarily provide good habitat for prairie warblers.

Table 26. List of landscape cover class and spatial parameters selected using information complexity measures in multiple regression analyses to identify landscape determinants of prairie warbler demographics. Regression statistics (mean, S.D.) for each spatial parameter and regression coefficients for the selected parameters and four demographic variables – numbers of adults (AHY), adult population trend (AHY/yr), numbers of young (YNG), and the mean annual reproductive index (RImean) -- are given.

Landscape class	Spatial parameter	Mean	S.D.	AHY	AHYyr	YNG	Rimean
WATER	Edge(m/ha)	3.59	7.94	-0.2994	0.4133	-0.0770	-0.0106
SHRUBLAND	%Cover	6.92	5.89	-0.1416	-0.4168		
FOREST	%Cover	85.04	11.68	0.2010		0.0572	0.0038
FOREST	Edge(m/ha)	59.56	21.55	-0.1908		-0.0620	
AGRI	%Cover	6.44	9.29	0.4641		0.1517	0.0077
	N = 11						
	R-squared			0.848	0.135	0.901	0.263
	F			8.25	1.34	23.76	1.528
	P			0.013	0.267	<0.001	0.274

Synthesizing the above information, we suggest that the optimal management strategy for prairie warblers is to maintain relatively small brushy openings in extensive forested habitat. This could be accomplished by appropriate forestry practices, including creation of small clearcuts, group selection, or even mechanical thinning, or by carefully controlled fire practices. A critical consideration on the landscape scale is to maintain an appropriately scaled mosaic of appropriate successional-stage habitats. It may be possible to integrate such a management strategy into efforts to increase military readiness and range sustainment, as well as into large-scale fire-control efforts.

Field sparrow

Background

Although widely distributed across eastern and central North America, BBS data show significant declines field sparrow populations for the period 1980-2001, both survey-wide and in all FWS regions. Despite being found in a variety of shrubland-grassland habitats, field sparrows face loss of breeding habitat through forest regeneration and conversion to agriculture or residential and commercial development. One habitat suitability model for field sparrows (Sousa 1983) suggests that they are area-sensitive, requiring two or more hectares of suitable habitat in which to breed. Other studies, however, suggest that they can breed in smaller patches (Kupsky 1970, Petter et al. 1990, Herkert 1991a,b). It is likely that microhabitat characteristics provide better determinants of optimal habitat than do landscape characteristics. Optimal habitat seems to involve areas where 50-75% of the shrub cover is less than 1.5m tall, but with areas of tall dense grass and tall shrubs covering between 15 and 35% of the area. These taller shrubs are required as singing perches and their absence is indicative of sub-optimal breeding habitat. Adult densities in the grassland barrens of Maine (Vickery 1993, Vickery et al. 1994) and riparian habitats of Iowa (Stauffer and Best 1980, Best et al. 1981) increase with the overall patchiness of forest, shrubland, and grassland.

Optimal habitat can be maintained using a variety of techniques. Non-breeding season mowing on a 2-3 year cycle, or pre-breeding season grazing or burning can eliminate undesirable vegetation. Predator control, especially of feral cat populations, can also reduce mortality among adults, young and eggs. Snakes are common predators of field sparrow nests, which also face moderate levels of cowbird parasitism.

Landscape model

Not surprisingly, field sparrow demographics are functions of the cover and shape of forest, grassland, and agricultural land that might provide oldfield habitat. Shrub cover, however, contributed only about 8% to the total number of parameters chosen in the top 10 models (Appendix 6). Mean forest cover on the landscapes surrounding the 16 stations contributing to the field sparrow models was about 50%, but total forest cover varied widely among the landscapes surrounding the 16 stations, as did other landscape elements (Table 27). This suggests that these analyses involved patchy landscapes. Of the top-selected models for each of the four demographic parameters, only the models for adult population trend and reproductive index were statistically significant, with the model for reproductive index being highly significant (Table 27).

Overall, numbers of adult and young field sparrows tended to increase with increasing forest cover and increasing amounts of grassland edge, although these models were not significant. The top model for reproductive index, which was highly significant, also showed increases with increasing forest cover, as well as increases with increasing grassland core and decreasing amount of agricultural edge, the latter two relationships presumably reflecting the higher levels of cowbird parasitism and nest predation associated with grassland and agricultural edges. In contrast, adult population trends were more positive with decreasing forest cover and increasing amounts of agricultural edge. Indeed, adult population trends were found to increase as an increasing function of the total amount of edge in the landscape ($r = 0.536$, $P < 0.05$). The fact that field sparrow reproductive index and adult population trends showed opposite relationships to several landscape variables suggests that reproductive index was increased by a decrease in numbers of adults, rather than by an increase in numbers of young. This suggests that low adult survival rates (high adult mortality), perhaps during the winter months, may be important in driving the population declines of this species.

Table 27. List of landscape cover class and spatial parameters selected using information complexity measures in multiple regression analyses to identify landscape determinants of field sparrow demographics. Regression statistics (mean, S.D.) for each spatial parameter and regression coefficients for the selected parameters and four demographic variables – numbers of adults (AHY), adult population trend (AHY/yr), numbers of young (YNG), and the mean annual reproductive index (RImean) -- are given.

Landscape class	Spatial parameter	Mean	S.D.	AHY	AHYyr	YNG	RImean
FOREST	%Cover	50.27	37.94	0.1083	-0.1550	0.0400	0.0049
GRASSLAND	Core Area	97.7	150.8				0.0030
GRASSLAND	Edge(m/ha)	52.48	57.77	0.0638		0.0151	
AGRI	Edge(m/ha)	45.34	44.81		0.0735		-0.0049
	N = 16						
	R-squared			0.051	0.377	0.059	0.631
	F			0.73	7.99	0.933	10.82
	P			0.407	0.013	0.350	0.002

For field sparrows, we recommend that managers maintain a fragmented landscape of forest (about 50% of the landscape) with many patches of grassland covering 25-40% of the total landscape, each of a size less than about 150 ha (about 100ha of core area). Ideally, these grassland areas should be proximal to areas of shrubland or abandoned agriculture (covering 10-25% of the landscape) along the edges of forest. In this way, management can maintain the open patchy landscape that provides good habitat for field sparrows. Rotation of "disclimax" management among the different patches may provide the key for optimal field sparrow management, and will likely benefit other species of successional and scrubland habitats as well.

Painted Bunting

Background

BBS data indicate that painted bunting populations are generally stable or increasing except in the eastern region where they are declining significantly by nearly 5% per year. Populations in this region include those in the piedmont and coastal portions of the Carolinas, Georgia, and Florida; most individuals of these populations overwinter in the Caribbean area. This disjunct eastern population, which extends west to eastern Texas, is considered a sub-species, or even separate species (Thompson 1991), from the remainder of central and western populations that overwinter from Mexico through Central America to Panama. As with field sparrows and prairie warblers, conversion of agricultural land to development or by succession to forest may be one factor responsible for declines in painted bunting populations, especially in the southeastern coastal populations (Joe Meyers pers. comm.). Although their preferred winter habitats in forest edge and savannah are not considered particularly threatened, degradation of migration stopover habitats (especially riparian habitats) in Texas and Mexico are cause for concern. Another threat to these populations is that, because of their colorful plumage, they are highly sought after by the pet trade in Central America.

Management guidelines are as yet unpublished for painted buntings. With regard to the non-breeding season, legislation and enforcement of laws to control exploitation by the pet trade along with effective conservation of stopover habitat should help the species. Although quantitative management designs for breeding habitat are unavailable, mowing, burning, and thinning could be used to maintain the existing mosaic of mid-successional forest habitat and more open shrubby areas. Like field sparrows, painted buntings are found successfully breeding in patchy landscapes of forest, shrubland, grassland, and oldfield. In the southeast, painted buntings are known to nest in open forest and make extra-territorial flights to wet and marshy areas (Meyers et al. 1999). Further west they prefer semi-open habitats with scattered trees and shrubs, riparian areas, and early successional stages such as abandoned farmland (Parmalee 1959, AOU 1998). Ongoing painted bunting studies by Michael Meyers in Georgia and South Carolina may provide more specific management plans.

Landscape model

At the landscape level (results not tabulated), painted bunting demographics respond to patchiness in the landscape as indicated by weakly significant positive relationships with patch diversity (using Shannon's index of diversity) for numbers of adults (non-sig.), adult population trends ($r=0.450$, $P<0.10$), numbers of young ($r=0.492$, $P<0.10$), and mean annual reproductive success (non-sig.). Shannon's index of diversity increases, as do the values of demographic parameters, when the percentages of water, shrub, and forest are large and not dominated particularly by any single cover type.

The class level species-landscape model for painted buntings incorporated elements of water, forest, grassland, and agricultural land (Appendix 6). The top-selected models for each of the four demographic parameters were significant except the model for numbers of adults, which was nearly significant (Table 28). Numbers of adults increased with small, but increasing amounts of water and agricultural land in the landscape, and with increasing amounts of forest edge, but decreased with increasing amounts of grassland cover. Numbers of young increased with increasing amounts of water edge and agricultural land. Reproductive index showed relationships to the amounts of water, grassland and agricultural land in the landscape that were opposite to those for numbers of adults, suggesting that many of the habitats with higher adult population levels were actually population sinks. Increased amounts of water edge and grassland cover had the largest positive effects on reproductive index; the landscape parameters also caused increases in numbers of young and adult population trend, respectively. Adult populations trends were strongly positively driven by amounts of water and grassland cover but negatively driven with amounts of forest and agricultural cover. The negative relationships between agricultural cover and both adult population trend and reproductive index suggest likely problems with cowbird parasitism and, perhaps, pesticide and herbicide effects.

Table 28. List of landscape cover class and spatial parameters selected using information complexity measures in multiple regression analyses to identify landscape determinants of painted bunting demographics. Regression statistics (mean, S.D.) for each spatial parameter and regression coefficients for the selected parameters and four demographic variables – numbers of adults (AHY), adult population trend (AHY/yr), numbers of young (YNG), and the mean annual reproductive index (RImean) -- are given.

Landscape class	Spatial parameter	Mean	S.D.	AHY	AHYyr	YNG	Rimean
WATER	%Cover	4.62	9.13	0.2790	0.4222		-0.0541
WATER	Edge(m/ha)	5.69	5.20			0.2085	0.1043
SHRUBLAND	%Cover	22.04	24.18				-0.0040
FOREST	%Cover	51.85	30.66		-0.1571		
FOREST	Edge(m/ha)	76.09	21.59	0.1037			
GRASSLAND	%Cover	12.97	7.76	-0.2213	0.7342		0.0134
AGRI	%Cover	7.32	7.99	0.4733	-0.4191	0.2327	-0.0191
	N = 16						
	R-squared			0.485	0.576	0.348	0.861
	F			2.909	5.44	7.30	6.90
	P			0.078	0.014	0.017	0.005

We suggest that the ideal landscape pattern for painted bunting populations may be similar to that for field sparrows populations, whereby a mosaic of relatively large sized patches of forest (with a total landscape coverage of 40-70%), shrubland (10-20%), grassland (10-20%), and agriculture (10-20%) are actively maintained in the landscape. Importantly, many small, scattered sources of water, including riparian areas and other wetlands, should be conserved or restored because the shrubby vegetation at the water's edge is likely to be an important resource for foraging. In areas where cattle grazing is allowed, lush waterside vegetation is often lacking alongside such water sources, because it is either trampled or eaten by cattle. Cattle grazing also undoubtedly increases the probability of cowbird parasitism. Thus, cattle should be excluded from all or part of these natural water sources.

DISCUSSION

The model descriptions and management guidelines proposed in this report are based on the relationships between demographic parameters calculated from MAPS data collected on 78 DoD installations, and spatial statistics (landscape metrics) obtained from analyses of two kilometer radius areas of reclassified NLCD (1992) data surrounding each station. The study focused on 10 target species that are both well represented in the MAPS database and also listed as bird species of conservation concern by the U.S. Fish and Wildlife Service (2002) within the southeastern region of the Unites States. Although species-landscape models could be constructed for 21 other landbird species for which sufficient banding data were available, the U.S Fish and Wildlife Service did not list those species as birds of conservation concern and, therefore, species-landscape models for them are not included in this report.

MAPS data

One assumption of our approach is that the MAPS protocol samples the adult and juvenile populations from the landscape surrounding the station. In the early part of the breeding season adults pass through the station looking for new or vacant territories or they are *en route* to reclaim existing territories. In the late part of the breeding season adults and young pass through the station during post-fledging dispersal. In the middle of the season a greater proportion of adults are breeding individuals whose territorial movements encounter a mistnet, floating females seeking unpaired males and extra-pair copulations, or males seeking new/vacant territories. This assumption is supported by the results of an analysis of the seasonal and diurnal patterns of mist-net captures in national forests of the Pacific Northwest (Nott and DeSante 2002). The results showed that captures of "resident" birds (captured in multiple years or multiple times in one year but more 7 days apart) are most likely in the beginning and middle of the season, whereas individuals captured only once are more likely to occur at the beginning and end of the season. There are also differences in the diurnal patterns of captures. Some species are more likely to be captured in the first few hours of banding than towards the end of the banding period, whereas other species exhibit a more uniform pattern of activity during the day, or in the case of flycatchers are less active in the early hours.

Corrections for missed effort

Correcting numbers of captures based solely upon the proportion of the expected banding effort achieved is not sufficient. This because missed banding effort introduces bias into indices of reproductive success consistent with the species-specific temporal patterns of age-specific activity observed in MAPS data, and the timing of the missed effort. We are confident that the four-dimensional (net x 20 minute period x visit x year) missing effort correction model we constructed effectively removes much of the bias. Generally, the corrected numbers of adult and young individuals differ little from the raw numbers except when effort is missed over a time period during which we expect a disproportionate number of adult or young captures of that species. After correcting for missing effort, we use the year-specific corrected numbers of adults and young to calculate the annual reproductive indices.

Model selection and parameterization

Typically, a single species-landscape model involved 598 possible relationships among 13 demographic parameters calculated from MAPS data (we utilized only four in this study), and 46 landscape metrics calculated from NLCD data. Accordingly, the matrix of covariance among the landscape metrics contains 2116 elements. For each species in this study the initial visual inspections of the species-landscape correlation matrices revealed a number of strong relationships between demographic parameters and landscape metrics. For each demographic, we selected up to 10 parameters and included them in fully permuted multiple regression models. In these models, we performed multiple regression analyses on all combinations of parameters.

A considerable problem exists with multiple regression models of this type. If the “best” models are chosen based on simple statistical significance (i.e., lowest P values), those models tended to be overparameterized, statistically indefensible, and extremely difficult to interpret given our knowledge of the species’ ecology. Although we alleviated the problem to some extent by applying a more advanced method of model selection based on the Akaike Information Criterion (AIC; Akaike 1973), models for some species and demographics still included numerous (>5) parameters. However, by selecting the “best” models using an index of information complexity, or ICOMP (Bozdogan 1990, 1994), we typically reduced the number of parameters in the top selected models to two or three parameters. The advantage of this method is that it considers the matrix of covariance among the independent variables and penalizes those models that contain high levels of covariance. We believe that the models selected by this process are statistically defensible, more easily interpreted, and convey more biological and ecological sense.

Forest species

Overall, selected models for those species that prefer to nest in forests and woodlands suggest that land managers should conserve large areas of contiguous forest (upwards of 700 ha) in a 2-km-radius area (1250 ha). Clearly, within those patches, canopy cover as well as the density of undergrowth and ground cover should be managed in a manner consistent with published microhabitat management procedures for the species of conservation interest. Possibly the best central source of such information can be found on the NatureServe Explorer website (NatureServe 2003) where species-specific literature, citations and management reviews can be found. We summarized relevant management information for each species and provided that information in the management section of the results.

Models for one or more demographic parameters for a few species included positive relationships with forested core area (as defined by subtracting a 90m buffer) in preference to total percentage cover. This suggested the existence of edge effects that, for example, negatively impact Acadian flycatcher reproductive success and adult abundance of worm-eating warblers. For these species, the conservation of forested core area is essential. Although the forested core term was not chosen for the other three species, the results suggest that forest patches should be of a more uniform shape and not elongate or complexly shaped. Generally, for forest species, the perimeter:area ratio of forest tracts should be minimized, but this may not benefit species that regard forest edge as ideal habitat and typically prefer a “feathered” edge.

Other interesting details emerged from various species-landscape models. For instance, shrubland cover emerged as a positive term in models for all species except Louisiana waterthrush. For this species, extensive forest edge is apparently beneficial to adult abundance and reproductive success. Not surprisingly the Acadian flycatcher and Louisiana waterthrush models both feature parameters associated with the water cover class that includes emergent herbaceous wetlands and other bodies of still or running water. Small areas of agricultural land cover also seem beneficial to several species. Whether these areas are in fact agricultural land may be disputed (see section entitled Concerns and Caveats below). It is likely that some land classified as agricultural land is in fact successional habitat that results from clearcutting activities. This and shrubland habitat are perhaps important to these species for utilization by post-fledging juveniles and post-breeding adults.

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Scrub/successional species

Species-landscape models for scrub/successional species typically suggest that maintenance of a heterogeneous mosaic of different habitat types is desirable. These species were captured at those stations surrounded by various levels of forest fragmentation resulting from either a drastically fragmented forested landscape or habitat types that naturally form heterogeneous mosaics such as the shrublands of central Texas. There, Bewick's wren appears to benefit from maintaining a large core area of shrubland that perhaps provides refuge from some predators. The other four species are typically associated with patches of early successional habitats that form as a result of natural (e.g senescence, fire and windthrow) and anthropogenic perturbations (e.g. silviculture, logging, agriculture, and development) that help form the patchy landscape.

Interestingly, all of these models feature positive terms for a mid-range of forest cover (40-70%). We assume that these species are evolutionarily adapted to natural forest dynamics in which fire, windthrow, and senescence created and maintained adjacent grass-shrubland-forest ecotones that were patchy in both space and time. In Texas and Missouri, for instance, large herds of grazing ungulates (as well as fire) maintained the grassland areas in pre-settlement times. The models presented in this report support this evolutionary assumption and suggest that active management of those habitats, at least within the limited spatial extent of a military installation or other federal property, requires the creation and management of shifting mosaics of early to mid-successional habitats that mimic the pre-settlement dynamics.

Landscape change and avian community shifts

By the early part of the 20th century, across much of southern United States, clearcut forestry practices had leveled a large percentage of the mature forests. By 1900, in most counties, 50-100% of land was farmed. By 1950, these percentages had dropped to 50% or less. Much of the abandoned farmland that has not been developed for housing, commercial use, or returned to an agricultural cycle has regenerated, in some cases to the extent of forest canopy closure. This is reflected in the Breeding Bird Survey (Sauer et al. 2002) trend analyses (1966-1999) for Fish and Wildlife Service Region 4 (southeastern US). For woodland species, 50% of the trend estimates showed increases, but 59% of the trend estimates for scrub/successional species showed declines (Patuxent Wildlife Research Center, MD: http://www.mbr-pwrc.usgs.gov/bbs/trend/guild99.html). MAPS data for 1992-2001 show a similar pattern in that 71% (10 of 14) of woodland species' showed increasing trends and 59% (10 of 17) of non-forest species showed declining trends. This suggests that one major focus of conservation efforts should be to target scrub/successional species. This may be particularly true on military installations where range sustainment activities impact breeding populations through the creation and maintenance of early successional habitat. Military installations can play an important part in providing refugia for these species through appropriate management of critical breeding habitat.

Natural succession may also bring about shifts in avian communities. A well-developed shrubland that is not the expected climax community might succeed to young woodland capable of supporting low abundances of forest species. Such succession can increase the effective core area of adjacent forested patches by enlarging them, or by effectively filling gaps between forested patches. On many installations, range abandonment and curtailment of disclimax management also allows the regeneration of forest. Managers need to consider whether management of those areas should be continued in order to conserve the early successional bird communities, or whether the regeneration of forest better benefits forest species of concern that breed there.

Concerns and caveats relating to NLCD accuracy and resolution

Clearly, the species-landscape models presented in this study provide cost-effective and useful management tools for some species. However, several problems exist that may affect the accuracy of these models. One problem of the spatial analyses presented here is that the NLCD dataset represents a snapshot of landscape patterns that existed in 1992, a year or two prior to, the establishment of most of the 78 DoD Legacy funded stations in the southern United States. We must assume that in the meantime landscape alteration and succession have occurred. Indeed, data from several installations suggested that an avian community shift, consistent with a pattern of natural succession, occurred. When the NLCD 2001 dataset becomes available, we will be able to document changes that occurred since 1992 in the patterns of each landscape. These changes may have been caused by human activities such as development, logging, reforestation or changes in management regimes. For instance, curtailing grassland management might have resulted in shrub invasion and a corresponding change in the relative abundance of different bird species. Likewise, abandoned agricultural land that previously supported few species may have become capable of supporting an oldfield community and providing foraging opportunities for adjacent shrubland specialists. Relating demographics to land use changes will allow us to refine these models.

A second problem is that the National Land Cover Dataset is based upon spectral analyses of remotely sensed Landsat 30m resolution cells and the predominance of land cover classification (vertical resolution) within that cell. Thus, although the cell may be predominantly covered by vegetation that resembles trees, there may be gaps between those trees. NLCD documentation defines forest cover as "*Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover*." Considering that the diameter of an average tree crown varies from 5 to 10m, this means that managed forested parkland could be classified the same as open natural/semi-natural woodland or mature forest. The avian communities of these habitat types might differ considerably.

More seriously, the NLCD documentation associated with state coverages describes possible confusion among clear-cuts, regrowth in clear-cuts, forested areas, and shrublands, as well as between certain row crops, and “leaves off” sensing of recent clear-cuts. Without intensive ground-truthing surveys and manual correction, these problems will persist in these data. In this report, we grouped transitional barren cells with shrubland and non-natural woody (e.g. orchards) classification because, according to the NLCD documentation, “the majority of pixels in this class correspond to clear-cut forests in various stages of regrowth”. We decided that, functionally, such coverage is more similar to shrubland than to any other classification.

Canopy closure, while beneficial to some species such as Cerulean warbler (*Dendroica cerulia*), tends to cause the understory to thin out or disappear, which creates habitat less suitable for those species that prefer to forage and nest in the understory. The National Land Cover Dataset (1992) does not discriminate between open forest/woodland and dense, mature forest with a closed canopy. The MAPS program provides an effective monitoring strategy for many species that nest and forage in the understory of mid- to late-successional forest, but the shortcomings of the NLCD data described here will inevitably lead to unexplained variation in species-landscape models constructed in this way.

How seriously do these problems affect the value of the models presented here? Without extensive, expensive ground-truthing this question cannot be answered. One might argue that misclassifications (e.g. between shrubland and forest) work in both directions and therefore by analyzing a sufficient number of large areas they should cancel out. On the other hand, in some areas the misclassification may be unidirectional and consistent due to the spectral signature of a particular species. For example, a consistent and possibly spatially extensive misclassification may occur in a landscape covered by a dense shrubland in which a dominant species spectrally resembles a woodland or forest. Visual inspection of the landscapes surrounding MAPS stations, however, did not reveal such spatially extensive anomalies given our knowledge of those areas. Nevertheless, some small scale errors were noticed in some landscapes.

Avian conservation on DoD lands

The U.S. Department of Defense manages over 420 military installations throughout the United States that cover approximately 10 million hectares. These lands provide important habitats for many bird species because they often contain portions of important ecosystems, hotspots of biodiversity, or critical habitat, have been federally protected, and are unavailable to property development and other anthropogenic disturbance. For example, Crane Naval Weapons Research Center, Indiana is heavily forested. Forestry practices on the installation remove only 30% of the annual growth, thus providing the only extensive tract of mature deciduous forest in the region that covers an area easily recognizable from commercial aircraft. Fort Leonard Wood provides mature closed canopy forest in which Cerulean warblers breed. Further west, natural resource management at Fort Hood, Texas, provides breeding habitat for two federally endangered species, the black-capped vireo and golden-cheeked warbler. Much of the critical habitats for these two species in the region have disappeared through commercial or residential development or remain in agricultural use. Camps Swift and Bowie in Texas provide protected and managed breeding habitat for painted buntings and Bewick's wrens, both of which are listed as national BCC species.

The impact of range sustainment

Upon initial consideration, most activities on military installations might not be thought of as having conservation value. However, operational range sustainment on military installations can impact natural resources in many ways. The management and maintenance of military ranges can potentially alter the pattern and composition of critical habitats within the landscape and affect the ability of resident and migrant bird species to successfully breed. Generally, range sustainment does not benefit forest species, because ranges tend to be open and highly disturbed with patchy shrubland and grassland areas that experience frequent fires. Such heterogeneous landscapes, however, provide highly suitable breeding habitats for scrub/successional species that depend upon a temporal mosaic of early to mid-successional habitats. For example, at Fort Leonard Wood, Missouri, land management relating to range sustainment maintains low fuel levels in the areas between military range and surrounding forest, which provides breeding habitat for species such as field sparrows and prairie warblers. The consensus of opinion is that both of these species are declining in North

America, due, in some degree, to the loss of land maintained in traditional agricultural rotation.

Since the 1930's, agricultural practices have become more efficient and intensive with the development of agribusiness. Consequently, the more traditional crop rotation and fallow practices have disappeared, agricultural techniques that favored those bird species adapted to breeding in successional mosaics. This has led to a nett loss of oldfield acreage where species such as field sparrows and prairie warblers can successfully breed. Traditionally, farmland tended to be lower elevation, relatively flat land, which more recently has attracted developers of residential and commercial properties thereby removing large acreages of excellent landbird habitat.

Also, forest fires prior to the early twentieth century were less suppressed than they are now and would leave tracts of burned forest, some with trees left and others in which trees were burned to the ground. Such burns also created natural mosaics of successional seres. These would provide primary shrubland and edge breeding habitat for a variety of bird species for differing periods of time.

Clearly, range sustainment has great conservation value if the resulting landscape will attract shrub/successional species that are currently in decline at the continental or regional scale. The creation and maintenance of firebreaks create many breeding opportunities for species that prefer grassland, less dense shrubland and forest edge habitats. For instance, early successional stages that develop in areas laid barren by exploding ordnance or tank activity can create summer and winter habitat for a range of grassland/shrubland species. However, quantitative estimates of the effects of such practices on habitat utilization by birds need to be made.

Many installations in the south-central states manage non-range areas for cool season grassland using techniques such as plowing, disking, seeding (direct & no-till), fertilization, and mulching in order to promote cool season grass, legume, and nurse (quick cover) plant species. Periodic mechanical maintenance, spot seeding, and chemical applications prevent erosion and maintain the grassland habitat. Such areas include agricultural hay leases, open training areas, pond dams, airfields, construction site buffers, and rehabilitated soil-borrow sites. At other installations, such as Big Oaks NWR in Indiana (formerly Jefferson Proving Ground), such areas are managed to provide breeding habitat for Henslow's sparrows. Such grasslands may also provide winter habitat for short-distance migrants. For example, at the Rabbit's Demise and Sparrow's Haven stations associated with the Fort Leavenworth MAPS location, the grassland areas are inhabited by field sparrows during the winter.

Other installations are developing management programs for the restoration of critical habitats damaged by mission activities or other land uses such as grazing. The Texas National Guard manages Camps Bowie, and Swift. Management plans include restoration of wet-season riparian corridors at Camp Bowie requiring removal of stock ponds and restoration of the natural watercourse and vegetation. At Camp Swift, new fire management regimes are proposed to restore natural grassland communities in oak-prairie dominated areas. There we propose to monitor the impact of the new fire regimes on declining painted bunting populations. These more southerly stations also attract overwintering migratory species such as field sparrow populations that breed further north.

Applying management recommendations

The recommendations in this report are designed for land management at the "landscape" scale (1000's of hectares). They are not intended to replace finer scale (10-100 hectares) management recommendations that influence microhabitat characteristics, but should be used in conjunction with them. Management actions that influence microhabitat conditions might include maintaining threshold levels of canopy cover and understory density of individual forest stands using logging, brush cutting, fire or herbicide treatments, for example. Clearly, maintaining the microhabitat structure of a woodlot for a particular forest-interior species may be ineffective if that woodlot becomes too isolated from larger "source" tracts of forest. Conversely, maintaining large tracts of forest for a forest-interior species that relies upon dense understory would be ineffective without appropriate forestry practices (e.g. selective thinning) that would prevent canopy closure and the subsequent reduction of the understory.

more parameter values to a level(s) that would benefit the population. Such virtual ("what if?") management involves changing the values associated with cells in the GIS-NLCD coverage. This might include filling gaps between forest patches, creating a mosaic of clearcut patches, or even smoothing the edges of a forest patch to decrease the edge to area ratio. If the virtual management is successful in benefiting target species, then the decision to apply it in the field can be made.

Alternatively, for a number of reasons, land managers are sometimes committed to changing the landscape to accommodate, for example, changes in the military mission, new building or road development, or to reduce fire risk in a particular area. In these cases, the GIS model can be altered to reflect those changes and spatially analyzed. The new values of landscape parameters can now be used to predict the effects of the management plan on one or more species. The plan may then be modified to ameliorate any predicted detrimental effects on species of conservation concern.

Future research

We believe that the models proposed here are generally useful but, in some cases, suffer from misclassifications of land cover. Subsequent to the inception of this project, other fine resolution, stereo capable satellite derived datasets have emerged that may provide more accurate and finer resolution coverages.

There are several advantages to using fine resolution satellite data. At the 4m resolution offered by these data the patterns of each cover type will be more complex allowing more precise estimates of many parameters including edge statistics. Narrower streams, roads, tracks, and other sub-5m features that define edges will be better defined at this resolution, whereas they may not appear at all at 30m resolution. These data can even be used to determine the dominance of individual tree species in a forest or woodland because the resolution is finer than the 5 to 10m diameter of an average tree crown. They can also provide the opportunity to remotely sense such variables as canopy density, understory density, and leaf area index more accurately. In fact, the U.S. Army is developing methods to determine environmental conditions of potential battlegrounds using multispectral (4m) data derived from the IKONOS satellite.

Full coverage of all 13 DoD installations in this study may require up to 20 scenes, plus the cost of classification tools. These datasets range from $350 to $3000 per 100 sq. km. scene (May 2003).

The importance of edge

This study focused on 10 species listed by US Fish and Wildlife (FWS 2002) as “Birds of Conservation Concern”. In total, the 44 top selected models included 117 landscape parameters, of which 43 (~37%) described the amount of edge of individual cover types in the landscape. This suggests that edge statistics are important determinants of avian demographics. For a forest interior species, the amount of forest edge in a given landscape may indicate high levels of fragmentation or complex forest patch shapes. In either case, as the amount of edge increases, the forest core area decreases and, as many studies suggest, the levels of cowbird parasitism will likely increase.

In this study we did not discriminate between the types of edges in the landscape but for several reasons believe that this may be an important factor in the construction of species-landscape models. Consider a large tract of forest that abuts shrubland on one side, agricultural grassland on another, a large water body on the other, and also features a small interior clearcut. It is likely that the amount of forest-grassland edge contributes more to the risk of cowbird parasitism than do the forest-shrubland edge, forest-water edge or any interior edges created by the clearcut. Likewise, for a species that is attracted to forest edges in which to breed, the type of edge may be more or less beneficial to nesting success.

We feel it is important to investigate the effects of edge type in species-landscape models. Accordingly, we are developing a GIS algorithm to quantify the length, complexity, and relative amounts of each type of edge in a landscape. The method involves buffering all but the smallest patches of each habitat type and applying a “unique combination” model to distinguish between the different types of edge. We expect that some of these parameters will feature prominently in future species-landscape models.

Targeting scrub/successional species

In this study we identified five scrub/successional species listed as BCC species in the Bird Conservation Regions and/or FWS Region 4 (Table 2). Of these, three species, Bewick’s wren, prairie warbler and painted bunting, are listed as species of concern at the national level (continental United States). Although, the species-landscape models appear to be useful management tools, larger sample sizes would be preferable. Also, in the context of range sustainment, these species, which utilize the grassland-scrub-forest ecotone, may be more impacted than other species by the management regimes that curtail encroachment of woody plants into grassland areas. It is therefore critical that newly established clusters of MAPS stations target these species in areas that are heavily managed for range sustainment and nearby areas that are left to succeed and develop a more natural ecotone.

We intend to monitor the demographics of these species at several installations. Existing MAPS stations at Fort Leonard Wood effectively monitor field sparrows and prairie warblers. Two of these stations are managed by fire to reduce fuel and consequently provide firebreaks between military range and woodland – this "disclimax management" reduces the biomass of dead and live woody vegetation and maintains the area in an early successional state. The remaining two stations that are currently situated in mature forest are to be relocated (2003 breeding season) to oldfield/scrub areas where woody encroachment will be allowed to progress. In the long term, this process will increase the area of forest and provide a more natural grassland-scrub-forest ecotone. Camps Swift and Bowie in Texas are actively managing habitats within a framework of ecological restoration. At Camp Swift we intend to monitor the effects of state-of-the-art burning techniques intended to restore the natural diversity of oak-prairie habitats on painted bunting demographics. At Camp Bowie we intend to monitor the effects of riparian restoration on the mostly declining avian community, including three BCC species, Bewick's wren, field sparrow, and painted bunting.

There is great potential for establishing new clusters of MAPS stations on a number of DoD installations that manage active military ranges and also support abundant populations of BCC species. For instance, active range sustainment management is practiced at Fort Campbell on the Kentucky-Tennessee border. Existing monitoring programs target grassland interior species such as Henslow's sparrows (Beuhler, University of Tennessee), but this installation also supports abundant populations of Kentucky warblers, prairie warblers, and field sparrows that breed close to the edges of forest. Here there is a need to monitor survival rates and reproductive success of those species (Jeff Jones, Natural Resource Manager, pers. comm.).

Summary

In summary, we conclude that a) the NLCD dataset provides an effective but coarsely scaled tool for constructing species-landscape models. The resultant models are applicable at the scale of hundreds of hectares; b) alternatives to NLCD data (e.g. classified 4m resolution IKONOS data) may provide more robust models, a range of new metrics, and enable the capture of more finely detailed species-habitat relationships; c) the development of a "unique combination" GIS layered model may reveal important relationships between avian demographics and the types, amounts and shapes of edge; d) the MAPS protocol should be used to monitor the effects of range sustainment on a number of target species of conservation concern; and e) more clusters of MAPS stations should be established on installations that support abundant or declining populations of non-forest target species.

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