USERS GUIDE

Recommendations for Monitoring and Managing Source Populations of Species of Concern on Military Installations

SERDP Project RC-2121

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The goal of this User Guide is to provide monitoring and management recommendations to DoD Natural Resources Managers interested in identifying, monitoring and managing for persistence of source populations of migratory birds. This Guide provides information and recommendations on basic and detailed monitoring strategies that will assist installation managers in ensuring they have appropriate information to initiate investigations of source and sink populations, as well as how and why source/sink investigations might be incorporated into Integrated Natural Resources Management Plans (INRMPs).

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User Guide: Recommendations for Monitoring and Managing Source Populations of Species of Concern on Military Installations

Preface

This User Guide is intended as a stand-alone companion document to the Final Report for SERDP Project RC-2121, "Using a Hierarchical Approach to Model Regional Source-Sink Dynamics for Neotropical-Nearctic Songbirds to Inform Management Practices on Department of Defense Installations." Our goal with this User Guide is to provide monitoring and management recommendations to DoD Natural Resources Managers interested in identifying, monitoring and managing for persistence of source populations of migratory birds. This Guide provides information and recommendations on basic and detailed monitoring strategies that will assist installation managers in ensuring they have appropriate information to initiate investigations of source and sink populations, as well as how and why source/sink investigations might be incorporated into Integrated Natural Resources Management Plans (INRMPs). We also provide general guidelines for forest management of benefit to Wood Thrush, the focal species of our investigation, and potentially for other migratory birds, on military lands. The reader should consult the SERDP RC-2121 Final Report for more detailed information on study results.

Introduction

Monitoring Techniques on DoD Lands. Avian inventory and monitoring efforts on Department of Defense (DoD) lands include a wide variety of methods and approaches, some of which are focused on specific management questions. Our SERDP investigation focused on validating and testing the efficacy of three avian sampling approaches (point-counts, MAPS [Monitoring Avian Productivity and Survivorship], and intensive demography), varying in effort and data resolution, to identify source-sink dynamics of Wood Thrush (WOTH) in Indiana. These three techniques have been used to varying degrees on military lands to inventory and monitor migratory birds, but until now no such efforts have investigated the relative efficacy of each to identify source and sink populations. Our results provide an important step forward in assisting installations making proactive management decisions on DoD properties.

Point Counts. Point-counts provide coarse demographic data on distribution, abundance, and richness and can be implemented over large spatial-scales with low unit effort. Point counts, and to a lesser degree line transects, have been used extensively on military lands as a means to develop baseline inventories, monitor seasonal bird populations, assess changes in bird communities over time in response to a management practice, and to identify abundance and distribution of priority species such as those listed under Endangered Species Act (ESA) (Bart et al. 2012).

MAPS. The MAPS monitoring protocol is a standardized breeding season mist-netting and banding protocol that has been used by more than 450 monitoring stations continent-wide (DeSante, 1999; DeSante et al. 2005; Saracco et al. 2009). MAPS monitoring is the most

widespread tool used to estimate vital rates of bird populations in the continental US (Desante et al. 1995) and has been used extensively to collect data at the scales needed for assessing regional population dynamics. Initial goals of MAPS were focused on two demographic parameters, productivity, as indexed from constant effort capture data, and adult apparent survival rate (survival), as estimated from capture-recapture models. MAPS data can provide higher resolution demographic data on some vital rates (e.g., survival), but is limited in scale largely because of unit effort. A variety of DoD installations have successfully used MAPS data to address specific management questions (Bart et al. 2012), such as assessing effects of varying fire regimes for preventing wildfires (Fort Bragg, NC; Fort Leonard Wood, MO); Red-cockaded Woodpecker management (Fort Bragg, NC); effects of fire regimes and buffer forest thinning on priority forest bird species (Jefferson Proving Ground, IN); powerline corridor management (Fort Knox, KY); effects of forest management related to weapons storage facilities on forest birds (NWS Crane, IN); management of oak-prairie habitats for military drop zone using prescribed fire (Fort Hood, TX); and effects of fire and habitat alteration used to manage military drop zone activities on performance measures of Painted Bunting populations (Camp Swift, TX).

Intensive Demography. Intensive demographic monitoring provides the most detailed information on bird communities since one is able to derive fine-scale estimates of most vital rates, including fecundity, recruitment, survival, and immigration. However, this technique is also limited in spatial monitoring extent and requires the greatest unit effort. Few installations have conducted monitoring at this level of intensity for any species.

Prior to implementing results of this SERDP investigation on an installation, and in particular, to begin investigating sources and sinks, one should consider how much is known about migratory bird populations on the installation. At the very least, a basic migratory bird baseline survey should have been completed. This is important not only for supporting Integrated Natural Resources Management Plans (INRMP) objectives, but would be essential for assessing distribution and relative abundance throughout the installation of any focal species for source/sink investigations. DoD PIF strongly recommends that installation natural resources managers consult the DoD Coordinated Bird Monitoring Plan (CBMP) (Bart et al. 2012) available on the DoD PIF website (www.dodpif.org). The CBMP provides the best source of information for developing a monitoring strategy at either the installation, or the regional, level; and it details how to develop and implement basic inventory and monitoring programs, how to select a survey method based on management objectives, and how to manage and analyze data. The CBMP also outlines how to conduct inventory and monitoring of priority species (e.g., DoD Mission-sensitive Species, USFWS Birds of Conservation Concern), as these likely would be the focus of any population source/sink investigation. The two best resources to assist managers in identifying priority species are the DoD PIF website and the USFWS Information for Planning and Conservation (IPaC) system (https://ecos.fws.gov/ipac/). The recent guidance from the Office of Secretary of Defense, DoD Natural Resources Program, recommending how to incorporate migratory birds in INRMPs also provides numerous recommendations and resources for monitoring and managing birds on installations to protect mission capabilities (18

Aug 2017; Guidance for Addressing Migratory Bird Management in Integrated Natural Resources Management Plans).

Source and Sink Populations on DoD Lands. DoD installations have long been considered as source habitats for a variety of taxa, producing surplus individuals through high survival and fecundity that subsequently disperse to lower quality habitats both inside and outside of the installation boundaries. This notion has been widely described anecdotally because many installations include large blocks of relatively undisturbed habitat that serve as "buffers" to more intensively used training areas, drop zones, and artillery impact areas. Some investigators have explored this notion by attempting to characterize, through field demographic monitoring, whether animal populations on installations act as either regional sources or sinks. For example, Giocomo (2005) investigated grassland birds on Fort Campbell, KY, producing population viability plots with curves representing thresholds between source and sink populations. Eggert et al. (2015) investigated how landscape heterogeneity influenced source-sink dynamics of ringed (*Ambystoma annulatum*) and spotted (*A. maculatum*) salamanders on Fort Leonard Wood, MO. Lawler et al. (2016) investigated Black-capped Vireo (*Vireo atricapilla*) source-sink dynamics on Fort Hood, TX, concluding that the installation included both source and sink areas, and that management efforts should be focused almost solely within installation boundaries rather than including peripheral sink populations. Other less recent empirical work described the importance of DoD lands as source habitats for Gopher Tortoise (*Gopherus polyphemus*) (Theodorakis 2008).

Linking SERDP Research Results With DoD Mission Requirements. While our investigation of Wood Thrush (WOTH) and their habitats in southern Indiana was among the largest of any landbird investigation in North America, there is little return on investment for DoD if results are not translated such that managers can readily use the information to enhance migratory bird habitat and populations both within and outside of installation fence lines. Our results are intended primarily for installations currently managing forested habitats (and with a focus on WOTH), and are applicable to individual installations as well as to larger conservation programs (e.g., those designed, in part, to manage priority species for enhancement of mission activities). As examples of the latter, the Army Compatible Use Buffers (ACUB) and DoD Readiness and Environmental Protection Integration (REPI) programs are focused on promoting off-base conservation to enhance on-base operational flexibility. Our investigation provides important information to assist in making decisions about where and how land acquisitions adjacent to installations can have substantial ecological values that can promote habitat and support populations of sensitive species as a means to assist in protecting mission capabilities. Our SERDP investigation characterized WOTH population dynamics with sampling techniques of varying intensity and scale, resulting in important new information on how to select a sampling technique relative to management questions and scale of investigation. This new information supplements monitoring recommendations in the CBMP as detailed below. There also is much that can be learned and of value to informing the conservation and management of other priority bird species on military installations. Although this work focused on WOTH we believe the results and recommendations are applicable to a number of interior forest species of

migratory birds (see interior species Fig 1.9 below, and in the SERDP Report). Those recommendations are outlined in this Guide.

Applying Research and Monitoring to Develop and Enhance INRMPs

The management and conservation of migratory birds on DoD installations is addressed in installation INRMPs. One of our goals is to provide information of relevance that can be included in INRMPs to assist installations in managing priority birds and their habitats, as well as assisting in complying with applicable natural resources related laws (e.g., Migratory Bird Treaty Act, Endangered Species Act), Executive Orders (EO) (e.g., EO 13186), and Military Services regulations. INRMPs and National Environmental Policy Act (NEPA) environmental analyses constitute the principal tools for effectively integrating mission needs with ecosystem-based natural resource management and serve as primary mechanisms for ensuring this compliance.

Current guidance from the Office of Secretary of Defense regarding the incorporation of migratory birds into INRMPs recommends each installation ensure that INRMPs and NEPA analyses adequately address migratory bird management, and the potential impacts of proposed military activities—readiness and non-readiness related alike—on migratory birds (18 Aug 2017; Guidance for Addressing Migratory Bird Management in Integrated Natural Resources Management Plans). Section 315 of the 2003 National Defense Authorization Act and the Migratory Bird "Readiness" Rule (Military Readiness Rule; 50 CRF Part 21) implementing Section 315 authorize, with certain limitations, the incidental take of migratory birds during military readiness activities. Executive Order 13186 (Responsibilities of Federal Agencies to Protect Migratory Birds) mandated that all federal agencies work with the U.S. Fish and Wildlife Service (USFWS) to complete a Memorandum of Understanding (MOU) between action agencies and the USFWS that provides details on proactive management and monitoring for migratory birds. The DoD signed a MOU for migratory birds, under EO 13186, with the USFWS in July 2006, which was revised and again signed by both agencies in 2014. The MOU states that for actions on military installations not considered as readiness activities, prior to initiating any activity likely to affect populations of migratory birds, DoD shall (1) identify the migratory bird species likely to occur in the area of the proposed action and determine if any species of concern could be affected by the activity, and (2) assess and document, using NEPA when applicable, the effect of the proposed action on species of concern. By following these procedures, DoD will minimize the possibility for a proposed action to unintentionally take migratory birds to a level that would violate any of the migratory bird treaties and potentially impact mission activities. In addition, implementing conservation and monitoring programs for migratory birds and their habitats as a means to comply with regulatory requirements, as well as to remain sound stewards of the Nation's natural resources, aids in maintaining realistic training environments that support the military training and testing mission.

Conducting monitoring efforts to identify source and sink populations on installations, and managing habitats to improve conditions that enhance source populations, provides direct INRMP support. This is particularly true for species of concern to DoD. For example, DoD Partners in Flight (DoDPIF), which focuses on management of migratory birds in support of DoD missions, maintains a Mission-sensitive Species list for those species that should have focus for

monitoring and management. Mission-sensitive Species are those that if federally listed in the future under the Endangered Species Act, would have the largest impact to the testing and training missions. These species include WOTH and several other forest-dwelling migratory birds. Installations that conduct appropriate monitoring and management for source populations of these species, and articulate these approaches in INRMPs, are proactively addressing future potential mission/bird conflicts.

Habitat Management for Source Populations of Wood Thrush

There were several key findings in our SERDP study that provide significant insight into monitoring and habitat management for WOTH and other forest-interior priority species. We provided both specific (monitoring recommendations) and general (habitat management) information that can directly assist natural resources managers with monitoring and management of priority birds and their habitats. Our investigation also provides a more complex set of objectives that then could be addressed more readily once appropriate installation migratory bird baseline information is available. Subsequently, if bird population source/sink investigations are of particular interest to an installation, we discuss the relative advantages and disadvantages of varying monitoring and management techniques, detailed in the final SERDP report, and in summary below.

Our results indicate that basal area of trees with diameter at breast height (DBH) > 30 cm was the most powerful predictor of WOTH recruitment. Our Indiana sites with high basal area also tended to also have high shrub density, complex vertical structure (i.e., sub-canopy) and high leaf litter depth all of which are likely important for WOTH (and other forest-interior species) habitat selection as well as productivity. For species such as WOTH (and other forest-interior species noted in the SERDP Report, Figure 1.9 below), minimizing selective timber harvest, which impacts both overstory and understory forest structure, should have a net positive effect on populations. Encouraging growth and retention of large trees within management units, particularly those with interior-forest, will create sites that are of high quality. Thus, managers may be able to provide highly productive habitat for WOTH and other priority migratory forest birds using simple fine scale management (e.g., not undergoing selection-cutting in some large, older stands; managing for large blocks of uneven-aged forests). In addition to having a positive demographic impact, management practices that encourage retention of large trees also will be preferentially selected by WOTH thereby increasing overall occupancy. Increasing regional occupancy will undoubtedly buffer and increase the likelihood of persistence for local and regional populations in a source/sink or metapopulations framework. This is a key point, and reiterates the need for coordinated base-wide management strategies at large spatial scales, given the dynamics (immigration and emigration) of most migratory bird populations. Implementation of the management practices noted above should be at the largest scale possible to increase probabilities for persistence of source populations. Implementation in small subsets of habitat likely will not promote this persistence.

At Naval Support Activity (NSA) Crane, IN, (a focal installation for our research) intensive forest management, including timber stand improvement and commercial harvests, is outlined as a goal in the Installation INRMP. In general, the intensity and extent of forest management

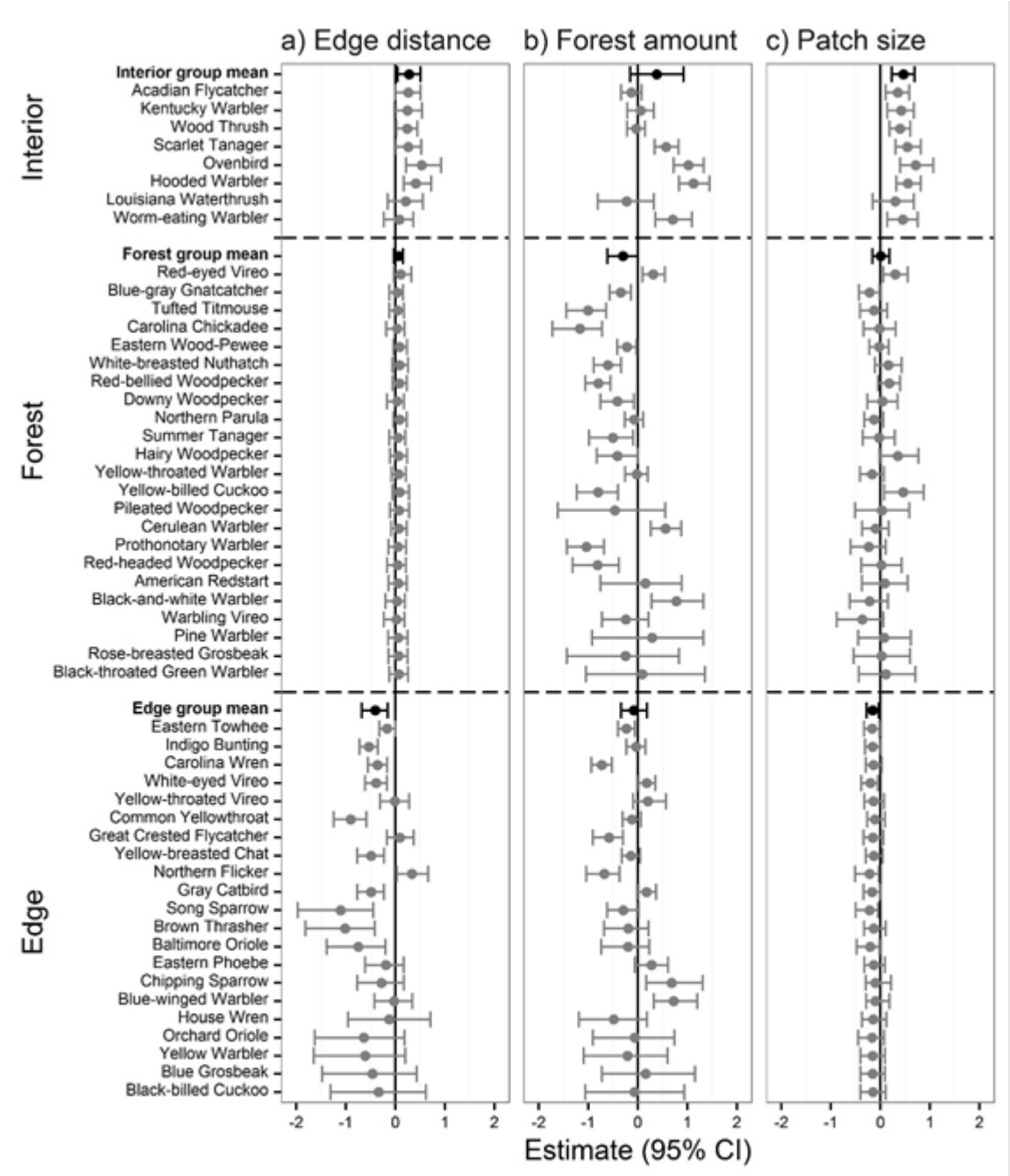

Figure 1.9. Posterior means and 95% credible intervals for the effects of a) edge distance, b) amount of forest within 2 km, and c) log-transformed patch size on probability of occupancy for breeding forest bird communities. Species were divided into three forest habitat groups (interior specialist, forest generalist, or edge specialist), and the mean effect of the covariate on members of each group was estimated along with individual effects. Within each habitat group, species are listed from most common (top) to least common, or equivalently, from most influential on the group mean estimate, to least. Note that all covariates were standardized with a mean of 0 and standard deviation of 1 prior to model fitting.

(selection harvesting) on NSA Crane resulted in a net loss of productive WOTH habitat (i.e., low or negative population growth) on the installation during our investigation. This is supported with data and analyses from all monitoring methods as outlined in our report. Conversely, Big Oaks National Wildlife Refuge (BONWR), another focal site in our study, had both the greatest population growth, and the least amount of local vegetation management.

However, the more intensive forest management on NSA Crane likely has a net positive effect for other migratory birds that prefer lower tree densities and basal area, distance to edge, and more canopy gaps. It is worth noting, however, that the suite of species inhabiting these more intensively managed forests often are not those of conservation concern. In instances where installations desire to manage both for forest productivity and priority migratory birds, management decisions will need to strike a delicate balance between life-history needs of priority focal species and the desire to undergo intensive forest management (e.g., for revenues or maintenance of training areas). In Chapter 1 of our report, we also provided some insights into how distance to forest edge, forest patch size, and forest amount influence three different guilds of migratory birds (interior specialist, forest generalist, and edge specialist). Managers wishing to manage for other forest-dwelling priority species of management concern (e.g., Cerulean Warbler) that we monitored as part of our overall investigation should consult Figure 1.9 (and in the SERDP report) as a start to understand how general forest characteristics influence those species.

Our report also details the key drivers of habitat specific demography and how these variable demographic rates differentially contribute to population dynamics. These results provide the DoD an essential understanding of which vital rates drive population growth, how those processes vary with habitat quality, and details the role of breeding vs. non-breeding season population limitation.

Because results of our study underscore the importance of both the breeding and migratory periods, and we clearly show that breeding season processes account for the vast majority of variation in population growth. Our study also investigated some general habitat management and forest prescriptions undertaken on our study sites. Managers can make positive impacts on species of concern through habitat management approaches that can maximize survival, recruitment, and fecundity, and our results show that vital rates make differential contributions to population growth depending on the quality of the habitat. This suggests that managing populations for persistence, via increasing specific vital rates, may need to be done in a habitat-specific manner.

Although our models of local productivity underscore the importance of large trees and higher basal area, landscape scale features on and around installations should not be ignored. Regional processes, especially immigration, can play an essential role in converting sink habitats into sources. For example, our MAPS results showed that regional forest cover with 2km was a significant predictor of local productivity. We also showed, using our integrated population model, that immigration processes are important across a gradient of habitat quality. Ultimately, our results show clearly that local land management can have a positive

demographic impact, yet land managers must consider regional land use especially when considering the rescue of populations in demographic deficit. These results have very important implications for DoD REPI and Army ACUB programs that strive to enhance on-base operational flexibility through off-installation acquisition of lands that buffer installation borders. Our results can be applied both locally to new land acquisitions (e.g., manage for large forest patches with high basal area) and regionally to provide additional habitat patches on the landscape within a metapopulation context.

This work also was able to decouple the relative contribution of habitat amount vs. habitat fragmentation on the distribution of birds in managed landscapes (Fig. 1.9), though impacts of these variables on demography is still lacking. Achieving this goal may require diverse monitoring approaches because demographic vital rate data can only be collected on finer spatial scales while distribution, richness, and abundance data can be collected at much larger spatial scales. Regardless of scale, studies that inform how habitat quality (amount and fragmentation) shape the contributions of overall distribution, abundance and demography to population growth as well as which aspect of landscape structure are most critical to population persistence, are essential for proactive conservation. Ultimately, understanding these relative contributions can inform how resource managers allocate resources towards fine-scale habitat protection and management vs. base wide or even larger regional management strategies to conserve avian populations.

Below are more detailed results from our study to support this, and other recommendations for habitat management.

1. Local habitat was a significant predictor of self-recruitment rate. Specifically, forest structure as measured by the number of trees with greater than 30 centimeters' DBH, was a very strong predictor of high quality source WOTH habitat. As such, habitat management recommendations for WOTH will require growth and retention of large trees as well as the encouragement heterogeneous vertical foliage structure and understory shrub cover for nesting habitat. These same habitat characteristics also provide favorable habitat for other interior-forest dwelling species. Although patch size and forest cover within 2 km were not strong predictors of self-recruitment rate, both variables had a positive influence on WOTH occupancy. Thus, regional management should consider these variables for large-scale management decisions.
2. Regarding the growth and retention of large trees in management units, the factors that attract breeding WOTH are the same as those that result in positive population growth. These results are emphasized by the fact that the BONWR sites in our study had both the greatest population growth, and the least amount of local vegetation management. Sites where selective harvesting of large trees was common (e.g., Crane plots) tended to have low or negative population growth. That said, harvesting is almost certain to benefit other avian and mammalian species, even if it does not directly benefit WOTH. It should also be noted that while the count of large trees is the single greatest predictor of self-recruitment rate, this does not mean that landscape features have no influence on WOTH population persistence because of metapopulation dynamics.

3. We provided a wealth of information about WOTH population dynamics, yet management decisions often need to be made based on competing demands and often take into consideration multiple taxonomic groups. Although managing suites of species can be difficult, we believe our results provide some key insight into the ecological processes that influence the distribution and population dynamics for birds on DoD installations in Southern Indiana and more broadly across the eastern deciduous forest region.
4. The occupancy of forest interior species is maximized by increasing patch size, and to a lesser degree, by overall forest cover. As such, maximizing avian diversity on installations will require managers to maintain a heterogeneous configuration of patch sizes as well as compositional makeup.

These strategies may not be mutually exclusive, but the complexity and diversity of species of breeding birds monitored suggested that no single catch all management solution is likely to exist.

Frequently Asked Questions

Our SERDP investigation provided significant insights into relative advantages and disadvantages of using 3 different monitoring methods to improve understanding of source-sink dynamics for subpopulations or populations of species of relevance to DoD resource managers. Regardless of whether this is an on-installation goal, there is very useful information provided on these 3 methods that can assist in improving monitoring and management of priority bird species on installations. That information is provided below in a "Frequently Asked Questions" format.

This investigation compared 3 different monitoring techniques for assessing source and sink populations for WOTH. Which is the best, and which should I employ?

Each monitoring strategy could be considered the "best" depending on installation-specific objectives. One must first determine goals of a monitoring effort before selecting any specific methodology. Monitoring should nearly always be management-based, that is, a monitoring technique should be selected that will help answer a particular management question of interest on the installation. As noted above, the DoD CBMP (Bart et al. 2012) provides specific recommendations for monitoring on DoD installations and should be consulted, prior to developing any inventory or monitoring program, to match the objectives set by installation natural resources personnel (or as detailed in the installation INRMP). Investigating source/sink population dynamics can have significant management implications for an installation, such that if this an objective, on-the-ground management of habitat may be warranted to either sustain habitats as sources, or to implement changes in management regimes to improve those habitat areas identified as sinks.

Without question, our study suggested that intensive demography, because of the level of detailed information derived for demographics, provided the best means of identifying source and sink populations. Our report provided detailed methodology for conducting intensive demographic studies should DoD need to assess source-sink dynamics of priority species other

than WOTH. However, this method is expensive and should not be used as a monitoring strategy unless there is a specific requirement to ensure best-available information on population demographics. Interestingly, we also showed that point counts provided very similar estimates of lambda (λ; the finite rate of increase of the population over one annual life-cycle) when compared to results from intensive demographic monitoring. This result is encouraging for land managers wishing to estimate λ with point count data, as point counts in general are less costly and require less intensive fieldwork. If using point counts to estimate demographic parameters of migratory bird populations, we strongly recommend consulting the CBMP, and then closely adhering to the point count protocol outlined in Chapter 1 of the SERDP report to ensure sufficient data are collected.

Despite a correlation between point count and demographic estimates of λ, these approaches often came to different conclusions about a site being a source vs. a sink. Viewed broadly, our results suggest the methodological approach chosen for sampling avian populations to identify sources and sinks will be dependent upon the scale at which management decisions need to be made. In higher quality habitats or at larger spatial scales, some species of concern may be monitored with less expensive count based and MAPS approaches, however, in lower quality habitat or smaller spatial temporal demographic stochasticity will require the more detailed intensive demographic approach.

The MAPS protocol produced estimates that were not significantly, and in some cases not positively, correlated with either the point count or demographic estimates, and this likely is due to spatial scales at which these techniques were applied (see SERDP Report, Chapter 4). However, there is merit in using the MAPS protocol for specific objectives as we detail below.

We have been using point count methodology for many years. What kind of information can I derive from my data?

Point counts are by and large the most extensively used method for avian monitoring on installations. They are used primarily for inventories, and for monitoring seasonal bird communities over time. If conducted with sufficient replication, with adequate repeated visits within a season, point counts can be used as a means to identify population sources and, to some degree, sinks. Doing so requires adequately accounting for imperfect detection with sampling design, and sampling over multiple years to estimate the rate of change in expected abundance among years. In our study, a comparison of point count and demographic data suggest that although count data are less precise when it comes to understanding species-specific demography, they can be used as a heuristic tool. Specifically, congruence between the point-count abundance and occupancy results and the key drivers of self-recruitment rate for WOTH suggest that count data can be an indicator of demographic performance for a broader suite of interior forest birds.

Point counts also can be used to estimate spatial and temporal changes in relative abundance among multiple management units. Our investigation showed that point counting in a grid pattern over a spatial area also sampled by intensive demographic work produced similar demographic estimates for WOTH, potentially indicating that point count results can provide

source-sink information at the same spatial scale as demography. Advantages of point counts include (a) the ability to cover more landscape and with larger sample sizes, and typically at significantly less cost, than MAPS or demographic monitoring; and (b) the ability to produce species distribution maps which are not possible with MAPS or demographic sampling. If installations are interested in attempting to estimate distribution patterns, or to estimate immigration or emigration rates, one should consult the results of this SERDP investigation for more detailed recommendations for point count sampling design.

In summary, point count data are likely most valuable for monitoring changes in spatial or temporal distributions over time, and comparing abundances and occupancy among points in space. Though λ estimates from point count data are correlated with those generated by intensive demographic monitoring, they may be too imprecise for definitively determining whether an area is a source or a sink. We do offer a caveat, however, in that our results technically only apply to WOTH in Indiana, and future studies should investigate whether point counts can be used universally as a reasonable substitute for demographic monitoring for other species. For instance, we may not expect to find similar correspondence between point count and demographic estimates of λ for species with larger home ranges, or more cryptic vocalization tendencies.

We have been using the MAPS protocol. Should we continue investing in MAPS monitoring on our installation?

The DoD has invested significant funding and resources into MAPS stations for more than two decades and has played a key role in the development of, and contribution of data to, the MAPS program. Since 1992, DoD has supported the operation of approximately 150 MAPS landbird demographic monitoring stations on military lands. This extensive effort has provided significant information on presence, relative abundance, and local productivity estimates, as well as contributed to landbird management guidelines and management decision support tools (Bart et al. 2012). To provide some perspective of the utility of MAPS for DoD, Bart et al. (2012) noted that MAPS stations on DoD lands were "strategically placed to monitor the demographics of landbird populations in the context of military mission-oriented land management." MAPS has provided more than 200,000 data records of birds on DoD installations, and these data have been archived for inclusion into the national Avian Knowledge Network (AKN) under a DoD Legacy Resources Management Program effort initiated in 2017.

For installations with prior or current MAPS investigations, decisions to continue use of this protocol as a monitoring strategy should be based on installation monitoring and management objectives, and should reflect results of our investigation, especially the issues of scale at which management decisions need to be made. In our study, each of the three monitoring techniques provided varying degrees of useful information. We offer the following specific recommendations for MAPS;

1) Clearly, MAPS was more valuable than intensive demographic work for gathering composition and abundance data across multiple species, and may be as useful as point counts for estimating composition and relative abundance over time.
2) MAPS provided robust estimates of apparent survival, so is useful if one's goal is to

monitor species-specific survival on an installation.

3) MAPS can provide robust demographic rates for larger spatial areas, although the scale dependence in precision and accuracy of these estimates requires further study. For example, the MAPS reproductive index does not measure local fecundity. It may be a solid measure of fecundity at some broader scale, but we simply don't currently understand those geographic scale boundaries.
4) The use of MAPS for identifying population sources and sinks was less clear. MAPS generated indices of breeding productivity and estimates of density and apparent survival rates, but its power to quantify source-sink dynamics was scale dependent. MAPS λ estimates were not correlated with the "true" estimates from demographic monitoring since MAPS includes data from birds captured from a larger spatial area than the other two techniques. However, MAPS may provide useful information for identifying population sources, particularly at larger spatial scales than investigated with point counts or intensive demography. Results were not as robust for identifying population sinks.
5) The results of our research suggest that MAPS may not accurately inform population dynamics at fine spatial scales (e.g., single forest patches). However, while individual habitat patches are often viewed as tractable management units, this may not be the only scale at which to measure source-sink dynamics. Indeed, growth rate estimates for any area of interest ultimately depend on the boundary delineation (e.g., Schumaker et al. 2014). MAPS may be very useful for quantifying source-sink dynamics at broader scales (e.g., installation-wide). Future work needs to identify the spatial scale(s) at which MAPS-generated demographic rate estimates apply and how to appropriately apply that information to effective conservation management strategies.
6) It is import to note that we compared MAPS with point count and intensive demography techniques with a single species. Results for other species, and in other geographic regions and ecosystems, may be different.

Is intensive demographic sampling necessary on our installation?

This depends on whether there are very specific needs to identify source and/or sink populations or to focus in on species vital rates relative to spatially explicit management prescriptions. There is no substitute for intensive demographic monitoring if local population management is the goal. However, as noted above, this is a relatively expensive technique. If interest is simply in spatial variation in population growth rate, repeated point count sampling over multiple years may provide reasonable approximations at substantially reduced cost, and over much broader spatial scales. When information is needed about local productivity/ fecundity then intensive demographic monitoring is likely to be the most accurate approach. If knowledge of how demographic vital rates change with land-use or military activity then intensive demography can also inform how specific activities affect avian demography. Moreover, given the finding that the contribution of specific demographic vital rates can vary with habitat quality there may be instances where intensive demographic work can inform spatially explicit management practices within and across DOD installations (as well as with ACUB and REPI programs where both on and off-installation management may be a priority).

This study identified WOTH as breeding-season limited. What does that mean for our installation as we attempt to manage for WOTH? What about other migratory birds on our installation?

DoD has invested $100's of millions on land and training area management to both enhance habitat and to provide realistic training environments. A sizeable, but unknown, proportion of those funds have been directed at habitat management for migratory birds. This has been an essential component of natural resources management for DoD for many years, as maintaining habitats for declining birds, as well as continuing to adhere to federal legislation designed to protect these species (e.g., MBTA, ESA, NEPA), ultimately supports the ability of DoD to conduct testing and training activities.

Although our results do underscore the importance of the migratory period, they also show clearly that breeding season processes account for the vast majority of variation in population growth and this general pattern of breeding season limitation appears to hold for numerous other forest breeding species. Understanding that WOTH populations are largely breeding season limited is essential for making proactive conservation decisions. This result further highlights that managers can make positive impacts on species of concern through habitat management approaches that can maximize survival, recruitment, and fecundity. Our results also show that habitat specific demography contributes to spatial variation in source sink dynamics in previously unforeseen ways. Specifically, our results show that vital rates make differential contributions to population growth depending on the quality of the habitat. This suggests that managing populations for persistence, via increasing specific vital rates, may need to be done in a habitat-specific manner.

This is an important finding and one that helps provide support to the large investments by DoD. Other recently published work (Rushing et al. 2016A & B) that used point count data across large spatial and temporal scales suggests that other bird species also are breeding season limited and that investments in North American breeding habitat can mitigate potential declines. Because the vast majority of the vital rates that contribute to population growth are heavily influenced during the breeding season, it is critical that DoD continues to invest in migratory breeding bird habitat management and maintenance, particularly for those species of specific management interest (e.g., DoD PIF Mission-sensitive Species). These same investments to breeding bird habitat are also important for migratory stopover habitat. A prior SERDP investigation (SI-1439; Fischer et al. 2012A & B) documented the importance of DoD installation lands as stopover habitat for a wide array of migratory birds.

Should DoD be investigating migratory birds during their full annual life-cycle?

It is worth mentioning there is growing evidence that despite large investments on the breeding grounds (e.g., on DoD and other federal lands), many migratory bird species continue to decline because of impacts along migration routes or on wintering grounds largely out of our control. Although we suggest DoD maintain a focus on management of breeding habitat on installations to have strong local, and potentially regional, impacts on WOTH and other populations of priority migratory bird species, we should not discount that some species incur greater limiting

factors and stressors during the non-breeding season and/or migration. In fact, our results highlight that migration also may be a critical phase of the annual cycle for WOTH population dynamics. Though not quantified at this time, there certainly must be examples where DoD is investing significantly in habitat management on installations for breeding birds, and those efforts have limited positive effects on population trajectories because of non-breeding season stressors.

There is growing interest in North America to investigate the stressors on migratory birds throughout the full annual life-cycle, which includes those that impact birds wintering in Mexico, the Caribbean, and Central and South America where approximately half of North American birds overwinter. Further investigation of those stressors, and their relative impacts on survival and fecundity, will help elucidate where efforts should be focused to assist in stemming declines. Better information can assist in determining where to focus limited funding to have the greatest positive impact on migratory bird populations. As more information becomes available on seasonal limitations to priority migratory bird populations, particularly for species with limiting factors at migratory stopover, or wintering, habitats off of installations, one could envision a future scenario where less funding is directed at on-installation management and more directed to migratory stop-over and/or non-breeding sites. This is a substantial leap that would require a paradigm shift. Nonetheless, this type of approach would ultimately benefit the DoD mission by providing lift to populations that otherwise might not be realized if investments continue to be made during the period of the annual cycle where they have the smallest effect. Better science on other priority species, similar to that conducted in our study for WOTH, will help pinpoint where DoD will get the highest return on investment for management efforts for those species.

I use the DoD Coordinated Bird Monitoring Plan. Does information from this investigation alter any recommendations?

Results of our investigation provide support and additional scientific insight for using point counts, MAPS, or intensive demographic sampling in the appropriate context. While the CBMP should be the first resource one reads to develop an inventory or monitoring investigation, we add important information not previously considered in the CBMP. For example, point count sampling could be conducted in a more intensive means when more than just inventory, seasonal abundance, and distribution, is needed (e.g., detailed demographic information is of interest). We also provide additional insight into the type of information derived, and spatial applicability of, MAPS monitoring stations.

Viewed broadly, our results suggest the methodological approach chosen for sampling avian populations will be dependent upon the scale at which management decisions need to be made. In higher quality habitats or at larger spatial scales, some species of concern may be monitored with less expensive count based and MAPS approaches, however, lower quality habitats with higher demographic stochasticity will require the more detailed intensive demographic approach. We recommend that installation managers consult the CBMP as a starting point, and then the SERDP RC-2121 report if more intensive sampling is needed to address demographic questions.

Because point count sampling of sufficient intensity could be used to generate insight into sources and sinks, are there sufficient data available on and off installations that could be mined and analyzed?

Yes. Many installations have monitoring data from on-installation efforts. Much of these data have been provided to DoD PIF for long-term archiving. The DoD Legacy Resources Management Program currently is investing in a new investigation aimed at working collaboratively with the USFWS to archive all DoD data in the Avian Knowledge Network (AKN) (www.avianknowledge.net). The AKN is rapidly-growing as the primary multi-agency clearinghouse for all bird data from surveys and projects that contribute to monitoring data across the nation. These data are used to make important decisions on species health, population status, population trends, specific stressors, and even conservation measures and actions on the species contained therein. USFWS and its partner Point Blue Conservation Science have been developing a new Federal Node to connect federal agency data with this larger global dataset. The Legacy investigation has a goal of formatting and uploading all DoD data (currently >1.2 million records from across the U.S.) and make them available to users for environmental analyses. When installation data are combined with large and extensive data sets collected outside of DoD installations, there is a wealth of information available for analyses. Although not mandated, OSD recommends installations use the AKN for this purpose, and to assist in identifying species of greatest conservation and mission concern on installations (18 Aug 2017; Guidance for Addressing Migratory Bird Management in Integrated Natural Resources Management Plans).

When completed, the AKN will provide DoD with a ready capability to upload, archive, access, and use extensive avian monitoring data to assist with NEPA environmental reviews, and assessing impacts of DoD readiness and non-readiness activities on migratory birds for MBTA and the DoD Migratory Bird "Readiness" Rule. These data also may be extremely useful for conducting more thorough analyses to identify source and sink populations. Through the Legacy Program, DoD PIF will be providing instructions on how installations can upload data, and how to use available tools for analyses. DoD PIF and others also are working collaboratively to develop a list of common military-readiness and non-readiness activities, along with recommended conservation measures, and integrate them into the USFWS Information for Planning and Conservation (IPaC) system (https://ecos.fws.gov/ipac/), for use in the NEPA process.

What other resources are available to assist installations in implementing guidance for monitoring and managing migratory birds?

As part of DoD's Natural Resources Program, DoD established an ad hoc network of subject matter experts, called DoD Partners in Flight, who provide technical information in support of migratory bird management and monitoring on DoD lands. The DoD PIF Steering Committee, provides technical support and expertise regarding migratory bird issues, coordinates inputs from this group, and is charged by the DoD Natural Resources Program to (a) collect/compile relevant technical information; (b) distribute DoD approved information to all interested and

appropriate stakeholders; (c) monitor bird population trends; and (d) serve as a resource center for relevant technical information and materials. DoD PIF offers a wide variety of resources to help natural resources managers better comply with relevant laws and policies, and incorporate migratory bird information into installation INRMPs. DoD PIF representatives also provide assistance to installation natural resources managers for monitoring and inventory, research and management, and education programs involving birds and their habitats. For more information on DoD PIF, please visit the DoD PIF website (https://www.denix.osd.mil/dodpif/home/).

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